The Effects of Venture Capital Investments on Industrial Innovative Opportunities and Technological Arbitrage Opportunities

Abstract

Innovative opportunities and technological arbitrage opportunities are two types of entrepreneurial opportunities that could lead to technological progress and economic growth. This study investigates how venture capital investments flowing into an industry may impact both innovative opportunities and technological arbitrage opportunities presented in the industry. After examining 45 industries in the United States over the period of 1980-2015, we find that venture capital investments positively influence innovative opportunities and technological arbitrage opportunities at the industry level. In addition, the findings show that industry characteristics such as industry growth rate and industry dynamism could moderate the impact of venture capital investments on innovative opportunities. Moreover, this study verifies that innovative opportunities mediate the positive relationship between venture capital investments and technological arbitrage opportunities.

Keywords: Venture capital investments; Innovative opportunities; Technological arbitrage opportunities

1. Introduction

Recently entrepreneurship researchers have paid attention to entrepreneurial opportunities that introduce new products or services, new process, new materials, new markets, and new business models (Eckhardt and Shane, 2003; Shane, 2000; Shane and Venkataraman, 2000;). Specifically, two primary kinds of entrepreneurial opportunities have been identified in the literature: *innovative opportunities* and *technological arbitrage opportunities* (Anokhin et al., 2011). Both opportunities have been found important in the entrepreneurial process as they contribute to technological progress and eventually lead to economic growth (Anokhin, et al., 2011).

Innovative opportunities, on one hand, relate to new goods, new services, new raw materials, new markets and new organizing methods (Eckhardt and Shane, 2003; Schumpeter, 1934), which are typically created by innovative entrepreneurs. By introducing the new-to-the-world resource combinations, innovative entrepreneurs disrupt the original market equilibrium and obtain the temporary monopoly rents (Schumpeter, 1934; Anokhin et al., 2011). More importantly, they put ahead the production frontier and greatly improve technologies at the industry level. On the other hand, *technological arbitrage opportunities* are caused by markets inefficiencies (Eckhardt and Shane, 2003; Kirzner, 1997) and derived from the imitation of innovation, that is, imitator-entrepreneurs benefit from imitating the new means-ends frameworks created by innovative entrepreneurs (Anokhin et al., 2011; Anokhin and Wincent, 2014; Shin and Lee, 2013). As a result, technological arbitrage opportunities can accelerate the diffusion of new technologies and decrease the gap between imitators and innovators.

Although both innovative opportunities and technological arbitrage opportunities are important ingredients of entrepreneurial activities, entrepreneurs, more often than not, find themselves difficult in creating or discovering these entrepreneurial opportunities due to constraints such as funding shortage and liability of newness. To overcome the constraints, entrepreneurs sometimes turn to seasoned equity investors such as venture capital (VC) investors for assistance. The literature has shown that VC investors help entrepreneurs integrate and optimize financial and managerial resources; in other words, VCs not only bring money to entrepreneurial firms, but also provide entrepreneurs with significant amounts of valuable non-financial services such as coaching (Gorman and Sahlman, 1989; Hellmann and Puri, 2002, Sapienza, 1992; Sørensen, 2007), monitoring (Kaplan and Strömberg, 2003; Lerner, 1995; Sahlman, 1990), and valuable alliance networks (Colombo et al., 2006; Hsu, 2006; Lindsey, 2008), amongst others. Albeit some previous theoretical and empirical studies have suggested a positive relation between VC investments and startups' innovation performance and productivity growth (e.g., Bertoni and Tykvová, 2015; Bottazzi et al., 2008; Chemmanur et al., 2011; Croce et al., 2013; Sun et al., 2018), the impact of VC investments has not been extensively investigated in the literature on innovative opportunities and technological arbitrage opportunities, two critical factors that could contribute to technology progress and economic efficiency improvement.

To fill the gap in the literature, our study attempts to address the research questions of (1) whether the inflow of VC investments has positive impacts on innovative opportunities and technological arbitrage opportunities in an industry, and (2) whether such relationships are contingent upon industry conditions and how. Based on a sample of 1,518 industry-year observations in the United States during the years of 1980 to 2015, we find that VC investments flowing in an industry is a positive and significant predicator of innovative opportunities and technological arbitrage opportunities presented in the industry. Our findings also show that industry characteristics such as industry growth rate and industry dynamism moderate the effects of VC investments on innovative opportunities. Additionally, this study verifies that innovative opportunities mediate the positive relationship between VC investments and technological arbitrage opportunities.

Our study makes contributions to both academics and practitioners in a couple of ways. First, it adds to the growing research on innovative opportunities and technological arbitrage opportunities by revealing VC investments as antecedent of both opportunities at the industry level. The literature has suggested that both opportunities stimulate entrepreneurial activities and lead to economic growth (Anokhin et al., 2011), but relatively fewer studies have empirically investigated which factors could contribute to generating these opportunities. This study provides evidence in support of VC investments as significant predictor of entrepreneurial opportunities. The finding also enriches the VC literature by advancing the understanding of the impacts of VC investments on innovation. The prior studies have shown that VC investments lead to firm growth (e.g., Bertoni et al., 2011; Grilli and Murtinu, 2014; Puri and Zarutskie, 2012), productivity (e.g., Chemmanur et al., 2011; Croce et al., 2013), and innovation (e.g., Arqué-Castells, 2012; Bertoni and Tykvová, 2015); our study, on the other hand, links VC investments to entrepreneurial opportunities, another type of innovative outcomes that have not been investigated in the VC literature. In addition, the prior literature seems to focus on either innovative opportunities (e.g., Becker et al., 2006; Holmén et al., 2007; McGrath, 2001; Mckelevy et al., 2015; Newbert et al., 2013) or technological arbitrage opportunities (e.g., Anokhin et al., 2010; Anokhin and Wincent, 2014; Román et al., 2013; Shin and Lee, 2013), but seldom examines both opportunities altogether either theoretically or empirically (e.g., Anokhin et al., 2011; Anokhin, 2013). Our findings demonstrate that the two opportunities contribute to industry technology progress in different ways: Innovative opportunities disrupt the market equilibrium through new-to-the-world technological advancement, which gives rise to technological arbitrage opportunities that serve to diffuse the new technologies. Last, the results of our study also have managerial implications for entrepreneurs and policy makers. That is, when attempting to attract VC investments into their firms or industries, they should take into consideration industry conditions such as growth rate and dynamism.

2. Theoretical framework and hypotheses development

2.1. Market disequilibrium theory and entrepreneurial opportunities

Market equilibrium is a situation in which market participants are satisfied with current resource combinations and production modes, and therefore not motivated to explore new production behaviors (Eckhardt and Shane, 2003). However, when entrepreneurs are not satisfied with the status quo, they may take actions to seek extra profits by breaking the market equilibrium. The market disequilibrium then gives rise to two important types of entrepreneurial opportunities: *innovative opportunities* and *arbitrage opportunities* (Anokhin et al., 2011). Innovative opportunities refer to opportunities that largely relate to innovation with three key elements—economic value, mobilization of resources and appropriability (Holmén et al., 2007). This type of opportunities arises when innovative entrepreneurs create or discover the new-to-the-world resource combinations and production modes. By doing so, they break the original market equilibrium and push ahead the production frontier of the industry, thereby obtaining temporary monopoly economic rents. Sequentially, the rents generated by market disequilibrium may give rise to technological arbitrage opportunities (Eckhardt and Shane, 2003; Kirzner, 1997) as imitator-entrepreneurs will imitate the advanced technology/product and even make some incremental innovation in order to obtain the rents (Baum et al., 2000). Along the process, the market will move to a new equilibrium with advanced technology frontier until all arbitrage opportunities are exhausted (Anokhin et al., 2011). The cycle will continue when new resource combinations and production modes are introduced to the industry again.

So far, the literature has extensively studied the consequences of innovative opportunities, and linked innovative opportunities to various outcomes such as entrepreneurial performance (Zahra et al., 2014), competitive advantage (Newbert et al., 2013), and venture migration (Anokhin, 2013). On the other hand, technological arbitrage opportunities have received less attention in the literature until recently. It is observed that more ventures are launched by imitator entrepreneurs than innovative entrepreneurs because of the high costs and risks associated with breakthrough innovation (Anokhin et al., 2011). Empirically, researchers have found that technological arbitrage opportunities positively influence both business entrant rates (Anokhin and Wincent, 2014) and venture migration (Anokhin, 2013). Although the literature has investigated the two opportunities from different perspectives, the prior studies seem to focus on either innovative or technology arbitrage opportunities. As discussed earlier, the two opportunities are indispensable in the entrepreneurial process, both of which are central to entrepreneurial activities and contribute to technology advancement in a complementary way. Thus, it is necessary to empirically examine both innovative opportunities and technological arbitrage opportunities together, especially their complementary relationship.

A number of prior studies have also developed theoretical frameworks to analyze the antecedents of the two entrepreneurial opportunities (e.g., Acs et al., 2009; Acs et al., 2013; Eckhardt and Shane, 2003; Shane, 2000). There are in general two primary views that exist in the literature—*discovery view* and *creative view* (Sarasvathy et al., 2003). The discovery view argues that entrepreneurial opportunities objectively exist in the society and can be discovered by entrepreneurs who will create new ventures to exploit such opportunities (Kirzner, 1997); that is, these opportunities are exogenous to entrepreneurs' venturing activities, and may be largely brought by factors such as cultures, social norms, laws, regulations, and institutional transitions (Acs et al., 2004; Spencer and Gómez, 2004; Tonoyan et al., 2010). The creative view, on the other hand, emphasizes that entrepreneurial opportunities are created by entrepreneurs who introduce the new means-ends relationships (Schumpeter, 1934); that is, these opportunities are endogenous, and the market disequilibrium is mainly driven by entrepreneurs' innovative activities. Thus, factors that directly support entrepreneurs' innovative activities become salient antecedents of entrepreneurial opportunities. For instance, Shane (2000) has found that the prior knowledge of entrepreneurs creates entrepreneurial opportunities.

The debate over what factors lead to entrepreneurial opportunities may be due to limited empirical findings in the literature that could support either of the views. Given the idiosyncrasies associated with different entrepreneurial opportunities, we, in this study, propose that the two views may be reconciled in a framework where the two entrepreneurial opportunities are linked together. Specially, we argue that innovative opportunities are largely endogenous to entrepreneurs' innovative activities, and therefore, resources that could facilitate entrepreneurs in the innovation process become critical. In this study, we identify VC investments as such an antecedent that will help entrepreneurs create innovative opportunities. As the literature has shown (e.g., Croce et al., 2013; Sun et al., 2018), VC investors tend to invest in ventures with innovative technology/product, and help entrepreneurs integrate and optimize financial and managerial resources to overcome constraints in the innovation process. Moreover, the impact of VC investments may be contingent upon exogenous factors such as industry concentration, growth rate, and dynamism. On the other hand, we argue that technological arbitrage opportunities are those that await entrepreneurs to discover. Different from the prior studies that examine the arbitrage opportunities from the institutional perspective (Anokhin et al., 2011), our research focuses on its complementary relationship with innovative opportunities. That is, innovative opportunities, by breaking the market equilibrium, will give rise to technology arbitrage opportunities that imitator entrepreneurs will discover and take advantage of, thereby improving the market to a new equilibrium in a more efficient state. Fig. 1 presents our proposal conceptual model, and we develop each of the hypotheses in the next section.

Insert Fig. 1 about here

2.2. VC investments and innovative opportunities

As discussed, innovative opportunities are created by the formation of new means-ends framework (Anokhin et al., 2011), thereby putting ahead the production frontier; in other words, this kind of opportunities have the properties of innovativeness and creativity. However, the creation of innovative opportunities typically require significantly resources and efforts (Choi et al., 2008), and are accompanied with high risks and uncertainty because innovation indicates novelty technology/products or untapped market. Additionally, the creation of innovative opportunities requires high personal qualities and knowledge skills of entrepreneurs. Thus, facing financial constraints and liabilities of newness, entrepreneurs dare not easily attempt to create or exploit such opportunities (Anokhin et al., 2013).

To overcome these constraints, entrepreneurs may seek assistance through equity investors such as VC investors. Indeed, VC investments as an important and widely accepted financing mode for entrepreneurial firms have caught attention of both academics and practitioners (Croce et al., 2013), and prior studies find that VC-backed firms have better performance in terms of firm growth, productivity and innovativeness than non VC-backed firms (Balboa et al., 2011; Bertoni et al., 2011; Bertoni and Tykvová, 2015; Croce et al., 2013; Hellmann and Puri, 2002; Puri and Zarutskie, 2012). On one hand, VC investors could provide entrepreneurs with significant amounts of financial resources that relieve financial burdens facing entrepreneurial companies (Bertoni and Tykvová, 2015; Grilli and Murtinu, 2014). On the other hand, VC investors bring various non-financial value-adding services to entrepreneurial companies to help them overcome liabilities of newness and improve their managerial competence (Large and Muegge, 2008; Proksch et al., 2017). For example, through coaching, VC investors can provide entrepreneurs with assistance in strategic decision making, capital structure optimizing, marketing, team building, thereby improving the latter's managerial skills and competences (Hellmann and Puri, 2002; Luukkonen et al., 2013). In addition, VC investors possess high-quality human resources and long-term strategic horizon, wait patiently for the long-term value yielded by innovation, and actively and positively put resources in risky and innovative activities (Bertoni and Tykvová, 2015). Moreover, VC investors have access to networks including partners, supplier, and customers, which is critical for entrepreneurs to obtain resources and further develop their businesses (Bertoni and Tykvová, 2015; Grilli and Murtinu, 2014).

These financial and managerial resources/supports by VC investors are especially important when entrepreneurs create or discover new-to-the-world resource combinations and production modes because such innovative activities require many resources and present a high level of uncertainty. Under such circumstances, the flowing of VC investments into an industry will support entrepreneurs disrupt the original market equilibrium and create innovative opportunities. Therefore, we propose the following hypothesis:

H1. VC investments positively facilitate innovative opportunities in an industry.

2.3. Moderation effects of industry characteristics on VC investments and innovative opportunities

Industries vary in many aspects, and thus the impacts of VC investments on entrepreneurial opportunities may be contingent upon industry characteristics. In this study, we identify three major industry characteristics—*industry concentration*, *industry growth rate*, and *industry dynamism*, and discuss the moderation effects of each industry characteristic on the relationship between VC investments and innovative opportunities in the following subsections.

2.3.1. Industry concentration

Industry concentration reflects the extent to which market shares are occupied by a number of firms; in other words, an industry is highly concentrated if the majority of market shares are occupied by one or a few firms (Melville et al., 2007; Qu et al., 2011). Industry concentration is often associated with industry competitiveness. Typically, higher concentration in an industry leads to less competition. As one of the most important structural elements in the field of industrial organization economics (Qu et al., 2011), industry concentration has been extensively used in the organization and strategy research to analyze market power and industry performance (Melville et al., 2007).

In high concentrated industries, a small number of large incumbents occupy most market shares. Their dominant positions of resources and technologies make them able to control prices and obtain monopoly-type benefits (Gayle, 2008; Qu et al., 2011). Under such circumstances, the incumbents tend to be satisfied by the status quo and not motivated to engage in creatively self-destructive innovation (Granstrand and Alänge, 1995) because the creation of new ways of resource combinations and production modes may disrupt the core competencies of incumbents, and threaten their sustainable competitive advantage (Anokhin and Wincent, 2012). Sometimes, they may even take actions to ward off other firms from creating or discovering novel means-ends frameworks to break the present market equilibrium. On the contrary, VCs tend to devote funding and managerial resources to helping entrepreneurs create new means-ends frameworks, break market equilibrium through disruptive innovation, and push the industry production frontier forward (Bertoni and Tykvová, 2015). Therefore, when VCs flow into an industry with high concentration, the large incumbents, given their dominant market position and adequate resources, may present a strong force against VC-backed entrepreneurial companies from creating innovative opportunities. Under such circumstances, entrepreneurial companies passively develop cutting-edge innovation to challenge the status quo while taking advantage of resources provided by their VC investors.

On the other hand, in a low concentrated industry with plenty of small companies, each company has the similar market position, and thus the competition between companies is fierce (Qu et al., 2011). Each company attempts to innovate in both products and processes, find new resource combination methods to provide customers with unique products and services, and/or improves economic efficiency to defend themselves from the rivals (Cui et al., 2005). Imitation not only reduces the positivity of learning new things, but also decreases the companies' flexibility to handle the competitive environment, and thus weakens the competitive advantage of entrepreneurial companies. Therefore, imitation is not the better choice in low concentrated environments. Nevertheless, innovation generates variation (e.g., new technology, new products) for entrepreneurial companies thus ward off the competitors. Under such circumstances, VC-backed entrepreneurial companies are more likely to stand out in the competition because VCs bring financial and non-financial resources that will support entrepreneurial companies to create or discover the novelty resource combination methods. Based on the above argument, we propose:

H2a. Industry concentration moderates the relationship in H1. Specifically, in high concentrated industries, the relationship becomes weaker. In low concentrated industries, the relationship becomes stronger.

2.3.2. Industry growth rate

Industry growth rate is a simple way to estimate the future growth of an industry, and it has been identified as one important determinant of environmental munificence (Dess and Beard, 1984). A high growth industry is typically characterized by rapid growth with greater opportunities and managers' decision-making freedom (Datta et al., 2003; Guthrie and Datta, 2008). To some extent, industry growth rate reflects the degree of environmental munificence (Park and Steensma, 2012), thus high growth industries indicate abundant resources and better industry basic conditions (e.g., infrastructures, distribution, marketing, networks, technological research). Firms in industries with high growth typically have strategic goals that go above and beyond merely survival, and they are willing to value innovation (Chatman and Jehn, 1994). When facing rapid market growth, firms are more likely to strategize how to increase business scales and expand business scopes. In the meantime, abundant resources also make it possible for at least some of the firms to explore new technological territories (Dess and Beard, 1984; Qu et al., 2011). Additionally, it is necessary and important to quickly adapt to the new market conditions in high growth industries (Guthrie and Datta, 2008). Thus, when entrepreneurial companies enter high growth industries, the ideal basic conditions and rich resources available in such industries will make the VC-backed companies focus on utilizing VC supports in creating or discovering novel resource combinations, cutting-edge production modes, and disruptive technological innovation.

In industries with low growth, entrepreneurs may be restricted by scarce resources, poor industry infrastructure, and fierce competitions with incumbents (Datta et al., 2003; Qu et al., 2011). Although VC investors may bring significant amount of financial and non-financial resources to the investee firms, they may spend resources mainly for infrastructure construction rather than exploratory activities in low growth industries (Goll and Rasheed, 2004; Qu et al., 2011). In addition, when survival becomes strategic priority for entrepreneurial companies, they typically possess a short-term horizon and tend to devote more resources to maintaining their survival rather than undertake risk taking activities like innovation (Goll and Rasheed, 2005). As a result, these entrepreneurial companies have less incentive to pursue innovative opportunities. The above argument leads to the following hypotheses:

H2b. Industry growth rate moderates the relationship in H1. Specifically, in high growth industries, the relationship becomes stronger. In low growth industries, the relationship becomes weaker.

2.3.3. Industry dynamism

Industry dynamism relates to the unpredictable change which causes uncertainty in the process of management (Dess and Beard, 1984; Melville et al., 2007). Typically, the more dynamic a market is, the greater the uncertainty (Qu et al., 2011).

Industry dynamism makes it difficult for managers to make strategic decisions due to the market uncertainty (Ensley et al., 2006). In high dynamic industries, the causes of market changes are ambiguous, and the future events cannot be reliably predicted (Anderson and Tushman, 2001; Patel et al., 2013), and thus the strategic decision makers will typically experience an elevated level of stress and anxiety given the uncertain and rapidly changing industry environments (Ensley et al., 2006; Waldman et al., 2001). To entrepreneurs, the dynamic industry environments add more risk and uncertainty to innovative opportunities. Specifically, a rapidly changing industry environment could turn novel technologies obsolete; in other words, an advanced technology may become unapplicable or inferior very quickly. In this situation, entrepreneurs, even with VCs' assistance, may not be able to capture the right direction of technology advancement. As a result, the resources for pursuing innovative opportunities are more likely to become a waste, which presents substantial risk for entrepreneurs. In addition, VCs carry managerial resources (e.g., coaching, monitoring) to investee companies and help the latter become professional and rational in business operations. The rational entrepreneurs will be very cautious when pursuing the innovative opportunities in order to avoid the extra risk caused by the high dynamic industry environments. They may choose the existing production modes to avoid the resources waste and obtain the steady benefits.

On the other hand, in low dynamic industries, the entrepreneurs face few risk and uncertainty since the stable industry environments has less ambiguity and more predictability (Azadegan et al., 2013). Thus, entrepreneurs can more easily respond to the market changes and capture the technological trends. Especially, when they are equipped with substantial amount of resources offered by VCs, they will have more confidence and more incentives to denote the resources to pursue innovative opportunities. Therefore, we propose the following hypotheses:

H2c. Industry dynamism moderates the relationship in H1. Specifically, in high dynamic industries, the relationship becomes weaker. In low dynamic industries, the relationship becomes stronger.

2.4. VC investments and technological arbitrage opportunities

Technological arbitrage opportunities focus on the imitation or incremental changes of innovation (Baum et al., 2000). When innovative entrepreneurs, with the help of VC investors, create novel means-ends relationships, the market equilibrium is disrupted (Schumpeter, 1934). Players in the market originally believe that they are doing the same by making the best possible choices. With the introduction of novel technologies/business processes into the market, some of the players (innovative entrepreneurs) now can make productions more efficient than the rest, thereby increasing their profitability. The discrepancy between the new business order and the old one gives rise to arbitrage opportunities that a few alert imitator-entrepreneurs would first try to take advantage of. They will copy the new ways of resource combination and innovative production modes so that they could reduce costs, improve efficiency and productivity, and obtain the temporary entrepreneurial rents as well (Anokhin, 2013). In addition, the exploitation of technology arbitrage opportunities exposes entrepreneurs to less uncertainty and risks (Anokhin et al., 2011; Anokhin, 2013). By utilizing the imitation strategy, the imitator-entrepreneurs face low probability of failure in entrepreneurial activities. Moreover, as followers, the imitator-entrepreneurs can probably better forecast the effects of new technologies and avoid the first mover's mistakes. Thus, the existence of technology arbitrage opportunities will lead more and more entrepreneurs move into the market to exploit such opportunities until they are exhausted. Along the process, the market eventually will reach a new equilibrium in a more efficient and productive status (Anokhin, 2013). In other words, innovative opportunities open the door for technological arbitrage opportunities (Anokhin et al., 2011). In line with the abovementioned argument, we propose the following hypothesis:

H3. Innovative opportunities mediate the positive effect of VC investments on technological arbitrage opportunities in an industry.

3. Methods

3.1. Data and Sample

The data used in this research are collected from three data sources: VentureXpert database, Compustat North America, and PatentsView database. First, we collect the VC investments data from VentureXpert database, an official database for the National Venture Capital Association (NVCA) by Thomson Financial. Our initial sample includes 13,317 industry-year observations during years 1980 to 2015 based on Thomson Financial industry classification VEIC codes (1000 to 9999). To compute innovative opportunities and technological arbitrage opportunities, we retrieve financial data from Compustat North America, and then aggregate to the industry level based on the SIC codes (4 digit). Also we collect patent data from PatentsView database, which provided by US Patent and Trademark Office (USPTO), and then match them to Compustat. To combine the data from VentureXpert to those from Compustat, we match the VEIC codes to the SIC codes based on the matching scheme used by Dushnitsky and Lenox (2006). As a result, a total of 45 SIC codes (2741 to 8731) are matched to 190 VEIC codes (1110 to 3940), and all the unmatched VEIC codes are removed from the sample, which yields a final sample of 1,518 SIC-based industry-year observations from 1980-2015.

3.2. Measures

3.2.1. Dependent Variables

Innovative opportunities and technological arbitrage opportunities. Following Anokhin et al. (2011), we employ the data envelopment analysis (DEA) based Malmquist productivity index decomposition to measure both innovative opportunities and technological arbitrage opportunities. For innovative opportunities, the DEA-based Malmquist productivity index decomposition, as Anokhin et al. (2011) point out, may help eliminate the limitations of traditional innovation measurement such as patent applications (Acharya et al., 2013) and R&D expenditures (Tihanyi et al., 2003). For example, not every patent can be successfully converted into a product, and to some extent patents represent more inventions instead of innovations (Bertoni and Tykvová, 2015; Carlsson and Fridh, 2002). For R&D expenditures, no one can guarantee R&D expenditures yield a successful, economically viable invention (Aghion and Tirole, 1994). Moreover, high R&D expenditures may be due to agency problems rather than innovation (Anokhin et al., 2011; Zahra, 1996). For technological arbitrage opportunities, there is no widely accepted measures in the literature due to limited research in this area. A number of researchers recently have proposed the DEA-based Malmquist productivity index decomposition as measure of technological arbitrate opportunities (Anokhin et al., 2011).

DEA is an effective, nonparametric programming approach to estimate the efficient production frontier by comparing the decision-making units (DMUs, in this study, the DMUs refer to 45 industries) with multiple inputs and multiple outputs (Charnes et al., 1978). In general, the efficient production frontier defined by DEA indicates the optimal resource combination under a given technological condition, and the most efficient DMU are located on the efficient frontier and the inefficient units are away from the efficient frontier. The DEA technique has been widely used in operations management and economics area. Recently, this useful tool has been applied to research in strategic management (e.g., Chen et al., 2015; Delmas and Tokat, 2005; Durand and Vargas, 2003; Majumdar and Venkataraman, 1998), innovation (e.g., Thursby and Thursby, 2002), and entrepreneurship (e.g., Anokhin and Schulze, 2009; Anokhin et al., 2011; Anokhin and Wincent, 2012).

The DEA-based Malmquist productivity index proposed by Färe et al. (1994) provides a dynamic perspective to measure the productivity change of DMUs between two time periods. The index can be decomposed into two parts: *efficiency change* and *technical change*. *Efficiency change* measures the relative efficiency changes over time; that is, how much the DMUs move toward or move away from the frontier over time. It reflects the diffusion of technology (Färe et al., 1994) and optimization under given technologies. Following Anokhin et al. (2011), we use the inverse of efficiency change to measure technological arbitrage opportunities. On the other hand, *technical change* relates to the efficient frontiers shift between two time periods, which has been used as a measure of innovation in the literature (e.g., Färe et al., 1994; Thursby and Thursby, 2002; Anokhin et al. 2011). In consistent with Anokhin et al. (2011), we use technical change to measure innovative opportunities in this study.

To calculate the DEA-based Malmquist productivity index, we choose the *number of employees* and *capital stock* as inputs and *value added* as the output as suggested by Chen et al. (2015) and Lieberman and Dhawan (2005). Capital stock is calculated based on $\text{Capital stock}_{t+1} = \text{Capital}_{t+1} + (1-\theta)\text{Capital stock}_t$, and θ is a depreciation rate. In this study, we use 10% depreciation rate to calculate the capital stock (Chen et al., 2015; Lieberman and Dhawan, 2005). Value added relates to the monetary value created and retained by the firm, and is equal to the firm's sales during the fiscal year minus the costs of purchased materials and services (Chen et al., 2015; Lieberman and Dhawan, 2005).

Additionally, we use patent as an alternative measure for innovative opportunities in this work although it has some limitations as a proxy for innovation as aforementioned. The total number of patent applications by all firms in an industry is used as a proxy for industry innovative opportunities. All dependent variables are adopted one-year lag.

3.2.2. Independent Variable

Venture capital investments. We obtain the total VC investments of each VEIC based industry during year 1980 to year 2015 from VentureXpert, and then aggregate them to 45 SIC based industries (4 digit) as mentioned in the previous section. The logarithm of industry VC investments is used in the regressions.

3.2.3. Moderator Variables

Industry concentration. The production and technology advances vary among different industries since some industries tend to be more fragmented and entrepreneurial in nature while others are more concentrated. The measure of industry concentration is calculated as the sum of the market shares of the four largest firms in the focal industry (Anokhin and Wincent, 2014; Park and Steensma, 2012).

Industry growth rate. Industry growth rate describes the degree of growth or decline within an industry over the measured period. It is measured as the growth of sales of all firms in the focal industry (Park and Steensma, 2012).

Industry dynamism. In this paper, the industry sales data was used to compute industry dynamism. Based on the well-established measure of environmental dynamism introduced by Dess and Beard (1984), the natural logarithm of sales for the previous five years is regressed on time. Then the industry dynamism is indicated by the standard error of the regression slope (Azadegan et al., 2013; Qu et al., 2011). The data for moderator variables are obtained from Compustat North

America.

3.2.4. Control variables

Industry profitability. In the regression analyses, we control for *industry profitability*. Generally, VC investors select firms which have high performance (Croce et al., 2013). An industry with high profitability releases a good performance signal that may attract more VC investments. In addition, high industry profitability may motivate entrepreneurs to devote more resources to innovative activities. We use ROA (return on assets), the average ratio of net income to total assets of the industry as measure of industry profitability in the regression models.

R&D intensity. We also control for industry *R&D intensity* in consistent with the literature (Anokhin and Wincent, 2014). Malerba and Orsenigo (1997) find that innovative opportunities are strongly related to R&D activities. Baumol (1993) and Nelson and Winter (2009) also suggest that companies with specialized R&D sections may have efficient R&D capability that may lead to high innovative activities. In addition, Dosi et al. (2006) find that more innovative opportunities may be created under a higher level of R&D intensity circumstances. Industry R&D intensity is measured by the ratio of R&D expenses to total sales.

Finally, we include *year dummies* in the regression analyses to account for the temporal effects caused by macro-economic conditions.

3.3. Analytical Process

To test our hypotheses 1 and 2a-2c, the following regression model is used:

$$\begin{aligned}\mathrm{IO}_{i,t} = \alpha + \textstyle\sum_{j=1}^{2} \beta_j \mathrm{Control}_{ji,t-1} + \beta_3 \ln(\mathrm{VC\ investments})_{i,t-1} + \\ \beta_4 \mathrm{Ind\_chara}_{i,t-1} + \beta_5 \ln(\mathrm{VC\ investments})_{i,t-1} \times \mathrm{Ind\_chara}_{i,t-1} + \varepsilon_{i,t}\end{aligned} \quad (1)$$

where dependent variable $\text{IO}_{i,t}$ denotes $\text{Innovative Opportunities}_{i,t}$. Independent variable $\ln(\text{VC investments})_{i,t-1}$ is the natural logarithm VC investments of the industry at time *t*-1. Control variables in regression (1) respectively indicates $\text{ROA}_{i,t-1}$ and $\text{R\&D intensity}_{i,t-1}$. Moderator variable $\text{Ind\_chara}_{i,t-1}$ denotes three industry characteristics respectively; that is, $\text{industry concentration}_{i,t-1}$, $\text{industry growth rate}_{i,t-1}$, and $\text{industry dyanmism}_{i,t-1}$. To test the moderation effects, the interactions between the three industry characteristics and VC investments are first individually and then all together added to the regressions.

To test the mediation hypothesis 3, we first follow the steps suggested by Baron and Kenny (1986) as expressed by the three regression models below:

$$\text{TAO}_{i,t} = \varphi + c\ln(\text{VC investments})_{i,t-1} + \sum_{j=1}^{5}\gamma_j \text{Control}_{ji,t-1} + \varepsilon_{i,t} \quad (2a)$$

$$\text{IO}_{i,t} = \varphi + a\ln(\text{VC investments})_{i,t-1} + \sum_{j=1}^{5}\gamma_j \text{Control}_{ji,t-1} + \varepsilon_{i,t} \quad (2b)$$

$$\text{TAO}_{i,t} = \varphi + c'\ln(\text{VC investments})_{i,t-1} + b\text{IO}_{i,t} + \sum_{j=1}^{5}\gamma_j \text{Control}_{ji,t-1} + \varepsilon_{i,t} \quad (2c)$$

where dependent variable $\text{TAO}_{i,t}$ denotes $\text{Technological Arbitrage Opportunities}_{i,t}$. We also include $\text{industry concentration}_{i,t-1}$, $\text{industry growth rate}_{i,t-1}$, and $\text{industry dyanmism}_{i,t-1}$ as control variables in regressions (2a)-(2c). We conduct the Sobel-Goodman test to further examine the mediation relationship.

All the analyses are completed in STATA 14.

4. Results

Table 1 reports descriptive statistics and pairwise correlations of major variables used in the regression analysis. Since innovative opportunities and technological arbitrage opportunities are calculated by the DEA based Malmquist index, according to Wilson (1995), measurement errors or original data errors may cause efficiency outliers. By checking the results of technological arbitrage opportunities, we find the minimum and maximum values are respective 0.0044 and 168.8148. Therefore, to eliminate the potential influence of outliers, technological arbitrage opportunities are winsorized at 1% and 95% (Lemmon and Lins, 2003). The variables exhibit reasonable correlations and can be employed in the regression analysis.

Insert Table 1 about here

We first examine the effect of VC investments on technical change, a Malmquist productivity decomposition index for innovative opportunities. As Table 2 reports, Model 1 only includes control variables. ROA was a strong, significant, negative predictor of innovative opportunities ($\beta = -0.33$, $p<0.01$), which means the creation of innovative opportunities may be reduced in an industry with high profitability. Model 2 added VC investments to test its effect on innovative opportunities. VC investments emerges as a significant and positive predictor of innovative opportunities in the industry ($\beta = 0.02$, $p<0.05$). Thus, Hypothesis 1 is supported. Model 3 added industry concentration to test its role as a moderator, and the results show that VC investments remain a significant predictor of innovative opportunities ($\beta = 0.03$, $p<0.05$), while either industry concentration or its interaction term with VC investments are not significant. Thus, Hypothesis 2a is not supported. Model 4 added industry growth rate to test its role as a moderator, and industry growth rate attains significance ($\beta = -0.39$, $p<0.01$) and the interaction term is also significant ($\beta = 0.10$, $p<0.01$). This lends support to Hypothesis 2b. Model 5 added industry dynamism to test its role as a moderator and industry dynamism attains significance (β=2.64 , p<0.01) and the interaction term is also significant ($\beta = -0.45$, p<0.01). Thus, Hypothesis 2c is supported.

Insert Table 2 about here

To further probe the directions of moderation effects, we plot the relationship between VC investments and innovative opportunities in Figs. 2 and 3 at one standard deviation above and below the mean value of the industry growth rate and industry dynamism, respectively. Fig. 2 shows that the flowing of VC investments leads to increased innovative opportunities in high growth industries, but in low growth industries, the relationship becomes negative. Fig. 3 shows that in low dynamic or stable industries, the flowing of VC investments leads to increased innovative opportunities, but leads to reduced innovative opportunities in highly dynamic industries. The findings further support H2b and H2c.

Insert Figs. 2 and 3 about here

Table 3 presents the results of VC investments on patents, an alternative measure for innovative opportunities. We can see that VC investments positively and significantly influence innovative opportunities across Models 7-10. Additionally, only the interaction term between VC investments and industry concentration is significant ($\beta = -0.52$, p<0.01), but the other two interaction terms are not significant (p>0.10), which are different with the results in Table 2.

Insert Table 3 about here

Table 4 exhibits the mediation results regarding the mediation role of innovative opportunities (measured by technical change) on the relationship between VC investments and technological arbitrage opportunities. Consistent with Baron and Kenny (1986), to investigate the mediation of innovative opportunities, regressions (2a)-(2c) are estimated one by one. First, VC investments positively affect technological arbitrage opportunities ($c=0.03$, $p<0.05$). Second, VC investments positively affect innovative opportunities ($a=0.02$, $p<0.05$). Third, innovative opportunities positively affect technological arbitrage opportunities ($b=0.45$, $p<0.05$), but the positive effect of VC investments on technological arbitrage opportunities is no longer significant ($c'=0.02$, $p>0.10$). Moreover, we test the mediation of innovative opportunities based on Sobel (1982), the Sobel-Goodman mediation results show that the proportion of total effect that is mediated is 0.37, the ratio of indirect to direct effect is 0.58, and the ratio of total to direct effect is 1.58.

Insert Table 4 about here

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5. Discussion

The purpose of our study is to examine the effect of VC investments on entrepreneurial opportunities at the industry level. In line with the market disequilibrium theory, entrepreneurial opportunities are primarily divided into innovative opportunities and technological arbitrage opportunities. Although a body of literature investigate the relationship between VC investments and performance or productivity growth (e.g., Bertoni and Tykvová, 2015; Chemmanur et al., 2011; Croce et al., 2013), very few studies have explored the impact of VC investments on entrepreneurial opportunities. We fill this gap by examining the impact of VC investments on innovative opportunities as well as the mediation role of innovative opportunities on the relationship between VC investments and technological arbitrage opportunities. Therefore, this study makes contributions to both VC and entrepreneurial opportunities studies.

On one hand, the empirical results show that VC investments are positively affect innovative opportunities in the industry. Because of innovative opportunities contributes to the radical improvement of the technologies, even create the new business models (Cohen and Winn, 2007), we suggest that entrepreneurial companies should attract more VC investments because it is positively related to the innovative activities. In addition, when technical change index is used as a measurement of innovative opportunities, the results of this study demonstrate that industry growth rate and industry dynamism significantly moderate the relationship between VC investments and innovative opportunities in the industry. VC-backed companies in high growth industries typically have more market opportunities and enhanced decision-making discretion (Datta et al., 2003; Guthrie and Datta, 2008), and the abundant resources facilitate these companies taking full advantage of the supports provided by VCs to conduct innovative activities and finally create more new means-ends frameworks. Whereas the external dynamic environments increase the uncertainty and risk of the innovative opportunities, in this case, VC-backed companies may face high possibility of failure, therefore they will reduce the exploratory activities in dynamic industry environments. One interesting thing should be noted that when patents are used as an alternative measure for innovative opportunities, only one interaction term shows significance (Model 8). As explained by Anokhin and Wincent (2012), who found that the coefficient of start-up rates on patents are not significant but the coefficients on total factor productivity based on Malmquist productivity are marginal significant, perhaps using patents to measure innovative opportunities is not precisely since the patents may neglect the record of radical technology breakthroughs, but technical change index based on Malmquist productivity may grasp the innovative opportunities which are not filed as patents (e.g., new production mode).

On the other hand, this study verifies that innovative opportunities play a mediation role on the positive relationship between VC investments and technological arbitrage opportunities. With the help of VC investments, the innovators move to a new market and create new opportunities that unknown to the other entrepreneurs. By creating new markets or technologies, the first movers create opportunities not only for themselves but also for the followers (Cohen and Winn, 2007), the alert arbitrageurs notice the imperfect of the market and will imitate the new innovations created by pioneers (Anokhin, 2013). They may obtain superior profits in the short term by using the imitation strategy. That is, imitator-entrepreneurs face the low uncertainty and low probability of failure in the entrepreneurial process since they imitate the mature and repeatedly practiced technology and could obtain a quick return in a short period of time. Thus, more and more imitators move into the market to exploit technological arbitrage opportunities until entrepreneurial rents are disappeared, and finally the markets move to a new and more efficient equilibrium status.

In the *ad hoc* analysis, we further explore the effect of VC investments on technological arbitrage opportunities via the moderator: *industry concentration*, *industry growth rate*, and *industry dynamism*. While VC investments significantly and positively influence technological arbitrage opportunities at the industry level, the moderation effect of the industry characteristics on the relationship between VC investments and technological arbitrage opportunities is not significant. In fact, we should acknowledge the importance of technological arbitrage opportunities. Many entrepreneurs who start a new company, prefer going after technological arbitrage opportunities to innovative opportunities because imitation is relatively easier than innovation and exposed to lower risk and lower uncertainty (Anokhin et al., 2011). Indeed, the previous literature has found that technological arbitrage opportunities positively relate to the creation of new firms (Anokhin et al., 2011), firm migration (Anokhin, 2013), and firm entry rates (Anokhin and Wincent, 2014). Therefore, academics and practitioners should acknowledge the importance of technological arbitrage opportunities in that they contribute to higher efficiency and productivity by imitating novel means-ends frameworks (Anokhin et al., 2011). Nevertheless, the entrepreneurs should not pursue technological arbitrage opportunities blindly, that is imitation will reduce their enthusiasm of learning new knowledge and new skills, even worse they will lose the competitive advantage (McGrath, 2001).

It should be note that there are several other interesting avenues for future research on this topic. First, this study examines the relationship of VC investments and entrepreneurial opportunities at the U.S. industry level (45 industries belong to SIC codes 2741 to 8731). We could further test the same relationship in the other U.S. industries such as Energy industry, Chemical industry etc. Additionally, it would be interesting to see if such relationships hold at regional or national levels. Exploring the effect of VC investments on entrepreneurial opportunities at different levels could reveal new insights for academics and practitioners. Different from industry, the economic development levels as well as the institutional conditions are main external factors when examine the relationship between VC investments and entrepreneurial opportunities at national level, even the institutional theory can be introduced to the explain such relationship, thus the results may suggest different implications from those obtained at industry level.

Second, our empirical analysis demonstrates the significant influence of VC investments on entrepreneurial opportunities. On the other hand, the reciprocal relationship entrepreneurial opportunities and VC investments may also exist; that is the existence of entrepreneurial opportunities may attract VC investments into an industry. Moreover, it deserves future research to study which type of entrepreneurial opportunities, i.e., innovative opportunities or technological arbitrage opportunities, attract VC investments more than the other.

6. Conclusions

In this work, using a novel United States industry level panel data, we investigate the effect of VC investments on innovative opportunities and examine the mediation effect of innovative opportunities on the relationship between VC investments and technological arbitrage opportunities. The results of this study find that VC investments positively influence innovative opportunities and innovative opportunities mediate the positive effect of VC investments on technological arbitrage opportunities. In addition, when the innovative opportunities are measured by technical change, a Malmquist productivity decomposition index, the results show that high growth environments enhance the effect of VC investments on innovative opportunities, however, dynamic industry environments weaken the effect of VC investments on innovative opportunities. Therefore, the VC-backed entrepreneurs should carefully take the external industry environments into consideration when creating or discovering innovative opportunities. At last, we hope this study stimulates such research of VC investments and entrepreneurial opportunities, and we encourage more research efforts devoted to this specific area.

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Table 1
Descriptive statistics and correlations

		Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1	IO (Technical change index)	1.09	0.71	1.00											
2	IO (Patent applications)	3.56	2.00	0.05*	1.00										
3	TAO	1.26	0.94	0.35***	0.05*	1.00									
4	VC	3.57	2.31	0.08***	0.49***	0.08***	1.00								
5	Industry concentration	0.22	0.18	0.01	-0.21***	0.00	-0.34***	1.00							
6	Industry growth rate	0.32	5.57	-0.03	-0.03	-0.02	0.00	0.11***	1.00						
7	Industry dynamism	0.05	0.07	0.12***	-0.09***	0.04*	-0.04	0.13***	0.01	1.00					
8	ROA	0.01	0.14	-0.08***	0.07**	0.06**	0.02	-0.18***	0.01	-0.10***	1.00				
9	R&D intensity	0.04	0.05	0.04	0.59***	0.01	0.31***	-0.07***	-0.03	-0.02	-0.06**	1.00			
10	Year 1987 dummy	0.03	0.17	-0.01	-0.03	-0.04	-0.05*	-0.03	0.00	-0.02	0.00	0.00	1.00		
11	Year 2000 dummy	.0.03	0.17	-0.06**	0.04	0.16***	0.05*	0.00	-0.01	0.03	-0.04	0.06**	-0.03	1.00	
12	Year 2008 dummy	0.03	0.17	0.28***	0.03	0.16***	0.07**	-0.03	-0.01	0.03	-0.05**	0.01	-0.03	-0.03	1.00

Note: n=1,518. IO, TAO, and VC respectively stands for Innovative opportunities, Technological arbitrage opportunities, and Venture capital investments.

* p<0.1

** p<0.05

*** p<0.01

Table 2

Results on the impact of VC investments on innovative opportunities (technical change index)–panel regression random models

	Innovative Opportunities (Technical change index)				
Variables	(1)	(2)	(3)	(4)	(5)
ROA	-0.33***	-0.28**	-0.26*	-0.26**	-0.21
	(0.12)	(0.13)	(0.14)	(0.13)	(0.13)
R&D intensity	0.55	0.23	0.16	0.22	0.23
	(0.38)	(0.45)	(0.47)	(0.45)	(0.46)
Year 1987 dummy	-0.03	-0.03	-0.03	-0.03	-0.02
	(0.10)	(0.12)	(0.12)	(0.12)	(0.12)
Year 2000 dummy	-0.26**	-0.27**	-0.29**	-0.26**	-0.32***
	(0.11)	(0.11)	(0.12)	(0.11)	(0.11)
Year 2008 dummy	1.16***	1.05***	1.04***	1.06***	1.03***
	(0.11)	(0.12)	(0.12)	(0.12)	(0.12)
Venture capital investments (X)		0.02**	0.03**	0.01	0.05***
		(0.01)	(0.01)	(0.01)	(0.01)
Industry concentration (M1)			0.13		
			(0.19)		
X×M1			-0.03		
			(0.06)		
Industry growth rate (M2)				-0.39***	
				(0.12)	
X×M2				0.10***	
				(0.03)	
Industry dynamism (M3)					2.64***
					(0.49)
X×M3					-0.45***
					(0.13)
Constant	1.05***	1.00***	0.97***	1.03***	0.85***
	(0.03)	(0.04)	(0.06)	(0.04)	(0.05)
Significance test	Wald	Wald	Wald	Wald	Wald
Chi square	142.38	97.19	95.93	108.80	127.42
Probability	<0.001	<0.001	<0.001	<0.001	<0.001
Observations	1,515	1,179	1,149	1,179	1,149
Number of industry	45	45	45	45	45

* p<0.1

** p<0.05

*** p<0.01

Table 3

Results on the impact of VC investments on innovative opportunities (patents)–panel regression random models

	Innovative Opportunities (Patents)				
Variables	(6)	(7)	(8)	(9)	(10)
ROA	0.21	0.38*	-0.05	0.38*	0.41**
	(0.20)	(0.21)	(0.20)	(0.21)	(0.20)
R&D intensity	13.84***	12.31***	11.61***	12.47***	12.82***
	(1.26)	(1.37)	(1.30)	(1.37)	(1.35)
Year 1987 dummy	-0.60***	-0.46***	-0.53***	-0.45**	-0.43**
	(0.17)	(0.18)	(0.17)	(0.18)	(0.18)
Year 2000 dummy	0.46***	0.25	0.27*	0.22	0.24
	(0.17)	(0.16)	(0.16)	(0.17)	(0.16)
Year 2008 dummy	0.35**	0.25	0.16	0.24	0.27
	(0.17)	(0.17)	(0.16)	(0.17)	(0.17)
Venture capital investments (X)		0.23***	0.27**	0.24***	0.22***
		(0.02)	(0.03)	(0.02)	(0.02)
Industry concentration (M1)			-0.68**		
			(0.31)		
X×M1			-0.52***		
			(0.09)		
Industry growth rate (M2)				0.40	
				(0.27)	
X×M2				-0.10	
				(0.06)	
Industry dynamism (M3)					3.72***
					(1.00)
X×M3					-0.26
					(0.23)
Constant	2.49***	1.89***	2.19***	1.85***	1.72***
	(0.20)	(0.20)	(0.21)	(0.18)	(0.19)
Significance test	Wald	Wald	Wald	Wald	Wald
Chi square	150.73	304.46	438.16	313.20	342.51
Probability	<0.001	<0.001	<0.001	<0.001	<0.001
Observations	1,185	969	969	969	969
Number of industry	44	43	43	43	43

* p<0.1

** p<0.05

*** p<0.01

Table 4

Results on the mediation of innovative opportunities

Variables	Technological Arbitrage Opportunities (Y)	Innovative Opportunities (M)	Technological Arbitrage Opportunities (Y)
Venture capital investments (X)	0.03**	0.02**	0.02
	(0.01)	(0.01)	(0.01)
Innovative opportunities (M)			0.45***
			(0.04)
ROA	0.60***	-0.21	0.69***
	(0.19)	(0.14)	(0.18)
R&D intensity	-0.36	0.24	-0.47
	(0.63)	(0.47)	(0.59)
Year1987 dummy	-0.16	-0.02	-0.15
	(0.16)	(0.12)	(0.15)
Year2000 dummy	1.07***	-0.31***	1.20***
	(0.16)	(0.11)	(0.15)
Year2008 dummy	0.66***	1.04***	0.20
	(0.16)	(0.12)	(0.16)
Industry concentration	0.11	0.05	0.08
	(0.18)	(0.14)	(0.17)
Industry growth rate	-0.12**	-0.04	-0.10**
	(0.05)	(0.04)	(0.04)
Industry dynamism	0.45	1.32***	-0.14
	(0.45)	(0.33)	(0.42)
Constant	1.10***	0.91***	0.69***
	(0.08)	(0.06)	(0.08)
R-squared	0.07	0.08	0.17
Adj. R-squared	0.07	0.16	0.17
Observations	1149	1149	1,149

* p<0.1

** p<0.05

*** p<0.01

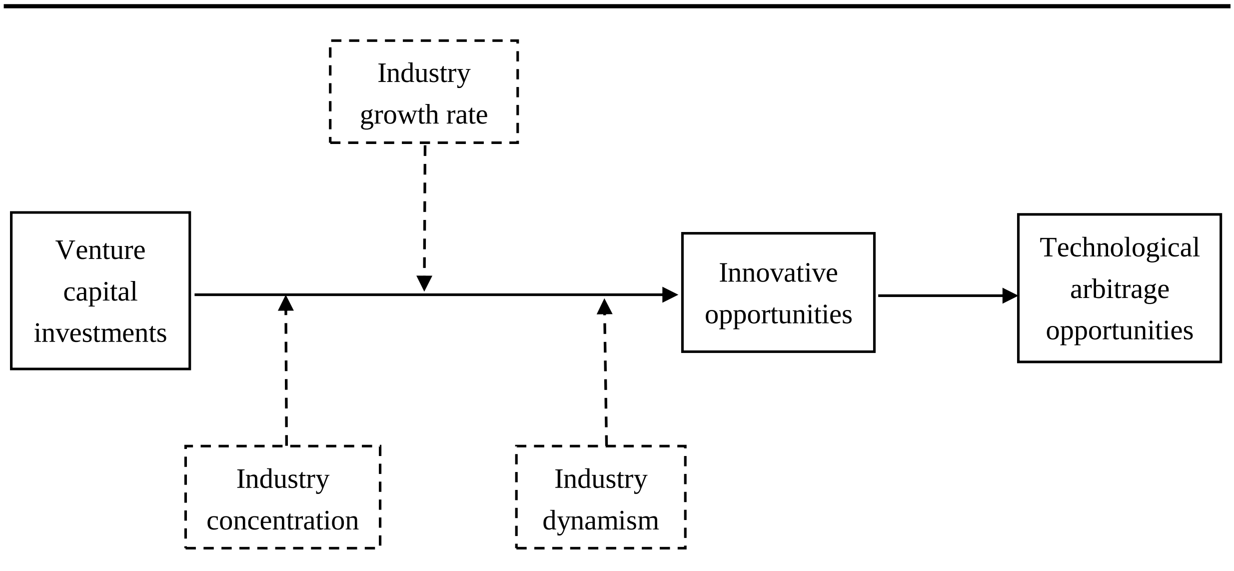

Fig. 1. Conceptual model

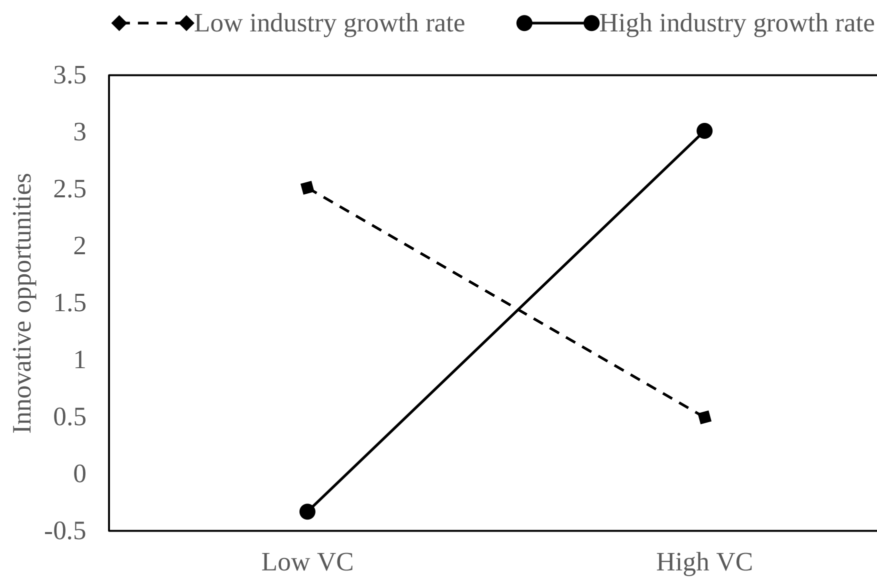

Fig. 2. Moderation effects of industry growth rate

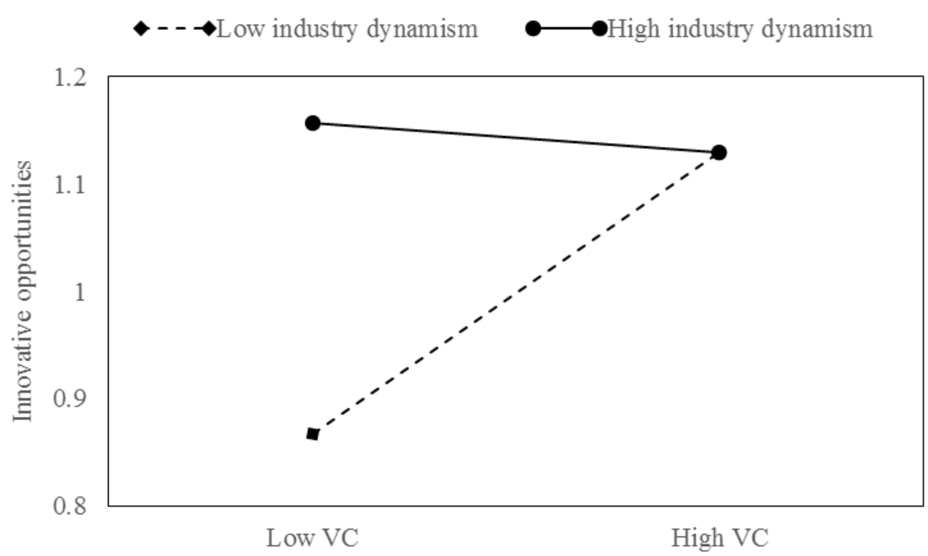

Fig. 3. Moderation effects of industry dynamism