Original Research

Does Venture Capital Investment Spur Innovation? A Cross-Countries Analysis

Nawab Khan1, Haitao Qu1, Jing Qu2, ChunMiao Wei1, and Shihao Wang1

Abstract
This article examines venture capital composite impact on innovation. For this purpose, we made venture capital index using principal component analysis methodology to test the composite impact of venture capital impact on innovation. We constructed our sample of 41 countries on the basis of venture capital fundraising from 2006 to 2016. First, we empirically tested index individual component, for which we used ordinary least square regression with robust standard error. In the second stage, we made VC index using principal component analysis methodology to analyze the composite effect of VC on patents generation. Empirical results show strong significant venture capital investment impact on patents generations. Overall, our findings suggest that venture capital investment significantly spur innovation, when we analyzed the individual factors of the index as well as compositely. These results encourage governments and policy makers to promote innovation through facilitating venture capital investment which provide an alternative source of finance to startups which find hard to raise fund in conventional fund market. This also suggest that policy maker should consider the composite effect of the venture capital in an economy to robustly encourage innovation.

Keywords
VC fund, VC backing companies, VC firms, innovation, principal component analysis

Introduction
The role of venture capital as alternative source of finance is extensively debated in recent years. This debate still continues to dig out the positive role VCs play in portfolio companies’ development and financial stability. Literature identified three basic roles venture capitalist can play as alternative source of finance: First is the selection of sound firms with promising future growth prospects, second is the venture capital financing role, and finally the added value service role (Anderson et al., 2017; Arqué-Castells, 2012; Dushnitsky & Lenox, 2006; Megginson et al., 2019; Megginson & Weiss, 1991; Pierrakis & Saridakis, 2017). García-Quevedo et al. (2018) and Megginson et al. (2019) argued that innovative startups find it difficult to get fund from conventional sources of finance because of lacking asset tangibility and operational history. Information asymmetry and lack of collateral make it difficult for startups to get funds. Due to financial constraints and not easily securing finance most of such projects abandoned (García-Quevedo et al., 2018).

To finance innovative project, there is need of specialized sources of finance which not only has risk appetite but also expertise in evaluation and analyzing such project feasibility and growth prospects. This job is done well by venture capitalists in American economy which was first introduced in 1946 (L. Zhang, 2014). The impressive success of American venture capital which promoted entrepreneurship and innovation in American economy, and attracted other governments and policy maker to replicate American success into their markets. Most of the past studies’ analysis and investigation...
are based on venture capital activities’ impact on firm innovation. Very few studies investigated VC macro-level impact on patents generation. Because macro environment has impact not only on venture capital performance but also on patents generation. Therefore, it is important to analyze the impact of venture capital on micro level as well as the macro level. Cheng et al. (2018) suggested that VC investment has a positive impact on regional economic growth. Pradhan et al. (2018) investigated venture capital investment determinants at the macro level and found a positive relationship between macro variables and VC investment. Similarly, Pradhan et al. (2018) investigated the endogenous dynamic of venture capital investment and economic growth and found a positive relationship. This shows the important impact of venture capital at micro as well as macro level. Venture capital has different types on the basis of geography and affiliation, for example, we have domestic, foreign, and independent affiliated venture capital firms, which are also debated in the literature for their different role and impact.

Researchers investigated the venture capital type impact on innovations and that how they differently affect backed companies. Academics and practitioners recognize venture capital (VC) as a driver of the success of entrepreneurial ventures. Several studies have argued that companies backed by VCs growing fast, have better financial and operating results, are more innovative, and are more likely to go public compared with their non-VC-backed peers (Gompers & Lerner, 2004). VC literature identified several kinds of VC firms like government venture capital (GVC), private venture capital (PVC), and corporate-affiliated venture capital (CVC), and bank-affiliated venture capital (BVC). Many studies revealed that the impact of the different types of VCs is different in portfolio firms (Alperovych et al., 2015; Cumming et al., 2017; Minola et al., 2017). Similarly, the screening process of the VCs selects those companies for VC finance, which fulfill or consistent with the strategic objectives of the different types of VC firms. Therefore, we argue that the different types of companies’ impact will be changed on innovation.

It is also vital to investigate the effect of the portfolio companies’ impact on innovation financed by different types of VCs. To capture the VCs types and portfolio companies’ effect on innovation, first we separately investigated venture capital investment, VC firms, and VC backed companies’ impact on innovation, and in the second stage, we investigated the composite impact of venture capital on innovation and found a positive relationship between VC investment and innovation. To the best of our knowledge, this is the first study of this kind investigating the composite impact of VC on innovation. The rest of the article is organized as follows: Section second analyzes relevant past literature, followed by Theoretical Background. The fourth section reports data sources and sample construction, fifth section discusses methodology, Section sixth reports empirical results, and the final section is of conclusion and recommendations.

**Literature Review**

Venture capital as an alternative source of finance attracted the attention of policy makers, researcher, and academicians for the role it plays in firm financial stability and innovation. Researchers (Bamford & Douthett, 2013; Gupta & Sapienza, 1992; Megginson et al., 2016; Sandberg & Hofer, 1987; Timmons & Spinelli, 1994; Vesper, 1990) analyzed the venture capital role in young firms. Similarly, researchers (Cheng et al., 2018; Galloway et al., 2017; Kortum & Lerner, 2001; Pierrakis & Saridakis, 2017, 2019; Pradhan et al., 2018; Wadhwa et al., 2016; Zou & Cheng, 2017) investigated VC role in promotion of innovation. Wadhwa et al. (2016) investigated CVC impact on 40 telecommunication equipment manufacturer firms innovation. They reported inverted U shaped relation of corporate portfolio investor CVC and backed startups innovation. They further reported that the resources diversity available to corporate investor through CVC has positive effects on startups innovation. Pierrakis and Saridakis (2017) in their research work reported that British firms backed by public VCs are more innovative compared with other types of VC. Cheng et al. (2018) analyzed Chinese firms’ venture capital and growth (VC) impact on innovation and employment generation in metropolitan. They reported VC investment has positive relationship with innovation employment and payroll. Similarly Sun et al. (2018) analyzed the venture capital role in emerging economies ecosystem transformation from a weak ecosystem into productive innovative one. They reported positive relations between VC investment and patents applications in their empirical result. Pradhan et al. (2018) analyzed 23 European countries’ relationship among growth innovation and venture capital investment. They reported that VC investment positively impacted growth. Similarly, Samila and Sorenson (2011) conducted panel data analysis for investigating venture capital (VC) impact on entrepreneurship and growth of metropolitan area of the United States. Their research work findings are that venture capital investment has significant impact on firms’ starts, employment generation. They argued that venture capital (VC) promote entrepreneurship through two ways. The first way is the VC finances available to entrepreneur through which entrepreneur can promote their innovative ideas. The second way of encouraging entrepreneurship through know how which employees gain and which may spin off. Because promoting entrepreneurship and startups increase innovative actives in economy. Kortum and Lerner (2001) assessed venture capital contribution in innovation in United States from 1965 to 1992. They reported association between venture capital activities in the given industry and patenting. There is a positive impact of VC activities on patenting. Innovation is not only important for firms in specific industry but also for an economy to increase its efficiency, export, and GDP growth. Lee et al. (2016) investigated cross countries information and communication innovation. They found that innovation in information and communication
technology (ICT) positively impacting economy productivity and growth. Zouaghi et al. (2018) investigated innovation impact on financial crises that innovation reduces financial crises effects.

World market has become more competitive in the 21st century. Competing the global challenges, every economy of the world needs to sustain economic growth. To sustain high growth for any economy around the world, it is necessary to increase innovative ability and product efficiency. The innovative ability at firm level is important because corporations are the main center of innovation of any economy. Governments are working on number of policies and programs to support firms innovation (Hou et al., 2017). There is a need of special financial institutions to take risk of innovative project and fulfill financial needs of firm. Mohnen et al. (2008) reported that financial constraints negatively impact innovative projects while the tax treatment of R&D is supportive of innovation. The financing problem of innovative projects can be solved through venture capitalist. Colombo et al. (2016) documented in their research that VC backing positively impact the new technological startups and their R&D activities are more as compare with the non-backed firms. Migendt et al. (2017) documented that institutional investor venture capital and policy maker interaction and interdependence promote innovation. If government policies are not supportive, it affects financial market which directly and indirectly affect institutional investor and VC fundraising from institutional investor which can affect innovation. Therefore, promoting innovation through venture capital channel the governments support is necessary. Belderbos et al. (2018) reported the corporate venture capital (CVC) positive technology performance of backed firms. They argued that CVC backed firms technology performance is better in diverse regions. Gorman and Sahlman (1989) investigate that VC helping portfolio firms in shaping their organization strategy and improve operational capabilities. The recent focus of researcher and academician fall on beyond VC financing role of value addition and extra than providing finances to investee firms (Gompers & Lerner, 1999). Researcher investigated the diverse effect of venture capital investment on backed firms. Venture capitalists have expertise in sector in which they work and provide value advices to management of backed firms which positively impact entrepreneurship in economies. Dushnitsky and Lenox (2005) discussed the conditions in which corporations invest in startups through corporate venture capital. They reported that corporations most likely invest through CVC in startups where there are greater innovation and technological opportunities. Different types of VC have different strategic objectives. The country legal regime also impacts the VC investment. Dushnitsky and Shaver (2009) reported that corporate venture capital (CVC) finance startups less likely under weak intellectual property rights regimes and the same industry and it is most likely that corporation invest in the same industry. Similarly, Galloway et al. (2017) documented that CVC influences management and founder of startups to enter into exploratory innovative alliance. Cox Pahnke et al. (2015) reported the multiple startups portfolios held by VC have negative impact on investee firm innovations. They documented that if VC has multiple ties with investee which are competitor that will negatively impact innovation. Lynskey (2004) investigated the determinants of Japanese startup innovativeness. They find that positive cash flow, venture capital backing, and industry linkages with research centers promote innovation. Bertoni and Tyková (2015) reported the european private equity activity (EVCA) that in 2013 40% fund raised by venture capitalist came from government and the taxpayer is the single largest source for the VC fundraising. This shows the government’s interest in promoting entrepreneurship through the venture capital investment. The fund need of innovative startups can be well served by venture capitalist. Venture capitalists are the specialized alternative source of finance which has the appetite of taking risk of new innovative project. It is important to investigate the VC fundraising relationship with the country patents generation. For this purpose we are investigating the research question that the number of VC backed firm number of VC firms and VC fund raised compositely impacting innovation. The fund raised by the VC firms is capital which flow to the new startups and the number of VC firms can bring diversified expertise, ideas and management skill to backed firms which can result in increased innovation of the country. Similarly, different type of VC firms and VC backed companies can also impact patents generation. In the second stage, we make VC index to analyze the composite impact of VC investment number of VC firms and VC backed companies. For this purpose, we take 41 countries by venture capital fundraising to investigate the fundraising impact on country patents generation. Recent growth of VC market and fundraising need to be investigated for their impact on innovation.

Theoretical Background

The above discussion from previous venture capital literature shows that venture capital investment has positive impact on innovation and the impact of different type of venture capital on innovation is significantly different (Guo & Jiang, 2013; Minola et al., 2017). Minola et al. (2017) pointed out that private VCs are shy out from investment in small risky companies while government venture capital are suitable to investment in such risky companies. Y. Zhang and Mayes (2018) argued that government venture capital underperform compare with private venture capital. These studies pointed out that different type of venture capital firms impact on backed companies is not similar. Similarly, the investee companies’ patents generations speed is different (Nagaoka, 2007). Therefore, the backed firm’s number and VC firm’s
heterogeneity, market size, and stage of investment will impact innovation differently. To capture these factors, and their impact on innovation. We built our investigation theory on the argument that because of different types of VCs firms’ investment in different sector and their different appetite for taking risk and different stages impact innovation differently. For this purpose we construct venture capital index of VC firms investing in an economy their investment amount and the number of companies backed by VCs. To test VC composite impact on innovation, we are expecting positive impact of the individual component and index impact on innovation. The investigation of composite impact is important because of the nature of venture capital investment VC firms’ types and strategic objectives of VC firms and investee companies that they consider their own priorities, investment stage amount, control right an exit time which impacting value addition and patents generation of investee companies. Therefore, it is important to study composite impact of VC on innovation. Our study will be a valuable addition to the existing venture capital literature which innovatively investigates VC composite impact on innovation.

**Variables Measurement and Data**

Generally innovation refers to the creation of new and economically viable and novel products, new processes, and organizations structures (Feldman, 2000). It accounts for a major portion of the growth in developing industrial economies. It takes different type and forms of product design and services. Innovation is changes in the organization existing structure to increase efficiency and effectiveness (Yusuf, 2009). Different proxies are being used for measuring innovation; every proxy has their own strengths and weaknesses. Major innovation proxies identified by literatures are patents trademarks and research and development expense. Patents represents valid and robust indicators of knowledge creation (Trajtenberg, 1987). It can be used to proxy for an organization’s knowledge creation. This offers a measurement of novel invention that is externally validated through the patent examination process (Griliches, 1998b). Inventor submits patents application who has positive expectation of the economic significance of the invention because obtaining such protection is costly (Griliches, 1998a). This shows that patents reflect the output of a firm’s innovation process. While patents measure a modifiable and advancement of firm’s technological knowledge, they correlate with measures that incorporate tacit knowledge and are a good measure of firm innovation (Hagedoorn & Cloost, 2003). Based on the previous literature, patents is the appropriate proxy to be used for innovation. Following literature, we took total number of patents as dependent variable to measure innovation. For this purpose, we first identified countries on Thomson One Reuter where VC raised fund at least for two consecutive years for the period 2006 to 2016. This gave us in total 41 countries from developed and developing countries. In the second stage, we collected data for the sample countries of patents and controls from World Bank development indicators.

Table 1 reports the list of the countries of our sample. We include those countries in our sample which has VC investment for at least 2 consecutive years. There is a problem of missing values we have had two choices either compromise on the inclusion of countries in our sample size or compromise on the time period. To keep the sample large and include more countries will help us to cover larger geographical area with diverse economies and legal regimes. Therefore, we kept the country data for which at least 2-year consecutive year. This left us with 41 countries, including both developing and developed countries. We measure innovation of the country through the log of total number of patents as register by domestic and foreign residents (TPAT). Our study main explanatory variables are venture capital (VC) fundraising (VCFND), total VCs firms (VCF), total VC backed companies (VCBCOMP), and VC index (VCINDEX). This raises a question that patents maybe influence by other factors. For this purpose, we include number of control variable to analyze venture capital impact on patents generation. The first control variable we used is financial development (FDEV), which calculated domestic credit by banks. The second control we used is number of total listed companies (LCOMP) in the country because enterprises are considered as center of innovation, by this we can control size of market. We also used imports of computer and communication services (TECHIMP) because computer and communication services provide infrastructure for patents generation it is important to control for computer and communication services. Our fourth control variable of our model is R&D expense ratio to GDP which is reported in the literature that R&D investment positively impacts patents generation. Our fifth control variable is growth of gross domestic product (GDP) in literature (Pradhan et al., 2018); it reported that GDP has casual relation with patents generation it is important to control it. We also control trade openness. For the variables’ definitions, see Table 2.

**Research Methodology**

The methodology we followed for this study is ordinary least square regression (OLS) and principal component analysis (PCA). First, we used OLS regression to investigate venture capital fundraising impact on country innovation. As literature reported VC firms’ heterogeneity impacting differently backed portfolio companies. Similarly, number of VC backed companies also differently impact country innovation belong to different sectors. Therefore, it is important to investigate VC fund VC number of firms and number of VC backed companies’ composite impact on patents generation. For this
purpose, we used PCA methodology to investigate VC fund VC firms and backed companies combine impact on patents generation. PCA methodology is used to reduce dimensionality of the feature vectors derived from data which make analysis simpler and interpretation easy (Labib & Vemuri, 2006). PCA can also be used for explanatory variables indexation (Constantin, 2014; Stock & Watson, 2002); this study use PCA for indexation of explanatory variables. A composite variable is appropriate in the case when the individual component variables have combined economic affect that need to be interpret (Kennedy, 2003). In many cases, it is important to reduce number of variables through indexing (Kendall, 1975). First component captures maximum variation and reduces the dimensions of the components. Another major problem is of collinearity among explanatory variables; PCA index is the exact and has unique solution to overcome on collinearity problem (Callahan et al., 2003). We used PCA method to make VC index of three variables VC fund number of firms and number of VC backed companies. Because VC component variable are highly collinear to use at one time in model, the VCINDEX solves the issue of collinearity and gives a composite impact of the three VC variables. VC index capture the VC fun raised, VC firm different objective in each economy with different legal regime and market and VC companies in different industries. The main OLS regression model of our study is the following:

\[ \text{INNOV} = \alpha + \beta_1 \text{VC} + \beta_2 \text{MCAP}_a + \beta_3 \text{TRDOPN} + \beta_4 \text{DEV} + \beta_5 \text{R&D} + \beta_6 \text{TECHIMP} + \beta_7 \text{GDP} + \beta_8 \text{Year Dummy}_t + \varepsilon_t \]

We used OLS regression with robust standard error to control for possible heteroscedasticity in panel. We also used year dummies to control for regularity and legal changes in countries.

### Empirical Results and Discussion

Table 1 reports list of countries include in our sample. Our sample consist of 41 countries which we chose on the basis of VC raised amount. Table 3 reports the main regression results of VC raised fund, VC firm, VC backed companies, and VC index impact on total number of patents. We used OLS regression with robust standard error to empirically test the impact of venture capital raised fund amount, number of VC firms, VC backed companies, and VC index on innovation. First, we used individual variables in our main regression model to investigate their impact on total number of patents register for the period 2006 to 2016. In the second stage, we analyzed composite impact of the three explanatory variables on innovation. For this purpose, we use PCA to construct VC index. Using PCA, it is important to check appropriateness of variable for index construction. We found strong correlation among index variable and sample adequacy is more than 0.50; this shows the appropriateness of variables for index construction. Kaiser–Meyer–Olkin (KMO) test suggests that if the overall KMO measure of sampling adequacy is greater than 0.50, then the variable can be used for PCA indexing (Kaiser, 1974). In our case, the overall KMO measure of sampling adequacy is 0.7492 which is appropriate for PCA. To decide on component, use for index Kaiser rule suggests that those components can be keep for analysis which has eigenvalue greater than 1. As our

| No. | Country name   | Years available | No. | Country name   | Years available |
|-----|----------------|-----------------|-----|----------------|-----------------|
| 1   | Argentina      | 3               | 21  | Kenya          | 6               |
| 2   | Australia      | 11              | 22  | Luxembourg     | 9               |
| 3   | Austria        | 8               | 23  | Malaysia       | 9               |
| 4   | Belgium        | 10              | 24  | Mauritius      | 4               |
| 5   | Brazil         | 9               | 25  | Mexico         | 9               |
| 6   | Canada         | 10              | 26  | Morocco        | 8               |
| 7   | China          | 11              | 27  | Netherlands    | 10              |
| 8   | Colombia       | 9               | 28  | New Zealand    | 7               |
| 9   | Czech Republic | 5               | 29  | Norway         | 9               |
| 10  | Denmark        | 10              | 30  | Poland         | 7               |
| 11  | Egypt          | 6               | 31  | Portugal       | 6               |
| 12  | Finland        | 9               | 32  | Russia         | 7               |
| 13  | France         | 11              | 33  | Singapore      | 11              |
| 14  | Germany        | 11              | 34  | South Africa   | 11              |
| 15  | Hong Kong      | 11              | 35  | South Korea    | 8               |
| 16  | India          | 10              | 36  | Spain          | 11              |
| 17  | Ireland        | 9               | 37  | Sweden         | 9               |
| 18  | Israel         | 11              | 38  | Switzerland    | 11              |
| 19  | Italy          | 8               | 39  | United Arab Emirate | 5   |
| 20  | Japan          | 11              | 40  | United Kingdom | 3               |
|     |                |                 | 41  | United States  | 11              |
We used four models for robust checking of VC impact on patents. In each model, we run regression with single explanatory variable of concern and controls but in all four model our dependent variable is total patents. In the first model, we used VC raised fund amount as explanatory variable of concern. VC raised fund amount as explanatory variable of concern. VC raised fund amount as explanatory variable of concern.

Table 2. Reports Variable Names Used in Our Study.

| No. | Variable name         | Symbols | Description                                                                                                                                                                                                 |
|-----|-----------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Total number of Patents | Ln_Patents | We take log of total patents register by foreign and domestic residents to proxy country innovation.                                                                                                     |
| 2   | Forward Year total Patents | FLn_Patents | To robustly analyzing VC impact on country patents generation, we took 2 years forward total number of patents.                                                                                               |
| 3   | Residents Register Patents | Ln_RPatents | For analyzing the separate impact, we investigate VC investment impact on patents registered by domestic residents. For this purpose, we take log of the patents register by domestic residents. |
| 4   | Foreign Register Patents | Ln_FPatents | Similarly, we also investigated VC investment impact on log of foreign register patents.                                                                                                                  |
| 5   | VC Raised Fund         | VCF     | VCF is fund raised by VC firms. We take top 41 countries on the basis of VC raised fund from 2006 to 2016 to investigate their impact on country patents generation. The amount is in millions of dollars as their large differences in fund raised among countries to make the data smooth, we took log of raised fund amount. |
| 6   | VC Firms               | VCFRM   | VCFRM is the number of VC firms investing in a country. Because there is difference of strategic objective of different types of VC firms. Companies are either financed by a single VC firms or syndicate. Therefore, it is important to capture number of VC firms' impact on innovation. |
| 7   | VC Backed Companies    | VCBACK  | VCBACK is the number of companies financed by VC firms. As the VC financed companies' patents generation is not consistent so it is important to investigated the backed number of backed companies' impact on patents generation. For this purpose, we took VCBACK to investigate its impact on patents generation. |
| 8   | VC Index               | VCINDEX | For analyzing composite impact of venture capital on innovation. We made Index of VC raised fund, number of VC firms, and number of VC backed companies using principal component analyses. VCINDEX investigated the composite impact on patents generation. |
| 9   | Market Capitalization  | M_CAP   | We use Market Capitalization to control Market Size.                                                                                                                                                        |
| 10  | R&D Expense            | RDEXP   | R&D Expense is the ratio of R&D expense to GDP.                                                                                                                                                            |
| 11  | Financial Development  | FDEV    | We calculate financial development by summing Domestic credit to private sector (% of GDP) and Domestic credit provided by financial sector (% of GDP).                                                        |
| 12  | Technology Imports     | TECHIMP | We used Technology important Computer, communications, and other services (% of commercial service imports) as control variable.                                                                          |
| 13  | Trade Openness         | TRDOPN  | We take Trade Openness as trade ratio to GDP.                                                                                                                                                              |

Note. Again, VC has highly significant impact on patents for both foreigner and residents which support previous result of VC impact on total patents. While VC impact on foreign register patents is higher than residents. Furthermore, Market capitalization and R&D Expense ratio to GDP, GDP growth financial development, Technology Imports (TECHIMP) trade to GDP ratio (TRDOPN), and year dummies were used as control variables. Financial development is calculated as total domestic credit ratio to GDP. Literature used domestic credit ratio to GDP as financial development. Similarly, we take computer and services import ratio to GDP control variable because this provide infrastructure for innovation spurring. OLS = ordinary least squares; VC = venture capital; GDP = gross domestic product.

*First, we collected data of VC fundraising and arranged in the descending order. Second, if a country has at least 2 years data we include that in our sample. This gave us 40 top countries on the basis of VC fundraising. Domestic credit to private sector (% of GDP) refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable, that establish a claim for repayment. Domestic credit provided by financial sector (% of GDP), includes all credit to various sectors on a gross basis. Examples of other financial corporations are finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies. Computer, communications, and other services (% of commercial service imports) include such activities as international telecommunications, and postal and courier services; computer data; news-related service transactions between residents and nonresidents; construction services; royalties and license fees; miscellaneous business, professional, and technical services; and personal, cultural, and recreational services.
variables which reports significant result. The VC raised fund impact on patents generation is 42.8% which is significant at 1%. In second model, we used number of VC firms investing in an economy and their impact on total number of patents which is significant at 1% and the result shows that VC firms number impact on patents generation is 68.5%. Similarly, in the third model, we used number of VC backed companies as our explanatory variable. Again, the result is significant at 1% and the impact is 38.7%. Next, we constructed VC index of the three explanatory variables. Because we cannot use these three variables in one model because of high correlation among these variables which make difficult the result interpretation. But index can make results interpretation simple (Labib & Vemuri, 2006). The VC index gives composite impact of VC raised fund amount, number of VC firms investing in an economy, and number VC backed companies. Results show that VC index is highly significant at 1%. R square is satisfactory which is above 50%. R square reported in Table 3 is 58.7%, 60.9% and 53.9% and 48.4% for Models 1, 2, 3, and 4 respectively. While imports of technology and trade openness have negative relationship with patents. While all other controls financial development (FDEV), market size (MCAP), R&D expense (RDEXP), and GDP have positive significant relation with total patent. Our main explanatory variables are highly significant. We also used year dummies as control variable to control law and regulation changes during our sample period. Variance inflation factor (VIF) result tables are given in the appendix, which reports that in all model VIF value is less than 2, which show that there is no issue of severe multicollinearity among explanatory variables.

To robustly analyze the VC impact on patents we take dependent variable separately as log of foreign residents register patents and domestic residents’ patents the results are reported in Appendix, which shows that VC raised fund, number of VC firm and number of VC backed companies

Table 3. Table 3 Reports OLS Regression Results of Four Models We Used VCF Raised, Raised VC Backed Companies and VC Index Impact on Patents.

| Independent variables | (1) Ln_Patents | (2) Ln_Patents | (3) Ln_Patents | (4) Ln_Patents |
|-----------------------|----------------|----------------|----------------|----------------|
| VCF                   | 0.428***       | 0.100***       | 0.136***       | 0.143***       |
|                       | (0.046)        | (0.035)        | (0.043)        | (0.053)        |
| MCAP                  | 0.116***       | 0.444***       | 0.556***       | 0.661***       |
|                       | (0.038)        | (0.114)        | (0.123)        | (0.118)        |
| RDEXP                 | 0.539***       | 0.105***       | 0.133***       | 0.142***       |
|                       | (0.110)        | (0.032)        | (0.040)        | (0.047)        |
| GDP                   | 0.129***       | 0.002***       | 0.003***       | 0.003***       |
|                       | (0.037)        | (0.001)        | (0.001)        | (0.001)        |
| FDEV                  | 0.002***       | -0.023***      | -0.031***      | -0.031***      |
|                       | (0.001)        | (0.006)        | (0.007)        | (0.008)        |
| TECHIMP               | -0.025***      | -0.006***      | -0.007***      | -0.006***      |
|                       | (0.007)        | (0.001)        | (0.001)        | (0.001)        |
| TRDOPN                | -0.008***      | 0.685***       | 0.387***       | 0.218***       |
|                       | (0.001)        | (0.068)        | (0.054)        | (0.040)        |
| VCFRM                 | 0.685***       |                |                |                |
| VCBACK                |                |                |                |                |
| VCINDEX               |                |                |                |                |
| _cons                 | 2.855***       | 5.016***       | 3.760***       | 4.770***       |
|                       | (0.988)        | (0.971)        | (1.175)        | (1.478)        |
| Obs.                  | 250            | 250            | 247            | 247            |
| R²                    | .587           | .609           | .539           | .484           |
| Year dummy            | Yes            | Yes            | Yes            | Yes            |

Note. Standard errors are in parenthesis. While MCAP and RDEXP to GDP, GDP growth, FDEV, Technology Imports (IMPORTS) trade to GDP ratio (TRDOPN) and year dummies were used as control variables. VC fund raised is in million dollar; we used log of the VC fund raised amount for the smoothness of data. Financial development is calculated as total domestic credit ratio to GDP. Literature used domestic ratio to GDP as financial development. Similarly, we take computer and services import ratio to GDP control variable because this provides infrastructure for innovation spurring. OLS = ordinary least squares; VCF = venture capital firms; VC = venture capital; MCAP = market capitalization; RDEXP = R&D expense ratio; GDP = gross domestic product; FDEV = financial development; TECHIMP = technology imports; VCFRM = VC firms; VCBACK = VC backed companies; VCINDEX = VC index.

*p < .1. **p < .05. ***p < .01.
and VC index impact on foreign register patents is larger than resident register patents. The three VC explanatory variables and VC index impact on foreign register patents impact is 52.4%, 83.3%, 46.4%, and 31.0%, respectively. Similarly, VC fund, VC number of firms invested in an economy, VC number of backed companies, and VC index impact on resident register patents impact are 36.9%, 56.0%, 33.4%, and 18.2%, respectively. VC index impact of foreign register patents is 12.8% larger than impact on residents register patents.

Next, we take dependent variable as 1, 2, and 3 year forward using three models to analyze VC fund and VC index impact on forward period patents. We only reported VC fund raised and VC index impact on 1, 2, and 3 years forward log patents. The number of VC firms and number of VC backed companies impact on forward patents is also statistically significant but not reported here to save space. Patents generation takes time; therefore, R&D investment, imports, and VC have lag impact on patents generation. Therefore, there are two ways to analyze VC lag impact on patents generation. First to take explanatory variables lag period and analyze their impact on patents, but in this way, we have to take explanatory and controls lag period. Second way is to take dependent variable forward period so by this way we can analyze all independent variables lag period impact on dependent variable. We follow the second way and take dependent variable forward period. We took 1, 2, and 3 years forward of dependent variable to analyze the lag period impact on patents generations. See the appendix, which reports VC fund raise impact on first, second, and third period forward patents is 45.8%, 46.3%, and 49.7%. Similarly, VC index impact on forward 1, 2, and 3-year patent is 20.7%, 21.1%, and 23.2%. These results support our previous regression results that VC impact patents generation. Furthermore, research and development expense, economic growth, financial development, and market size had positive relationship with patents while imports of computer technology and trade openness have negative relationship with patents generation. This study results suggest that government and policy maker must devise policies to encourage venture capital investment which will promote innovation. It must also ensure that the ecosystem and legal environment is favorable to attract VC investment (Groh & Wallmeroth, 2016). Venture capital industry should be diversified with different types of VC firms like government VCs Bank affiliated corporate VCs and Independent VCs to target different industries at different stages to promote innovation and increase competitiveness. Our research limitations regarding data are that we include countries which has maximum for two consecutive years which made an unbalance sample, but in the last model, VC raised fund amount has insignificant impact on patents. Overall, VC has composite and positive impact on patents generation. These results support our research question that VC investment has positive impact on patents generation. Appendix reports summary statistics pairwise correlations and VIF. Overall, there is no issues of collinearity by checking through Pearson Correlation Matrix and Variance Inflation among our model variables.

### Conclusion and Recommendations

In this research work, we investigated our hypothesis that venture capital play positive in innovation promotion. We first separately analyzed VC raised fund, VC firms, and VC backed companies’ impact on innovation. In the second stage, we made VC index of VC fund, number of VC firms invested in an economy, and number of VC backed companies through PCA. This gave us composite VC impact on patents generation. The fund raised by the VC firms is the fund available to VC to invest in new startups and the number of VC firms can either finance startups individually or can make syndicate of VC firms, which can bring diversified expertise, ideas, and management skill to backed firms which can result in increased innovation of the country similarly backed companies in different sector and at different stages and the VC exit period from the portfolio is also different which impact patents generation differently. Therefore, it is important to investigate the composite impact of VC on innovation. For this purpose, we took 41 countries to investigate the VC impact on country patents generation. We in our study take both developing and developed countries to investigated VC fund-raising impact on innovation from 2006 to 2016.

All our four main explanatory variables have positive impact on innovation. Our results support previous literature that VC investment promote and spur innovation. Furthermore, the empirical analyses suggest that research and development expense economic growth financial development and market size had positive relationship with patents while imports of computer technology and trade openness have negative relationship with patents generation. This study results suggest that government and policy maker must devise policies to encourage venture capital investment which will promote innovation. It must also ensure that the ecosystem and legal environment is favorable to attract VC investment (Groh & Wallmeroth, 2016). Venture capital industry should be diversified with different types of VC firms like government VCs Bank affiliated corporate VCs and Independent VCs to target different industries at different stages to promote innovation and increase competitiveness. Our research limitations regarding data are that we include countries which has maximum for two consecutive years which made an unbalance sample, future studies can increase the horizon with balance panel to see the impact of VC on innovation. Overall, this research will be a valuable addition to the existing venture capital and innovation literature.

### Appendix

**Table A1.** Reports One Year Lag Regression Results.

|       | (1) Ln_FPatents | (2) Ln_FPatents | (3) Ln_FPatents | (4) Ln_FPatents | (5) Ln_RPatents | (6) Ln_RPatents | (7) Ln_RPatents | (8) Ln_RPatents |
|-------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| VCFND | 0.524*** (0.059) | 0.369*** (0.042) | (continued) |
Khan et al. (1) (2) (3) (4) (5) (6) (7) (8)

| Ln_FPatents | Ln_FPatents | Ln_RPatents | Ln_RPatents | Ln_RPatents | Ln_RPatents | Ln_RPatents | Ln_RPatents |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| MCAP | 0.097** (0.043) | 0.078** (0.039) | 0.123** (0.051) | 0.124** (0.061) | 0.145*** (0.027) | 0.134*** (0.026) | 0.162*** (0.032) | 0.169*** (0.041) |
| RDEXP | 0.549*** (0.108) | 0.434*** (0.114) | 0.562*** (0.121) | 0.673*** (0.114) | 0.785*** (0.148) | 0.715*** (0.150) | 0.818*** (0.159) | 0.910*** (0.158) |
| GDP | 0.190*** (0.040) | 0.161*** (0.036) | 0.196*** (0.044) | 0.206*** (0.051) | 0.101*** (0.037) | 0.082** (0.034) | 0.108*** (0.040) | 0.115*** (0.046) |
| FDEV | 0.001 (0.001) | 0.000 (0.001) | 0.002*** (0.001) | 0.003*** (0.001) | 0.003*** (0.001) | 0.003*** (0.001) | 0.004*** (0.001) |
| TECHIMP | −0.052*** (0.008) | −0.050*** (0.008) | −0.060*** (0.009) | −0.058*** (0.009) | −0.012*** (0.006) | −0.011*** (0.006) | −0.011*** (0.005) | −0.011*** (0.007) |
| TRDOPN | −0.006*** (0.002) | −0.004*** (0.001) | −0.004*** (0.002) | −0.004*** (0.002) | −0.004*** (0.001) | −0.004*** (0.001) | −0.004*** (0.001) | −0.004*** (0.001) |
| VCF | 0.833*** (0.081) | 0.464*** (0.068) | 0.310*** (0.046) | 0.334*** (0.055) | 0.182*** (0.039) |
| VCBCOMP | 0.464*** (0.068) | 0.310*** (0.046) | 0.334*** (0.055) | 0.182*** (0.039) |
| VCINDEX | 0.310*** (0.046) | 0.458 (0.045) | 0.182*** (0.039) |
| _cons | 2.602** (1.146) | 5.240*** (1.103) | 3.699*** (1.378) | 5.086*** (1.691) | 0.458 (0.747) | 2.274*** (0.751) | 1.216 (0.895) | 2.066* (1.157) |
| Obs. | 250 | 250 | 247 | 247 | 250 | 250 | 247 | 247 |
| R² | 0.541 | 0.564 | 0.482 | 0.436 | 0.675 | 0.679 | 0.650 | 0.616 |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Note. Standard errors are in parenthesis. For robustly analyzing VC impact on innovation, we take forward period of patents. Because there can be two ways to analyze lag impact of VC on patents, either take VC lag period or patents forward period. We follow the second way because this will capture the lag impact of all explanatory variables. Table A1 reports OLS regression results of VC fund raised VCF VCBCOMP and VCINDEX impact forward period of 1 year (F1Ln_Patents), 2 years (F2Ln_Patents), and 3 years (F3Ln_Patents) of total patents. Again, VC has highly significant impact on total patents which support previous result of VC impact on total patents. While VC impact on foreign register patents is higher than residents. Furthermore, Market capitalization and RDEXP to GDP, GDP growth FDEV, Technology Imports (IMPORTS) trade to GDP ratio (TOPN) and year dummies were used as control variables. Financial development is calculated as total domestic credit ratio to GDP. Literature used domestic ratio to GDP as financial development. Similarly, we take computer and services import ratio to GDP control variable because this provides infrastructure for innovation spurring. VCFND = VC fundraising; MCAP = market capitalization; RDEXP = R&D expense ratio; GDP = gross domestic product; FDEV = financial development; TECHIMP = technology imports; VCF = venture capital; VCBCOMP = VC backed companies; VCINDEX = VC index; VC = venture capital; OLS = ordinary least squares; TRDOPN = trade to GDP ratio. *p < .1, **p < .05, ***p < .01.

Table A2. Reports Two Years Lag Regression Results.

| (1) | (2) | (3) | (4) | (5) | (6) |
| F1Ln_Patents | F2Ln_Patents | F3Ln_Patents | F1Ln_Patents | F2Ln_Patents | F3Ln_Patents |
|-------------|-------------|-------------|-------------|-------------|-------------|
| VCFND | 0.458*** (0.046) | 0.463*** (0.046) | 0.497*** (0.045) | 0.127*** (0.022) | 0.112*** (0.048) | 0.089** (0.043) |
| MCAP | 0.102*** (0.033) | 0.094*** (0.030) | 0.075*** (0.022) | 0.127*** (0.048) | 0.112*** (0.043) | 0.089** (0.035) |
| RDEXP | 0.498*** (0.110) | 0.488*** (0.114) | 0.460*** (0.106) | 0.637*** (0.129) | 0.638*** (0.136) | 0.618*** (0.138) |
| GDP | 0.166*** (0.031) | 0.174*** (0.029) | 0.197*** (0.031) | 0.193*** (0.038) | 0.205*** (0.037) | 0.240*** (0.040) |
| FDEV | 0.003*** (0.001) | 0.003*** (0.001) | 0.003*** (0.001) | 0.004*** (0.001) | 0.004*** (0.001) | 0.004*** (0.001) |
| TECHIMP | −0.024*** (0.007) | −0.027*** (0.007) | −0.028*** (0.007) | −0.029*** (0.008) | −0.032*** (0.008) | −0.030*** (0.008) |
| TRDOPN | −0.007*** (0.007) | −0.007*** (0.007) | −0.006*** (0.007) | −0.006*** (0.008) | −0.006*** (0.008) | −0.005*** (0.008) |

(continued)
Table A2. (continued)

|        | (1)         | (2)         | (3)         | (4)         | (5)         | (6)         |
|--------|-------------|-------------|-------------|-------------|-------------|-------------|
|        | F1Ln_Patents | F2Ln_Patents | F3Ln_Patents | F1Ln_Patents | F2Ln_Patents | F3Ln_Patents |
|        | (0.001)     | (0.001)     | (0.001)     | (0.001)     | (0.001)     | (0.001)     |
| VCINDEX| .027***     | .021***     | .032***     | .027***     | .022***     | .034***     |
|        | (0.038)     | (0.039)     | (0.044)     | (0.038)     | (0.039)     | (0.044)     |
| _cons  | 2.778***    | 3.003***    | 3.045***    | 4.822***    | 5.185***    | 5.265***    |
|        | (0.909)     | (0.850)     | (0.738)     | (1.349)     | (1.217)     | (1.062)     |
| Obs.   | 222         | 196         | 173         | 219         | 193         | 171         |
| R²     | .622        | .627        | .674        | .511        | .519        | .543        |
| Year dummy | Yes       | Yes        | Yes         | Yes        | Yes        | Yes         |

Note. Standard errors are in parenthesis. VCFND = VC fundraising; MCAP = market capitalization; RDEXP = R&D expense ratio; GDP = gross domestic product; FDEV = financial development; VCINDEX = VC index; TRDOPN = trade to GDP ratio; TECHIMP = technology imports.

*Significance at the .01 level.

Table A3. Summary Statistics.

|        | N     | SD      | Minimum | Maximum   | Kurtosis | Skewness | t value |
|--------|-------|---------|---------|-----------|----------|----------|---------|
| PATENTS| 354   | 160,595.52 | 18.00   | 1,338,503.00 | 23.74    | 4.14     | 7.08    |
| FOREIGN PATENTS | 354 | 48,543.87 | 14.00   | 310,244.00 | 20.96    | 4.13     | 7.78    |
| RESIDENTS PATENTS | 354 | 124,887.45 | 1.00    | 1,204,981.00 | 38.23    | 5.26     | 6.08    |
| VCFND  | 354   | 75,437.46 | 1.10    | 578,985.31 | 34.93    | 5.67     | 4.34    |
| VCF    | 354   | 106.62   | 1.00    | 793.00     | 32.10    | 5.44     | 5.23    |
| VCBCOMP| 349   | 505.65   | 1.00    | 4,129.00   | 32.69    | 5.18     | 5.83    |
| MCAP   | 313   | 4.40     | 4.17    | 30.94      | 20.60    | -4.11    | 105.46  |
| RDEXP  | 295   | 1.03     | 0.15    | 4.41       | 2.34     | 0.47     | 30.66   |
| GDP Gro| 343   | 3.46     | -8.27   | 25.56      | 8.86     | 0.88     | 15.16   |
| FDEV   | 354   | 128.42   | 0.00    | 546.49     | 2.44     | 0.09     | 33.01   |
| TECHIMP| 344   | 13.87    | 3.22    | 85.34      | 3.65     | 0.53     | 56.24   |
| TRDOPN | 354   | 93.81    | 22.52   | 442.62     | 7.03     | 2.18     | 20.93   |
| YEARS  | 354   | 2.99     | 2,006.0 | 2,016.00   | 0.07     | 12,652.5 | 33.57   |
| COUNTRY ID | 354 | 11.61  | 1.00    | 41.00      | 1.77     | 0.04     | 33.57   |

Note. VCFND = VC fundraising; VCF = venture capital firms; VCBCOMP = VC backed companies; MCAP = Market capitalization; RDEXP = R&D Expense ratio; GDP = gross domestic product; FDEV = financial development; TRDOPN = trade to GDP ratio; TECHIMP = technology imports.

Table A4. Pairwise Correlations.

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| (1) Patents | 1.00  |     |     |     |     |     |     |     |     |     |     |     |     |     |
| (2) VCFND   | .545* | 1.00 |     |     |     |     |     |     |     |     |     |     |     |     |
| (3) VCF     | .645* | .858* | 1.00 |     |     |     |     |     |     |     |     |     |     |     |
| (4) VCBCOMP | .497* | .749* | .864* | 1.00 |     |     |     |     |     |     |     |     |     |     |
| (5) VCINDEX | .424* | .576* | .683* | .584* | 1.00 |     |     |     |     |     |     |     |     |     |
| (6) F1Patents | .998* | .556* | .663* | .506* | .428* | 1.00 |     |     |     |     |     |     |     |     |
| (7) F2Patents | .995* | .563* | .682* | .524* | .438* | .998* | 1.00 |     |     |     |     |     |     |     |
| (8) F3Patents | .991* | .585* | .709* | .543* | .449* | .994* | .998* | 1.00 |     |     |     |     |     |     |
| (9) MCAP     | .184* | .179* | .186* | .131* | .210* | .177* | .166* | .159* | 1.00 |     |     |     |     |     |
| (10) RDEXP   | .218* | .216* | .247* | .266* | .137 | .227* | .212* | .179* | .049 | 1.00 |     |     |     |     |
| (11) FDEV    | .205* | .275* | .244* | .183* | .255* | .207* | .213* | .213* | .038 | .291* | 1.00 |     |     |     |
| (12) GDP     | .074 | .003 | .041 | .015 | .049 | .115 | .131 | .173 | .004 | -.203* | -.237* | 1.00 |     |     |
| (13) TECHIMP | -.119 | .041 | .014 | .030 | -.099 | -.130 | -.160 | -.164 | .227* | .238* | .086 | -.135 | 1.00 |     |
| (14) TRDOPN  | -.309* | .035 | -.094 | -.087 | -.160* | -.299* | -.280* | -.271* | .073 | -.088 | .106 | .097 | .153* | 1.00 |

Note. VCFND = VC fundraising; VCF = venture capital firms; VCBCOMP = VC backed companies; VCINDEX = VC index; MCAP = market capitalization; RDEXP = R&D Expense ratio; FDEV = financial development; GDP = gross domestic product; TRDOPN = trade to GDP ratio; TECHIMP = technology imports.

*p Significance at the .01 level.
Table A5. Reports VIF Results.

| Variance inflation factor | VIF  | 1/VIF |
|---------------------------|------|-------|
| VCFND                     | 1.313| .761  |
| MCAP                      | 1.14 | .877  |
| RDEXP                     | 1.233| .811  |
| GDP                       | 1.481| .675  |
| FDEV                      | 1.293| .774  |
| TECHIMP                   | 1.189| .841  |
| TRDOPN                    | 1.084| .922  |
| Mean VIF                  | 1.571|       |
| VCINDEX                   | 1.335| .749  |
| MCAP                      | 1.152| .868  |
| RDEXP                     | 1.212| .825  |
| GDP                       | 1.478| .676  |
| FDEV                      | 1.298| .77   |
| TECHIMP                   | 1.197| .835  |
| TRDOPN                    | 1.118| .895  |
| Mean VIF                  | 1.567|       |
| VCF                       | 1.458| .686  |
| MCAP                      | 1.167| .857  |
| RDEXP                     | 1.286| .778  |
| GDP                       | 1.504| .665  |
| FDEV                      | 1.337| .748  |
| TECHIMP                   | 1.195| .837  |
| TRDOPN                    | 1.091| .917  |
| Mean VIF                  | 1.589|       |
| VCBCOMP                   | 1.314| .761  |
| MCAP                      | 1.112| .899  |
| RDEXP                     | 1.254| .797  |
| GDP                       | 1.48 | .676  |
| FDEV                      | 1.262| .792  |
| TECHIMP                   | 1.161| .861  |
| TRDOPN                    | 1.091| .917  |
| Mean VIF                  | 1.575|       |

Note. VIF = variance inflation factor; VCFND = VC fundraising; MCAP = market capitalization; RDEXP = R&D expense ratio; FDEV = financial development; GDP = gross domestic product; VCINDEX = VC index; VCF = venture capital firms; VCBCOMP = VC backed companies; TRDOPN = trade to GDP ratio; TECHIMP = technology imports.

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ORCID iD
Nawab Khan https://orcid.org/0000-0002-9080-9895

References
Alperovych, Y., Hübner, G., & Lobet, F. (2015). How does governmental versus private venture capital backing affect a firm’s efficiency? Evidence from Belgium. Journal of Business Venturing, 30(4), 508–525.
Anderson, H. D., Chi, J., & Wang, Q. S. (2017). Political ties and VC exits: Evidence from China. China Economic Review, 44, 48–66.
Arqué-Castells, P. (2012). How venture capitalists spur invention in Spain: Evidence from patent trajectories. Research Policy, 41(5), 897–912.
Bamford, C. E., & Douthett, E. B., Jr. (2013). Venture capital and risk management: Evidence from initial public offerings. *Journal of Managerial Issues*, 25, 220–240.

Belderbos, R., Jacob, J., & Lokshin, B. (2018). Corporate venture capital (CVC) investments and technological performance: Geographic diversity and the interplay with technology alliances. *Journal of Business Venturing*, 33(1), 20–34.

Bertoni, F., & Tykvová, T. (2015). Does governmental venture capital spur invention and innovation? Evidence from young European biotech companies. *Research Policy*, 44(4), 925–935.

Callahan, W. T., Millar, J. A., & Schulman, C. (2003). An analysis of the effect of management participation in director selection on the long-term performance of the firm. *Journal of Corporate Finance*, 9(2), 169–181.

Cheng, C., Sun, Y., Su, Y., & Yang, S. (2019). Venture capital, innovation, and growth: Evidence from Chinese metropolitan data. *Applied Economics Letters*, 26, 549–553.

Colombo, M. G., Cumming, D. J., & Vismara, S. (2016). Governmental venture capital for innovative young firms. *The Journal of Technology Transfer*, 41(1), 10–24.

Constantin, C. (2014). Principal component analysis—A powerful tool in computing marketing information. *Bulletin of the Transilvania University of Brașov*, 7(2), 25.

Cox Pahnke, E., McDonald, R., Wang, D., & Hallen, B. (2015). Exposed: Venture capital, competitor ties, and entrepreneurial innovation. *Academy of Management Journal*, 58(5), 1334–1360.

Cumming, D. J., Grilli, L., & Murtinu, S. (2017). Governmental and independent venture capital investments in Europe: A firm-level performance analysis. *Journal of Corporate Finance*, 42, 439–459.

Dushnitsky, G., & Lenox, M. J. (2005). When do firms undertake R&D by investing in new ventures? *Strategic Management Journal*, 26(10), 947–965.

Dushnitsky, G., & Lenox, M. J. (2006). When does corporate venture capital investment create firm value? *Journal of Business Venturing*, 21(6), 753–772.

Dushnitsky, G., & Shaver, J. M. (2009). Limitations to interorganizational knowledge acquisition: The paradox of corporate venture capital. *Strategic Management Journal*, 30(10), 1045–1064.

Feldman, M. S. (2000). Organizational routines as a source of continuous change. *Organization Science*, 11(6), 611–629.

Galloway, T. L., Miller, D. R., Sahaym, A., & Arthurs, J. D. (2017). Exploring the innovation strategies of young firms: Corporate venture capital and venture capital impact on alliance innovation strategy. *Journal of Business Research*, 71, 55–65.

García-Quevedo, J., Segarra-Blasco, A., & Teruel, M. (2018). Financial constraints and the failure of innovation projects. *Technological Forecasting and Social Change*, 127, 127–140.

Gompers, P. A., & Lerner, J. (1999). *What drives venture capital fundraising?* National Bureau of Economic Research.

Gompers, P. A., & Lerner, J. (2004). *The venture capital cycle*. MIT Press.

Gorman, M., & Sahlman, W. A. (1989). What do venture capitalists do? *Journal of Business Venturing*, 4(4), 231–248.

Griliches, Z. (1998a). Patent statistics as economic indicators: A survey. In *R&D and productivity: The econometric evidence* (pp. 287–343). University of Chicago Press.

Griliches, Z. (1998b). Productivity, R&D, and the data constraint. In *R&D and productivity: The econometric evidence* (pp. 347–374). University of Chicago Press.

Groh, A. P., & Wallmeroth, J. (2016). Determinants of venture capital investments in emerging markets. *Emerging Markets Review*, 29, 104–132.

Guo, D., & Jiang, K. (2013). Venture capital investment and the performance of entrepreneurial firms: Evidence from China. *Journal of Corporate Finance*, 22, 375–395.

Gupta, A. K., & Sapienza, H. J. (1992). Determinants of venture capital firms’ preferences regarding the industry diversity and geographic scope of their investments. *Journal of Business Venturing*, 7(5), 347–362.

Hagedoorn, J., & Cloodt, M. (2003). Measuring innovative performance: Is there an advantage in using multiple indicators? *Research Policy*, 32(8), 1365–1379.

Hou, Q., Hu, M., & Yuan, Y. (2017). Corporate innovation and political connections in Chinese listed firms. *Pacific-basin Finance Journal*, 46, 158–176.

Kaiser, M. (1974). Kaiser-Meyer-Olkin measure for identity correlation matrix. *Journal of the Royal Statistical Society*, 52, 296–298.

Kendall, M. (1975). *Multivariate analysis*. Charles Griffin & Company Ltd.

Kennedy, P. (2003). *A guide to econometrics*. MIT Press.

Kortum, S., & Lerner, J. (2001). Does venture capital spur innovation? In *Entrepreneurial inputs and outcomes: New studies of entrepreneurship in the United States* (pp. 1–44). Emerald Group Publishing Limited.

Labib, K., & Vemuri, V. R. (2006). *An application of principal component analysis to the detection and visualization of computer network attacks*. Annales des Télécommunications, 61, 218–234.

Lee, S., Nam, Y., Lee, S., & Son, H. (2016). Determinants of ICT innovations: A cross-country empirical study. *Technological Forecasting and Social Change*, 110, 71–77.

Lynskey, M. J. (2004). Determinants of innovative activity in Japanese technology-based start-up firms. *International Small Business Journal*, 22(2), 159–196.

Megginson, W. L., Meles, A., Sampagnaro, G., & Verdoliva, V. (2016). Financial distress risk in initial public offerings: How much do venture capitalists matter? *Journal of Corporate Finance*.

Megginson, W. L., Meles, A., Sampagnaro, G., & Verdoliva, V. (2019). Financial distress risk in initial public offerings: How much do venture capitalists matter? *Journal of Corporate Finance*, 59, 10–30.

Megginson, W. L., & Weiss, K. A. (1991). Venture capitalist certification in initial public offerings. *The Journal of Finance*, 46(3), 879–903.

Migendt, M., Polzin, F., Schock, F., Täube, F. A., & von Flotow, P. (2017). Beyond venture capital: An exploratory study of the finance-innovation-policy nexus in cleantech. *Industrial and Corporate Change*, 26(6), 973–996.
Minola, T., Vismara, S., & Hahn, D. (2017). Screening model for the support of governmental venture capital. *The Journal of Technology Transfer, 42*(1), 59–77.

Mohnen, P., Palm, F. C., Van Der Loeff, S. S., & Tiwari, A. (2008). Financial constraints and other obstacles: Are they a threat to innovation activity? *De Economist, 156*(2), 201–214.

Nagaoka, S. (2007). Assessing the R&D management of a firm in terms of speed and science linkage: Evidence from the US patents. *Journal of Economics & Management Strategy, 16*(1), 129–156.

Pierrakis, Y., & Saridakis, G. (2017). Do publicly backed venture capital investments promote innovation? Differences between privately and publicly backed funds in the UK venture capital market. *Journal of Business Venturing Insights, 7*, 55–64.

Pierrakis, Y., & Saridakis, G. (2019). The role of venture capitalists in the regional innovation ecosystem: A comparison of networking patterns between private and publicly backed venture capital funds. *The Journal of Technology Transfer, 44*, 850–873.

Pradhan, R. P., Arvin, M. B., Nair, M., Bennett, S. E., Bahmani, S., & Hall, J. H. (2018). Endogenous dynamics between innovation, financial markets, venture capital and economic growth: Evidence from Europe. *Journal of Multinational Financial Management, 45*, 15–34.

Samila, S., & Sorenson, O. (2011). Venture capital, entrepreneurship, and economic growth. *The Review of Economics and Statistics, 93*(1), 338–349.

Sandberg, W. R., & Hofer, C. W. (1987). Improving new venture performance: The role of strategy, industry structure, and the entrepreneur. *Journal of Business Venturing, 2*(1), 5–28.

Stock, J. H., & Watson, M. W. (2002). Forecasting using principal components from a large number of predictors. *Journal of the American Statistical Association, 97*(460), 1167–1179.

Sun, S. L., Chen, V. Z., Sunny, S. A., & Chen, J. (2018). Venture capital as an innovation ecosystem engineer in an emerging market. *International Business Review, 28*, Article 101485.

Timmons, J. A., & Spinelli, S. (1994). *New venture creation: Entrepreneurship for the 21st century* (Vol. 4). Irwin.

Trajtenberg, M. (1987). *Patents, citations and innovations: Tracing the links*. National Bureau of Economic Research Cambridge.

Vesper, K. H. (1990). *New venture strategies*.

Wadhwa, A., Phelps, C., & Kotha, S. (2016). Corporate venture capital portfolios and firm innovation. *Journal of Business Venturing, 31*(1), 95–112.

Yusuf, S. (2009). From creativity to innovation. *Technology in Society, 31*(1), 1–8.

Zhang, L. (2014). *China’s venture capital market: Current legal problems and prospective reforms*. Elsevier.

Zhang, Y., & Mayes, D. G. (2018). The performance of governmental venture capital firms: A life cycle perspective and evidence from China. *Pacific-Basin Finance Journal, 48*, 162–185.

Zou, S., & Cheng, L. (2017). Effects of venture capital entry on enterprise innovation performance: Evidence from manufacturing enterprises on the GEM by PSM method. *Science of Science and Management of S. & T, 2*, 68–76.

Zouaghi, F., Sánchez, M., & Martínez, M. G. (2018). Did the global financial crisis impact firms’ innovation performance? The role of internal and external knowledge capabilities in high and low tech industries. *Technological Forecasting and Social Change, 132*, 92–104.