

Venture Capital Early Stage Investment Success in ICT Industry: The Role of Technological and Financial Expertise

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Abstract

Using a human capital perspective, this study investigates the relationship between the specific human capital of the top management teams of venture capital firms (VCFs) and the firms' investment performance.

The results of this study demonstrate that, in the early-stage information technology and communication (ICT) industry, VCFs' *technological expertise* strongly predict better venture capital firm performance in the form of greater portfolio exit ratio. While *financial expertise* shows a positive but not significant effect. This study finds that although venture capital investing is a financial activity, *technological expertise* is the human capital characteristic that is more appropriate for this sub-environment. Future research is suggested.

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1 Introduction

Venture capital (VC) investment has attracted widespread attention as one of the significant sources of financial support (Maier and Walker, 1987). Venture capital firms (VCFs) allow entrepreneurs to explore uncertain but innovative ideas to be tested in practice (Dimov, de Holan & Milanov, 2012). Early academic writing and practical discourse on VC has focused on what venture capitalists typically do and VCF's positive contribution as a homogeneous concept (Landström, 2012). There was much less focus on the differences among VCFs (Dimov and De Clercq, 2006). VCFs make heterogeneous investment decisions because VCFs are different in terms of legal form, size, motives, and criteria for investing, timing, and exit methods (De Clercq and Dimov, 2008). VCFs also report wide variations in the outcomes of their investments, with roughly one-quarter losing money and almost 10% earning ten times their investment (Gompers et al., 2016). Therefore, to fill this gap, this study focuses on the differences among VCFs and explores the reasons that lead to VCFs' performance difference from a human capital perspective.

While there is a large amount of management literature that investigates the role of human capital on organizational outcomes (e.g., Beckman, Burton & O'Reilly, 2007), there is comparatively little research that applies a human capital lens to explain differences in VCFs' investment performance (Zarutskie, 2010; Milosevic, 2018). Making and managing investments is a research- and information-based activity that requires a large amount of human effort (Zarutskie, 2010), therefore, human capital should be a key factor that influences performance. Recent research also shows that variations in human capital can explain differences in both the types of investments VCFs make (e.g., Dimov, Shepherd & Sutcliffe, 2007; Patzelt, zu Knyphausen-Aufsess & Fischer, 2009) and the performance of investments (e.g., Dimov and Shepherd, 2005; Zarutskie, 2010; Milosevic, 2018; Milosevic, Le Pendeven & Fendt, 2018). However, existing research gets mixed results regarding the relationship between various human capital characteristics and performance.

Recent research argues that previous human capital studies on VC have mainly focused on the quantitative nature of an individual venture capitalist's human capital (Dimov and Shepherd, 2005). Researchers have generally focused on the breadth or amount of variety within a team, i.e., the idea that more is better, and have accordingly used measures such as years of experience or degree of education (Bruderl, Preisendorfer & Ziegler, 1992; Cooper, Gimeno-Gascon & Woo, 1994;

Gimeno et al., 1997), thereby overlooking the “relevance” of the variety. Recent work calls for the qualitative understanding of human capital in entrepreneurship research (Dimov, 2017) by using the type of human capital rather than the amount as factors to explain its influence (e.g. Dimov and Shepherd, 2005; Dimov, Shepherd & Sutcliffe, 2007; Zarutskie, 2010; Milosevic, 2018; Milosevic, Le Pendeven & Fendt, 2018). The type of human capital should be a significant influence factor because performance depends on the “appropriateness” of the team’s specific knowledge for the organization’s environment or strategy (Dimov, Shepherd & Sutcliffe, 2007). The higher appropriateness of the team's knowledge for the organization's environment or strategy, the higher performance should be yielded (Dimov, Shepherd & Sutcliffe, 2007).

To study the “appropriateness” of human capital, more and more researchers realize the significance to distinguish between general human capital and specific human capital and study the effect of specific human capital on VCFs’ performance (e.g. Dimov and Shepherd, 2005; Dimov and De Clercq, 2006; Dimov, Shepherd & Sutcliffe, 2007). Specific human capital is specific to a particular time or setting, such as human capital specific to a firm, industry or task (Murray, 1995; Manigart, Baeyens & Van Hyfte, 2002). General human capital is defined as skills that can be generally applied across most firms and settings (Becker, 1964). This study follows the stream of studies that focus on the effect of specific human capital and try to answer the call of qualitative understanding of VCFs’ human capital.

In line with Milosevic (2018) and Zarutskie (2010), this study defines specific human capital as accumulated education and experience related to important tasks that contribute to VCFs’ investment success. The specific human capital of VCFs in this study is represented by a firm’s top management teams (TMTs). There is increasing acknowledgment that the impact of human capital composition on VC investment performance should be studied at the team-level (Carpenter, Geletkanycz & Sanders, 2004) because strategic decisions at the organizational level are made by entire top management teams rather than by individual VC managers (Hambrick and Mason, 1984).

To test the effect of specific human capital at a team-level, this study introduces two new specific human capital- *technological expertise* and *financial expertise*, which capture key team-level characteristics in a more specific way. Some of the items comprising this two construct have been tested in prior research as separate variables (e.g., Dimov and Shepherd, 2005; Casson and Martin,

2007; Zarutskie, 2010), but this study shows that they jointly represent the broader concept of a TMT's perceived readiness to engage in its portfolios.

To further explore the effect of “appropriateness” of human capital on VCFs performance, this study confines the investments to a specific sub-environment. Prior research suggests that VCFs' invest environment is not an undifferentiated whole (Dimov, Shepherd & Sutcliffe, 2007). VCFs make heterogenous investments in terms of the preferences of geographic location, investment stages and investment industries (De Clercq and Dimov, 2008). Also, the needs of portfolio companies from VCFs are heterogeneous when they are in different industries and development stages (Knockaert et al., 2006). A team's expertise must be “appropriate” for the tasks and challenges posed by the sub-environments that VCF faces to yield competitive advantages for the VCFs (Dimov, Shepherd & Sutcliffe, 2007). To test the implications of VCFs' *financial expertise* and *technological expertise* on investment success, this study sets the investment sub-environment as investing in the early-stage information technology and communication (ICT) start-ups.

Overall, accumulated empirical evidence on the relationships between specific types of human capital and specific types of investment performance (early-stage technology-based investment) is still relatively limited. This research is important since it further theorizes how differences in the human capital of venture capital management teams may give their investment a performance advantage. By drawing on an upper echelon theory, the theoretical insights of this research will also add important team- and firm-specific elements to the understanding of VC investment performance. To fill this gap, the following question is studied in this study:

To what extent are specific human capital characteristics of venture capital firms' top management teams associated with their early-stage investment performance in the information and communication technology (ICT) industry?

Inquiry into this research question may provide three major benefits. For the scholar, this study will gather empirical evidence on the relationships between specific types of the human capital of VCFs and investment outcome. For VCFs, they may benefit from the improved selection and development of upper-level executives to better execute their portfolio strategy and achieve higher economic returns. For entrepreneurs seeking venture capital finance, this study may increase their

awareness of the value a VCF can bring to their start-ups. An analysis of VCFs' top management teams may help them choose a VCF that could make the greatest contribution to their success.

The remainder of the article is structured into the following sections. Section 2 presents a systematic literature review and demonstrates all the related theories that back up this study. Section 3 discusses the theoretical framework and hypotheses, which will guide the study. Section 4 describes the research methodology, specifically the data and analytical approach to be utilized in the study. Section 5 presents the results of the analysis. Section 6 demonstrates the limitations of the study. Section 7 concludes with the research and outlines future implications.

2 Theories

Venture capital firms (VCFs) provide new ventures with funds when entrepreneurial firms cannot obtain them from traditional channels, such as banks or other sources of debt financing (Maier and Walker, 1987). Venture capital is a financial intermediary, meaning that it raises funds from various investors and then seeks to invest these funds in private companies to achieve superior investment returns (Podolny, 2001). The existing literature suggests that the returns from their investments are achieved by realizing an “exit” five to seven years after the investment, thereby turning their illiquid stakes in private ventures into realized returns in the form of cash distributions or stock distributions (Gompers and Lerner, 1998; Gompers and Lerner, 2001). In between raising venture funds and finally returning capital to investors, the venture capital cycle is comprised of pre-investment activities: screening and investing, and post-investment activities: monitoring and adding value and exiting (Gompers and Lerner, 1998). VCFs can increase the return potential of their investments by (1) selecting ventures with the highest potential pre-investment and (2) engaging in value-adding services post-investment (Baum and Silverman 2004; Landström, 2007).

2.1 VC investment success

According to Cumming and MacIntosh (2003) and Cumming (2008), there are five types of VC exits: (a) an IPO, in which a significant portion of the investee firm is sold to the public; (b) an acquisition exit, in which the entire firm is bought by a third party; (c) a secondary sale, in which only the VCs’ shares are sold to a third party while the owners of the investee firms maintain their shares and ownership; (d) a buyback, in which the owners repurchase the shares from the VCs; and (e) a write-off, in which the VCs withdraw from their investment. An IPO or an M&A is typically considered as a “successful” VC exit (Gompers & Lerner, 1998; Nitani & Riding, 2013). Although it is imperfect as it does not account for investment costs or ownership stakes, the venture capital literature mostly relies on ‘exits’ as a measure of performance (Gompers and Lerner, 1998; Brander et al., 2002).

The success of a start-up is a joint effort that is made by both entrepreneurs and VCFs. Besides financial resources, VCFs contribute to entrepreneurial companies through active managerial involvement, strategic oversight, and corporate governance (Bottazzi, Da Rin & Hellmann, 2008).

Entrepreneurs specialize in the development of knowledge about combining resources to exploit new opportunities and in the day-to-day development of new business activities, while VCs focus mainly on creating networks to reduce the cost of acquiring capital, to find customers and suppliers and to establish the venture's credibility (MacMillan, Kulow & Khoylian, 1989).

The venture capital literature has identified a broad role for the investor that goes beyond the simple provision of finance. For instance, VCs often serve as a sounding board for management ideas, have an operational/networking role as a provider of contacts with customers and recruits, and play an interpersonal role as a friend, mentor, and confidant (Sapienza, Amason, and Manigart 1994; Sapienza, Manigart & Vermeir, 1996). During the whole venture capital cycle, VCFs' jobs include the monthly monitoring of financial performance and operational milestones, corporate governance, the formulation of the business model, the development of relationships with resource providers and customers, membership on the board of directors, and the recruitment of important personnel (Hellmann and Puri, 2002). Those activities are largely non-contractible yet may have real consequences (Bottazzi, Da Rin, & Hellmann, 2008).

The human capital theory posits that individuals with higher-quality human capital achieve higher performance in executing such pre- and post-investment activities of the venture capital process (Dimov and Shepherd, 2005). Specifically, higher-quality human capital can result in effective portfolio selection, which results in funding the most promising projects; an effective post-investment monitoring process, which can help enhance information availability for VCs, aid in early problem detection, and promote effective decision making in the investee companies (Mitchell, Reid & Terry, 1997); and effective value-adding behavior, which leads to more explosive growth and more sustainable advantages for portfolio companies, translating into higher company and shareholder value. Lower human capital was identified as one of the key determinants of the lower performance of VCFs, impairing both firm selection (Wright et al., 2006) and value-adding behavior (Sapienza, Manigart & Vermeir, 1996). As stated before, the human capital study of VC used to focus on the individual VC managers and employed a quantitative way to evaluate the "quality" of the human capital (Carpenter, Geletkanycz & Sanders, 2004; Dimov and Shepherd, 2005). Therefore, this study is trying to evaluate the "quality" of the human capital from a qualitative perspective at the team level.

2.2 Early-stage investment in the technology industry

This study evaluates the human capital effect of VCFs that prefer investing in early-stage information technology and communication (ICT) start-ups. This setting gives us a great opportunity to observe how significant specific human capital can be to VC investment performance. Knockaert and Vanacker (2013) suggest that the requirement of VCFs that invest in early-stage high-tech companies is different from their peers, who focus on later-stage companies' activities in low-tech industries. The appropriateness of the team's specific human capital can play a greater role when VCFs invest in the early-stage technology start-ups than start-ups in other industries and stages (Dimov, Shepherd & Sutcliffe, 2007).

While technology-based start-ups can offer a significant potential contribution to innovation, new employment creation, export sales growth and regional development (Freeman, 1983), public securities markets and institutional lenders are hesitant to provide credit to such start-ups (Gupta and Sapienza, 1992). This is because of the high cost of lending to technology-based start-ups in terms of information asymmetry, the high risks associated with repayment, and a lack of collateral (Amit, Brander & Zott, 1998). Venture capital, therefore, becomes a significant financial source for technology-based new ventures. The percentage of venture capital invested in technology firms never falls below 70% of annual investments (Acs, 2010). Approximately 90% of all venture capital (VC) investment in the US and Canada is in technology investments (Cumming, 2007). VCFs allow entrepreneurs to explore the merits of various technologies outside the rigid confines of large corporations, permitting uncertain but interesting ideas to be tested in practice (Dimov, de Holan & Milanov, 2012; Landström, 2012). In return, the success of technology portfolio firms generates a great economic return for VCFs.

Previous studies provided evidence showing that early-stage VCs differ from late-stage VCs (Elango et al. 1995), and that high-tech VCs differ from non-high-tech VCs (Lockett, Murray & Wright, 2002). In particular, the majority of early-stage investments tend to be in high-technology industries (Dimov, Shepherd & Sutcliffe, 2007). Early-stage technology-related investments are risky in general because of the uncertainty surrounding the existence and size of the markets they are expected to serve (Knockaert, Clarysse & Wright, 2010). The market uncertainty and significant monitoring costs of assessing early-stage seed investments in technology and science-

based fields mean that few venture capital investments are made before a proof of concept becomes available (Lockett, Murray & Wright, 2002). Also, studies show that the early-stage high-tech sector particularly requires VCFs, on average, be more involved in value-adding activities (Sapienza, Manigart & Vermeir, 1996), which require a huge amount of human capital to be involved.

Early-stage investment

The aggregate availability of funding for early-stage companies has historically been important for economic growth and technological innovation (Chaplinsky and Gupta-Mukherjee, 2016). In terms of the preference of investment stages, VCFs make heterogeneous investment decisions because VCFs are different in terms of legal form, size, motives, and criteria for investing, timing, and exit methods (De Clercq and Dimov, 2008). Some prefer to invest in early-stage companies in the process of exploring ideas for which commercial products or tested markets have not yet been developed, while others prefer late-stage companies with well-defined markets and product characteristics that are seeking to expand or improve their established business (Dimov, Shepherd & Sutcliffe, 2007). Although early-stage financing faces a lower probability of success, it generates higher cash flows from successful projects (Kang, Burton & Mitchell, 2011). Prior research has shown that an early-stage fund strategy is likely to post a higher Internal Rate of Return (IRR) than a late-stage fund strategy in the long run (Stevenson, Muzyka, & Timmons, 1986). However, venture capitalists are not known for having the significant first-mover advantage of the sort that theoretical research has emphasized (Kulatilaka and Perotti, 1998). Instead, it has been well documented that the less developed a prospective company, the higher the uncertainty of a VCF when making investment decisions (Podolny, 2001). Investment in an early-stage company tends to entail higher project-specific uncertainty concerning the costs and benefits of the project (Li and Mahoney, 2011). A previous study also found that an early-stage focus of VCFs is negatively correlated with a firm's success (Lindsey, 2008).

The proportion of VC investments in early-stage companies has varied from a high of 44% in 1986 to a low of 20% in 2001, with considerable variation in between (Chaplinsky and Gupta-Mukherjee, 2016). According to NVCA 2017 Yearbook, there are \$24.11 billion VC deals (35%) are invested

in the early-stage compared to \$38.39 billion (55%) in later stage and \$6.61 billion (10%) on angel/seed stage (*Figure 1*).

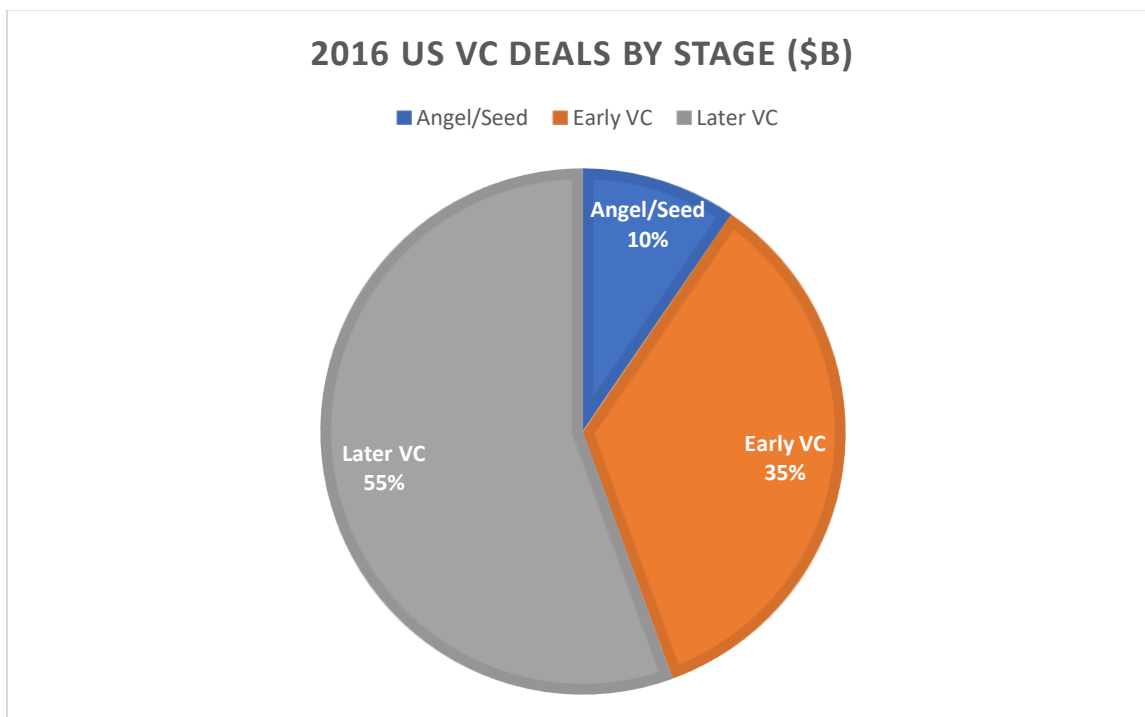


Figure 1: VC INVESTMENT BY STAGE (NVCA 2017 Yearbook)

Investment in the ICT industry

The percentage of venture capital invested in technology firms never falls below 70% of annual investments (Acs, 2010). Approximately 90% of all venture capital (VC) investment in the US and Canada is in the technology industry (Cumming, 2007). As shown in the *Figure 2*, within the technology industry, the software takes a large proportion of the investment- \$32.98 billion in 2016 (NVCA 2017 Yearbook), compared to the second-largest investee industry- pharmaceutical & biotech, which was \$7.79 billion in 2016 (NVCA 2017 Yearbook). The investments in “IT hardware”, “Software” and “Media” take around 54% of all VC deals in 2016 (NVCA 2017 Yearbook). Therefore, this study mainly focuses on the VCFs that invest in the information and communication technology (ICT) industry according to the North American Industrial Classification System (NAICS). Using this classification system, the ICT industry is defined as the sum of ICT manufacturing (NAICS 334: Computers and Electronic Products, including

Computer and Peripheral Equipment, Communication Equipment and Semiconductors), and ICT services (NAICS 5112: Software Publishers; NAICS 517: Telecommunications, including Wired and Wireless Telecommunications; NAICS 518: Data Processing, Hosting, and Related services; NAICS 5415: Computer Systems Designs and Related Services; and NAICS 51: Information), excluding traditional paper publishing.

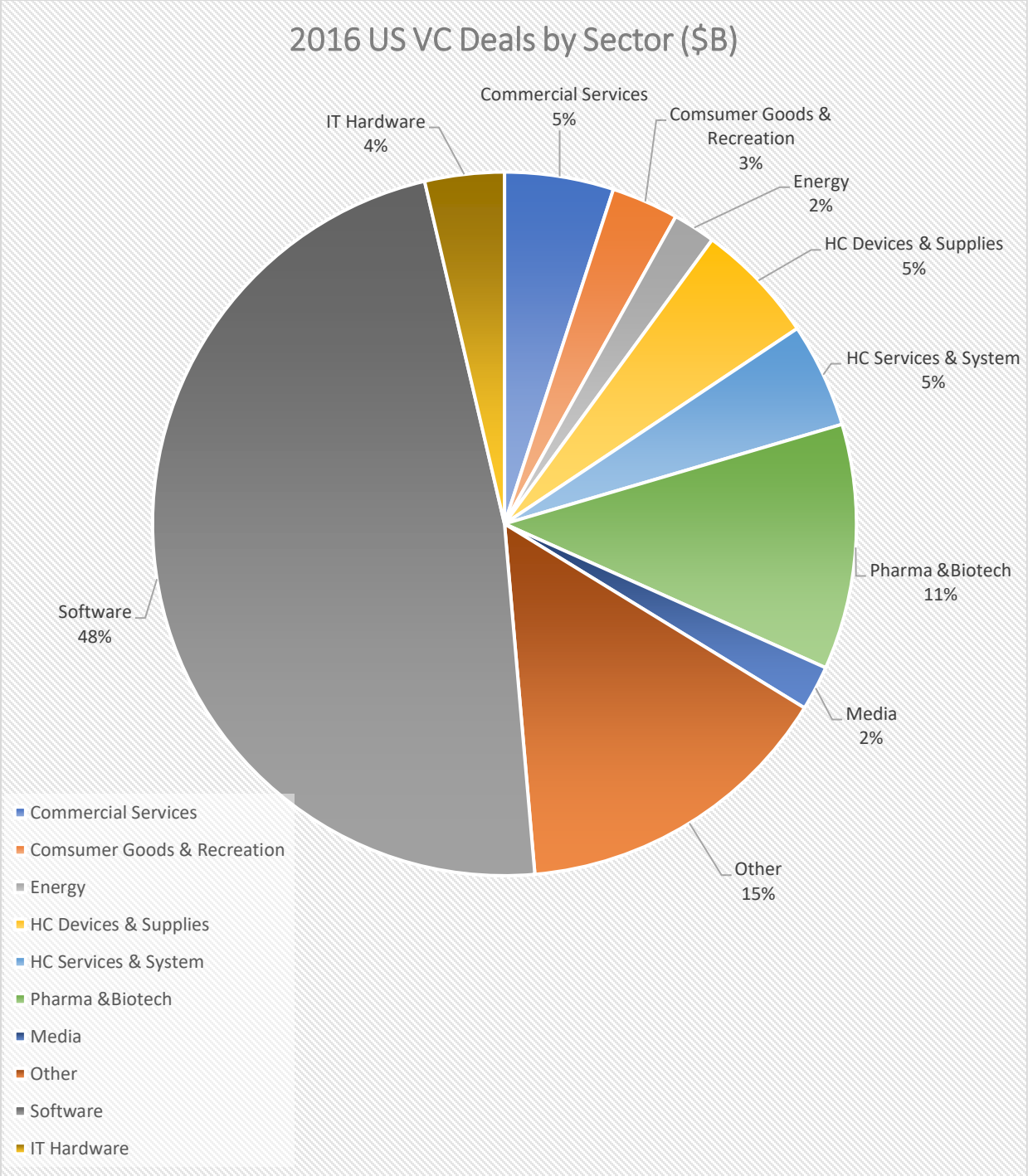


FIGURE 2: VC INVESTMENT BY INDUSTRY (NVCA 2017 Yearbook)

Commercializing new technologies is a process fraught with difficulties, given that early-stage high-tech ventures often operate in emerging, rapidly changing and global markets and exploit technologies that are radically new (Knockaert, Clarysse & Wright, 2010). Late-stage ventures

have well-defined product-market characteristics that allow for a better estimation of the potential portfolio company's future payoffs and level of unsystematic risk. As a consequence, late-stage investments represent a context in which risk (including agency risk) can be better managed (Amit, Brander & Zott, 1998; Carter and Van Auken, 1994; Eisenhardt, 1989). Auerswald and Branscomb (2003) show that independent VCFs often appear to shy away from risky high-tech entrepreneurial firms (i.e., the financial returns are not high enough to justify the investment risk), and they prefer business ideas (and associated firms) that are already significantly developed. Therefore, investing in early-stage technology start-ups could be a real challenge to VCFs that requires VCFs to perform effective pre-investment and post-investment activities. The following section reviews the existing argument regarding how human capital plays a role in the pre-investment and post-investment process in early-stage technology investment.

Pre-investment activities

Since emerging markets typically lack well-developed networks of intermediaries and consultants, VCs in these regions have been found to rely more on the internal expertise of the venture capital firm when appraising investments (Wright, Lockett & Pruthi, 2002). The existing literature has shown that organizational-level strategic decisions to build portfolios with a focus on specific investment stages are influenced by the composition of VC organizations' TMTs (e.g. Patzelt, zu Knyphausen-Aufsess & Fischer 2009). Decisions to invest in ventures are likely to hinge on the extent to which decision-makers perceive the venture to be risky and the extent to which they expect there will be a proper risk-return balance (Dimov and Shepherd, 2005; Dimov, Shepherd & Sutcliffe, 2007).

Some literature that explored the relationship between specific human capital and portfolio selection strategy has been included in this study as support literature, which mainly focuses on the decision of whether to invest in the early-stage technology firms. For instance, Dimov, Shepherd & Sutcliffe (2007) did an empirical study in the US and found that financial expertise is associated with a lower proportion of early-stage investments. Patzelt, zu Knyphausen-Aufsess & Fischer (2009) found that VCFs with higher proportions of TMT members with science/engineering education and entrepreneurial experience are more likely to invest with an early-stage focus. Knockaert et al. (2010) categorized one type of VC investor as "technology

investors”. They argue that “technology investors” seem to invest to a large extent in the seed phase and they may therefore mainly base their decision on the characteristics of the technology.

Based on previous literature, risk recognition is the main theoretical mechanism used in the literature to explain why VCFs make various investment decisions (Fiet, 1995; Wright, Lockett & Pruthi, 2002). This is because the failure rate of new ventures is high, and failed investments may yield considerable losses for VC investors (Wright, Lockett & Pruthi, 2002). The literature suggests that information asymmetries that typically exist between entrepreneurs and VCFs are specifically important in high-tech companies, where investors may find it difficult to evaluate technology and its potential market (Gompers and Lerner, 1998). Three risks are most prevalent: market risk, technological risk, and agency risk (Fiet, 1995; Sapienza and Gupta, 1994). Individuals tend to focus their attention on aspects of their environment where they have prior knowledge (Levinthal and March, 1993). That is, VC managers will choose portfolio strategies based on the perceptions of the types of risks that are related to their prior knowledge. For example, a VC manager with a technical background will assess a particular portfolio strategy using their perceptions of technological risk and less so based on their perceptions of market and agency risks.

Also, to secure privileged knowledge, VCs seek out external expertise before committing themselves. In many cases, investors screen the deals by consulting the board or an external expert source (Casson & Nisar, 2007). Therefore, the risk of individual investments by constructing a portfolio of investments can be minimized if the investors within their specific technical and product expertise (Sapienza and Gupta, 1994; Manigart et al., 2002) have the connections with the professionals who have specific technical and product expertise. Murray (1995) indicates that, given the complexities of technologies, the professional investor must be highly informed on both technical and commercial-related issues.

Therefore, to early-stage high-tech investing, technological knowledge may be crucial to evaluating the potential of new technology during the selection process. However, Wright et al.’s (2006) study in Continental Europe found that over 70% of high-tech investors did not have a formal science education with a level higher than that taught at high school. They also suggest that an emphasis on financial expertise and limited experience in science and technology may have a detrimental influence on the types of early-stage investment opportunities that are likely to be

supported (Wright et al., 2006). Other studies also found that financial expertise is associated with a lower proportion of early-stage investments (Dimo, Shepherd & Sutcliffe, 2007), and VCFs with higher proportions of TMT members with science/engineering education and entrepreneurial experience are more likely to invest with an early-stage focus (Patzelt, zu Knyphausen-Aufsess & Fischer, 2009). Financial expertise is rooted in TMT members' abilities to assess the future payoffs of potential investments and the risks associated with those payoffs (Dimov, Shepherd & Sutcliffe, 2007).

Post-investment activities

As mentioned, VCFs actively participate in the processes of the investment, including pre-investment screening, post-investment monitoring, and value-adding. Sørensen (2007) estimates the contribution of VC value-add to be 40% and that of deal sourcing and selection combined to be 60%, which means pre-investment screening is a huge determinant of portfolios' subsequent performance. The VC's ability to screen start-up projects more efficiently is likely to increase the chances of entrepreneurial success (Roure and Maidique, 1986). VCs generally responded that they provide a large number of services to their portfolio companies post-investment—strategic guidance (87%), connecting investors (72%), connecting customers (69%), operational guidance (65%), hiring board members (58%), and hiring employees (46%) (Gompers et al., 2016).

The findings indicate that early-stage high-tech VCs do not only invest in 'perfect deals', meaning that the business proposal has a well-established founding team, clear market vision and has secured its first customers, a strong proprietary position and good financial prospects (Knockaert et al., 2010). They may invest in 'imperfect deals' and be directly involved in the management of portfolio companies at the early stages of venture developments. When VCs invest in early-stage ventures, they often need to put more effort into post-investment activities, such as helping shape the product categories, business models and standards that will define future markets (Sarasvathy, 2001; Berglund, Hellström & Sjölander, 2007). Post-investment activities include all actions by the VCFs after the initial investment deal has been signed (Sandberg and Hofer, 1987).

Berglund (2011) concluded that there are three roles in the early-stage investment: "investor", "coach" and "partner". To perform these functions, VCs must develop an understanding of the

characteristics of the businesses they fund as well as the specific industries in which they specialize (Hsu et al., 2014). In firms in which technical specialized knowledge is important to commercial success, VCs develop a unique understanding of the interface between the technical capabilities of the venture and commercial markets, which can be difficult to transfer to other parties.

In the post-investment phase, *financial expertise* is a source of knowledge on how to best manage the risks of a particular investment, such as determining the most appropriate financial structure (e.g., a mix of voting and preference shares), as well as on how to improve portfolio firm performance, such as through introducing more “sophisticated” financial and information systems (Dimov, Shepherd & Sutcliffe, 2007).

2.3 Upper echelon theory and specific human capital

A question in the financial economics literature is whether there are differences in the abilities of investment managers that exhibit superior investment performance (e.g., Malkiel & Fama, 1970). The management and strategy literature is also concerned about how top management teams affect a firm’s decisions and subsequent performance (e.g., Hambrick and Mason, 1984). Fundamentally related to both of these bodies of literature is the labor and organizational economics literature on human capital (e.g., Becker, 1964).

Human capital is comprised of skills and knowledge gained through formal education and professional experience (Becker, 1964). The value of human capital lies in people’s possession of knowledge and skills that are not easily appropriable and that therefore can yield competitive advantages for their firms (Barney, 1991; Pennings, Lee & Witteijstuijn, 1998) and increase organizational performance (Bruderl, Preisendorfer & Ziegler, 1992; Gimeno et al., 1997). In the entrepreneurial literature, human capital has been found to be critical to many firm developments in terms of opportunity recognition (Gruber, Macmillan & Thompson, 2012), radical innovativeness (Marvel and Lumpkin, 2007), patenting behavior (Allen, Link & Rosenbaum, 2007), firm legitimacy (Packalen, 2007) and access to external financial resources (Beckman Burton & O’Reilly, 2007).

Regarding human capital research in the VC literature, researchers have generally focused on the breadth or amount of variety within a team, i.e., whether the different dominant functional perspectives across team members cover a broad range of functional categories or are restricted to a subset of categories, thereby overlooking the “relevance” of the variety (Dimov, Shepherd & Sutcliffe, 2007). Although studies have assumed that any variety will do, a growing body of work suggests that variety alone is insufficient to benefit an organization (Dimov, Shepherd & Sutcliffe, 2007). Rather, researchers argue that performance depends on the appropriateness of the team’s specific knowledge for the organization’s environment or strategy (Dimov, Shepherd & Sutcliffe, 2007). Relevant expertise affects the team’s understanding of the uncertainty that exists and is likely to influence the team’s decisions to enter particular market segments (Dimov, Shepherd & Sutcliffe, 2007).

Human capital literature typically distinguishes between general human capital, which pertains to overall education and life experience, and specific human capital, which relates to education and experience specific to a particular activity or context (Becker, 1964), such as an industry (Gimeno et al., 1997), company (Pennings, Lee & Witteostuijn, 1998) or managerial function (Dimov and Shepherd, 2005). Whereas general human capital can be used in a variety of activities and transfers easily from one activity or situation to another without any significant loss of value, specific human capital is more limited in its use and cannot transfer easily across activities (Becker, 1964; Gimeno et al., 1997).

While all education may make some contribution to general human capital, some of it contributes more to specific human capital. Education that is not directly related to the tasks of the VCF can be considered more general in its contribution to human capital. For example, in Dimov and Shepherd (2005)’s study, education in humanities is designed to be broad in its application. In addition, education in science, although more specialized, is not directly related to the pre- and post-investment activities of a VCF. Therefore, they regard these types of education as contributing to general human capital, too.

While previous research has focused on individual venture capitalists’ human capital to explain variance in firm success (Cooper, Gimeno-Gascon & Woo, 1994), recent studies have suggested the importance of the human capital characteristics of entire teams for firm success (Amason,

Shrader & Tompson, 2006; Gruber, Macmillan & Thompson, 2012; Milosevic, 2018). Upper echelon theory suggests that the cognitive models of TMT members determine how managers perceive their task environment, and these perceptions mediate the effect of the objective environment on strategic choices (Bateman and Zeithaml, 1989; Carpenter, Geletkanycz & Sanders, 2004; Hambrick and Mason, 1984). Over the last 20 years, an impressive body of upper echelon literature has used TMT human capital characteristics as a proxy for the cognitive attributes of managers and predictors of organizational-level strategic preferences and performance (Bantel, 1992; Carpenter, Geletkanycz & Sanders, 2004; Grimm and Smith, 1991; Hambrick and Mason, 1984; Jensen and Zajac, 2004; Michel and Hambrick, 1992; Wiersema and Bantel, 1992; Patzelt, zu Knyphausen-Aufsess & Fischer, 2009). However, within the VC sector, the studies that have used an upper echelon lens have mainly focused on start-ups rather than VC investors.

Upper echelons consist of both board members and top managers and, oftentimes, research on these two core groups of leaders has proceeded in parallel. Dimov, Shepherd & Sutcliffe (2007) and Patzelt, zu Knyphausen-Aufsess & Fischer (2009) define TMTs in the context of the VC industry as all individuals with the highest-ranking titles within the VCFs (individuals holding the title “general partner” or, in the absence of such a title, the highest-ranking title in the firm hierarchy, such as “partner”, “managing director”, “director”, or “principal”). Milosevic (2018) included only partners of independent VCFs and principals or/and directors for captives. They excluded senior management members who do not have an investment or investor-relations responsibilities, such as chief financial officers.

2.4 Literature review

This study uses a systematic literature review to deal with a large number of papers published in this area. By performing a systematic literature review, this research integrates existing information and provides a theoretically-founded framework for understanding various changes to the theory in the new era. A detailed systematic literature review process is included in *Appendix 1*. Overall, we find that most of the “human capital” literature in the venture capital context has focused on the “entrepreneurial” side of the story. Only a few studies applied a human capital lens to evaluate the relationship between VCFs and their investment performance. This finding is

consistent with the observation of prior studies, such as Milosevic (2018). The number of studies that focused on the relationship between “venture capital firm’s human capital” and “portfolio firm performance” is limited. A systematic and broader investigation of the impact of TMT characteristics on VCFs’ portfolio performance is missing from the literature. *Appendix 1* also includes a table that summarizes the findings of the key studies.

Most of the selected work has been done between 2005 and 2010, and the most recent work has been published in 2018. Dimov and Shepherd (2005)’s work can be considered as the starting point of this set of literature. It was published in the “Journal of Business Venturing” in 2005 and cited 534 times until March 2018. Most of the selected studies here have cited this article at least once. Dimov is one of the scholars that has published more than one article on this topic and he also published articles focused on the other effects of specific human capital in the VC industry (e.g. investment decisions). Zarutskie and Milosevic also published two articles regarding this topic. Some of the support articles are also analyzed in Section 3.2 and show that Knockaert is another scholar who has focused on exploring the effect of venture capital’s human capital. Overall, this is a very confined group with a few researchers leading the direction of the research.

Despite the differences between the studies, a common finding is that team management team’s human capital plays a key role in managing and adding value to their portfolio. Researchers argue that previous literature has mainly considered the venture industry as a whole but ignored the fact that both the skills of VCFs and the needs of investee companies are heterogeneous (Knockaert et al., 2006). This stream of literature has addressed the human capital differences among the venture capital firms.

Another common ground of this stream of literature is that most papers have differentiated between the specific and general experience embodied in the human capital of the investment manager. Since Dimov & Shepherd (2005) stated that qualitative aspects of human capital should be considered when it comes to understanding knowledge as a key resource of a firm, specific human capital has been emphasized in the following studies. Most of the studies investigated the performance effects of education and experience that are general, task-related and industry-related. However, the results of the studies are not very consistent. For instance, Dimov & Shepherd (2005) found that specific human capital did not have a positive association with the proportion of IPO,

but both Milosevic (2018) and Zarutskie (2010) found a positive relationship between task-specific human capital variables and the exit success of VC-backed firms. This reflects significant heterogeneity in the studied relationships based on different conceptualizations of human capital as well as the contexts in which it is developed, which will be further discussed in Section 3.3.

Besides, a part of these articles investigated the direct relationship between human capital and investment performance (e.g. Dimov and Shepherd, 2005; Zarutskie, 2010), and some also considered the causal mechanisms between the two (e.g. Bottazzi, Da Rin & Hellmann, 2008; Knockaert et al., 2006). This section analyzes the selected key articles in detail and *Table 1* summarizes the theoretical lenses, research method and variables of selected empirical studies.

Table 1. Summary of selected key studies

Author	Theoretical lenses	Research target	Industry	Independent variables	Dependent variables
Dimov and Shepherd, 2005	Human capital theory	Top management team	Wireless communication industry	General human capital and specific human capital	The firms' performance (IPOs & bankrupt)
Dimov and De Clercq, 2006	Investment strategy	Firm	Nine categories based on Venture Economics	Specialized expertise	Failure rates (portfolio bankruptcy or cease trading)
Knockaert et al., 2006	Agency theory and self-efficacy theory	VC executives	High-technology	General human capital and specific human capital	Involvement in post-investment behavior (Monitoring, value-adding activities)

Casson and Martin, 2007	Human capital theory	General partners	All	Human capital	Interaction & Performance (portfolio companies exited)
Bottazzi, Da Rin, & Hellmann, 2008	Human capital theory	Partner/senior manager	Industry controls are included but not reported	Human capital characteristics; contractual characteristics; company characteristics	Involvement with portfolio companies; performance (exit)
Walske and Zacharakis, 2009	Evolutionary theory	Founding partners	Internet, computer, medical, communications, and consumer	Experience	VCF success (raise subsequent funds post first fund)
Zarutskie, R., 2010	Human capital theory; Upper echelon theory	Top management team	six VentureXpert industries	Task- and industry-specific and general human capital	Performance (portfolio company exit)
Milosevic, 2018	Human and social capital theory	Top management team	i) Manufacturing and Construction, ii) Life Sciences, iii) IT and Telecommunications and iv) Wholesale, Retail, and Services	Specific human capital	Performance (Exit; Trade sale; IPO)
Milosevic, et al., 2018	Human capital theory	Top management team	High-technology industries (IT and biotech)	General human capital and specific human capital	Subsequent rounds syndicated; the amount of funding raised from syndicate VC partners

In these nine articles, six employed human capital theory as their theoretical framework, which is the most commonly used one. Other theoretical frameworks include evolutionary theory (Walske

and Zacharakis, 2009), agency theory and self-efficacy theory (Knockaert et al., 2006). Although most of the work studied the human capital of top management team (partners or executives), only Zarutskie (2010) mentioned that they used upper echelon theory as one of their theoretical bases. Dimov and De Clercq (2006)'s study is the most unique one among the nine, which studied the firm-level investment strategy. They investigated the relation between firm-level specific expertise (the VCFs' investments were concentrated in particular industries and stages) and investment performance.

In term of the dependent variables that have been tested in the selected studies, the definitions of VCF performance are different from study to study. For instance, Dimov and Shepherd (2005) define that VCFs' performance is enhanced when their portfolio companies go public (IPOs), Walske and Zacharakis (2009) defined VCF success as raising subsequent funds post first fund. Among all nine selected studies, five of them measured VCFs' performance by portfolio company exits. Three of the studies (Casson and Martin, 2007; Zarutskie, R., 2010; Milosevic, 2018) focused on the successful performance of investments (IPOs and M&A) and only Dimov's two works (Dimov and Shepherd, 2005; Dimov and De Clercq, 2006) studied the failure rate of portfolio investments (bankruptcies). These two works also argued that the venture capital and entrepreneurship literature have focused on understanding investment success (portfolio company IPOs), but have relatively ignored the potential downside of performance outcomes (portfolio company).

Moreover, most of the selected studies tested their theories in all primary industries. Only Knockaert et al. (2006) and Milosevic, et al. (2018) confined their study in the high-technology industries (IT and biotech) and Dimov and Shepherd (2005) tested theirs in a very specific industry (wireless communication industry). A more detailed discussion of all the theories that will be used in this research will be presented in the following sections.

Many of the management team characteristics studied in the context of upper echelons are measures of educational level, educational specialty and work background, which are classical measurements of human capital. *Table 2* summarizes the measurements and the data sources of human capital in selected and supportive studies.

Table 2. Human capital definition and data source of selected studies

Author	Human capital measurement	Data source
Dimov and Shepherd, 2005	General human capital: Science education, Humanities education, and Entrepreneurial experience	VentureXpert
	Specific human capital: MBA education, Law education, Law experience, Finance experience, and Consulting experience	
Knockaert et al., 2006	General human capital: academic and entrepreneurial experience	Interviews
	Specific human capital: Consulting experience, Financial experience, Business experience, Investment management experience	
Casson and Martin, 2007	Human capital: Venture-experience, Business-experience, Directorship, Science-education	Survey
Bottazzi, Da Rin & Hellmann, 2008	VENTURE-EXPERIENCE: number of years of experience in venture capital of the venture firm's partners	Survey, Amadeus, Worldscope, and VentureXpert, as well as trade publications
	BUSINESS-EXPERIENCE: the fraction of the venture firm's partners who have prior business	
	SCIENCE-EDUCATION: the fraction of the venture firm's partners who have an education in science or engineering	
Walske and Zacharakis, 2009	Experience: venture capital experience, entrepreneurial experience, senior management experience, financial experience, technical experience, and consulting experience.	VentureXpert, Capital IQ, Zoom Info, company websites, and Internet searches
Zarutskie, 2010	General human capital: education in several fields of study at university – science and engineering, business administration and law	Thomson Financial/Venture Economics VentureXpert
	Task-specific human capital: past experience as venture capitalists and more managers having past experience as executives at start-up companies	
	Industry-specific human capital: strategy and management consulting, non-venture finance and professional science and engineering	

Milosevic, 2018	Task-specific human capital: accumulated experience related to specific tasks of importance for VC performance (prior R&D, entrepreneurship, VC and investment banking experience)	Thomson One Private Equity (VentureXpert), VC firms' websites, LinkedIn, Bloomberg Businessweek and press articles
Milosevic et al., 2018	Task-specific human capital: (i) innovation and (ii) investment-specific human capital, gained on tasks tightly linked to selection and development of entrepreneurial ventures.	Thomson One Private Equity
	General human capital: not specifically gained in the context related to entrepreneurial venture selection and/or value-adding: (i) business and (ii) investment skills.	

Overall, most of the studies suggest that measures of the task- and industry-specific human capital are stronger predictors of first-time venture capital fund performance than are measures of general human capital (Zarutskie, 2010). As we can see in the selected and support literature, they have focused on the effects of two dimensions of the human capital of the top management teams (TMTs)—education and experience. General and specific human capital are differentiated based on whether they provide skills that are directly used in carrying out the activities of investment selection and management. Education and experience were measured by whether they were gained in a particular domain. However, the judgment of “directly used” in different studies is various. For instance, Milosevic et al. (2018) considered business skills gained from business experience as “*general human capital*”, but Knockaert et al. (2006) treated the business experience as “*specific human capital*”. Dimov and Shepherd (2005) and Knockaert et al. (2006) categorized entrepreneurial experience as general, but Milosevic (2018), Milosevic et al. (2018) and Zarutskie (2010) considered it as specific.

According to the review of selected VC literature, human capital was measured using education and experience as measurement. For instance, Zarutskie (2010) used education in several fields of study at university to define general human capital and used experience as venture capitalists and experience as executives at start-up companies to define task-specific human capital. Moreover, the most human capital studies in the context of the VC industry are likely focused on the financial ability of TMT members (Patzelt, zu Knyphausen-Aufsess & Fischer, 2009; Dimov, Shepherd & Sutcliffe, 2007).

Effect of Education

Overall, all studies explored the effect of both education and experience, but there is an obvious tendency that researchers pay more attention to the experiences. This could be explained by Walske and Zacharakis (2009)'s work. They did a qualitative study and suggested that education was too far in the past to be relevant to VCF success (raise subsequent funds post its first fund). They also ran regressions with these education-related variables, including the undergraduate and graduate degrees of all founders, but neither the model nor the variables were significant (Walske and Zacharakis, 2009). Previous entrepreneurship research has also hinted that education might be less important than experience in predicting entrepreneurial success (Politis, 2005)

According to Zarutskie (2010), the dominant degrees possessed by VCF founders are in business administration (58 %) and science and engineering (39 %), with law held by far fewer VC founders (8 %). Research from Bottazzi, Da Rin & Hellmann (2008) states that VCFs benefit from having investors with education in science and engineering, as this knowledge aids them in overcoming the technological and operational challenges within portfolio companies. However, some found a negative impact of science education (e.g. Zarutskie, 2010). This negative impact can be explained by investment strategies that VCFs with higher proportions of TMT members with science/engineering education and entrepreneurial experience are more likely to invest with an early-stage focus (Patzelt, zu Knyphausen-Aufsess & Fischer, 2009). Moreover, when Zarutskie (2010) constrained the effect in the technology industry, science/engineering education shows a positive impact on exit performance.

Furthermore, only Dimov and Shepherd (2005)'s work has found a strong and significant impact of general humanity education. Zarutskie (2010) and Dimov and Shepherd (2005) assert that law degrees could help VC founders when structuring contracts with their portfolio companies. Zarutskie (2010) and Dimov and Shepherd (2005) also state that MBA degrees should help VC founders in advising their investees on best practices. Dimov and Shepherd (2005) also argue that business education helps VC principals screen deals, conduct deeper due diligence, and advise entrepreneurs on strategy and operational issues, even though these authors' combined results were inconclusive on the positive impact of MBAs on firm performance.

Effect of Experience

Two kinds of experiences have been explored in prior studies: work experience and entrepreneurial experience. Previous studies found that the most common form of experience for VC executives was in the financial services sector (46%), followed by accountancy (31%), the non-executive or executive director of a technology firm (30%), graduate qualifications in a tech subject (29%), managerial experience in a tech firm (28%), a Ph.D. in a technology-related subject (14%) and law (12%) (Wright et al., 2006).

Researchers believe that VCs with the same-industry work experience are more familiar with the business context (Becker, 1964; Davidsson and Honig, 2003) and can more readily delineate true investment opportunities (Patzelt, zu Knyphausen-Aufsess & Fischer, 2009; Knockaert, Clarysse & Wright, 2010). However, the impact of the industry-related experience is heterogeneous. Walske and Zacharakis (2009) found that technical experience did not significantly predict a firm's ability to raise follow-on funds. Zarutskie (2010) also found that fund manager with industry-specific human capital in science and engineering should matter more for funds with more high-tech investments.

Compared to financial backgrounds, the prior industry experience of venture capitalists has a much stronger impact on VCFs, whether they are going to adopt an active investment style or not (Bottazzi, Da Rin & Hellmann, 2008). VC managers with previous start-up experience were found to be more likely to take an active role in developing their portfolio firms (Knockaert et al., 2006) than those without this previous experience. Also, venture firms whose partners have prior business experience are significantly more active in the companies they finance (Casson and Nisar, 2007).

Table 3 summarizes the results of each human capital items from the selected literature. Among 9 selected literature, 8 studies are included, and Dimov and De Clercq (2006)'s work is not included here because they did not use individual human capital variables. Both Dimov and Shepherd (2005) and Knockaert et al. (2006) has two dependent variables tested in their study, and other studies have one dependent variable.

	Dimov and Shepherd, 2005		Casson and Martin, 2007	Zarutskie, 2010	Milosevic, 2018	Bottazzi et al., 2008	Knockaert et al., 2006		Walske and Zacharakis, 2009	Milosevic et al., 2018)
	Portfolio go public	Portfolio go bankruptcy					Involvement in monitoring activities	Involvement in value-adding activities		
General human capital	+	+								
Education in humanities	NS	-		NS						
Education in law	NS	+								
Industry experience—law	NS	+								
Academic experience							NS	NS		
Entrepreneurial experience	NS	+		+	+		NS	+	-	+
Education	NS	-		-					NS	
MBA	+	+		+		-				
Education in science			+							
R&D				-	+				NS	+
experience										
Exp VC			+	+	+	NS			+	+
Exp					+					
Investment banking							NS	NS		NS
Working in non-venture finance				0						
Experience (Finance)										
Exp business (consulting)	-	-		+			NS	+	+	-
Exp business (industry)			+			+	NS	NS		-
Senior management experience			+						+	

Note: “+” positive impact, “-” negative impact, “0” no impact, “ns” not significant, “blank” hypothesis not developed, or relationship not tested

Table 3. Human capital’s effects on performance in selected and supportive studies

3 Conceptual framework and Hypothesis development

In the following, this section first presents how the heterogeneity of VCFs' human capital composition and their early-stage technology investment performance are likely interrelated. We subsequently develop specific hypotheses on the association between specific human capital characteristics of VCFs and their portfolio success.

An investor's capabilities or skills should match the needs of the portfolio company in which it invests (Casson and Nisar, 2007). The early-stage technology sector raises particular issues since these firms need relationships with VCs to access human capital and financial resources that will help them to meet the challenge of realizing new opportunities. Not all VCFs may be capable of providing these specific resources (Lockett, Murray & Wright, 2002). Thus, both entrepreneurs and VCFs need to be aware of the differences within the investor of the early-stage technology industry to maximize the return of their entrepreneurial activities or investment. A key component of human capital is the possession of knowledge that is specific, not easily appropriable, and yields a competitive advantage (Barney, 1991; Pennings, Lee & Witteijstuijn, 1998; Wright, Smart, and McMahan, 1995) and increase organizational performance (Bruderl, Preisendorfer & Ziegler, 1992; Gimeno et al., 1997).

In line with Milosevic (2018) and Zarutskie (2010), this study defines specific human capital as accumulated education, and experience related to important tasks that contribute to VC success. In this study's sub-environment, VCFs' tasks are choosing their early-stage ICT portfolios and helping their portfolios successfully exit in the following years. Specialized expertise diminishes the uncertainty that surrounds venture capital investments and allows the VCF to add substantial value to its portfolio companies (Gupta & Sapienza, 1992).

For early-stage technology investment projects, both *technological expertise* and *financial expertise* are needed; while the effect of *financial expertise* on investment outcome has been studied in the previous studies, the effect of *technological expertise* on investment outcome remains unclear. *Technological expertise* has been widely studied in the technology entrepreneurial human capital study but not in the VC studies. Previous studies suggest that the main aims of VCFs that invest in high-tech ventures are to see science translated into a viable

business and revenue model and to ensure adequate returns given the risk profile of their portfolio (Baeyens et al., 2006). Since VCFs' goal is not having portfolio companies with superior technologies (Knockaert and Vanacker, 2013), *technological expertise* has been overlooked. Financial expertise has been studied widely maybe because it is the human capital that aligns with VC firms' goal.

Thus, by distinguishing between technology-related and financial-related specific human capital, this research has the opportunity to better understand how characteristics of specific human capital are associated with early-stage information and communication technology (ICT) investment outcome. This study categorizes education, work experience, and entrepreneurship experience into two characteristics of specific human capital: *financial expertise* and *technological expertise* based on what kind of human capital the TMT can accumulate during this education and experience.

The preceding literature suggests that VCFs, even those in the high-tech sector, are heterogeneous in terms of their expertise (Wright et al., 2006). Heterogeneity in TMTs' skills and the limited scalability of human capital can explain heterogeneity in fund performance (Dimov and De Clercq, 2006; Milosevic, 2018; Zarutskie, 2010). This study follows the extant literature and adopts an approach similar to Zarutskie (2010) and Milosevic (2018) of measuring performance by whether the invested companies experience a successful exit, defined either as an Initial Public Offering (IPO) or an acquisition.

3.1 Specific human capital - *Technological Expertise*

This study introduces a new specific human capital- *technological expertise*, which captures key team-level characteristics in a more specific way. The items comprising this construct have been used in prior research as separate variables (e.g., Dimov and Shepherd, 2005; Casson and Martin, 2007; Zarutskie, 2010), but this study shows that they jointly represent the broader concept of a TMT's perceived readiness to engage in its portfolios.

Technological expertise in this study is defined as the presence of an education degree, research experience, work and entrepreneurial experience that are technology-relevant. The VCs' technological skill level may also influence how they evaluate the type of deals they see. It is worth noting that most of the existing studies are concerned with the interaction between financially

relevant human capital and investment performance because *financial expertise* is in line with the goal of VCFs. This study argues that there should be more types of human capital examined (such as *technological expertise*). If *technological expertise* is lacking, VCFs may not be as capable of appreciating the potential of a given technology (Berglund, 2011). *Technological expertise* in this study is measured by five items: education in ICT industry (*Edu_ICT*), work experience in ICT industry (*WorkExp_ICT (R&D)*, *WorkExp_ICT (not R&D)*), and entrepreneurial experience in ICT industry (*EntreExp_ICT*) (for details, see Section 5.2).

Although similar variables have been tested in the previous studies, such as education in science and R&D experience, this research only concentrates on the education and experience that are related to the ICT industry. For instance, subjects like medicine and chemistry are science, but they are not included in education in ICT industry (*Edu_ICT*) in this study. Dimov and Shepherd (2005), Casson and Martin (2007) and Zarutskie (2010) have found a significantly positive relationship between education in science and investment exits in all industry. Formal education in science may give partners better and deeper knowledge that can facilitate an appreciation of the technological and operational challenges of the companies they oversee (Bottazzi, Da Rin & Hellmann, 2008). However, all these studies regard different levels of education in science as the same. Compared to undergraduate education in technology/engineering, this study argues that graduate studies give TMT members a better chance to access very sophisticated technologies and this study shows the differentiation in a way of coding which is demonstrated in Section 4.3.

In addition, to secure privileged knowledge, VCFs often seek out external expertise by consulting the board or an external expert source (Casson & Nisar, 2007). Both graduate studies and R&D experience can lead their technology networks to be larger because they have worked in a university or corporate research labs with technology researchers and have been exposed to more technological professionals. As a result, VCFs with higher *technological expertise* may have better resources for identifying more promising technologies when there are not many signs to help them make a decision and help their portfolio companies in the post-investing phase (Milosevic, 2018).

Moreover, the effect of experience also relates to specific industry sectors. That is, a TMT member's work experience in the biotechnology industry will not give him/her an advantage in the communication technology industry. Therefore, by evaluating the prior work experience of

technology R&D and entrepreneurial experience in the ICT industry, this study can predict the involvement of the VCFs and the performance of the investment.

To explore whether VCs with *technological expertise* can better gauge the potential of a portfolio company's invention and lead to a competitive advantage in the market. This research hypothesizes that TMTs with more *technological expertise* is positively related to the percentage of their portfolio achieving successful exits. Therefore, the first hypothesis of the study is:

Hypothesis 1: Venture capital firms' top management teams with greater technological expertise in the form of Edu_ICT, WorkExp_ICT (R&D), WorkExp_ICT (not R&D), and EntreExp_ICT at the team level will have a greater ratio of portfolio companies that exit successfully.

3.2 Specific human capital - Financial expertise

The *financial expertise* of a VCF refers to its top management team's abilities in evaluating the return potential as well as in managing the financial resources of a prospective venture (Dimov, Shepherd & Sutcliffe, 2007). *Financial expertise* in this study is defined as the presence of an education degree, work experience and entrepreneurial experience that is finance-relevant. The items comprising this construct have also been used in prior research as separate variables (e.g., Dimov and Shepherd, 2005; Casson and Martin, 2007; Zarutskie, 2010), but this study tests their joint effect. *Financial expertise* will be comprised by five items: *Edu_finance*, *WorkExp_finance (not invest)*, *WorkExp_investment* and *EntreExp_finance* (for details, see Section 5.2).

The *financial expertise* should be positively related to the portfolio because of two reasons: in the pre-screening process, teams with a greater *financial expertise* will also be more likely to recognize those contexts in which assessments of payoff and risk are not possible (or are too costly) (Dimov, Shepherd & Sutcliffe, 2007). Because it provides the team with a greater understanding of the investment potential, *financial expertise* improves the managers' comprehension of the requirements for making the potential investment successful. In the post-investment process, VCFs actively monitor portfolio firms through the use of specific financial instruments and contractual clauses (e.g., stage financing, allocation of control rights), which create high-powered incentives for entrepreneurs to pursue growth (Kaplan and Strömberg, 2004).

Moreover, the composition of entrepreneurial teams in early-stage technology ventures is often homogeneous in terms of education, experience, and skills, which are typically science-based (Ensley and Hmieleski, 2005). As such, these teams face a resource and knowledge gap related to the commercialization of technology, whereas knowledge related to technology is often abundantly available (Lockett et al., 2005). Portfolio companies often look to the VCFs to provide financial and accounting information (Mitchell, Reid and Terry, 1997). Furthermore, the founding teams generally have homogenous networks but lack valuable business contacts (Maurer and Ebers, 2006). Hence, VCFs need to help the entrepreneurial teams overcome these challenges by utilizing VCFs' internal human capital. From an 'objective function' point of view, the independent VCFs have two preferred exit routes: initial public offerings (IPOs) and acquisitions (i.e., trade-sales). Accordingly, independent VCFs push the growth of their portfolio firms to increase the likelihood of an IPO or to make them more attractive for trade-sale (Chemmanur, Krishnan & Nandy, 2011).

Also, the existing literature suggests that the previous work experience is an important determinant of their industry investment choices (Knockaert et al., 2010) and follow-on fundraising (Walske and Zacharakis, 2009; Milosevic et al., 2018). The relationship between the experience of investment and exits has been tested in the Casson and Martin (2007), Zarutskie (2010) and Milosevic (2018)'s work and it showed a positive effect. Previous investment experience enables VCFs to develop task-specific skills which can be beneficial for both development and exit of their portfolios. Prior VC experience allows VCFs to acquire competences in all areas of the venture capital cycle and as such this study expects their portfolio firms to perform better. Finally, former investment bankers come to the VC industry with their experience in trade sales and managing IPOs, as well as relations with investment bankers in capital markets which are key for preparing a successful exit and consequently for investment performance (Jain, Jayaraman & Kini, 2008).

To explore whether VCFs with higher *financial expertise* can better gauge the potential of a portfolio company's invention and lead to a competitive advantage in the market. This study hypothesizes that TMTs with more *financial expertise* is positively related to the percentage of their portfolio achieving successful exits. Therefore, the first hypothesis of the study is:

*Hypothesis 2: Venture capital firms' top management teams with greater financial expertise in the form of **Edu_finance**, **WorkExp_finance** (not invest),*

WorkExp_investment and EntreExp_finance at the team level will have a greater ratio of portfolio companies that exit successfully.

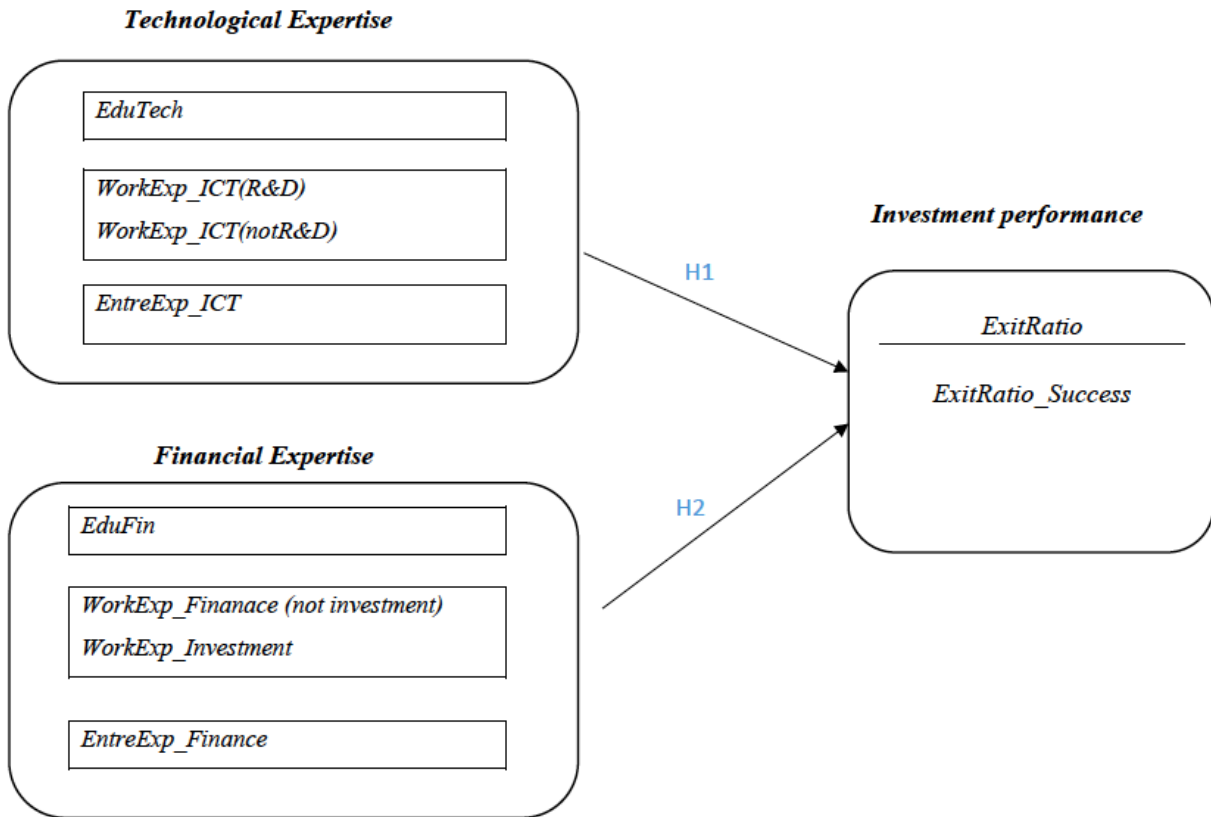


Figure 3: Conceptual Framework of Hypothesis 1 & 2

4 Research design

4.1 Data Collection

This research is developed based on an original, hand-built database. The database is built from a variety of publicly available resources and contains information on investments realized by venture capital firms and the human capital characteristics of their top management team. This study uses several data sources in the analysis. First, we use the S&P Capital IQ database to identify venture capital firms that focus their investments in early-stage information and communication technology (ICT) companies in the US. we also use the same database to identify the ICT portfolio companies in which they invested and the outcomes of those investments, which includes whether they went public, were acquired or were shut down. S&P Capital IQ database combines deep global company information and market research. S&P Capital IQ includes company financials, relationships among firms and people, biographical and contact data, transactions, events, securities data, ownership, brokerage estimates, corporate governance, regulatory filings, and news on private and public companies. Second, we use hand-collected information containing the work and educational histories of the individuals in the top management team of the venture capital firms identified in the S&P Capital IQ database. We use this hand-collected data to form the measures of top management team human capital and to test the hypotheses posited.

4.2 Sample selection

VCFs

First, the sample selection starts by constructing a list of venture capital firms that focus their investments in early-stage ICT companies in the US. To assess the success and failure rate of VCFs' investments over time, this study selects VCFs that had already made a substantial number of prior investments. Therefore, the initial population consists of all independent U.S.-based VCFs that at least have one prior portfolio investment company, as reported in the S&P Capital IQ database. This study also needs these VCFs had sufficient time for those investments to have reached an outcome (exit). Therefore, this study restricts the sample of venture capital firms along the following dimensions:

- (1) This study only includes independent VCFs who are funded privately (e.g. coming from financial institutions, institutional investors, large companies, private individuals, etc.) in the United States. In terms of organizational structure, this study emphasizes the distinction between private, independent venture capital firms and so-called captive firms, who are affiliated with corporations, banks or government. The impact of venture capitalists' human capital on the performance of portfolios connected to banks, corporations or governments may be different from its impact on funds managed by independent investment firms due to differing incentives and resources as a result of being connected to a larger organization (Zarutskie, 2010). There are reasons to expect that the type of VCFs influences the probability of success of their portfolio companies (Leleux and Surlemont, 2003). This study also excluded corporate VCFs, as they receive capital commitments from their parent corporations, as well as informal venture capitalists, who usually invest their own money.
- (2) This study only includes VCFs that primarily operate in the United States, since institutional influences of a country may explain heterogeneity in the decision policies of VCs (Zacharakis, McMullen & Shepherd, 2007). Besides, only the outcomes of their prior investments within the U.S. are evaluated in this study, since VCFs' cross-border investments may show different value-adding behavior and different levels of engagement effort result in different firm performance (Casson and Martin, 2007).
- (3) This study only includes the VCFs that were founded between 2000 to 2011. VC firms usually invest with the intent of exiting within five to seven years after their investments (Milosevic, 2018). The date that we collected investment outcomes was May 2019 and we collected the data of all prior investments and exits before 31st December 2018. Therefore, firms that started before the end of 2011 should have had enough time to exit their investments. The time bracket this study leaves is sufficient to capture a large proportion of exits.
- (4) This study only investigates the VCFs that prefer investing in the "early venture" or "seed/start-up" stage based on the information in the S&P Capital IQ database. The ideal dataset should only include the prior investments and exits when the investment was made in the portfolio firm's early stage (within five years after the founding year). However, due to the great number of portfolio firms, there is no way to check whether their investment is

made within their first five years one by one. Therefore, this could be a limitation of this research because VCFs that prefer investing in the “early venture” or “seed/start-up” stage may also invest in the other stages besides these two.

- (5) This study restricts the sample to include only venture capital firms that have at least 1 professional in the firm. Since the target of this study is to evaluate the effect of human capital, it needs a sufficient number of professionals to analyze.
- (6) This study restricts the sample to include only venture capital firms which had at least 3 prior investments (industry is not restricted) and have at least 40% of prior investment were made in the U.S. ICT industry. During the process of data collection, we notice that not all VCFs that claim they focus on investing in the ICT industry are investing mainly in ICT. Instead, they may invest mainly in the health care industry or energy industry and only invest a few ICT companies. The VCFs’ needed specific human capital for their investment will be different from industry to industry. Therefore, to make sure this study includes the VCFs who are focusing on investing in the ICT industry, we use “at least 40% of prior investment were made in the U.S. ICT industry” to restrict the sample.

TMT biographical information

After identifying the independent VCFs, we gather information on the human capital of those firms. To do so, we hand-collect data using Capital IQ, LinkedIn, Crunchbase, company websites, and Internet searches, in keeping with prior research (Dimov and Shepherd 2005; Scarlata, Walske, Zacharakis 2017; Zarutskie 2010). Firms are eliminated if the biographical information on the founders could not be located or incomplete. If partial biographical data on partners were available, firms were not included, because the target of this research is to find out the allocation of different specific human capital and partial data may mislead the result.

Although partners are responsible for one particular firm, investment decisions in VCs are usually made by all general partners (Guler, 2007). General partners are responsible for participating in the process of investing in portfolio companies. Consistent to prior study (Dimov and Shepherd, 2005; Milosevic, 2018), the operational definition of the top management team in this study is all people holding the title general partner or, in the absence of such a title, the highest-ranking title in the firm hierarchy. Among the alternative titles used are partners, managing directors, directors,

and principals. This study excludes partners who do not have an investment or investor-relations responsibilities, such as financial partners and managing partners. We use the names of the partners who work for venture capital firms recorded in S&P Capital IQ as the starting point for identifying the top management team in the sample.

The challenge here is distinguishing individual partners with decision-making abilities in the firm from individual partners who are primarily engaged in support activities. This study takes a two-step approach in identifying which individuals are engaged in venture capital investment. First, we check if any of the individuals identified in S&P Capital IQ served as a partner in the portfolio companies. It is important to note here that this study excludes peripheral individuals, such as “managing partners” and “venture partners”, who are people that are connected to the firm but do not act as investment managers. Such people may be called upon to serve as CEO of a portfolio company, provide occasional advice to the firm managers or add advertising value to the firm but who do not engage in active management of the investment (Zarutskie 2010). As a result, this study classifies “general partner,” “partner” and other such titles suggesting that they were investing professionals. This study classifies “chief financial officers (CFOs),” “VP of Human Resources,” “associates,” “assistants,” and “entrepreneurs-in-residence” as non-investing firm members and did not include them in this study. Also, according to upper echelon theory, the cognitive models of TMT members determine how managers perceive their task environment, and these perceptions mediate the effect of the objective environment on strategic choices (Hambrick and Mason, 1984). Therefore, the founders, co-founders, and founding partners of the VCFs will also be included in the sample even though they may not be directly involved in the investment activities.

For each top management team member that this study identifies, we further hand-collect information on the majors and degrees they attained, the firms for which they worked, and the positions held with these firms. For individuals who are still working for the venture capital firms, we collect information from the biographies listed on these websites. To get a complete and reliable dataset, we also use other databases: S&P Capital IQ, LinkedIn, Crunchbase, and Internet searches to collect additional information on the set of general partners.

After applying these restrictions, this study gets 207 venture capital firms and each VCF has 1-8 top management team members are included, the detail analyses are demonstrated in Section 6.1. The firm-level human capital characteristics that are constituted by the human capital of the individual top management team member is the research target of this study.

4.3 Measures

Dependent variable

This study aims to test how the specific human capital of the VCFs relates to their portfolio success. Ideally, this study would like to measure performance by the returns that VCFs realize when exiting their investments. However, VCFs are often reluctant to disclose their returns publicly (Milosevic, 2018). Hochberg, Ljungqvist & Lu (2007) note that, all else being equal, the more successful exits a fund has, the larger the internal rate of return will be. Therefore, this study uses measures of fund performance based on the number of successful exits, which has also been widely used in the academic community to measure success (Gompers and Lerner, 1998; Nahata, 2008). The measure of the dependent variable is ratio of successful exits (*ExitRatio_Success*), which is calculated as the ratio of the firm's portfolio companies that have been successfully exited via an initial public offering (IPO) or mergers and acquisitions (M&A) transaction. Gompers and Lerner (1998) note that VCs generate the bulk of their profits from firms that go public (IPO). However, Brander, Egan, and Hellmann (2005) show that in the North American context, IPOs constitute only 25% of exits by number (60% by value), with the rest being acquisitions. The approach that adopted in this study is to collect data on both IPOs and acquisitions. Ratio of successful exits is calculated as the ratio of ICT portfolios that exit by IPO and M&A verse all prior investments that VCFs have made in the U.S. after the founding. It is fractional, taking any real value between 0 and 1.

Independent variables

Technological expertise (ICT_teamlevel) and *financial expertise (Finance_teamlevel)* are the independent variables in this study. Both these two independent variables are calculated and measured at firm-level. When we collect the data, we first collect the data at the individual level,

then we calculate the firm-level variables by combining or summing up the individual-level variables.

Education (individual-level data collection)

Once we identify an individual as a partner who participates in the investment activity, we then begin coding his/her education information. The biographical sketch of each partner typically contains information on formal education are obtained. This study uses this information to measure the education-related human capital variables. The following variables related to the education obtained by TMT members are collected in the study: the major of education; the level of all education (bachelor, master, and Ph.D.). For each TMT member, code “1” if individual VC partner’s highest degree of ICT related education is “Bachelor”, “2” if the individual’s highest education level is “Master”, and “3” if individual’s highest education level is “Ph.D.”. Because this study mainly concerns the technological and financial expertise. During the data collection, we category all majors into three groups (*education in ICT industry; education in finance industry; education in other industry*) and code whether individual TMT member had attained any degrees in such specializations:

Education in ICT industry specializations include Computer Science, Mechanics & Computation, Mechanical Engineering, Telecommunications, Networks, Physics, Operations Research, Science and Technology, Communication, Mathematics, Operations Research and Industrial Engineering, Symbolic Systems, Systems Engineering, Advertising;

Education in finance industry specializations include Finance, Business, Management, Economics, International Business, Commerce, Industrial Administration, Industrial Distribution;

Education in other industry specializations include B.S., B.A., Law, International Studies, Biomedical Engineering, Biochemistry, Biology, Chemistry, Political Science, Quantitative Methods, Social Studies, Chemical Engineering, Journalism, Music.

When an individual’s education information only shows as B.S. or B.A. but without a specific specialization, we categorize it as “*education in other industry*” to avoid possible errors. Furthermore, this study only includes the firms with all TMT member’s information are complete.

When the education information of an individual remains unknown, we cannot be sure whether it is due to poor data quality or the individual do not obtain a degree higher than high school. Therefore, the information collected in this dataset is all above high-school degrees besides only one partner who mentioned that he dropped off college after two years. In addition, it is worth noticing that the education may provide graduates with the knowledge and capabilities needed to make prudent investment decisions but graduates of the same degree can possess very different skillset and even knowledge, depending on the courses taken, the institution in which the program was based, the interest and capabilities of the individual, etc.. This is a limitation of this study, which is also discussed in Section 6.

Experience (individual-level data collection)

There are especially two kinds of experience are collected in this study: work experience and entrepreneurial experience. The biographical sketch of each partner also contains information on the industries and positions in which the partner had worked before joining the VCF. Once we identify an individual as a partner, we then begin coding his experience. If a person had multiple experiences, he received a “1” for each experience category.

Because this study mainly concerns the technological and financial expertise, experiences in all other industries are categories as others. During the data collection, we category all majors into three groups (*Work experience in ICT industry*; *Work experience in finance industry*; *Work experience in other industry*) and code whether individual TMT had worked in the following industries:

Work experience in ICT industry (R&D) includes work that is related to the research and development (R&D) in Information Technology and Communication industries, such as an engineer, a researcher in the R&D department (not include product manager);

Work experience in ICT industry (not R&D) includes all positions other than R&D in Information Technology and Communication industries, such as sales, product management/manager, CEO, but not include CFO or accountant in the ICT industry;

Work experience in finance industry (not investment) includes work experience in the non-investment financial institutions, including institutions such as commercial and merchant banking and consulting firms. Also, work experience as a CFO is included in this category no matter in which industries.

Work experience in finance (investment) industry includes prior work at a venture capital firm, investment bank, private equity firms or investment fund management in both public and private markets.

Work experience in other industry includes all work experience in other industries besides ICT and finance. Academic work experience and postdoctoral experience are also included in this category.

The entrepreneurial experience was coded as “1” only if an individual had been entrepreneurs themselves (1 = entrepreneurial experience, 0 = no entrepreneurial experience). The previous literature has categorized entrepreneurial experience as general human capital (Dimov and Shepherd, 2005; Knockaert et al., 2006) and considered the entrepreneurial experience in different industries as the same. However, this study considers entrepreneurial experience as specific human capital if they had previously founded a for-profit firm within the IT industry and they have cumulated *technological expertise* during their entrepreneurial experience. Besides, if they had previously founded a for-profit firm in the finance industry, such as venture capital firms and consulting firms, this study considers that they have cumulated *financial expertise* during their entrepreneurial experience.

ICT_teamlevel and Finance-teamlevel

Since the unit of analysis is the firm, this study then sums up the items comprising two constructs (technological expertise and financial expertise) to get the firm-level variables: total ICT-related human capital (*Total_ICT*) and total finance-related human capital (*Total_Finance*). Total ICT-related human capital (*Total_ICT*) is the sum of all TMT members’ ICT related expertise in one venture capital firm, including *Edu_ICT*, *WorkExp_ICT (R&D)*, *WorkExp_ICT (notR&D)* and *EntreExp_ICT*. Total finance-related human capital (*Total_Finance*) is the sum of all TMT members’ financial related expertise in one venture capital firm, including *Edu_Finance*,

Edu_MBA, *WorkExp_Finance*, *WorkExp_Investment*, *EntreExp_Finance*. Because VCFs have the various number of TMT members (*TeamSize*), the VCFs that have larger number of TMT members possibly get higher scores on the total number of human capitals. To avoid the effect of number of TMT members, this study uses *TeamSize* to divide *Total_ICT* and *Total_Finance*, and gets a two new firm-level variables: team level technological expertise (*ICT_teamlevel*) and team level financial expertise (*Finance-teamlevel*). These two variables are the independent variables in this study.

Control variables

VCF characteristics other than human capital can influence performance. By controlling for these additional drivers of investment performance, this study can test the four primary hypotheses on human capital in the analysis better. The control variables in this study are all at the VC firm level: *VC_FirmAge*, *TeamSize*, *% investment in the US*, and *% prior investment in ICT*.

VC_FirmAge: As stated previously, this study chooses the years 2000 through 2011 for analysis. There is an 11-year difference between the earliest found firm and the latest found one. When VCFs tend to be older and larger, they thus have on average more experienced partners (Dimov, Shepherd & Sutcliffe, 2007) and younger firms exhibit a greater probability of failure (Lehmann, 2006). Therefore, this study controls for the firm's existing years until the end of 2018, which is the time frame that this study collects the data of prior investments and exits;

TeamSize: The number of members in the top management team. Consistent to prior study (Dimov and Shepherd, 2005; Milosevic, 2018), the operational definition of top management team in this study is all people holding the title general partner or, in the absence of such a title, the highest-ranking title in the firm hierarchy. This study expects a positive relationship between the number of top management team members and investment performance since more members will provide more human capital in general to the firm and provide more labor to monitor and screen investments (Zarutskie 2010).

% investment in the US: This is a VCF's level of investment concentration in the U.S. market. Although this study selects the VCFs that primarily operate in the United States, they show a different level of concertation. Also, this study only evaluates the performance of investments that

are made in the U.S. market. Therefore, it is necessary to control the level of investment concentration in the U.S. market.

% prior investment in ICT: This is a VCF’s level of investment concentration on ICT. Although all VCFs that this study selects are interested in investing in the ICT industry, they may show a various level of concentration on investing in this particular industry. Studies show that VCFs that continuously invest in particular types of ventures can maximally benefit from such learning curve effects through the accumulation of superior knowledge over time and can, therefore, reduce the likelihood of venture failure (Gupta & Sapienza, 1992; Hall & Hofer, 1993; Norton & Tenenbaum, 1993). New venture failure is less likely to occur, for instance, when VCFs better understand the critical success factors related to particular development stages of their portfolio companies or the competitive dynamics of particular industries (Dimov and De Clercq, 2006). Therefore, this study uses this investment concentration to control the test.

Table 4A and *4B* contain all the relevant individual- and firm-level variables that this study uses and *Table 4C* contains only the control, independent and dependent variables that are tested in the main hypothesis.

Table 4A: Individual-level partner variable names and descriptions

Variable name	Variable description
<i>Edu_ICT</i>	Code “1” if an individual VC partner’s highest degree of ICT related education is “Bachelor”, code “2” if the individual’s highest education level is “Master”, and code “3” if individual’s highest education level is “Ph.D.”. The sum of all TMT members’ highest education level in one venture capital firm, otherwise code “0”.
<i>WorkExp_ICT (R&D)</i>	Code “1” if an individual VC partner worked as researcher or engineer in corporate R & D departments, research centers or universities, otherwise code “0”.
<i>WorkExp_ICT (not R&D)</i>	Code “1” if an individual VC partner worked in the ICT industry, any positions but not researchers or engineer in a corporate R & D department, otherwise code “0”.
<i>EntreExp_ICT</i>	Code “1” if an individual VC partner previously started a company within the ICT industry, otherwise code “0”.

<i>Edu_Finance</i>	Code “1” if an individual VC partner’s highest degree of financial related education is “Bachelor”, code “2” if the individual’s highest education level is “Master”, and code “3” if individual’s highest education level is “Ph.D.”. The sum of all TMT members’ highest education level in one venture capital firm, otherwise code “0”.
<i>Edu_MBA</i>	Code “1” if an individual VC partner has an MBA degree, otherwise code “0”.
<i>WorkExp_Finance</i>	Code “1” if an individual VC partner has work experience in finance but not investment-related, such as banker, accountant, and CFO, or consultant in the consulting industry, otherwise code “0”.
<i>WorkExp_Investment</i>	Code “1” if an individual VC partner has investing experience, such as venture capitalist and investing bank, otherwise code “0”.
<i>EntreExp_Finance</i>	Code “1” if an individual VC partner previously started a company within the finance industry, otherwise code “0”.
<i>Edu_Other</i>	Code “1” if an individual VC partner’s highest degree of education that is not either ICT or financial related is “Bachelor”, code “2” if the individual’s highest education level is “Master”, and code “3” if individual’s highest education level is “Ph.D.”. The sum of all TMT members’ highest education level in one venture capital firm, otherwise code “0”.
<i>WorkExp_Other</i>	Code “1” if an individual VC partner has work experience in other industries besides ICT and finance, otherwise code “0”.
<i>EntreExp_Other</i>	Code “1” if an individual VC partner previously started a company in other industries besides ICT and finance, otherwise code “0”.

Table 4B: Firm-level top management team variable names and descriptions

Variable name	Variable description
<i>Total_HumanCapital</i>	The sum of all TMT members’ specific human capital in one venture capital firm.
<i>Total_ICT</i>	The sum of all TMT members’ ICT related expertise in one venture capital firm, including <i>Edu_ICT</i> , <i>WorkExp_ICT(R&D)</i> , <i>WorkExp_ICT(notR&D)</i> and <i>EntreExp_ICT</i> .
<i>Total_Finance</i>	The sum of all TMT members’ financial related expertise in one venture capital firm, including <i>Edu_Finance</i> , <i>Edu_MBA</i> , <i>WorkExp_Finance</i> , <i>WorkExp_Investment</i> , <i>EntreExp_Finance</i> .
<i>Total_Other</i>	The sum of all TMT members’ expertise that is not related to ICT or finance in one venture capital firm, including <i>Edu_Other</i> , <i>WorkExp_Other</i> , <i>EntreExp_Other</i> .

<i>Other_teamlevel</i>	<i>Total_Other divided by TeamSize is Other_teamlevel</i>
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Table 4C: Control, independent and dependent variable names and descriptions

Independent variables	
<i>ICT_teamlevel</i>	<i>Total_ ICT divided by TeamSize is ICT_teamlevel</i>
<i>Finance_teamlevel</i>	<i>Total_ Finance divided by TeamSize is Finance_teamlevel</i>
Dependent variables	
<i>ExitRatio_Success</i>	The ratio of a VCF's prior ICT portfolios that have been successfully exited via mergers and acquisitions (M&A) transactions or an initial public offering (IPO) verse all prior investment that has been made in the U.S. after founding.
Control variables	
<i>VC_FirmAge</i>	Until 2018, the number of years that VCF has been existing since the year they found.
<i>TeamSize</i>	The number of people holding the title general partner or, in the absence of such a title, the highest-ranking title in the firm hierarchy.
<i>% investment in US</i>	The ratio of the number of VCF's prior investment in the U.S. verse all prior investment.
<i>% prior investment in ICT</i>	The ratio of the number of VCF's prior investment in the U.S. ICT industry verse all prior investment in all industry within the U.S.

5 Results and Discussion

Firstly, this section describes the data collected by doing a descriptive analysis. The individual-level data and firm-level data are presented separately. Then, this section analyzes the data using linear regression methodology. Finally, this section checks whether there are multi-collinearity problems perform and perform a set of robustness checks to consider the possible bias.

5.1 Descriptive Statistics- Firm-level

This section firstly presents a description of the sample-207 venture capital firms at the firm-level (*Table 5*). The founding year of the sample VCFs is between 2000 and 2011. The year that has the highest number of VCFs founded is the year 2000, which has 28 firms are included in this study. The year 2002 has the lowest number of firms, which is 10. Other years all have similar numbers, which are between 15 to 21 firms (*Figure 4*).

The sample firms made 5550 prior investment in total at all geographic countries and in all industry. 5217 investments are made in the U.S., which accounts 94% of the all investment and within these investments, 4014 (std. dev. 22.25) investments are made in the ICT industry which accounts 76.94% of the U.S. investments. This result is consistent to National venture capital association yearbook (2017)'s observation that 54% of all VC deals in 2016 are made in "IT hardware", "Software" and "Media". Since this study purposely chooses the VCFs that are interested in and also are focusing on investing in ICT, it is normal that this study gets a higher percentage of investment in ICT. Within these Investments, 2935 (std. dev. 16.313) are made in IT industry (73%) and 1079 (std. dev. 7.455) are made in communication industry (27%) (*Figure 5*). On average, each VCF made 19.39 prior investments in ICT within the U.S. and has 8.61 ICT investments successfully exit. The dependent variable is the ratio of VCFs' portfolio companies that exit via IPO or acquisition. The average ratio of VCFs' portfolio companies that exit, via IPO or acquisition, is 31.89% (std. dev. 18.34%).

The data that this study collects shows that the composition of VCFs' human capital emphasizes financial expertise (average 46.82%, std. dev. 20.92%) more than *technological expertise* (average 34.03%, std. dev. 22.74%) even when they focus on investing in the ICT industry. This result consists of previous studies and theories (e.g. Dimov, Shepherd & Sutcliffe, 2007). Besides, we

notice that the human capital composed by the ICT-focused VCFs is relatively homogeneous. The VCFs either focus on cumulating *financial expertise* or *technological expertise*, with only 19.14% (std. dev. 16.19%) of other expertise.

This study also tests the correlation among these firm-level variables (*Table 6*). We find that “Year founded” is not highly correlated with any other variables, which means the VCFs that has founded earlier not necessarily have more professionals or make more investments than the firms that founded later. Moreover, there is a significant correlation between the “number of professionals” and “the number of investments”. Because developing portfolio firms demands a lot of time and effort, from pre-invest to post-invest actives, VCFs with more professionals may be more capable of screening protentional portfolios and provide advice to their portfolio firms. However, the quality of their investments cannot be shown here.

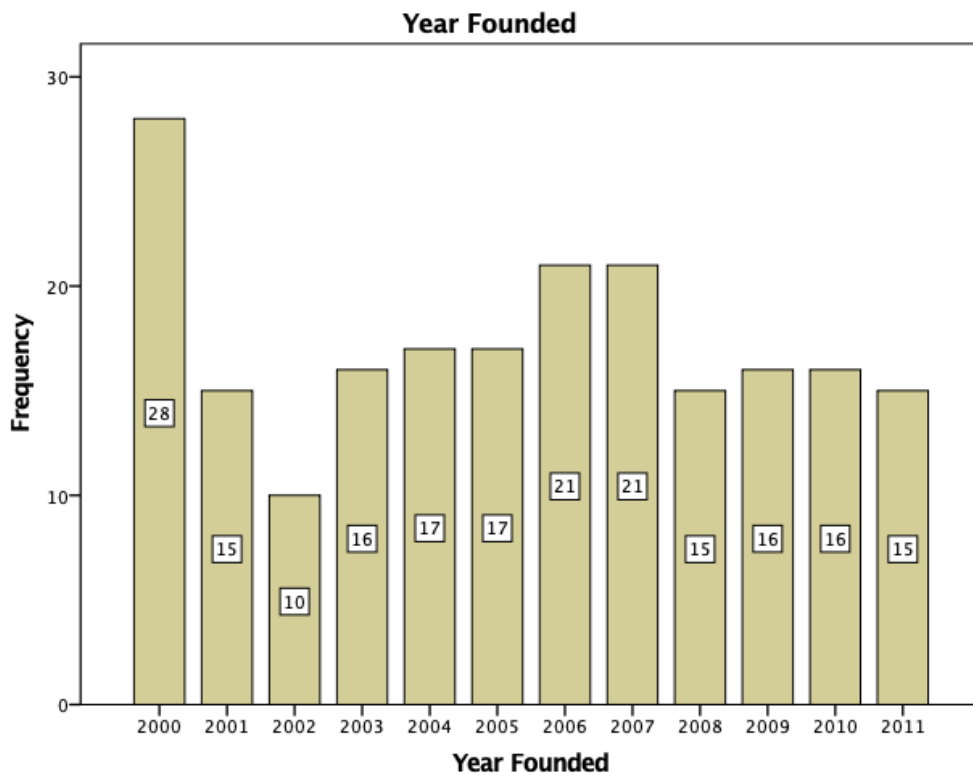


FIGURE 4. The number of VCFs at each “Year Founded”

OF PRIOR INVESTMENTS IN ICT

■ # of Prior Investments in IT ■ # of Prior Investments in communication

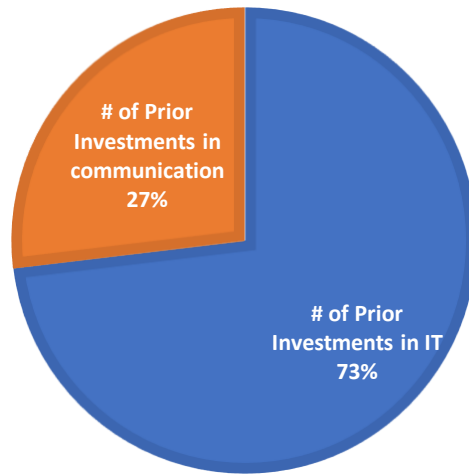


FIGURE 5. Number of prior investments in ICT

Table 5. Firm-level variables

	N	Minimum	Maximum	Mean	Std. Deviation
VC_FirmAge	207	7	18	12.70	3.503
Number of Current Professionals Profiled	207	1	43	8.66	7.608
TeamSize	207	1	8	2.67	1.276
# of Prior Investments	207	4	343	26.81	33.339
# of Prior Investments in US	207	3	285	25.20	30.017
% investment in US	207	.33	1.00	.9478	.09926
# of Prior Investments in IT	207	0	139	14.18	16.313
# of Prior Investments in communication	207	0	50	5.21	7.455
# of Prior Investments in ICT	207	2	173	19.39	22.25
% prior investment in ICT	207	.40	1.00	.7642	.1646
# of Prior ICT Investments EXITS	207	0	96	8.61	11.99
ExitRatio_Success	207	.00	1.00	.3189	.1834
ICT_teamlevel	207	.00	5.00	1.5378	1.14819
Finance_teamlevel	207	.00	4.50	1.9961	.91514
Other_teamlevel	207	.00	3.0	.8137	.68404

Table 6. Correlations between “number of professionals” and “number of investments”

	1	2	3	4
1 VC_FirmAge	1			
2 Number of Current Professionals Profiled	-.037			
3 TeamSize	-.037	.354**		
4 #of Prior Investments in ICT	.130	.259**	.322**	
5 #of Prior ICT Investments EXITS	.116	.297**	.359**	.893**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

5.2 Descriptive Statistics- Individual level

This section presents the characteristics of data collected at the individual-level for people who may interest. In this unique hand-collected dataset, there are 550 TMT members in total, with an average of 2.67 people per firm. Measures that are captured in this study allows me to observe the prevalence of particular educational specializations, particular experiences (*Table 7*) and the Pearson correlations of the individual-level variables (*Appendix 2*).

This study first collects the data of the gender of all recorded TMT members on S&P Capital IQ database and we notice that the TMTs of the sample VCFs are male-dominated, with 94.5% are male and only 5.5% are female.

In 550 TMT members, 36.2% had an ICT education degree, with 9.5% had a master degree and 5.1% had a Ph.D. Also, 59.6% of members had experience working in the ICT industry (not R&D), but only 12.7% had work experience in R&D. We suspect the reason behind this huge difference is that the work experience in R&D requires more technological knowledge, but work experience that is not in R&D, such as sales and marketing, requires less technology-related knowledge. This reason also is shown in the correlation table (*Appendix 2*), the *Edu_ICT* is much more highly correlated with *WorkExp_ICT (R&D)* than *WorkExp_ICT (not R&D)*. Furthermore, 22.7% of people had an entrepreneurial experience in the ICT industry, which is highly correlated to *WorkExp_ICT (not R&D)*. This correlation could have two meanings, either people with *WorkExp_ICT (not R&D)* more likely to start their own ICT business or people who found an ICT

firm more likely to work in this industry. We notice during the data collection that a large proportion of founders of the ICT firms act as CEO after the founding, but some do not.

Compared to technological education, financial education is more popular in the venture capital industry, with 36.4% of members had a bachelor education, 42.9% had an MBA degree. However, the graduate education of finance-related specializations is not very popular, only 6.2% had master's degree besides MBA and only 1.1% had a Ph.D. in the sample. People normally choose either taking an MBA or a traditional master's degree. In the sample, most TMT members chose MBA. We expect an MBA may highly correlated to the VCs who did not have a finance background, but the results suggest that MBA is not highly correlated with other variables. In opposite, it has a negative relation with *Edu_ICT* and *EntreExp_ICT*. In addition, compare to *WorkExp_Finance* (not investment) (33.6%), more members have work experience in investment 61.3%. The ratio of people who had an entrepreneurial experience in the finance industry is relatively low (9.6%), and most of the firms they founded before are venture capital firms and few numbers of consulting firms. Therefore, we suspect that, for most of the founders in the sample firms, this is the first VCF they founded.

Furthermore, we notice that the human capital of the sample firms is mainly related to either ICT or finance, with 33.8% people had an education in other specializations, 34.0% worked in other industries and 7.3% had an entrepreneurial experience in other industries. As stated before, all education and experience that are related to other industries are included in others. The most frequent other industries in the dataset are healthcare, construction, real estate, the energy industry, and law.

TABLE 7. Descriptive Statistics- Individual level

		Count	Column N %
Gender	Female	30	5.5%
	Male	520	94.5%
Edu_ICT	No (0)	351	63.8%
	Bachelor (1)	119	21.6%
	Master (2)	52	9.5%
	PhD (3)	28	5.1%

WorkExp_ICT (R&D)	No (0)	480	87.3%
	Yes (1)	70	12.7%
WorkExp_ICT (not R&D)	No (0)	222	40.4%
	Yes (1)	328	59.6%
EntreExp_ICT	No (0)	425	77.3%
	Yes (1)	125	22.7%
Edu_Finance	No (0)	310	56.4%
	Bachelor (1)	200	36.4%
	Master (2)	34	6.2%
	PhD (3)	6	1.1%
Edu_MBA	No (0)	314	57.1%
	Yes (1)	236	42.9%
WorkExp_Finance	No (0)	365	66.4%
	Yes (1)	185	33.6%
WorkExp_Investment	No (0)	213	38.7%
	Yes (1)	337	61.3%
EntreExp_Finance	No (0)	497	90.4%
	Yes (1)	53	9.6%
Edu_Other	No (0)	364	66.2%
	Bachelor (1)	151	27.5%
	Master (2)	28	5.1%
	PhD (3)	7	1.3%
WorkExp_Other	No (0)	363	66.0%
	Yes (1)	187	34.0%
EntreExp_other	No (0)	510	92.7%
	Yes (1)	40	7.3%

Before conducting the regression analysis, we first detect whether there is a multicollinearity problem. *Table 8* presents the correlation coefficients across predictor variables and the dependent variable (*ExitRatio_sucsess*). Correlations are all below 0.5. The calculated VIFs are all below 3 (see *Appendix 3*) (Wooldridge, 2016), multicollinearity is not an issue.

Table 8. Correlations of control, independent and dependent variables

Variable	1	2	3	4	5	6	7
1 VC_FirmAge	1						
2 % investment in US	.120						
3 % prior investment in ICT	-.081	-.181**					
4 TeamSize	-.037	-.026	.022				
5 ICT_teamlevel	.101	-.063	.363**	-.061			
6 Finance_teamlevel	-.004	-.034	-.091	-.029	-.393**		
7 Other_teamlevel	-.007	.190**	-.269**	.028	-.295**	-.159*	
8 ExitRatio_Success	.076	.041	.412**	.149*	.258**	-.030	-.176*

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

5.3 Regression models and results

Four linear regression models are employed in this study. The form of the linear regression equation that was used is:

$$p(x) = \alpha + \sum_{i=1}^2 \beta_i x_i + c_j z_j + \varepsilon$$

In the equation, $p(x)$ is the ratio of VCFs' portfolio companies that exit via IPO or acquisition. α is the intercept. x_i represents the two independent variables (*ICT_teamlevel*, *Finance_teamlevel*), z_j represents the control variable. β_i and c_j are regression coefficients or parameter estimates. ε is

the residual term. The model is measured for overall fit, the statistical significance of the parameter estimates (β_i and c_j), as well as their direction and magnitude.

Table 9. Regression Results

Dependent variable: <i>ExitRatio_Success</i>				
	1	2	3	4
	Base model	Base model +<i>ICT_teamlevel</i>	Base model +<i>Finance_teamlevel</i>	Full model
Control Variables				
VC_FirmAge	.104 (.101)	.099 (.116)	.104 (.101)	.098 (.118)
% investment in US	.111* (.083)	.122* (.079)	.112* (.081)	.116* (.069)
% prior investment in ICT	.437*** (.000)	.389*** (.000)	.439*** (.000)	.384*** (.000)
TeamSize	.146** (.020)	.155** (.014)	.146** (.020)	.159** (.011)
Independent Variables				
ICT_teamlevel		.133** (.048)		.166** (.023)
Finance_teamlevel			.018 (.769)	.079 (.243)
Model				
R^2	.214	.229	.215	.235
Adjusted R^2	.199	.210	.195	.212
F value	13.777***	11.973***	10.989***	10.224***
No. of observations	207	207	207	207

* p<0.1; ** p<0.05; *** p<0.01

β and p values are shown in table

The results are presented in *Table 9*. All models are statistically significant. Model 1 (base model + *Finance_teamlevel*) includes only the control variables (*% prior investment in ICT*, *TeamSize*, *VC_FirmAge*, *% investment in US*). Model 2 only adds one independent variable (*ICT_teamlevel*). Model 3 only adds another independent variable (*Finance_teamlevel*). Model 4 contains both

independent variables (*ICT_teamlevel* and *Finance_teamlevel*). The study separates the models to show additional variance explained by the new variables.

Besides model 1, adding specific human capital to the base models led to improvements. Both model 2 and model 4 have slight improvements over the base model, but they are not very significant improvements. Base model (model 1) accounts for 19.9% of the ratio of successful exits (adjusted $R^2 = .199$). After adding *ICT_teamlevel*, it accounts 21.0% (adjusted $R^2 = .210$) and full model (model 4) accounts for 21.2% (adjusted $R^2 = .212$) of the variance in successful exits. Also, after adding *Finance_teamlevel* in the base model, the adjusted R^2 drop to .195 (model 3), which demonstrates that *Finance_teamlevel* may not play a significant role in explaining the dependent variable.

Furthermore, the coefficient results show the relationship between the ratio of successful exits and two studied variables. Firstly, the regression results of both model 2 and full model (model 4) support *Hypothesis 1*. This study finds that the *technological expertise* of the VCFs' management team to be an important driver of the performance of investments and it positively relates to successful exit ratio (full model $\beta = .166$, $p = .023$). Secondly, although *financial expertise* positively affects the exit ratio, it does not contribute to the model significantly (full model $\beta = .079$, $p = .243$), which does not support *Hypothesis 2*. Therefore, VCFs that have greater *technological expertise* are associated with a greater ratio of portfolio companies that exit successfully, *financial expertise* does not affect much of the results.

Also, some of the control variables show that they have a great influence on the exit ratio. *% prior investment in ICT* shows a significant positive effect (full model $\beta = .384$, $p = .000$), and *TeamSize* is another significant variable that has a positive effect on exit ratio (full model $\beta = .159$, $p = .023$).

This study performs an additional robustness check. First, we try to introduce another independent variable (*Other_teamlevel*) into the regression (*Appendix 5*). *Other_teamlevel* represent the other expertise at the team level. The result of the regression is in line with the findings without it. *ICT_teamlevel* still plays a positive significant role and *Finance_teamlevel* is not significant. Also, we try to change a way to define the team-level *technological expertise* and *financial expertise*,

the regression result is also consistent (*Appendix 6*), except *technological expertise* shows a negative effect but still insignificant.

5.4 Discussion

The preceding analysis documents that specific human capital, defined as human capital specific to the tasks of venture investing and of managing an early-stage ICT portfolio, strongly predict better venture capital firm performance in the form of greater portfolio exit ratio.

This study extends the VC literature by highlighting the role of management teams and their compositions in the investment performance of VC firms. This study further provides evidence to the stream of research focusing on individual VC managers and their background to explain the variance between VCFs' investment performance needs to be complemented by research at the TMT level (Carpenter, Geletkanycz & Sanders, 2004). While the top management teams appear to be the appropriate level of analysis for organizational-level outcomes (Wright and Robbie, 1998), the results of this research support the view that the performance of portfolios is influenced by the composition of VCFs' top management team.

Besides, this study adds fuel to the argument that venture capital research needs to move beyond the assumption that VCFs' invest environment is an undifferentiated whole (Dimov, Shepherd & Sutcliffe, 2007). VCFs make heterogenous investments in terms of the preferences of geographic location, investment stages and investment industries (De Clercq and Dimov, 2008). Also, some research found the different effect of the same item when it was tested in a different investment environment. Zarutskie (2010) found a negative impact of science/engineering education when it was tested in six VentureXpert industries. However, when Zarutskie (2010) constrained the effect in the technology industry, science/engineering education shows a positive impact on exit performance. Therefore, a team's expertise must be "appropriate" for the tasks and challenges posed by the sub-environments that VCF faces (Dimov, Shepherd & Sutcliffe, 2007).

This study specifically sets the sub-environment in the early-stage U.S. ICT industry. This particular setting allows me to observe how significant two kinds of specific human capital trigger VCFs' different portfolio performances. The result suggests that, in this sub-environment, *technological expertise* has a significant positive effect on VCFs' investment

performance, meaning *technological expertise could* give competitive advantages for the firms. *Financial expertise* also has a positive effect, but it is not significant.

Most of the existing studies are concerned with the interaction between financially-relevant human capital and investment performance. This study introduces a new specific human capital- *technological expertise*, which captures key team-level characteristics in a more specific way. The items comprising this construct have been used in prior research as separate variables (e.g., Dimov and Shepherd, 2005; Casson and Martin, 2007; Zarutskie, 2010), but this research shows that they jointly represent the broader concept of a TMT's perceived readiness to engage in its portfolio companies. *Technological expertise represents* the joint effect of *Edu_ICT*, *WorkExp_ICT (R&D)*, *WorkExp_ICT (not R&D)*, and *EntreExp_ICT*.

There are several possible reasons why *technological expertise is* significantly associated with greater portfolio exit ratio. To have more successful exits from their portfolio companies and fewer portfolio companies that provide no return to them, VCFs need appropriate human capital to better assess and assist portfolio companies (Dimov and Shepherd, 2005). *Technological expertise* allows VCFs to be capable of appreciating the potential of a given technology (Berglund, 2011). In the pre-invest stage, VCFs with higher *technological expertise* can better identify promising technologies when there are not many signs to help them make a decision (Milosevic, 2018). The result provides evidence to the argument that VCFs with the same-industry work experience are more familiar with the business context (Becker, 1964; Davidsson and Honig, 2003) and can more readily delineate true investment opportunities (Patzelt, zu Knyphausen-Aufsess & Fischer, 2009; Knockaert, Clarysse & Wright, 2010).

In the post-investment stage, because early-stage ICT VCFs often need to invest in the 'imperfect deals', they need to be involved actively at the early stages of venture developments. VCFs often need to put more effort into activities, such as helping shape the product categories, business models and standards that will define future markets (Sarasvathy, 2001; Berglund, Hellström & Sjölander, 2007). These activities require *technological expertise* that can facilitate an appreciation of the technological and challenges of the portfolios they oversee (Bottazzi, Da Rin & Hellmann, 2008).

Furthermore, risk recognition is one of the main theoretical mechanisms used in venture capital literature (Wright, Lockett & Pruthi, 2002). Investment in an early-stage company tends to entail higher project-specific uncertainty concerning the costs and benefits of the project (Li and Mahoney, 2011). *Technological expertise* affects the team's understanding of the uncertainty that exists. Also, information asymmetries that typically exist between entrepreneurs and VC firms are specifically important in high-tech companies, where investors may find it difficult to evaluate technology and have difficulties in assessing the commercial implications of strategic choices (Cumming 2007; Knockaert et al. 2006). Dimov and Shepherd (2005) indicate that one key factor contributing to risk perception is problem domain familiarity. According to the result, *technological expertise* allows VCFs to better deal with potential risks that may lead to an unsuccessful result, which is also consistent to Knockaert, Clarysse & Wright (2010)'s findings. Therefore, the finding of this research suggests that one way for VCFs to reduce potential agency risks and costs is strengthening *technological expertise*. In order to accurately assessing risk, VCFs can recruit top management team members who have ICT education, previous ICT work experience, and ICT entrepreneurial experience.

Also, given the complexities of technologies, the VCFs must be highly informed on both technical and commercial-related issues (Murray, 1995). To secure privileged knowledge, VCFs often seek out external expertise by consulting the board or an external expert source (Casson & Nisar, 2007). The risk of individual investments can be minimized if the investors within their specific technical and product expertise (Sapienza and Gupta, 1994; Manigart et al., 2002) have the connections with the professionals who have specific technical and product expertise. Therefore, VCFs with higher *technological expertise* may have an advantage in seeking out for external resources, which may contribute to their portfolio success.

Besides, one of the separate variables within *technological expertise* is entrepreneurial experience in the ICT industry. VCFs with previous start-up experience can provide better strategic advice on company development, serve as coaches and mentors to entrepreneurs and use their expertise in managing crises and problems. Research also suggests that persons with previous entrepreneurial experience are more likely to continue searching for new opportunities (Marvel, 2013). Furthermore, VC managers with previous start-up experience are found to be more likely to take an active role in developing their portfolio firms (Knockaert et al., 2006) than those without this

previous experience. The activeness of the engagement with portfolio firms is associated with a higher ratio of portfolio exits (Knockaert et al., 2006).

Besides *technological expertise*, another specific human capital---*financial expertise* does not play a role as significant as we expect, although it has a positive effect. So, the result is against the argument that *financial expertise* plays a significant role in technology investments since it is the human capital that aligns with VCFs' goal. The *financial expertise* should positively affect portfolio performance by assessing payoff and risk and improving the managers' comprehension of the requirements for making the potential investment successful in the pre-investment process (Mitchell et al., 1995); and actively monitoring portfolio firms through the use of specific financial instruments and contractual clauses in the post-investment process (Kaplan and Strömberg, 2004). However, in the sub-environment of this study, results suggest that the "appropriateness" of *financial expertise* is lower than *technological expertise's* and *financial expertise* cannot yield competitive advantages for the VCFs. There could several potential reasons why it does not play a role in this study.

Compared to technology investors attach more importance to the appropriability of the technology and contact with the entrepreneur than the other groups of VCs, financial investors make their investment decision based on a limited set of factors such as ROI, growth and team completeness (Knockaert et al., 2010). However, Gompers et al. (2017) suggested 17% of early-stage investors do not use any quantitative deal evaluation metric. Furthermore, while only 7% of late-stage funds do not forecast, fully 31% of early-stage VCs report that they do not forecast cash flows. This is understandable given that early-stage start-ups are always far from generating profit and sometimes are not even generating revenue. For such early-stage companies, forecasting and discounting cash flows arguably would generate very imprecise estimates of value (Gompers et al., 2017). This also can explain why early-stage technology ventures may not need VCFs' *financial expertise* to complete their internal human capital. Although the composition of entrepreneurial teams is often homogeneous in terms of education, experience, and skills, which are typically science-based (Ensley and Hmieleski, 2005).

Secondly, the contribution that *financial expertise* offers to VCFs' portfolios may be more in the forms of social capital instead of human capital. Venture capitalists generally responded that they

provide a large number of services to their portfolio companies post-investment strategic guidance (87%), connecting investors (72%), connecting customers (69%), operational guidance (65%), hiring board members (58%), and hiring employees (46%) (Gompers et al., 2017). As we can see, there is a huge part of the work are related to networking. Also, TMT members come to new firms with alliances they developed with their former VC employers, with whom they can now syndicate deals (Milosevic, 2018).

Of all firm-level control variables, two variables are not significant--- “*VC_FirmAge*” and “*% investment in the US*”. The result that *VC_FirmAge* is not significant confirms the idea that early-found date is not a signal of quality and the ability of firms to develop successful ventures. Also, “*% investment in the US*” does not play a significant role either. There are two possible reasons why it is not significant. Firstly, according to *Table 6*, the mean of “*% investment in the US*” is .9478, with .09926 standard deviation. There is not much differentiation among the sample firms. Another reason could be that it is easier for VCFs to deal with the geographic scope of investments now than before (Cressy, Malipiero & Munari, 2014) since the process of integration of economic and financial markets which have been implemented worldwide over the last few years, coupled with the enabling role of new communication technologies. The previous study even suggests that higher levels of “Diversification by Country” might be beneficial in terms of VC performance, because it may be easier to benefit from the sharing of risks in different geographic markets (Cressy, Malipiero & Munari, 2014). However, since this research only evaluates the performance of the investments made in the US, we could not confirm their theory by using this dataset.

Besides these two, there are two control variables play a significant role in predicting the VCFs’ portfolio performance --- “*TeamSize*” and “*% prior investment in ICT*”. “*TeamSize*” is significant confirms the expectation that a positive relationship between the number of top management team members and investment performance since more members will provide more human capital in general to the firm and provide more labor to monitor and screen investments (Zarutskie 2010).

Also, “*% prior investment in ICT*” is extremely significant in the models. Therefore, the result of this research provides evidence to the theory that organizations which specialize in a particular activity exhibit better performance (e.g., Amit, Brander et al., 1998; Dimov and DeClerq, 2006;

Gupta and Sapienza, 1992). VCFs that continuously invest in particular types of ventures can maximally benefit from such learning curve effects through the accumulation of superior knowledge over time and can, therefore, reduce the likelihood of venture failure (Gupta & Sapienza, 1992; Hall & Hofer, 1993; Norton & Tenenbaum, 1993). New venture failure is less likely to occur when VCFs better understand the critical success factors related to the competitive dynamics of particular industries (Dimov and De Clercq, 2006). Also, Cressy, Malipiero & Munari (2014) confirm with UK data, the negative impact of "Diversification by Industry" on VC performance might suggest that different industrial sectors entail idiosyncratic knowledge and capabilities, which can be more easily developed through specialized investment strategies, as is also confirmed by the results of the studies based on US data by Knill (2009) and Gompers et al. (2009).

Overall, the findings also suggest that only employing a qualitative way to evaluate human capital is too simplistic based on the adjusted R^2 . The upper echelon research has shown that other TMT variables such as age (Bantel and Jackson, 1989; Datta and Rajagopalan, 1998; Wiersema and Bantel, 1992), functional background (Hambrick et al., 1996; Herrmann and Datta, 2006), and team heterogeneity (Knight et al., 1999) influence performance. Also, this study could not test the effects of each item within the two constructs since the sample size is limited and the separated variables do not have enough differentiation from firm to firm. There is no obvious pattern when testing the items that comprise these two constructs.

6 Limitations

It is important to consider the study's limitations since they suggest further topics which can be directly addressed by future research. The first consideration is on the generalizability of the findings. This study only investigates the VCFs that prefer investing in the "early venture" or "seed/start-up" stage based on their "Industries of Interest" and "Company Stage" record in S&P Capital IQ database. It must be noted that the result of this research may not be highly generalizable to those VCFs that are not focused on investing in early-stage ICT firms. However, it should apply to the VCFs who focus on early-stage ICT firms.

Secondly, the ideal dataset should only include the prior investments and exits when the investment was made in the portfolio firm's early stages (within five years after the founding year). However, due to the great number of portfolio firms, there is no way to verify whether each of the VCFs' investments are made within the first five years. We do not rule out the possibility that VCFs that prefer investing in the "early venture" or "seed/start-up" stage may also invest in the other stages, such as late stage. Investing in late-stages could cause a higher exit ratio. To avoid this issue, we randomly select 20 firms in the sample and confirm that most of their investments are made within the first five years of their portfolios founded. Therefore, this study assumes that VCFs made most of their investments in the portfolio firm's early stages.

Thirdly, this study is mainly concerned with the appropriateness of VCFs' specific human capital characteristics and their investment preference and focuses on the qualitative understanding of VCFs' human capital. This study does not include the quantitative measure of the human capital, such as "the years working in the industry" or "the hierarchy of their previous job". The adjusted R^2 of the model suggests that only employing a qualitative way to evaluate human capital is too simplistic. Therefore, investigating how to combine the qualitative and quantitative understanding of variables is an important avenue for future research.

Fourthly, by taking a single snapshot of the management team, this research is not able to consider the effects of changes in the management team composition prior to this study and within the specified investment period. This research only takes the current TMT member's biographic information into consideration. Because the number of prior TMT members is huge, it is

impossible to include them all. Although the influence of the prior TMT members is undeniable, this is a drawback of all TMT research (Dimov and De Clercq, 2006). Also, this study only includes the TMT's previous education and experience before they became a TMT member, however, the accumulation of experience or education after they became a TMT can also influence the investment performance and thus increase the ratio of portfolio exits. The previous study also mentioned that the learning capability of a given VCF can be enhanced by developing particular expertise through an investment specialization strategy (Dimov and De Clercq, 2006), therefore, there may be an interaction factor between the human capital accumulated after they became a TMT and firm's geographical or industrial specialization strategy. However, this is not the topic we focus on in this study and it can be tested in future research.

7 Conclusion

This study suggests that VCFs' investment performance needs to be complemented by research at the TMT level. While the VCF top management team appears to be the appropriate level of analysis for organizational-level strategic decisions (Wright and Robbie, 1998), the results of this research support the view that the performance of portfolios is influenced by the composition of the VCFs' top management team.

The higher appropriateness of the team's knowledge for the organization's environment or strategy, the higher performance should be yielded (Dimov Shepherd & Sutcliffe, 2007). To test the "appropriateness" of specific human capital. This study introduces two new specific human capital- *technological expertise* and *financial expertise* into the VC human capital research, which are comprised by the items that have been used in prior research as separate variables (e.g., Dimov and Shepherd, 2005; Casson and Martin, 2007; Zarutskie, 2010). This study shows that these items jointly represent the broader concept of a TMT's perceived readiness to engage in its portfolio companies. The results of this study demonstrate that, in the early-stage ICT industry, VCFs' *technological expertise* strongly predict better venture capital firm performance in the form of greater portfolio exit ratio. While *financial expertise* shows a positive but not significant effect. In this case, *technological expertise* is the human capital characteristic that is more appropriate for this sub-environment.

Overall, this study provides evidence to the argument that measures of specific human capital are strong predictors of venture capital firm performance (Zarutskie, 2010). Also, future research should continue to take a team perspective when analyzing the VC human capital effect at the organizational level. Also, the results of this study have some important implications for practitioners. VCFs may build their investment teams with a human capital consideration in mind. Understanding the human capital factors contributing to achieving greater portfolio exits ratio can help build teams that increase firm performance. Similarly, entrepreneurs seeking venture capital finance may increase their awareness of the value that a VCF could bring to their start-up company. By pre-examining the backgrounds of the VCF's top management team, entrepreneurs can target those VCFs that could make the greatest contribution to their success.

Appendix

Appendix 1: literature review procedure

This proposal used a systematic literature review to deal with the large number of papers published in this area. Although this method was developed for the medical discipline, it has already gained recognition in the management research field (Tranfield, Denyer & Smart, 2003). Traditional narrative literature review has been criticized for being highly subjective and open to potential biases (Mulrow, 1994), whereas systematic review aims to present an evidence-informed summary of the literature. Therefore, a systematic literature review is a trustworthy, rigorous and auditable methodology for evaluating and interpreting previous research that is relevant to a particular phenomenon of interest. By performing a systematic literature review, this article integrates existing information and provides a theoretically-founded framework for understanding various changes to the theory in the new era. This systematic literature review was following two steps that are particularly important: 1) setting the inclusion criteria, and 2) setting the strategy for locating and selecting the studies for potential inclusion.

Inclusion criteria

Three inclusion criteria were used as a guide for selecting and assessing the studies for potential inclusion. To be included in the systematic review, a study had to:

1. Be published as an article in a peer-reviewed scientific journal or be an article or book referred to in such peer-reviewed articles and include the keywords ‘human capital’, ‘venture capital’ and ‘performance’ (or its synonyms) in its title or abstract.
2. Be a theoretical, conceptual or empirical study focusing on the relationship between venture capital firm’s human capital and the performance of its portfolio investment companies.
3. Focus on independent VCFs, which excludes banks, corporation VCFs or government VCFs.
4. Focus on study portfolio company performance only; the studies that explored investment decisions or strategy will not be included as significant literature but interpreted as supportive literatures.

Although the role of inclusion criteria is to help limit selection bias, reduce the effects of chance and hence enhance the legitimacy of the literature review (Becheikh, Landry & Amara, 2006), it should be noted that if inclusion criteria are used too 'blindly', such a literature review may fail to uncover the effect of venture capital firm's human capital. To avoid this, this literature review includes several studies which did not meet the inclusion criteria but were nonetheless interpreted as significant in considering the research objective.

Without any confining criteria, the number of articles that included concepts of "venture capital" human capital' was as high as 139,000 on "Google Scholar" due March 2018. To create a reasonable, but still valid population of studies, a computerized search was carried out using multiple keywords in the following databases: ABI/INFORM Collection, Web of Science, Business Source Complete, and Scholars Portal Journals. These four databases include a great number of scientific journals that focus on business and financial. Search was confined only to articles that were published in peer-reviewed scientific journals. This choice is in line with the rationale behind the systematic literature review methodology: the accuracy and reliability of the review can be enhanced by focusing on studies of good quality (Mulrow, 1994).

To collect the articles that are closely related to the research question of this study, the search process was also further limited by using keywords, including '(venture capital)', 'perform*', and 'human'. However, we find that the result has a huge overlap with the literatures focusing on the new venture's human capital. Therefore, we used keywords 'invest*', 'portfolio', 'firm*' and 'fund*' to make sure the searched result is related to the venture capital firm's human capital instead of entrepreneurial firm's. In addition, the search was diversified to include synonyms of 'perform*'. The sensitivity and precision of search terms is crucial for the validity and reliability of a systematic literature review (Ciliska, Ganann & Thomas, 2010). The synonym selected was 'success*', 'fail*', and 'exit*'. In addition, we also used '(public offering)', 'IPO', 'bankrupt*' and 'M&A' to make sure we get all related articles. The combination of synonyms and keywords yielded 189 articles. After deleting the duplicates of the results, there were 96 articles that included the selected keywords.

Exclusion criteria

All 96 articles are first analyzed by reading the title and abstract first. We find that, only based on the keywords, there is a huge overlap between the irrelevant articles and the relevant ones. A great number of these 96 articles were not focused on studying the human capital of the venture capital firms but the human capital of VC-backed new ventures. Therefore, these articles are analyzed by reading abstract and full text. Also, by using the snowball method, studies that are not meet the criteria but cited by the key literature and are interpreted as significant in considering the research objective are also included. After precisely reading the abstract and full text, we only find 9 articles that are directly related to the research question. Due to the limited number of selected key literature. Some of the studies are categorized as support literature if these articles studied the VCFs' human capital, VCFs' support to the early-stage new venture or study's industry setting was in the ICT industry.

Overall, we find that most of the “human capital” literature in the venture capital context have focused on the “entrepreneurial” side of story. Only few studies applied a human capital lens to evaluate the relationship between VCFs and their investment performance (Milosevic, 2018). The number of studies that focused on the relationship between “venture capital firm’s human capital” and “portfolio firm performance” is limited. A systematic and broader investigation of the impact of TMT characteristics on VCFs’ portfolio performance is missing from the literature. Table below summarizes the findings of the relevant studies.

Findings of studies on TMT composition and performance

Author	Publication	Sample selection	Research method	Key Findings
Dimov and Shepherd, 2005	Journal of Business Venturing	United States	Empirical	General human capital had a positive association with the proportion of IPO, while specific human capital did not; however, specific human capital was negatively associated with the proportion of portfolio companies that went bankrupt.

Dimov and De Clercq, 2006	Entrepreneurship Theory and Practice	United States	Empirical	The likelihood of new venture failure is reduced when the venture is supported by a VCF that brings knowledge relevant to the specific situation of the venture.
Knockaert, Lockett, Clarysse, and Wright, 2006	International journal of technology management	Europe	Empirical	There is no indication that involvement in monitoring activities by the investment manager is determined by human capital characteristics. Concerning value-adding activities, human capital variables were the most important, with previous consulting experience and entrepreneurial experience contributing to a higher involvement in value-adding activities.
Casson and Martin, 2007	Management Decision	British	Empirical	VCFs' strategy of using experienced and educated employees act as an incentive for them to put forth higher levels of engagement effort, which results in improved firm performance.
Bottazzi, Da Rin, & Hellmann, 2008	Journal of Financial Economics	Europe	Empirical	The strongest predictor of whether a venture capital firm adopts an active investment style is whether the partners have prior industry experience. Moreover, activism seems to improve performance.
Walske and Zacharakis, 2009	Entrepreneurship Theory and Practice	United States	Qualitative and quantitative	Venture capital, senior management, and consulting experience aid VCF success, while entrepreneurial experience impedes it.
Zarutskie, 2010	Journal of Business Venturing	United States	Empirical	Fund management teams with more task-specific human capital and more industry-specific human capital manage funds with greater fractions of portfolio company exits, and teams that have more general human capital in business administration manage funds with lower fractions of portfolio company exits.

Milosevic, 2018	Research Policy	France	Empirical	Companies which are backed by VCFs with a higher proportion of managers with prior R&D, entrepreneurship, VC and investment banking experience have a higher probability of a successful exit.
Milosevic, Le Pendeven and Fendt, 2018	Venture Capital	France	Empirical	General, business and consulting experiences of first investors have a negative signaling effect on outside VC investors for follow-on fundraising. Also, homogenous finance experience sends negative signals to outside investors about portfolio quality and value-adding ability.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1Edu_ICT (bachelor)	1																
2Edu_ICT (master)	.463**	1															
3Edu_ICT (Ph.D.)	.294**	.337**	1														
4WorkExp_ICT (R&D)	.479**	.333**	.234**	1													
5WorkExp_ICT (not R&D)	.264**	.166**	.089*	.181**	1												
6EntreExp_ICT	.176**	.057	.111**	.105*	.437**	1											
7Edu_finance (bachelor)	-.503**	-.304**	-.176**	-.284**	-.114**	-.081	1										
8Edu_finance (master)	-.066	-.058	-.061	-.080	-.109*	-.011	.049	1									
9Edu_finance (Ph.D.)	-.005	.013	-.024	-.040	.015	-.015	.019	.106*	1								
10Edu_MBA	-.062	-.062	-.184**	-.044	-.050	-.137**	.048	-.188**	-.020	1							
11WorkExp_finance	-.200**	-.107*	-.112**	-.179**	-.183**	-.129**	.237**	.062	.036	.137**	1						
12WorkExp_investment	-.055	-.048	-.088*	-.111**	-.152**	-.077	.039	.010	-.024	.109*	.013	1					
13EntreExp_finance	-.063	-.068	.036	-.088*	-.121**	-.015	-.096*	.032	.025	-.022	.015	.222**	1				
14Edu_other (bachelor)	-.406**	-.217**	-.162**	-.208**	-.169**	-.082	-.344**	-.021	-.036	-.064	-.045	.037	.140**	1			
15Edu_other (master)	-.128**	-.074	-.025	-.098*	-.112**	-.049	-.091*	-.039	-.027	.006	-.023	-.028	-.033	.175**	1		
16Edu_other (Ph.D.)	-.084*	-.043	-.026	-.043	-.039	-.023	-.094*	.032	-.012	-.066	-.012	-.043	.018	.128**	.308**	1	
17WorkExp_other	-.181**	-.052	.043	-.159**	-.184**	-.133**	-.051	.016	.035	-.025	-.040	-.139**	-.013	.219**	.119**	.124**	1
18EntreExp_other	-.077	-.043	-.001	-.065	-.098*	-.002	-.005	-.047	-.029	-.031	-.036	-.022	-.003	.073	.073	.156**	.272**

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

88 Appendix 2: Correlations of individual variables

Appendix 3: VIFs of Model 1-4

Dependent variable: <i>ExitRatio_Success</i>				
	Base model	Base model	Base model	Full model
		<i>+ICT_teamlevel</i>	<i>+Finance_teamlevel</i>	
Control Variables				
VC_FirmAge	1.019	1.021	1.019	1.021
% investment in US	1.046	1.046	1.049	1.050
% prior investment in ICT	1.038	1.194	1.048	1.197
TeamSize	1.002	1.007	1.003	1.011
Independent Variables				
ICT_teamlevel		1.160		1.370
Finance_teamlevel			1.012	1.196
No. of observations	207	207	207	207

Appendix 4: Interaction between technological expertise and financial expertise

Previous studies suggest that early-stage technology VCs may mainly base their decision on the characteristics of the technology. One way for VC investors to reduce potential agency risks and costs is by strengthening human capital in order to mitigate these risks and costs (Knockaert, Clarysse & Wright, 2010). Therefore, in order to perform this technological assessment, VC funds tend to recruit investment managers who have an advanced science education (Knockaert, Clarysse & Wright, 2010). VCFs may develop abilities in selecting entrepreneurial projects, which decrease the chance of encountering adverse selection and moral hazard problems caused by information asymmetries (Amit, Brander & Zott, 1998).

In addition, a VCF that undertakes early-stage financing will need to engage in monitoring and intervention for longer periods and provide more units of effort than a VC with a later-stage investment (Sapienza et al. 1996). To deliver their value-adding services, this study suggests that VCFs that invest in early-stage technology firms need more technological resources. That is, an investor's capabilities or skills should match the needs of the portfolio company in which it invests;

for example, when VCs had previous education and experience specializing in a particular technology sector (Casson and Nisar, 2007).

However, previous studies suggest that the main aims of VCFs who invest in high-tech ventures are to see science translated into a viable business and revenue model and to ensure adequate returns given the risk profile of their portfolio (Baeyens et al., 2006). VCFs' goal is not having portfolio companies with superior technologies (Knockaert and Vanacker, 2013). This study suggests that *financial expertise* is still the dominant human capital characteristic in VCFs. Although *technological expertise* is an important form of human capital in high-tech investments, it is not the human capital that aligns with VCFs' goal.

Therefore, this study proposes the third hypothesis to address the question: is the performance of the early-stage investment in the information and communication technology (ICT) industry is determined by a combination of *technological expertise* and *financial expertise*? When VCFs possess a similar level of *financial expertise*, this research proposes that VCFs who possess a higher *technological expertise* have a better capability to offer "value-adding activities" in the post-investment phase. Thus, the higher *technological expertise* a VCF possesses, the more likely they are to have a higher percentage of investment exits:

Hypothesis 3: When VCFs possess a similar level of financial expertise, the higher level of technological expertise the VCFs possess, the more likely they are to have a higher percentage of successful investment exits.

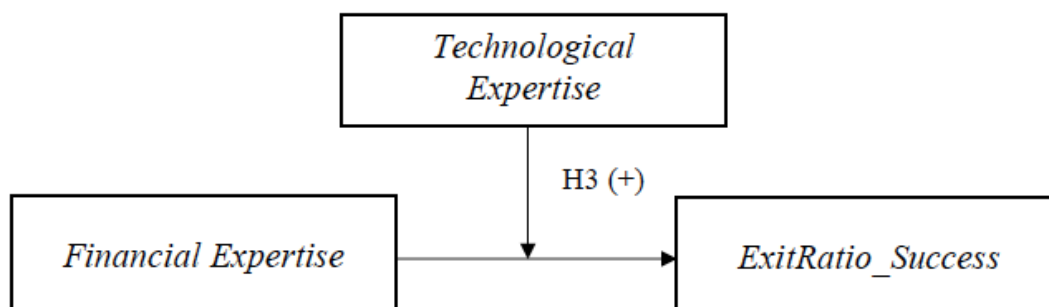


Figure 2: Conceptual Framework of Hypothesis 3

The result of the regression model below shows that the interaction between *financial expertise* and *technological expertise* does not play a significant role in predicting VCFs' investment performance.

Regression Model of *ICT*Finance*

Dependent variable: <i>ExitRatio_Success</i>			
	Base model	Full model	Full model + <i>ICT*Finance</i>
Control Variables			
VC_FirmAge	.104 (.101)	.098 (.118)	.099 (.116)
% investment in US	.111* (.083)	.116* (.069)	.114* (.074)
% prior investment in ICT	.437*** (.000)	.384*** (.000)	.381*** (.000)
TeamSize	.146** (.020)	.159** (.011)	.156** (.014)
Independent Variables			
ICT_teamlevel		.166** (.023)	.176** (.022)
Finance_teamlevel		.079 (.243)	.081 (.235)
ICT*Finance			.029 (.669)
Model			
R^2	.214	.235	.235
Adjusted R^2	.199	.212	.209
F value	13.777***	10.224***	8.754***
No. of observations	207	207	207

* p<0.1; ** p<0.05; *** p<0.01

β and p values are shown in table

Appendix 5: The effect of other expertise (*Other_teamlevel*)

Dependent variable: <i>ExitRatio_Success</i>			
	Base model	Full model	Full model + OTHER_teamlevel
Control Variables			
VC_FirmAge	.104 (.101)	.098 (.118)	.097 (.125)
% investment in US	.111* (.083)	.116* (.069)	.122* (.058)
% prior investment in ICT	.437*** (.000)	.384*** (.000)	.378*** (.000)
TeamSize	.146** (.020)	.159** (.011)	.159** (.011)
Independent Variables			
ICT_teamlevel		.166** (.023)	.149** (.053)
Finance_teamlevel		.079 (.243)	.065 (.362)
OTHER_teamlevel			-.047 (.506)
Model			
R^2	.214	.235	.236
Adjusted R^2	.199	.212	.210
F value	13.777***	10.224***	8.803***
No. of observations	207	207	207

* p<0.1; ** p<0.05; *** p<0.01

β and p values are shown in table

The result of regression shows that other expertise does not play a significant role in predicting the VCFs' investment success. Also, the results of *ICT_teamlevel* and *Finance_teamlevel* do not change because of adding another factor.

Appendix 6: Robustness check (definition of independent variables changed)

<i>Percent_ICT</i>	Ratio of a VCF's <i>Total_ICT</i> in the <i>Total_HumanCapital</i> .
<i>Percent_Finance</i>	Ratio of a VCF's <i>Total_Finance</i> in the <i>Total_HumanCapital</i> .

Dependent variable: <i>ExitRatio_Success</i>				
	Base model	Base model + <i>Percent_ICT</i>	Base model + <i>Percent_Finance</i>	Full model
Control Variables				
VC_FirmAge	.104 (.101)	.101 (.109)	.105* (.099)	.097 (.122)
% investment in US	.111* (.083)	.113* (.075)	.107* (.096)	.123* (.054)
% prior investment in ICT	.437*** (.000)	.384*** (.000)	.428*** (.000)	.374*** (.000)
TeamSize	.146** (.020)	.149** (.017)	.145** (.022)	.153** (.014)
Independent Variables				
<i>Percent_ICT</i>		.144** (.031)		.227** (.020)
<i>Percent_Finance</i>			-.049 (.444)	.108 (.241)
Model				
R^2	.214	.232	.217	.238
Adjusted R^2	.199	.213	.197	.215
F value	13.777***	12.166***	11.117***	10.388***
No. of observations	207	207	207	207

* p<0.1; ** p<0.05; *** p<0.01

β and p values are shown in table

Appendix 7: the effect of “current profiled professionals” and “PER_TMT”

Number of Current Professionals Profiled: This study focuses on the TMT members with the highest-ranking titles within the VCFs. However, besides the top management team, there are a large number of professionals who are working as a lower level of professionals. there are also advisors and consultant who are connected to the firm but do not act as investment managers. Such people may provide occasional advice to the firm managers or add advertising value to the firm but who do not engage in active management of the investment (Zarutskie 2010). They may also affect the outcome of the investment; The number of individuals identified in S&P Capital IQ

served as professionals in the venture capital firm, including highest-ranking titles, lower level of professionals, advisors, and consultants.

PER_TMT: Ratio of the number of highest-ranking professionals in the Number of Current Professionals Profiled.

This study further tests the effect of “*Number of Current Professionals Profiled*” and “*PER_TMT*”. We found that these two variables do not materially impact the overall reported results. This study therefore only reports standard results with the four controls. It is worth to be noticed that *PER_TMT* shows a significant negative effect on portfolio performance. However, the reason behind the result remains unknown.

	Dependent variable: <i>ExitRatio_Success</i>		
	Base model	Full model	Full model + OTHER_teamlevel
Control Variables			
VC_FirmAge	.104 (.101)	.104* (.099)	.109* (.082)
% investment in US	.111* (.083)	.125* (.054)	.133** (.041)
% prior investment in ICT	.437*** (.000)	.440*** (.000)	.442*** (.000)
TeamSize	.146** (.020)	.117* (.080)	.150** (.029)
Number of Current Professionals Profiled		.082 (.229)	-.043 (.638)
PER_TMT			-.172** (.046)
Model			
R^2	.214	.220	.235
Adjusted R^2	.199	.201	.213
F value	13.777***	11.337***	10.265***
No. of observations	207	207	207

* p<0.1; ** p<0.05; *** p<0.01

β and p values are shown in table

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