On the upside or flipside: where is venture capital positioned in the era of digital disruptions?

Abstract: Recent studies have found that disruptive technologies, such as FinTech, have the potential to overturn existing business models and overthrow incumbents. These studies have demonstrated that newly emerging digital platforms financing early-stage ventures threaten traditional venture capital (VC). We argue that, conversely, VC benefits from advances in information and communication technology (ICT), as ICT fosters entrepreneurship and mitigates agency issues in VC deals. This paper examines the impact of digitization on VC investments from 23 European countries spanning 2007-2019 using a dynamic panel two-step system generalized method of moments (GMM) estimation technique. The results show that the factors “ICT penetration” (a general measure of societal internet and computer access and use) and “digital economy” (a measure of ICT-powered economic activity) exert significant and positive effects on early-stage, later-stage, and total VC investments. Moreover, availability of bank credit moderates the effect of digital economy on VC investment. Finally, this study reveals that it is digital entrepreneurship (as reflected in our “digital economy” measure), and not total entrepreneurial activity, that attracts VC investment. We conclude that the VC industry is aligned with rather than threatened by the newly emerging digital environment. The empirical results are robust to different control variables and data sources. This paper offers useful implications for policy and contributes to the literature on digital entrepreneurship and venture capital.

Key words: Venture capital; Financial development; ICT; Digitization; FinTechs; Digital entrepreneurship.

1 Introduction

Information and communication technology (ICT) and finance have grown hand in hand throughout modern history. In the past, financial markets around the world were restricted to serving the local region, as they relied on the physical media of paper and coins and physical modes of transport, when people could not move faster than a horse could gallop. However, over time they changed enormously. The introduction of analog financial technologies such as the telegraph enabled the transmission of financial information more quickly, more accurately, and over larger distances (Alt et al., 2018). In particular, the publication of lists of stock prices by newspapers, from 1812, and the use of electric stock tickers using telegraphy, introduced in 1867, transatlantic cables from 1866, and the telephone from 1872 served the securities industry (OTA, 1984). This continuous transformation has now moved into the digital age of internet/mobile banking and electronic finance. Computers, the internet, automated teller machines (ATMs), and lately smart phones have revolutionized the customer service, the infrastructure, and the business models of the entire financial industry. These technologies have brought massive improvements to the financial system and an enormous increase in trading volumes. For instance, the US experienced an almost twelve-fold upsurge in annual stock turnover between 1988 and 2008, and the ratio of stock market capitalization to GDP increased from 58% in 1988 to 163% in 1999 (Stockhammer, 2013).

He *et al.* (2017) outline four game-changing technologies impacting financial services: artificial intelligence (AI) and big data, distributed computing, developments in cryptography, and mobile access and the internet. These technologies have enhanced financial participation, financial access (Pradhan et al., 2017), financial inclusion (Asongu and Acha-Anyi, 2017; Gabor and Brooks, 2017), financial literacy (Berger and Nakata, 2013; Masiero and Ravishankar, 2018), and financial development (Pradhan et al., 2015; Asongu and Moulin, 2016; Pradhan *et al.*, 2018; Lechman and Marszk, 2019)[1]. ICT has changed the landscape of business and technology during the last two decades – the period in which venture capital (VC) has also flourished enormously. During this phase of advancements in digital technologies and their impact on financial services, market institutions have experienced a transition, with some scholars predicting that it will lead to the end of banking era (Alt et al., 2018).

Like other financial markets, VC is deeply embedded in ICT. There are two contradictory explanations for how ICT has changed VC. One is that development of ICT attracts VC for two principal benefits it offers: enhanced efficiency and facilitated entrepreneurship. According to the *efficiency-enhancing* explanation, financial systems are deemed to be information systems (Ocampo, 2018). This information systems view applies to VC more than any other mode of financing as it is an information-problematic and knowledge-intensive area of the financial industry, so much so that it has to rely on informal informants (Fiet, 1995; Lockett et al., 2002). Venture capitalists (VCs) highly depend on pre-investment information to avoid adverse selection and post-investment information to evade moral hazard (Wright and Robbie, 1998). They invest in opaque, high-risk small and medium-sized enterprises (SMEs) with high growth potential but little or no transaction history, and other sources of finance are more reluctant to commit their

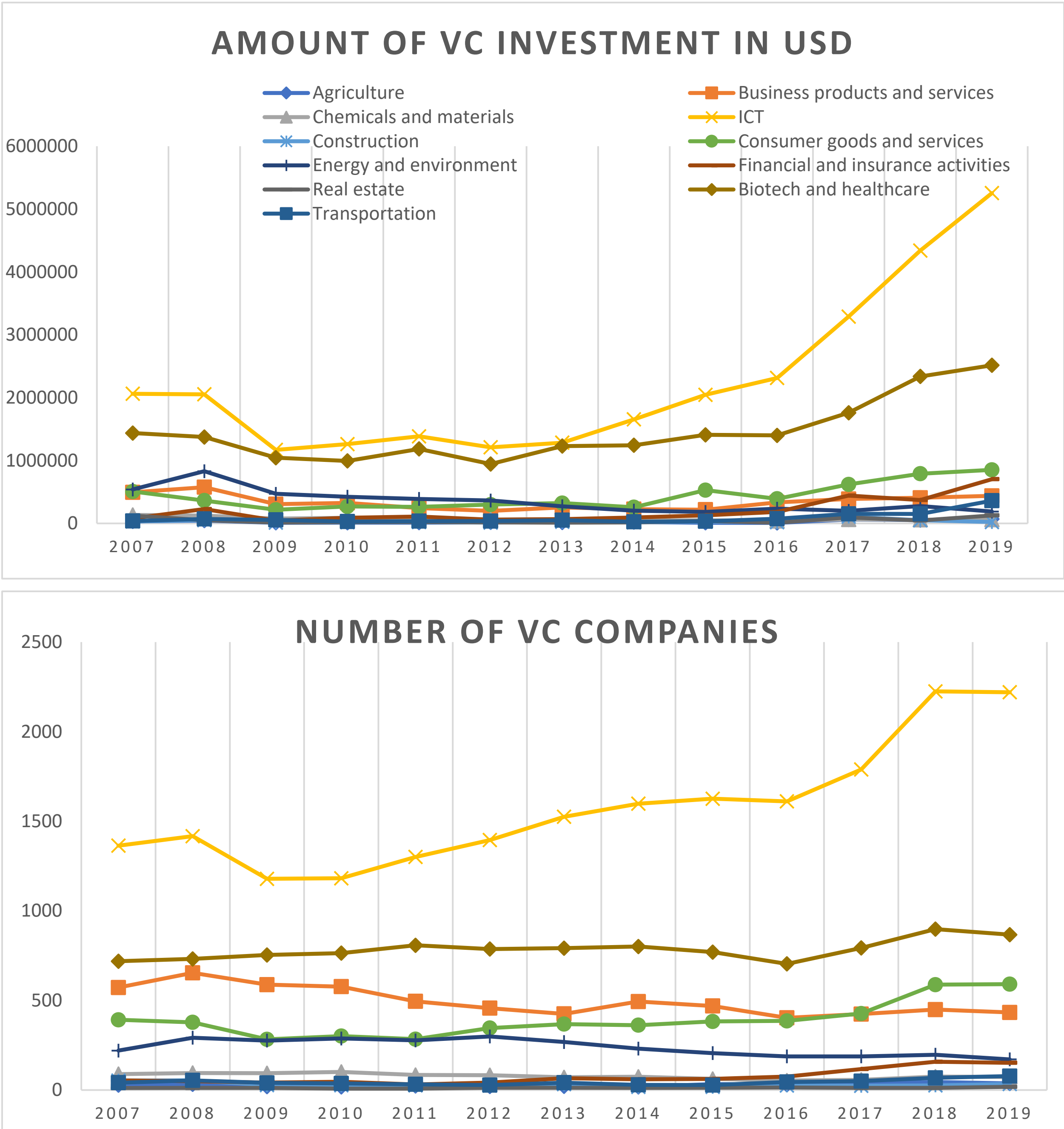
[1] For detailed literature see Lechman and Marszk (2019).

resources to such ventures. For this reason, such private investments involve more due diligence and monitoring than other financing alternatives (Carey et al., 1993). ICT has facilitated the collection of information for industry selection, firm selection, deal origination, monitoring and exit processes. The efficiency-enhancing view deems ICT to be a tool to make VC processes more efficient.

The *entrepreneurship* mechanism is the emergence of digital entrepreneurship facilitating deal flow to the VC industry. ICT has accelerated Schumpeter's *creative destruction* process whereby the shattering of some traditional industries creates many others. This happened after the rise of the internet in the 1990s and similarly web2.0 resulted in greater user innovation, bottom-up entrepreneurship, and crowdfunding platforms (Aldrich, 2014). ICT offers ample opportunities for entrepreneurs in different fields (social media, the entertainment industry, e-commerce, advertising, games and so forth) to create VC deals. ICT itself has been a top sector for VC investment during the last decade (Figure 1).

In contrast, some argue that the VC industry has shrunk and moved toward later-stage investment, as VCs have lost a substantial portion of their business – particularly early-stage financing – to newly emerging financing platforms such as angel groups, business accelerators, micro VC funds, and online platforms (Shane and Nicolaou, 2017). Shane and Nicolaou (2017) highlighted several reasons for this market institutional change: (i) traditional VCs handle too much money in too few investments, as transaction costs are very high and the labor involved in deal finalization is intense; (ii) the newly emerging platforms and software-based companies are much better suited to making

Figure 1: VC Investments in Europe by Sector, 2007-2018



Source: Eurostat[2].

[2] The countries include Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, UK and Ukraine.

investments in many early-stage companies with smaller investments; (iii) angel investors are less concentrated geographically and angel investments are generally smaller; and (iv) there have been both advances in digital practices such as cheaper software and a significant growth in online networking platforms. These views have been endorsed by other researchers (Bonini and Capizzi, 2019; Harrison and Mason, 2019).

This research addresses these conflicting views on whether ICT promotes the VC industry or, conversely, whether novel technologies threaten traditional VC, and, in the latter scenario, which stages of VC finance are more vulnerable to the digital technologies and newer platforms. The main aim of this paper is to investigate the impact of ICT on VC investment at its different stages and to analyze how different proxies of ICT have affected VC investments in Europe. The paper scrutinizes whether the VC market is positioned on the upside or flipside in the struggle between incumbents and new entrants.

2 Literature Review and Hypotheses

Financial commentators have coined the term "FinTech" to describe new financial technologies and the terms "FinTechs" or "FinTech ventures" to describe the institutions or enterprises practicing these innovations. Gimpel et al. (2018) state that FinTech "characterizes the usage of digital technologies such as the internet, mobile computing, and data analytics to enable, innovate, or disrupt financial services". In contrast to the incumbents (i.e., banks) that maintain legacy, tested systems, financial expertise, infrastructure, and a stable customer base, FinTechs are agile, innovative, and disruptive, have a largely prospective rather than actual customer base, and require highly data-sensitive algorithms and analytics to be regulated (Anagnostopoulos, 2018). Elsinger *et al.* (2018) argue that FinTechs have improved financial products in several ways: more variety, less cost, greater accessibility, and higher quality. They state that as contact between savers and investors is becoming more direct, such banks' role of intermediation is obviated. They also contend that FinTechs facilitate insurance, credit, and savings, and improve the payment and transfer system. Nevertheless, the digital revolution can have a flipside as well as an upside for different actors in the financial system.

On the flipside, FinTechs have created a challenge for regulators as well as those incumbents that resist disruptive innovations. They have the potential to overturn existing business models, take a significant market share and overthrow incumbents (Eckenrode and Friedman, 2017). For example, Drummer et al. (2017) demonstrate that the traditional banking model gave way to the securitization model after the 1960s, which in turn gave way to the marketplace lending model from around 2005. In the marketplace lending model, the platform for lenders and borrowers shifts from banks and special purpose vehicles (SPVs) to online networks – a process often referred to as the disintermediation of banks and SPVs (Drummer et al., 2017). Disintermediation and competition between incumbents and new entrants can be seen in almost all fields of digital finance, including digital financing, digital investment, digital money, digital payments, digital insurance, and digital financial advice (Koch et al., 2017). He *et al.* (2017) note that new entrants radically change the existing institutions and market structures as they bypass intermediaries, markets, and networks.

These existential threats have forced the established financial institutions to adapt to these disruptive advances. The incumbents – i.e., banks with vast knowledge of business expansions and regulations – have gradually teamed up with cutting-edge players such as the FinTech ventures – which are savvy about innovative products and new markets (Drasch et al., 2018). Because disruptive technologies are inevitably subject to less regulation, banks have a motive to venture into FinTechs (Douglas and Grinberg, 2017; Eckenrode and Friedman, 2017). Some observe that both incumbents and new technology entrants have prospered from competition and cooperation, and such antagonisms and partnerships have also benefited previously unserved and underserved consumers in terms of access to finance (Jagtiani and John, 2018). Yet others consider the disruptions beyond the threshold of competition and/or cooperation between incumbents and FinTechs. For them, financial innovation complements the market for financial services and addresses specific market niches. For instance, Dorfleitner et al. (2017) believe this to be the case in Germany.

On the upside, the digital revolution has reduced the overall costs of and removed infrastructural barriers to financial services in developing countries; a good example is mobile phone banking (Berger and Nakata, 2013). ICT has a strong positive effect on financial development (Alshubiri et al., 2019), financial inclusion (Andrianaivo and Kpodar, 2011; Bisht and Mishra, 2016; Mushtaq and Bruneau, 2019), and financial access (Asongu and Nwachukwu, 2017). There is a positive association between ICT penetration and financial development. Financial development with ICT leads to growth in per capita income (Sassi and Goaied, 2013) and not only in developing regions: ICT adoption has had a direct positive influence on economic growth in Europe (Fernández-Portillo et al., 2020). An ICT-based network in Brazil offered financial services to millions of poor people who would otherwise not have access to banking services (Diniz et al., 2012). Claessens *et al.* (2018) show that FinTech credit has grown rapidly, reaching high volumes in, for example, the US, the UK, and China, though it remains quite small in some other economies.

ICT has also played a significant role in stock market development by reducing transaction costs, improving execution speed, and increasing trade volume in the US market (Angel et al., 2011; Angel et al., 2015). Similarly, Hendershott and Madhavan (2015) show that algorithmic trading enhances liquidity and informativeness in the New York Stock Exchange. Bhunia (2011) finds that ICT has contributed to the growth of Indian stock market; in particular, mobile telephony is associated with the total value of stocks traded. Essendorfer et al. (2015) note that a new breed of software firms and technology-oriented small brokerage firms has led to a new market ecology and attracted an aggressive response from incumbent firms.

To the best of our knowledge there is very little existing research on the role of ICT and digital innovations in the context of VC investment[3] apart from the descriptive analysis of Shane and Nicolaou (2017). A review of the FinTech VC literature led to the identification of few relevant articles. Cumming and Schwienbacher (2018) showed that FinTech VC investments are more pronounced in locations with weaker enforcement and no major financial center. More recently,

[3] "A venture capital investment typically involves a commitment for four to eight years with little or no liquidity along the way and with the probability that additional funds will be required from time to time before success can be assured. Because of the very long-term nature of the investment, the venture investor often will be actively involved in providing advice and counsel to the management of the enterprise, either informally or through participation on the company's board of directors" (Dennis, 1981, p.108).

Khan et al. (2020) found that digitization has a strong positive effect on VC investment and that digitization influences the association of innovation and national cultures with VC investment. Estrin et al., (2017) note that crowdfunding platforms give advice to entrepreneurs through social networks, which is a quicker and cheaper way of communication, and offer possibilities to entrepreneurs to test and promote their products and to "turn customers into investors". However, they also suggest that these are still not a substitute for the expertise of the traditional early-stage financiers such as VCs and angels.

2.1 Hypotheses

As discussed above, the literature suggests that ICT exerts a strong effect on financial development, particularly financial inclusion and financial access. This motivates the current study to examine the influence of ICT on VC investments. There are two potential explanations for why ICT might positively influence VC investment. One argument is the process-facilitation or efficiency-enhancing perspective that borrows from *agency theory*. Financial systems – and for that matter VC, given that it is an information-problematic industry – are information systems (Ocampo, 2018). ICT is expected to facilitate information flow, enhance processing speed, and reduce transaction and agency costs in VC deals. Digital technology reduces the time and resources needed to perform an action, increases the availability of a resource, and replaces one resource with another (von Briel et al., 2018). Thus, it is expected to have a positive influence on VC processes by greatly reducing the risk of adverse selection while selecting deals, reducing time and costs while processing VC operations, and mitigating the chance of moral hazard while monitoring portfolio firms. The first hypothesis is therefore:

H1. ***ICT penetration exerts a significant positive impact on total VC investment***

There is also evidence that completely new institutional patterns and innovative practices are emerging while old established practices are disappearing (Drummer et al., 2017; Eckenrode and Friedman, 2017). Shane and Nicolaou (2017) show that newer platforms, such as angel groups, business accelerators, micro-VC funds, and online platforms, have led to a reduction in early-stage VC investment in the US. Some even talk about the death of the classic venture capital – "the provision of (relatively small) investment capital to startup and early-stage ventures by VC firms led and managed by executives with significant entrepreneurial experience" (Harrison and Mason, 2019, p.3). Bonini and Capizzi (2019) share similar concerns about the future of VC. Generalizing this to the VC industry, as a whole, one might think that ICT may have had a negative effect on early-stage VC investment in Europe as in the US. However, an increase in the number and types of financing channels for start-ups and early-stage firms does not necessarily mean a reduction in early-stage VC. Bonini and Capizzi (2019) argue that VC may withstand the digital disruptions because of the irreplaceable human skills involved in early-stage VC. We argue that if ICT enhances the efficiency of VC through reductions in the time and cost of information processing, as assumed in Hypothesis 1, then there is no reason to believe that ICT adversely affects early-stage VC investment. We conjecture as follows:

H2. ***ICT penetration exerts a significant positive impact on early-stage VC investment.***

A second explanation for the expected positive impact of ICT on total VC is that it creates a favorable entrepreneurial environment, particularly in relation to digital business activities. This explanation borrows from *entrepreneurship theory*, which asserts that ICT boosts an entrepreneurial environment. For example, Melissa et al. (2013) report a growing trend in social media entrepreneurship, and in particular the engagement of women entrepreneurs in online businesses. Cumming and Johan (2010) find that the internet fosters entrepreneurial activities by enabling agglomeration in densely populated urban areas. Moreover, Huang et al. (2020) find that the presence of advanced digital technologies, investment-based crowdfunding, stock markets, and financial development in a country offers a vibrant environment for digital entrepreneurship (in their study, in terms of initial coin offerings).

It is also argued that the internet caters to those groups 'who were previously excluded from the brick-and-mortar entrepreneurship' (McAdam et al., 2020, p.2; see also Aldrich, 2014). Some go beyond the concept that digital technologies merely foster entrepreneurial activity and suggest that such technologies are expanding the domain of entrepreneurship as a discipline, as they increasingly permeate the entrepreneurial processes and outcomes, and that this calls for adjustments to existing theories (Nambisan, 2017). There is also evidence that digitization influences economic processes and structures, as it enhances technology-powered productivity, employment, income, and trade (Matthess and Kunkel, 2020). Thus, ICT-based business activity, or in other words the *digital economy,* [4] is expected to have a positive effect on VC investments if the entrepreneurship logic prevails. Hence, we hypothesize as follows:

H3. ***The digital economy exerts a significant positive impact on total VC investment.***

Like ICT penetration, digital economic activities such as FinTechs and digital entrepreneurship are also expected to have a positive effect on early-stage VC. One reason is that FinTechs (such as equity crowdfunding) may address only small specific market niches and so not represent a genuine alternative to VC investments (Dorfleitner et al., 2017). Estrin et al. (2017) show that VC crowdfunding platforms offer additionality to the previous sources of entrepreneurial finance and do not pose a threat to the existing channels such as VCs and angels. Moreover, FinTechs themselves may be backed by early-stage VC. For instance, Haddad and Hornuf (2018) find that FinTechs develop in environments where VC is readily available, pointing to a complementarity between FinTechs and the early-stage VC rather than competition. Though frictions exist between VC funding and crowdfunding (Moedl, 2020) as VCs are less likely to be attracted by a venture that has received funding from large number of backers, crowdfunding platforms are more likely to provide equity investment in a start-up if it has already attracted traditional VC investment (Mamonov and Malaga, 2019). There is complementarity between VC financing and new technological ecosystems, particularly the new products offered over the cloud computing, and that complementarity strengthens with experience of VC fund managers in the IT industry (Breznitz et al., 2018). Additionally, the availability of VC fosters yet more FinTech

[4] ICT penetration is a measure of ICT use, and digital economy is ICT-driven economic activity, as detailed in section 3.

entrepreneurship in environments with already high levels of FinTech entrepreneurship (Kolokas et al., 2020). Moreover, if digital economic activity fosters demand for VC, as proposed in Hypothesis 2, then it is appropriate to hypothesize as follows:

H4. ***The digital economy exerts a significant positive impact on early-stage VC investment.***

We further argue that the effect of the digital economy might be dependent upon access to bank credit. While bank credit might be a substitute for VC, it can also complement it. The reason for complementarity is that bank credit supports the entrepreneurial environment and the digital economy – particularly ICT-driven enterprises, employment in ICT sector, or the overall ICT sector – and so facilitates deal flow to the VC market. Small credit facilities can have a substantial effect on individual ICT-based SMEs. In contrast, digital economy may not attract VC when bank credit is readily available due to the substitution effect. Any expansion in digital economy due to bank financing may be financed through further bank credit. We take the latter position and hypothesize that:

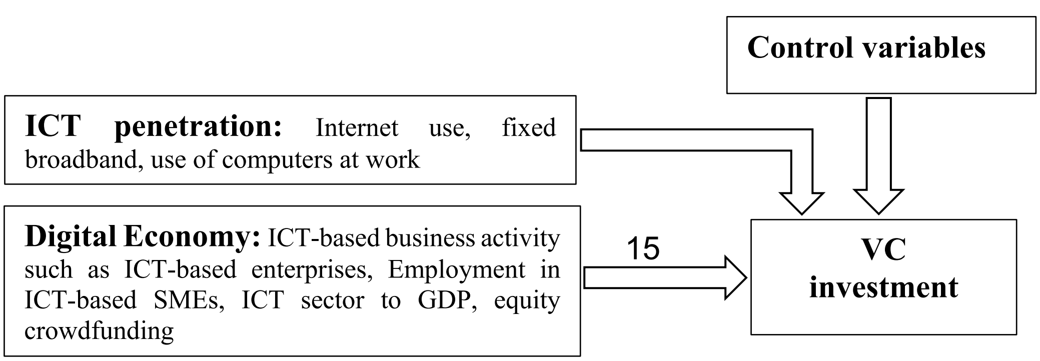
H5. ***Bank credit negatively impacts the association between digital economy and total VC investment.***

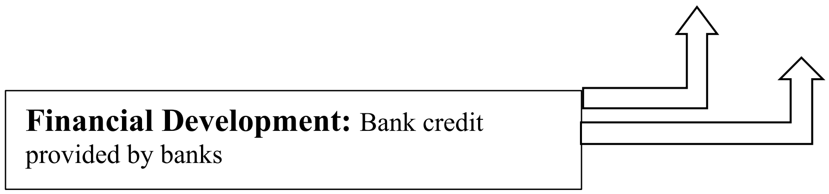
The five hypothesized relationships are presented in a conceptual model in Figure 2. ICT penetration influences VC investment through agency mechanisms, whereas the digital economy affects VC investment through the creation of entrepreneurship activities. The model proposes that ICT penetration, the digital economy, and financial development exert significant positive effects on VC investment. Additionally, a financial development also influences the association between digital economy and VC investment.

2.2 Control variables

Several papers report the effect of factors other than ICT on VC. They show that financial sector reforms (Pradhan et al., 2017), the presence of active stock markets and initial public offerings (IPOs) (Black and Gilson, 1999; Bonini and Alkan, 2012; Cherif and Gazdar, 2011; Gompers and Lerner, 1998; Jeng and Wells, 2000; Schröder, 2009), entrepreneurial activity (Romain and Pottelsberghe, 2004), high-tech investments (Da Rin et al., 2006), investment opportunities (Avnimelech et al., 2004), and research and innovation activities (Baygan, and Freudenberg, 2000; Groh and von Liechtenstein, 2009; Maas et al., 2018; Schertler, 2007) have a strong association with VC investments. Studies also show that GDP growth rate (Cherif and Gazdar, 2011), business cycles (Ning et al., 2015), and economic growth strategies (Pradhan et al., 2017) affect the risk preferences and investment strategies of VCs. Moreover, industrial production (Ning et al., 2015), labor market rigidities (Bonini and Alkan, 2012), and foreign direct investment (FDI) inflows (Schröder, 2009) are also positively associated with VC.

Figure 2: Conceptual Model





Source: Authors

Governments can also play a vital role in institutionalization of VC (Cornelius, 2005). However, there is debate about how a government should intervene to support VC. Some argue that direct support – e.g. subsidies, tax incentives, launching programs, and particularly government direct participation in economic activity, as a competitor to VC – is useful if managed well (Keuschnigg and Nielsen, 2003; Leleux and Surlemont, 2003; Lerner, 2009). Others argue that direct government intervention crowds out private VC activity (Da Rin et al., 2006). The control variables included in this study are therefore: GDP growth, bank credit, FDI outflows, unemployment, density of new business, government ownership of private equity, ease of doing business (measured through time to register a business), financial market depth, trend, and market crash. Following Li and Zahra (2012) and Khan et al. (2020), this study controls the regression models for market crash, as well as trend variables. The market crash variable captures the fluctuation caused by the 2008 market crash. It is a dummy variable which takes the value of 1 for the years 2007, 2008 and 2009, and 0 for the years 2010-2019. The inclusion of the trend variable tackles the issue of spurious correlation and captures the impact of omitted variables that vary over time (Li and Zahra, 2012).

3 Research Design

The present study uses VC investment (total, early-stage and later-stage) as a percentage of GDP as a dependent variable using a sample of 23 European countries[5] over the period 2007-2019. Total VC includes early-stage and later-stage capital. Throughout this paper, VC data has been sourced from Invest Europe except in Column 3 of Table 3, where OECD VC data has been analyzed as a robustness check. ICT variables have been divided into two categories: ICT penetration and the digital economy.[6] *ICT penetration* represents overall ICT usage, including individuals using the internet, the number of fixed broadband subscriptions, and the use of computers with an internet connection in the workplace. The *digital economy* represents ICT-driven economic activity, which includes both FinTech and non-FinTech factors. The FinTech factors consist of number of equity crowdfunding rounds and the amount of equity crowdfunding raised. Non-FinTech factors include ICT-based enterprises, employment in the ICT-based SMEs, and the ICT sector. Data on the

[5] The countries include Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, UK and Ukraine.

[6] Several measures of ICT are employed by scholars and databases. For example, Kauffman and Kumar (2005) examined different studies using ICT measures. They list a variety of dimensions of ICT: (i) economic, society and knowledge dimensions; (ii) ICT readiness, ICT intensity, and ICT impacts; (iii) discrete measures, economic measures, technology adoption and diffusion measures, single-item index measures of ICTs, and digital divide measures. Dimensions discussed in their work that are of interest to us are discrete measures, economic measures, and technology adoption/diffusion measures. The discrete factors as well as the technology adoption and diffusion measures include variables such as numbers of users of the internet, computers and mobile phones, quality of connections, number of internet hosts and so forth. The economic measures of ICT are productivity, growth, trade, and employment. The present study uses the term "ICT penetration" for the discrete measures as well as the technology adoption and diffusion measures. The study employs the term "digital economy" for the ICT-based economic activities. This categorization is orthogonal to the one used by Huang et al,. (2020). They used a composite index of ICT market development which consists of three sub-categories: ICT capability (skills and knowledge), ICT infrastructure, and ICT intensity. In our paper, the ICT penetration covers the latter two, but particularly ICT intensity. To be precise, the internet users, broadband subscriptions, and computers are represented by ICT penetration in this study. The digital economy represents ICT-backed economic and business activities. They include ICT-based enterprises, employment in ICT-based SMEs, and total ICT sector. We also use the term 'digital entrepreneurship' which represents ICT-based enterprises/SMEs.

dependent and independent variables of the paper have been gathered from various sources (see Appendix 1 for data description and sources).

Table 1 presents summary statistics. The maximum number of observations is 299. The average of total VC investments (as % GDP) is 0.03. The average number of internet users per 100 population is 74.4. This suggests the use of the internet was very common in our period of analysis, but the range is wide, from 6.55 to 98.14. There is also a large variation in equity crowdfunding rounds, which has a minimum value of 1 and a maximum value of 864.

Table 1: Summary statistics.

Variable	Obs.	Mean	Standard Deviation.	Min.	Max.
Dependent Variable					
Total VC investments	299	0.03	0.02	0.00	0.11
Independent Variables					
ICT Penetration					
Internet use	292	74.44	17.75	6.55	98.14
Fixed broadband	297	28.81	9.42	1.72	46.32
Usage of computers	181	50.72	11.32	32.75	100.00
Digital Economy: FinTech					
Equity crowdfunding rounds	105	54.44	152.83	1.00	864.00
Equity crowdfunds raised	105	10.65	21.42	0.00	112.99
Digital Economy: Non-FinTech					
Employment in ICT sector	149	2.73	0.72	1.32	4.75
Employment in ICT-based SMEs	215	4.28	1.31	1.89	7.35
ICT-based enterprises	237	4.92	2.06	1.44	10.47
ICT-based SMEs	229	1.51	0.46	0.36	2.35
ICT Sector	130	4.03	1.07	1.91	6.66
Control Variables					
GDP growth	299	1.50	3.31	-14.76	25.16
FDI net outflows	298	6.18	14.88	-43.54	140.10
Bank credit	296	95.44	41.79	22.83	201.26
Unemployment	299	8.00	4.50	2.01	27.47
Number of employers	299	4.09	1.54	0.88	8.34
New business density	267	4.78	3.52	0.47	17.55
Government PE	299	10.67	16.00	0.00	136.49
Financial markets depth	276	0.59	0.30	0.03	0.99
Trend	299	7.00	3.75	1.00	13.00
Market Crash	299	0.23	0.42	0.00	1.00

Table 2 presents the correlation matrix of our main variables. Financial market depth, internet use, bank credit, and government private equity are highly correlated with VC investment. Wooldridge (2016) suggests that multi-collinearity might be problematic in case of the high correlation

Table 2: Matrix of correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Total VC investments	1.000										
(2) GDP growth	0.239	1.000									
(3) FDI net outflows	0.034	0.036	1.000								
(4) Bank credit	0.469	-0.149	0.177	1.000							
(5) Unemployment	-0.212	-0.193	-0.015	0.102	1.000						
(6) Internet use	0.507	0.230	0.104	0.351	-0.252	1.000					
(7) Number of employers	0.259	0.027	0.024	0.364	0.327	0.242	1.000				
(8) New business density	0.282	0.186	0.123	0.232	-0.200	0.314	-0.177	1.000			
(9) Government private equity	0.499	-0.011	-0.041	0.374	0.102	0.281	0.248	0.095	1.000		
(10) Financial markets depth	0.647	0.026	0.211	0.775	-0.026	0.565	0.375	0.267	0.553	1.000	
(11) Trend	0.101	0.193	-0.196	-0.172	-0.066	0.384	-0.085	0.132	0.091	-0.029	1.000
(12) Market crash	0.051	-0.217	0.138	0.087	-0.137	-0.334	0.058	-0.077	-0.051	0.029	-0.732

Note: This table displays the coefficients of Pearson correlation of all variables of the study. The definitions of the study variables and the data sources for variables are reported in Appendix 1.

between variable of interest and any other variable. To avoid potential multicollinearity, appropriate balance has been maintained among variables for inclusion in the single regression model.

Before deciding on the model, it is pertinent to discuss whether VC investment is a dynamic process or a static one. Most earlier studies implicitly deem the phenomenon to be static, as they used static models, though some did use dynamic models (Aizenman and Kendall, 2008). However, studies suggest that VC process at time *t* is a function of past behavior, and that the causal process has memory, as VC investments have delayed effects (Kolmakov et al., 2015). Keele and Kelly (2006) state that if a process has memory and the past matters to the present, then lagged dependent variable (LDV) models should be used. Black and Gilson (1998, 1999) and Aizenman and Kendall (2008) argue that there is path dependency and persistence in VC flows. Manigart (1994) shows that every new entry to a VC market further eases new founding through legitimacy, expertise, and networking. Studies suggest that fund managers get more funding when they settle previous funding successfully (Milosevic, 2018). Unlike the securities market, VC investment is not a volatile market, as these investments are looked after for years and their effects have a longer duration.

Thus, dynamic panel data model is estimated to test hypothesis 1 to 4 as follows:

$$VC_{i,t} = \beta_0 + \beta_1 VC_{i,t-1} + \beta_2 ICT_{i,t} + \delta Z_{i,t} + \varepsilon_{i,t}$$

where $VC_{i,t}$ is the VC investment in country *i* at year *t*, $VC_{i,t-1}$ is the lag of VC investment. $ICT_{i,t}$ represents the ICT variables used in this study, such as internet use, broadband, and so forth. $Z_{i,t}$

represents all other control variables in country i at time t, and $\varepsilon_{i,t} = n_i + v_{i,t}$ represents the composite error term which consist of fixed effects n_i and idiosyncratic shocks $v_{i,t}$. β_1 is the autoregression coefficient. β_2 is the coefficient of ICT and δ measures the elasticity of control variables. In addition, we employ the market crash variable to capture the fluctuation caused by the 2008 crisis. The inclusion of trend variable tackles the issue of spurious correlation and captures the impact of omitted variables that vary over time (Li and Zahra, 2012). To test hypothesis 5, the following econometric model is considered:

$$VC_{i,t} = \beta_0 + \beta_1 VC_{i,t-1} + \beta_2 DE_{i,t} + \beta_3 Bankcredit_{i,t} + \beta_4 (DE_{i,t} \times \beta_4 Bankcredit_{i,t}) + \delta Z_{i,t} + \varepsilon_{i,t}$$

where model incorporates the interaction term (digital economy × bank credit) where $DE_{i,t}$ represents digital economy and $Bankcredit_{i,t}$ symbolize bank credit.

The Pagan/Cook-Weisberg, White/Koenker test, and modified Wald test confirm there is groupwise heteroscedasticity in the data. The Wooldridge test for autocorrelation suggests that there is a first-order autocorrelation. Moreover, there is an expectation of partial endogeneity (i.e., reverse causality) in GDP growth and FDI outflows, given that VC investment may lead to more economic growth in a country. This view is corroborated by the findings of Ning et al. (2015) and Khan et al. (2020). Moreover, VC investment may also lead to a reduction in FDI outflows because VC boosts entrepreneurial opportunities and creates an appetite for further local investment, which eventually leads to more FDI inflows and a reduction in FDI outflows. Unless otherwise mentioned in the notes to the tables, GDP growth and FDI outflows are listed in internal instruments throughout this study, while all other variables (including control variables) are listed in external instruments. We also treat equity crowdfunding, new business density, and government private equity as endogenous regressors.

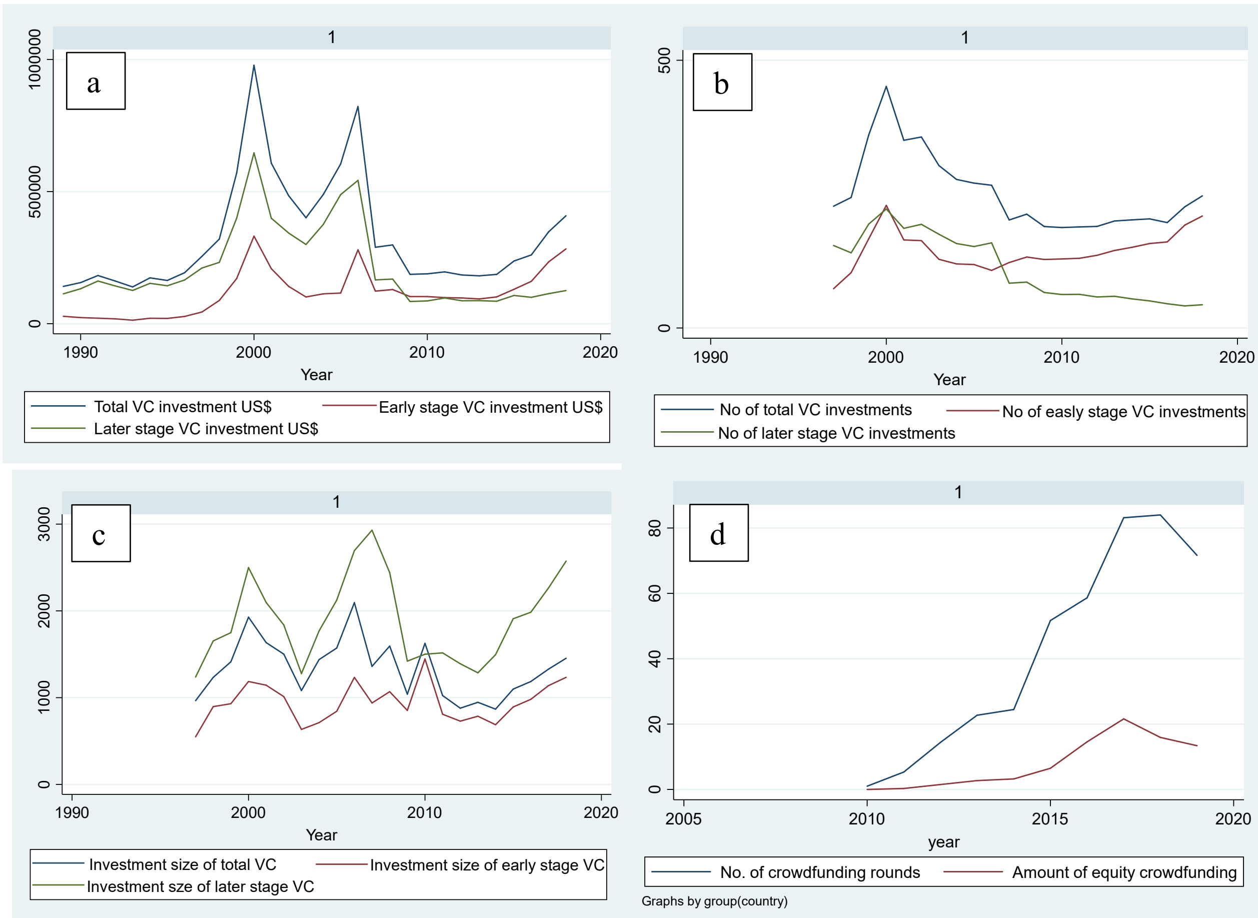
In the presence of heteroscedasticity, autocorrelation, and endogeneity, the generalized method of moments (GMM) is one of the best estimators (Baum et al., 2003). The current study uses LDV models; while these cause dynamic panel bias (Nickell, 1981), they also reduce autocorrelation (Bonardo et al., 2011). GMM is able to reduce the dynamic panel bias (Roodman, 2009). We employ a two-step system GMM estimation technique. A two-step procedure in the GMM framework improves the efficiency and power of statistical tests compared with a one-step procedure because it has less asymptotic variance (Hwang and Sun, 2015).

4 Results

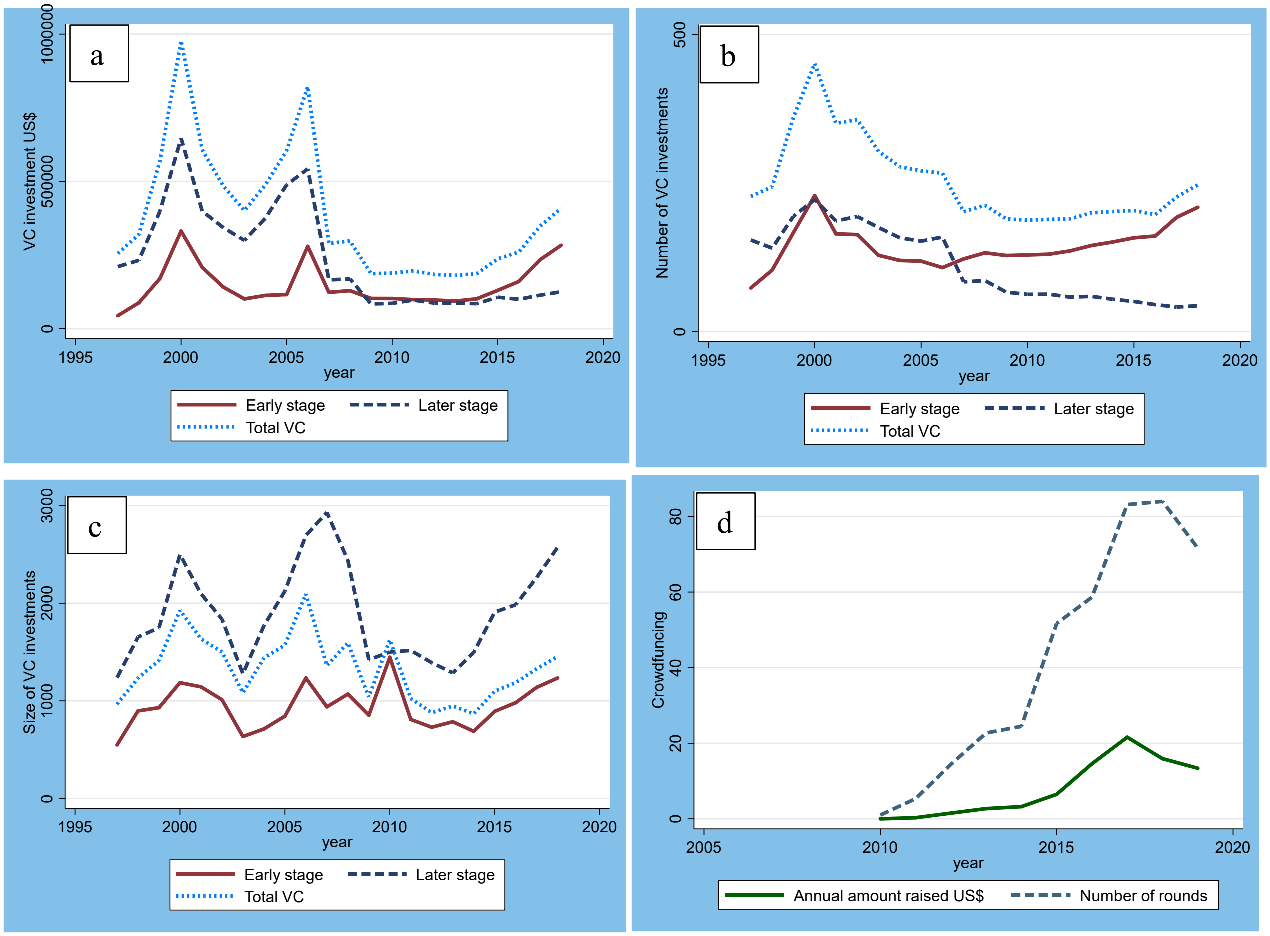
4.1 Trend Analysis

In this section, we show that early-stage VC is performing well compared with later-stage VC. Figure 3(a) depicts the amount of VC investment (in US dollars) during 1997-2018, whereas Figure 3 (b) and (c) display the number of VC investments and the average size of VC investment, respectively, during 1997-2018 in Europe. This is based on Eurostat data of VC investment by country of the VC firm. The amount of early-stage VC experienced recovery and growth particularly after 2015, unlike the later-stage VC, which received huge shocks during the dot-com bubble and the 2008 financial crisis and showed no signs of recovery thereafter. The number of later-stage VC investments also declined continuously after the last market crash. One the other hand, early-stage VC was less vulnerable to the market shocks and experienced vigorous growth in terms of investment and number of investments. The plot of early-stage VC investment crosses that for later-stage VC investment in terms of both investment and number of investments.

Figure 3: VC Investments in Europe over the period 1989-2018.



Data Source: Data for VC investment has been taken from Invest Europe and data of equity crowdfunding has been obtained from Crunchbase.


a
VC investment US$
0
500000
1000000
1995
2000
2005
2010
2015
2020
year
Early stage
Later stage
Total VC
b
Number of VC investments
0
500
1995
2000
2005
2010
2015
2020
year
Early stage
Later stage
Total VC
c
Size of VC investments
0
1000
2000
3000
1995
2000
2005
2010
2015
2020
year
Early stage
Later stage
Total VC
d
Crowdfuncing
0
20
40
60
80
2005
2010
2015
2020
year
Annual amount raised US$
Number of rounds

Concerning investment size,[7] the 2008 crisis led to a sharp decline in the average size of early-stage VC as well as later-stage VC, but both jumped back up thereafter.

The trend in the equity crowdfunding market is presented in Figure 3 (d) and demonstrates a tremendous increase in both number of crowdfunding rounds and amount of crowdfunds raised. Equity crowdfunding emerged after the 2008 financial crisis. Shane and Nicolaou (2017) show that, in the US, early-stage VC investment decreases when FinTechs are increasing. Conversely, we show that European early-stage VC investment increased at greater pace than later-stage VC investment when equity crowdfunding was becoming an established practice in the FinTech market.

4.2 Regression Results

Table 3 documents the impact of internet use on early-stage, later-stage and total VC investment and private equity investment.[8] Column 1 reports the results of total VC investment as a dependent variable. A one percentage point increase in internet use boosts total VC investment by 1.079 percentage points at the 1% significance level. This supports hypothesis 1, that ICT penetration exerts a significant positive effect on total VC investment. We add internet use as an

[7] Average investment size of total VC investment = Total VC investment in US dollars divided by number of total VC investments in a given year. The same formula applies to size of early-stage VC and later-stage VC.

[8] Throughout in present paper, Windmeijer (2005) finite sample corrected standard errors have been reported in parentheses in the two-step GMM estimation results. In all the GMM models, the instrument matrix has been collapsed with two to five lags to avoid instrument proliferation. The Hansen J -test for the presence of over-identification and endogeneity of instruments reports the p-values for the null hypothesis that instruments are valid. The Hansen tests are non-significant, showing the validity of the instruments in all the GMM systems. The Arellano Bond test for AR (1) and AR (2) report first- and second-order serially correlated disturbances in the first-differenced equation. The AR (1) p-value shows the existence of first-order serial correlation while the AR (2) rejects the null hypothesis of no second-order correlation in the errors.

endogenous regressor in Column 2, keeping in view the possibility of reverse causality, as discussed by (Pradhan et al., 2019). However, the coefficients do not change significantly, indicating that endogeneity is not a problem, hence we will treat internet use as an exogenous regressor in the rest of the models. For robustness, we also consider VC data from the OECD in Column 3, but the coefficient of internet use follows a similar pattern to that in the earlier columns. Total private equity (PE) investment (see Appendix 1 for definition) has been added in Column 4 to further check the robustness of results. One percentage point increase in internet use causes private equity investment to surge by 1.017 percentage points, at the 1% significance level. To test hypothesis 2, we add early-stage VC as a dependent variable in Column 5. The result shows that ICT penetration wields a positive effect on early-stage VC investment at the 5% level of significance, supporting the hypothesis. Economically, ICT penetration demonstrates almost the same effect on early-stage VC as on total VC. For comparison, we also add later-stage VC as a dependent variable in Column 6, which is also significant at the conventional level of 5%, though its impact is economically larger.

To further test hypothesis 1, we examine other proxies of ICT penetration in Panel A of Table 4. The results in Columns 2 and 3 of Table 4 (Panel A) reveal that the coefficients on the variables broadband subscriptions and usage of computers in the workplace are positive and statistically significant at the 1% level in explaining total VC investment. The coefficient estimates imply that a 1 percentage point increase in employees using computers with an internet connection at work leads to an increase of 1.53 percentage points in total VC investment. Similarly, a 1 percentage point increase in broadband subscriptions results in a 0.76 percentage point increase in total VC investment. The results in Columns 1 to 3 of Table 4 (Panel A) therefore further support hypothesis 1.

Table 3: Impact of internet use on the stages of VC investment and private equity investment: Two-step system GMM estimates.

	Dependent Variable					
Variables	**Total VC**	**Total VC**	**Total VC (OECD)**	**Private equity (PE)**	**Early-Stage VC**	**Later-Stage VC**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Dependent Variable $_{t-1}$	0.469***	0.495***	0.474***	0.412***	0.495***	0.452***
	(0.097)	(0.134)	(0.121)	(0.114)	(0.118)	(0.098)
GDP growth	0.891**	0.854*	0.854**	0.897**	0.915	-0.133
	(0.353)	(0.437)	(0.375)	(0.405)	(0.558)	(0.661)
FDI outflows	-0.377*	-0.530	-0.279	-0.135	-0.532**	-0.832
	(0.202)	(0.367)	(0.183)	(0.290)	(0.237)	(0.806)
Bank credit	0.615***	0.637**	0.534**	0.440**	0.644**	0.357
	(0.213)	(0.255)	(0.243)	(0.174)	(0.306)	(0.388)
Internet use	1.079***	0.961***	0.996***	1.017***	0.934**	1.439**
	(0.264)	(0.334)	(0.286)	(0.274)	(0.430)	(0.636)
Unemployment	-0.061	-0.081	-0.064	-0.157	-0.085	0.146
	(0.147)	(0.193)	(0.159)	(0.217)	(0.167)	(0.144)
Constant	-10.553***	-9.280***	-9.927***	-9.039***	-8.424***	-6.094*
	(1.650)	(2.871)	(1.897)	(2.864)	(2.232)	(3.522)
Observations	232	232	226	236	221	208
#Countries	23	23	22	23	23	23
Year Dummies	No	No	No	No	No	No
F test	48.566	52.479	33.609	31.991	35.307	16.053
#Instruments	22.000	22.000	22.000	22.000	22.000	22.000
AR (1) p-value	0.058	0.058	0.091	0.010	0.023	0.037
AR (2) p-value	0.396	0.409	0.379	0.421	0.387	0.347
Hansen p-value	0.202	0.145	0.240	0.242	0.181	0.304

Notes: This table shows the results of regressing ICT penetration and the control variables on total VC, total PE investment, early-stage VC, and later-stage VC. All the estimates are based on Invest Europe data except for the estimates in Column 3, which are based on OECD data. Lagged dependent variable, FDI outflows and GDP growth have been treated as endogenous regressors except in Column 2, where internet use has also been treated as endogenous regressor. The excluded instruments in all the models are hi-technology exports, patents, and gross capital formation. The dependent variable is different for each column and consists of total VC (Invest Europe) in columns 1 & 2, total VC (OECD) in Column 3, total private equity investment in Column 4, early-stage VC in Column 5, and later-stage VC in Column 6. *, **, and *** indicate the significance levels of standard errors at 10%, 5%, and 1%, respectively.

Table 4. Panel A: Impact of ICT penetration and digital economy on amount of total VC investment: Two-step system GMM estimates.

Variables	(1)	(2)	(3)	(4)	(5)
VC investment $_{t-1}$	0.469***	0.489***	0.476***	0.681***	0.770***
	(0.097)	(0.115)	(0.112)	(0.093)	(0.070)
GDP growth	0.891**	0.825**	1.055**	0.215	0.173
	(0.353)	(0.382)	(0.399)	(0.356)	(0.356)
FDI outflows	-0.377*	-0.392*	-0.251	0.787	1.070
	(0.202)	(0.210)	(0.188)	(0.536)	(0.834)
Bank credit	0.615***	0.505**	0.250	--	--
	(0.213)	(0.190)	(0.195)	--	--
Unemployment	-0.061	-0.070	0.134	-0.110	-0.059
	(0.147)	(0.169)	(0.114)	(0.167)	(0.181)
ICT Penetration					
Internet use	1.079***	--	--	--	--
	(0.264)	--	--	--	--
Fixed broadband	--	0.764***	--	--	--
	--	(0.185)	--	--	--
Usage of computers at work	--	--	1.526***	--	--
	--	--	(0.235)	--	--
Digital Economy: FinTechs					
Equity crowdfunding rounds	--	--	--	0.217**	--
	--	--	--	(0.079)	--
Equity crowdfunding amount	--	--	--	--	0.060**
	--	--	--	--	(0.023)
Constant	-10.553***	-7.610***	-11.435***	-4.427**	-5.263*
	(1.650)	(1.846)	(1.772)	(2.115)	(2.981)
Observations	232	234	149	96	96
#Countries	23	23	20	20	20
Year dummies	No	No	No	No	No
F test	48.566	34.630	70.624	22.087	56.290
#Instruments	22.000	22.000	22.000	21.000	21.000
AR (1) p-value	0.058	0.047	0.031	0.118	0.115
AR (2) p-value	0.396	0.339	0.300	0.805	0.294
Hansen p-value	0.202	0.203	0.565	0.406	0.593

Panel B. Impact of ICT penetration and digital economy variables on amount of total VC investment: Two-step system GMM estimates.

Variables	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
VC investment $_{t-1}$	0.451***	0.270*	0.458***	0.486***	0.347***
	(0.101)	(0.131)	(0.124)	(0.114)	(0.118)
GDP growth	0.965*	1.781***	1.036**	1.009**	1.650***
	(0.502)	(0.498)	(0.387)	(0.381)	(0.464)
FDI outflows	-0.101	-0.202*	-0.571	-0.762	-0.474
	(0.585)	(0.113)	(0.911)	(1.202)	(0.569)
Bank credit	0.541**	0.631*	0.687**	0.641**	0.819***
	(0.210)	(0.330)	(0.266)	(0.288)	(0.269)
Unemployment	0.029	-0.039	-0.028	-0.028	-0.138
	(0.233)	(0.194)	(0.201)	(0.228)	(0.119)
Digital Economy: Other		--	--	--	--
Employment in ICT-based SMEs	0.919***	--	--	--	--
	(0.286)	--	--	--	--
Employment in ICT sector	--	1.688***	--	--	--
	--	(0.475)	--	--	--
ICT-based enterprises	--	--	0.443***	--	--
	--	--	(0.155)	--	--
ICT-based SMEs	--	--	--	0.428**	--
	--	--	--	(0.165)	--
ICT sector	--	--	--	--	1.099***
	--	--	--	--	(0.299)
Constant	-8.342**	-11.585***	-6.589	-5.412	-10.299***
	(3.042)	(2.634)	(4.080)	(4.588)	(3.257)
Observations	187	144	205	198	126
#Countries	21	18	22	22	18
Year dummies	No	No	No	No	No
F test	14.791	14.576	14.018	12.944	24.711
#Instruments	22.000	16.000	22.000	22.000	16.000
AR (1) p-value	0.107	0.153	0.097	0.096	0.188
AR (2) p-value	0.309	0.235	0.335	0.312	0.273
Hansen p-value	0.275	0.541	0.288	0.214	0.649

Notes: Panels A and B of Table 4 show the results of regressing different ICT proxies on the amount of total VC investment and the control variables over the period 2007-2019 using the two-step system GMM approach. The dependent variable in Panel A and B is total VC. GDP growth and FDI outflows have been treated as endogenous regressors and all the other regressors have been considered as exogenous in Columns 1 to 3 and Columns 6 to 11. In these columns, patents, gross capital formation, and hi-technology exports have been added to the list of excluded instruments. In Columns 4 and 5 respectively, the crowdfunding rounds and crowdfunds amount raised have also been treated as endogenous regressors. To deal with the small sample size in Columns 4 and 5, patents have been removed from excluded instruments because their inclusion reduced the number of observations further, from 96 to 84. To deal with endogeneity of crowdfunding, number of employers has been added to the list of excluded instruments. *, **, and *** indicate the significance levels at 10%, 5%, and 1%, respectively.

Table 5: Impact of digital economy on stages of VC investment: Two-step system GMM estimates.

Variables	Digital economy treated as exogenous variable			Digital economy treated as endogenous variable		
	Early-stage VC	Later-stage VC	Total VC	Early-stage	Later-stage	Total VC
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable $_{t-1}$	0.514***	0.473***	0.413***	0.544***	0.364**	0.400***
	(0.117)	(0.114)	(0.111)	(0.074)	(0.159)	(0.132)
GDP growth	0.982**	0.523	0.984**	1.312***	0.481	1.266*
	(0.466)	(0.782)	(0.403)	(0.351)	(0.736)	(0.720)
FDI outflows	-0.453**	-1.277	-0.446**	-0.388**	-0.514	-0.273
	(0.173)	(0.766)	(0.168)	(0.138)	(1.050)	(0.305)
Bank credit	0.655***	0.738**	0.699***	0.620***	0.564	0.552*
	(0.227)	(0.325)	(0.234)	(0.165)	(0.404)	(0.283)
Unemployment	-0.085	0.042	-0.088	0.050	0.134	0.055
	(0.117)	(0.236)	(0.211)	(0.117)	(0.463)	(0.257)
Digital economy	0.512***	0.574	0.484***	0.706***	1.139	1.127***
	(0.144)	(0.352)	(0.151)	(0.191)	(0.791)	(0.396)
Constant	-5.529**	-2.186	-7.054***	-7.004***	-5.455	-9.052***
	(2.569)	(3.808)	(2.149)	(1.816)	(3.885)	(2.123)
#Observations	203	193	210	201	191	208
#Countries	22	22	22	22	22	22
Year dummies	No	No	No	No	No	No
F test	27.229	8.736	14.736	42.340	9.921	17.783
#instruments	19.000	22.000	22.000	27.000	27.000	27.000
AR (1) p-value	0.044	0.054	0.100	0.027	0.051	0.089
AR (2) p-value	0.440	0.207	0.318	0.444	0.212	0.309
Hansen p-value	0.285	0.203	0.322	0.857	0.667	0.647

Notes: This table shows the results of regressing the composite index of digital economy on stages of VC investment and the control variables over the period 2007-2019. The dependent variables consist of early-stage VC in Columns 1 & 4, later-stage VC in Columns 2 & 5, and total VC in Columns 3 & 6. In Columns 1 to 3, the lagged dependent variable, FDI outflows, and GDP growth have been treated as endogenous regressors whereas hi-technology exports, patents, and gross capital formation have been added to the list of excluded instruments. In Columns 4 to 6, digital economy has also been treated as an endogenous regressor, in addition to GDP growth and FDI outflows. To tackle the measurement error and reverse causality in the case of the digital economy index, internet use has also been added to the list of excluded instruments in Columns 4 to 6. The dependent variable is the early-stage VC in Columns 1 and 4, later-stage VC in Columns 2 and 5, and total VC investment in Columns 3 and 6. *, **, and *** indicate the significance levels of standard errors at 10%, 5%, and 1%, respectively.

To test hypothesis 3, the results reported in Columns 4 and 5 of Table 4 (Panel A) show the direct effect of FinTechs (proxied by number and amount of equity crowdfunding rounds) on total VC investment. We suspect equity crowdfunding is endogenously related to VC investment as there might be a measurement error or reverse causality (i.e., availability of VC investment might boost equity crowdfunding and vice versa). Bank credit has been removed from these two models to avoid potential multi-collinearity with crowdfunding as FinTechs and bank credit seem to have substitution relationship with each other. The results show that equity crowdfunding has a positive influence on total VC investment at the 5% level of significance.

Other aspects of the digital economy have also been examined for their potential impact on total VC investment. In Column 6 of Table 4 (Panel B), the coefficient of employment in the ICT-based SMEs (OECD data) is 0.92 and statistically significant at the 1% level in determining total VC, as expected. This estimate implies that a 1 unit increase in employment in ICT-based SMEs raises the VC investment level by 0.92 percentage points. For robustness, a largely similar indicator of digital economy from Eurostat ICT data, i.e., employment in the ICT sector, is shown in Column 7 of Table 4 (Panel B) and the result shows an even larger economic impact on VC investment.

In Column 8, the coefficient on ICT-based enterprises is positive and statistically significant at 1% level in explaining total VC investment. For robustness, we also examine the impact of ICT-based SMEs. As expected, the variable ICT-based SMEs also exhibits statistically and economically similar results to ICT-based enterprises. Finally, the influence of the variable ICT sector is reported in Column 10 of Panel B, and it also has large and statistically significant influence at the 1% level. A 1 percentage point increase in the ICT sector leads to an increase of one percentage point in total VC investment. The significant positive impact of the digital economy variables in Columns 4 to 10 in Table 4 (Panel A and B) supports hypothesis 3.

To test hypothesis 4, the association between the digital economy and early-stage VC investment is examined in Table 5. For brevity, we introduce a composite index of the digital economy rather than using all the components for early as well as later-stage VC investment. The composite index is the average of ICT-based enterprises, ICT-based employment, and the ICT sector to GDP. Columns 1, 2, and 3 of Table 5 report the results with early-stage, later-stage, and total VC investment as the dependent variable, respectively. The influence of digital economy on early-stage and total VC investment is positive and significant at the 1% level, whereas the effect on later-stage VC investment is trivial. Columns 4, 5, and 6 report the same results with the digital economy treated as an endogenous regressor on the ground of reverse causality. The pattern remains unchanged. This confirms hypothesis 4, which asserts that there is a strong and positive association between early-stage VC investment and the digital economy.

4.3 Additional Controls and Robustness Tests

Table 6 reports the results of different adjustments of the control variables for a check on robustness. Column 1 adds time dummies to the baseline regression model.[9] After taking time fixed effects into account, the effect of internet use is enhanced both statistically and economically

[9] With this inclusion, the number of lags of instruments was reduced from five to two, to avoid instrument proliferation. It is worth mentioning that the collapse option in xtabond2 routine of Stata 15 has been employed to keep the number of instruments below the number of groups throughout this study.

compared with the baseline regression model. In Column 2, we control for trend variable and market crash and the positive association between internet use and VC investment still holds. Following Li and Zahra (2012), we add new business density to the model, which is treated as endogenous regressor in Column 3. Those authors used self-employment and number of scientific articles as instruments for new business density. We take number of employers and patents as instruments. The coefficients on new business density is non-significant and negative, which supports the findings of Li and Zahra (2012). In Column 4, we control for trend and time to start a business. Time required to start a business has a negative effect on VC investment at the 10% level of significance. This finding is consistent with previous work by Oberli (2014). Next, we add financial market depth in Column 5, and it displays a significant positive impact, supporting previous research (Black and Gilson, 1999; Bonini and Alkan, 2012; Cherif and Gazdar, 2011; Gompers and Lerner, 1998; Jeng and Wells, 2000; Schröder, 2009). It eclipses the impact of bank credit, while the impact of internet use is still significant. The results of additional control variables supporting previous literature reinforce our confidence in the present results.

Finally, government ownership of private equity (PE) is added to Columns 6 and 7 of Table 6. Government PE[10] has been treated as an endogenous variable due to its endogenous relationship

[10] Da Rin et al. (2006) examine the impact of government VC on innovation ratios (early-stage to total VC and hi-tech VC to total VC). Cumming (2013) questions the method employed by Da Rin et al. (2006) and examines the impact of government VC to GDP on early-stage VC to GDP. We follow Cumming's (2013) strategy. However, due to data restrictions, we analyze the impact of government ownership of private equity as a percentage of GDP, on the venture capital as a percentage of GDP as well as private equity as a percentage of GDP (see Columns 6 and 7 of Table 6). We, however, consider the government ownership of private equity as endogenous regressor rather than an exogenous regressor as done by Cumming (2013).

Table 6: Impact of internet use on total VC investment and Private equity investment using additional control variables.

	Dependent Variable						
	Total Venture Capital Investment						Private equity investment
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable$_{t-1}$	0.257	0.264**	0.517***	0.477***	0.459***	0.413***	0.397***
	(0.185)	(0.107)	(0.084)	(0.071)	(0.075)	(0.076)	(0.111)
GDP growth	0.698	1.551***	1.117**	1.467***	1.187***	0.871*	1.121**
	(0.918)	(0.491)	(0.415)	(0.479)	(0.347)	(0.424)	(0.448)
FDI outflows	-0.651	-0.247**	-0.656*	-0.271	-0.388	-0.528	-0.308
	(0.508)	(0.099)	(0.321)	(0.173)	(0.231)	(0.340)	(0.291)
Bank credit	0.689**	0.706***	0.624***	0.597***	0.204	0.395*	0.240
	(0.317)	(0.229)	(0.160)	(0.156)	(0.167)	(0.216)	(0.156)
Internet use	1.943***	1.818***	1.261***	1.014***	0.793**	1.279***	1.117**
	(0.398)	(0.440)	(0.247)	(0.337)	(0.285)	(0.396)	(0.422)
Trend	--	0.026	-0.014	-0.021*	-0.016	-0.026	-0.032
	--	(0.027)	(0.017)	(0.012)	(0.013)	(0.019)	(0.022)
Market crash	--	0.627**	--	--	--	--	--
	--	(0.265)	--	--	--	--	--
New business density	--	--	-0.123	--	--	--	--
	--	--	(0.116)	--	--	--	--
Time required to start a business	--	--	--	-0.190*	--	--	--
	--	--	--	(0.092)	--	--	--
Financial markets depth	--	--	--	--	0.975***	--	--
	--	--	--	--	(0.325)	--	--
Government PE	--	--	--	--	--	0.226*	0.183
	--	--	--	--	--	(0.111)	(0.193)
Constant	-14.53**	-17.73***	-10.62***	-11.65***	-8.88***	-10.33***	-8.94***
	(5.257)	(2.707)	(1.729)	(1.951)	(1.804)	(1.976)	(2.569)
Observations	232	232	226	232	232	232	236
#Countries	23	23	23	23	23	23	23
Year dummies	Yes	No	No	No	No	No	No
F test	19.624	25.032	35.746	87.952	63.737	49.894	27.173
#instruments	22.000	17.000	24.000	20.000	20.000	24.000	24.000
AR (1) p-value	0.050	0.053	0.068	0.047	0.061	0.054	0.009
AR (2) p-value	0.505	0.354	0.335	0.306	0.340	0.481	0.429
Hansen p-value	0.051	0.349	0.258	0.413	0.172	0.207	0.301

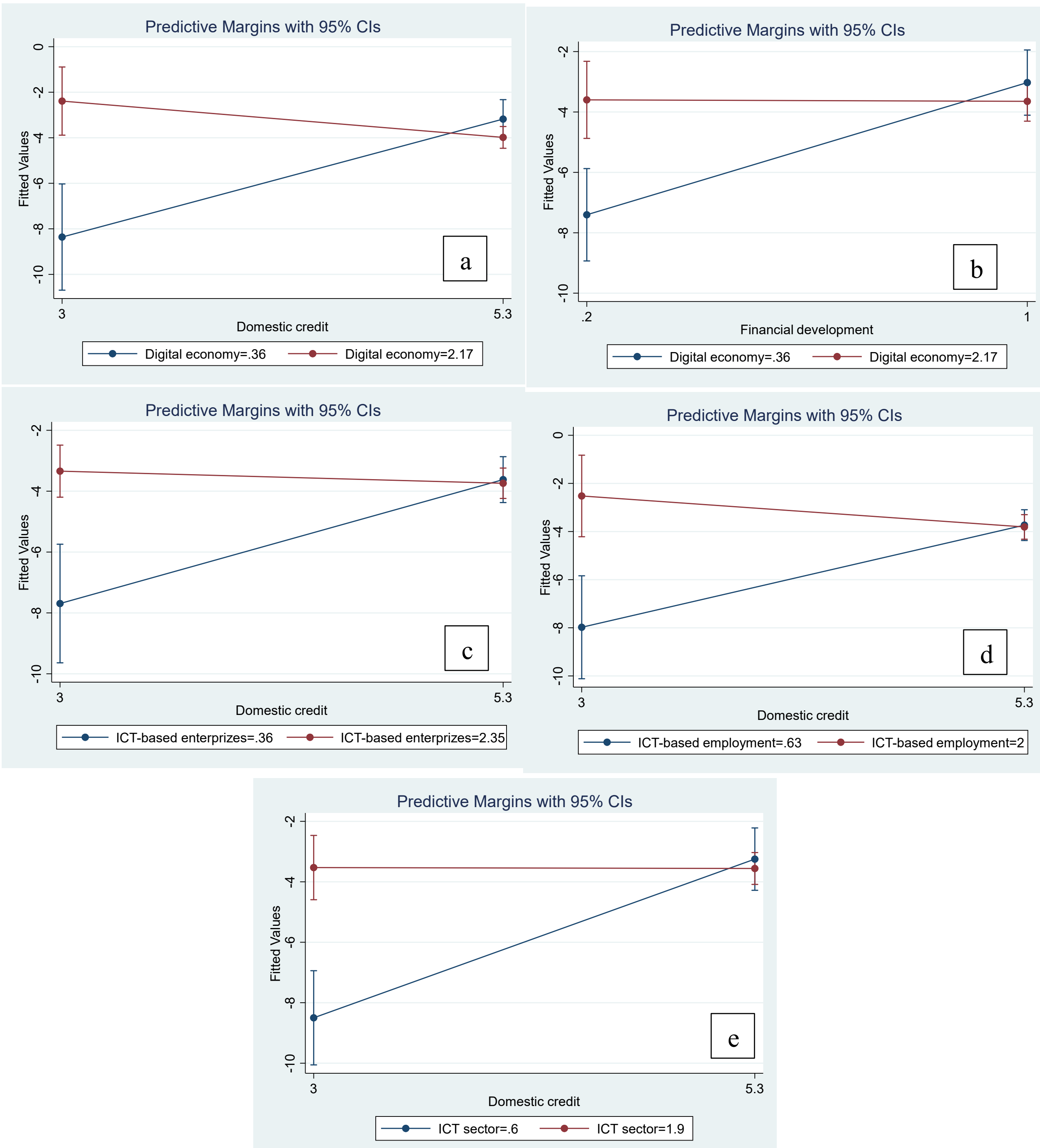
Notes: This table shows the results of regressing internet use on total VC investment and additional control variables using two-step system GMM estimation. FDI outflow and GDP growth have been treated as endogenous variables in Columns 1, 2, 4 and 5. In Column 3, we add new business density as an endogenous regressor, and in Columns 6 and 7, we add government PE as an endogenous regressor in addition to FDI outflows and GDP growth. In addition to the exogenous regressors, hi-tech exports, patents, and gross capital formation (GCF) have been added to the list of excluded instruments in all the models except Columns 3, 6, and 7. To tackle endogeneity of the variable new business density, the variable 'number of employers' has been added to the list of excluded instruments in addition to patents, hi-tech, and GCF. Similarly, unemployment has been added to the list of excluded instruments for government VC in Columns 6 and 7, in addition to patents, GCF, and hi-tech exports. *, **, and *** indicate the significance levels at 10%, 5%, and 1%, respectively.

Table 7: Interaction analysis: Effect of digital economy, bank credit, financial development index on total VC investment

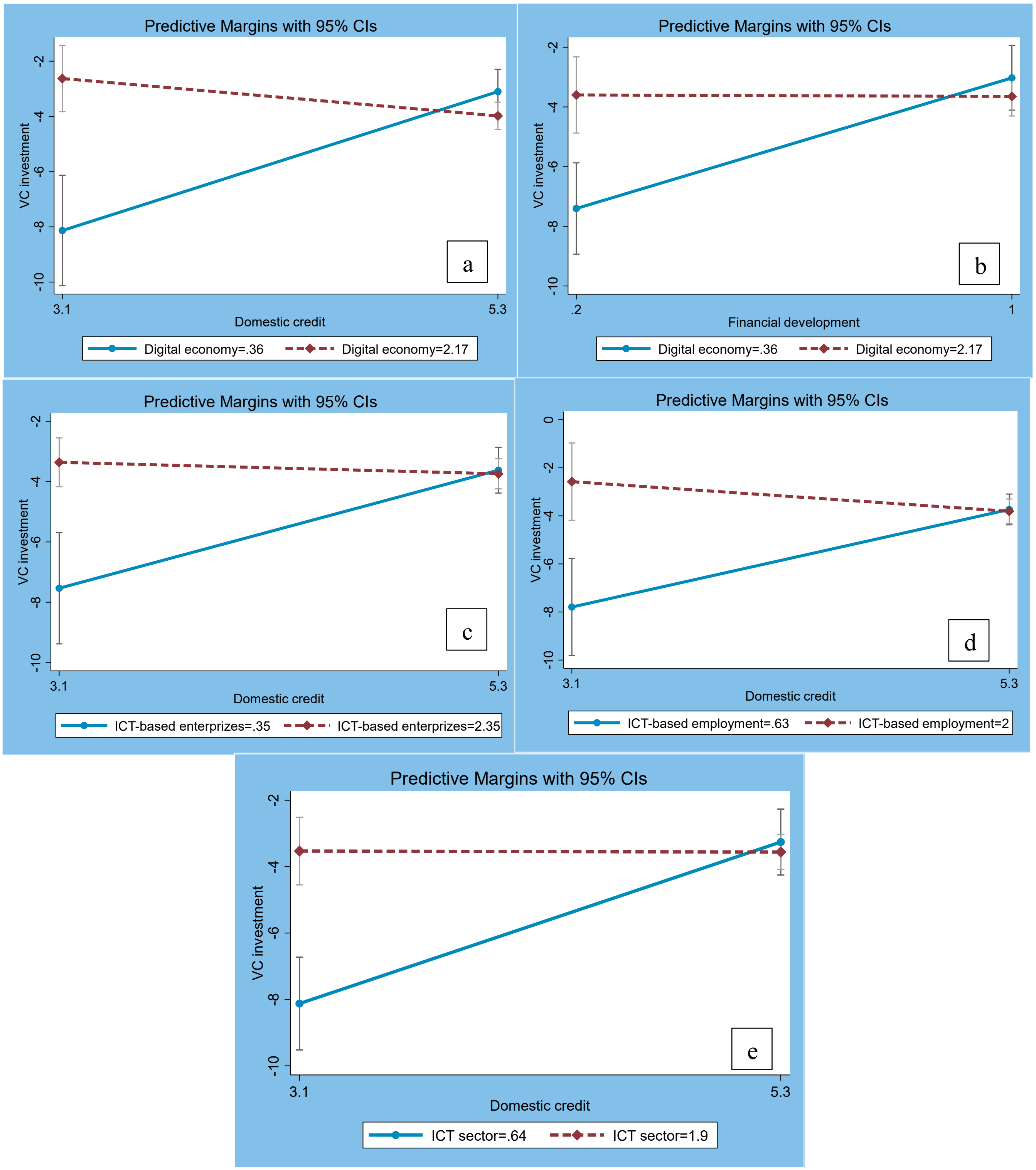
Variables	Dependent variable is total VC investment				
	(1)	(2)	(3)	(4)	(5)
VC investment $_{t-1}$	0.448**	0.340***	0.471***	0.450***	0.320**
	(0.191)	(0.114)	(0.114)	(0.135)	(0.114)
GDP growth	1.307**	1.119***	0.892*	0.753	1.808***
	(0.517)	(0.374)	(0.490)	(0.633)	(0.543)
FDI outflows	-0.546***	-0.419**	-0.077	-0.230	-0.538
	(0.162)	(0.192)	(0.730)	(0.594)	(0.864)
Unemployment	-0.090	-0.085	0.020	-0.010	-0.198
	(0.189)	(0.147)	(0.167)	(0.233)	(0.164)
Bank credit	2.865***	--	2.121***	2.951***	3.342***
	(0.790)	--	(0.698)	(0.973)	(0.851)
Digital economy	8.013***	2.714**	--	--	--
	(2.327)	(1.031)	--	--	--
Bank credit × Digital economy	-1.604***	--	--	--	--
	(0.485)	--	--	--	--
Financial development index	--	6.572***	--	--	--
	--	(2.059)	--	--	--
Financial development index × Digital economy	--	-3.057**	--	--	--
	--	(1.415)	--	--	--
ICT-based enterprises	--	--	5.115***	--	--
	--	--	(1.651)	--	--
Bank credit × ICT-based enterprises	--	--	-0.976**	--	--
	--	--	(0.347)	--	--
Employment in ICT-based SMEs	--	--	--	9.250***	--
	--	--	--	(3.171)	--
Bank credit × Employment in ICT-based SMEs	--	--	--	-1.756**	--
	--	--	--	(0.640)	--
ICT sector to GDP	--	--	--	--	9.120***
	--	--	--	--	(2.370)
Bank credit × ICT sector to GDP	--	--	--	--	-1.766***
	--	--	--	--	(0.522)
Constant	-17.539***	-9.343***	-15.052***	-18.606***	-21.931***
	(5.330)	(2.754)	(3.625)	(5.647)	(6.023)
#Observations	208	209	205	187	126
#Countries	22	22	22	21	18
Year Dummies	No	No	No	No	No
F test	40.134	64.028	29.807	92.734	84.790
#instruments	21.000	21.000	20.000	20.000	17.000
AR (1) p-value	0.098	0.092	0.093	0.111	0.185
AR (2)-value	0.298	0.302	0.341	0.319	0.273
Hansen p-value	0.295	0.255	0.192	0.108	0.577

Notes: Patents and GDP growth have been treated as endogenous regressors while patents, gross capital formation and hi-technology exports have been treated as excluded instruments. *, **, and *** indicate the significance levels at 10%, 5%, and 1%, respectively.

Figure 4: Graphical representation of the interaction analysis



Note: The graphs are based on regression results presented in Table 7.


Predictive Margins with 95% CIs
VC investment
-2
-4
-6
-8
-10
3.1
5.3
Domestic credit
Digital economy=.36
Digital economy=2.17
a
Predictive Margins with 95% CIs
VC investment
-2
-4
-6
-8
-10
.2
1
Financial development
Digital economy=.36
Digital economy=2.17
b
Predictive Margins with 95% CIs
VC investment
-2
-4
-6
-8
-10
3.1
5.3
Domestic credit
ICT-based enterprizes=.35
ICT-based enterprizes=2.35
c
Predictive Margins with 95% CIs
VC investment
0
-2
-4
-6
-8
-10
3.1
5.3
Domestic credit
ICT-based employment=.63
ICT-based employment=2
d
Predictive Margins with 95% CIs
VC investment
-2
-4
-6
-8
-10
3.1
5.3
Domestic credit
ICT sector=.64
ICT sector=1.9
e

with captive and independent VC. We introduce government PE investment in this study – instead of government VC investment – because Invest Europe only reports categorizations of government, independent, and captive PE investments. To tackle the potential measurement error and reverse causality, government PE has been instrumented with unemployment because government spending in the private sector is usually motivated by job creation. As can be seen in Columns 6 and 7, the positive association between government PE and VC investment indicates that government VC does not crowd out private VC investment, supporting the results of Cumming (2013).

4.4 Interaction Analysis

In Table 7, we allow bank credit to interact with digital economy variables. The results in Column 1 show that the interaction between bank credit and the digital economy index is statistically significant at the 1% level in determining VC investment. The coefficient of digital economy is 8.013, indicating that it has a positive effect on VC investment, whereas the negative coefficient of the interaction term between bank credit and digital economy (i.e., bank credit ×

digital economy) equals -1.604, implying that bank credit adversely affects the positive association between digital economy and VC investment. The positive effect of digital economy on VC investment disappears when bank credit reaches a threshold level of 5 (more precisely, 8.013/1.604 = 4.996). This implies that the state of the digital economy matters to VC investors more when bank credit is less readily available, which points to a substitution effect between bank credit and VC. On the other hand, any improvement in the digital economy does not attract further VC when bank credit is widely available. For a test of robustness, we replace bank credit with the IMF world financial development index in Column 2, and the results remain similar. Further, we add individual components of the digital economy i.e., ICT-based enterprises, employment in ICT-based SMEs, and ICT sector in Columns 3 to 5, respectively. The results are robust and remain largely the same in all the models.

The interaction relationships are plotted in Figure 4 (a) to (e). The red line depicts the highest level of digital economy and the blue line the lowest level. The right-hand side of the graphs represents the highest level of availability of bank credit (or financial development), while the left side marks the lowest level. In conditions with low levels of bank credit, the greater difference between lowest and highest levels of digital economy indicates that more ICT-backed business activities cause more VC investment as plotted on the y axis in Fig. 4. This leads us to accept hypothesis 5, which conjectured that financial development positively affects the association between the digital economy and VC investment.

5 Discussion

This paper empirically analyzes the effect of ICT on VC investments in 23 European countries over the period 2007-2019. The results demonstrate that ICT penetration and digital economy are strongly associated with early-stage VC and total VC investment. We conclude that ICT penetration positively influences VC investment through an efficiency-enhancing mechanism that facilitates VC processes of deal origination, deal structuring, and monitoring of portfolio companies, which eventually lead to a reduction in the selection of bad deals and an increase in the detection of fraud. Moreover, digital economy or digital entrepreneurship creates a vibrant entrepreneurial environment which generates deal flow for VC.

The assertion of Shane and Nicolaou (2017) that early-stage VC investments face decline due to newer platforms apparently does not hold in the European context. It is not only that early-stage VC investments have risen much more than later-stage VC in the era of mobile internet and FinTechs, but also the early-stage VC investments are less sensitive to business cycles than are later-stage investments. This is the age of Facebook, Twitter, LinkedIn, and WhatsApp. The trend analysis as well as regression results support our hypotheses that ICT penetration and digital economy lead to an increase in early-stage VC investments. The strong autoregressive coefficient of the early-stage VC also shows that this stage of VC investment has grown vigorously when FinTechs has also been growing very fast.

So why is all this happening? It is because the VC industry has aligned itself to the disruptive technologies and has invested in digital entrepreneurship (Kolokas et al., 2020). FinTech

VC investments have been on the rise since 2014. For example, KPMG reported the highest number of FinTech VC investments in 2018 in "The Pulse of FinTech 2019". It reported 2590 deals worth US$ 120 billion in 2018, compared with 2318 deals worth US$ 51 billion in 2017. Overall, the global market has experienced growth in FinTech from 1556 deals in 2014 to 2590 deals in 2018. The new platforms are not in competition with the VC industry. The rise of new platforms reflects the overall increase in the pie of entrepreneurial finance worldwide, rather than new platforms taking a share of the early-stage VC market in the existing pie. This supports the findings of Estrin et al. (2017) that entrepreneurs perceive crowdfunding platforms as differentiated as well as additional to the traditional platforms such as VC and angels. The results also support previous findings that newer platforms, such as crowdfunding, are more likely to support ventures that have already attracted VC, as VCs have the ability to ensure due diligence (Mamonov and Malaga, 2019). That is, newer platforms are not threatening traditional VC because of the human skills of VCs, in screening, negotiating, and monitoring (Bonini and Capizzi, 2019; Estrin et al., 2017).

It is concluded that digitization and VC complement each other and this supports the previous finding that FinTechs develop in environments where VC is readily available (Haddad and Hornuf, 2018; Kolokas et al., 2020). FinTech VC is where the newer platforms and the VC industry converge, where VCs invest in FinTechs, reflecting a win-win situation for both sectors. Unlike traditional large financial institutions, particularly banks, the VC industry has not been threatened by the digital revolution. The VC industry is designed to support new ideas, even if the new ideas (such as equity crowdfunding, micro-VC funding) are about changing the way the VC industry works. We thus argue that the VC industry is financing the digital revolutions and pivoting on those disruptions.

The results demonstrate a strong negative effect of the interaction term between bank credit and digital economy, implying that advances in digital economy attract more VC when bank credit is not readily available. We conclude that VC investments thrive in highly digitized economies when overall financial development is weak; however, VC investments make little difference when financial development is strong. When financial development is weak, there is substantial demand for VC to meet the capital requirement of digital enterprises. On the other hand, ICT-based enterprises prefer bank credit when it is readily available.

Finally, it is important to note that the influence of new business density on VC investment is negative and non-significant, supporting the findings of Li and Zahra (2012). Conversely, the impact of digital entrepreneurship (i.e., ICT-based enterprises/SMEs) is positive (at the 1% level of significance). This leads us to conclude that it is digital entrepreneurship – and not general entrepreneurship – that attracts VC investment in a country.

6 Conclusion

This is the first in-depth cross-country investigation of VC in the context of advances in disruptive technologies. The ICT indices employed in this paper are novel and relevant to the demand side as well as the information systems of the VC market. The study offers theoretical mechanisms on how ICT affects VC investments. The key mechanisms identified are as follows: (i) ICT penetration infuses efficiency into VC processes by reducing agency and transaction costs and enhancing the speed of VC deals; and (ii) ICT creates demand for VC through digital entrepreneurship. The paper contributes to the debate over complementarity versus substitution between VC and newer digital platforms (Bonini and Capizzi, 2019; Breznitz et al., 2018; Cumming and Schwienbacher, 2018; Haddad and Hornuf, 2018; Harrison and Mason, 2019; Kolokas et al., 2020; Shane and Nicolaou, 2017).

The findings have strong policy implications. While large traditional financial institutions, particularly banks, are struggling to team up with the FinTech disruptors, the VC industry is demonstrating that it is agile and naturally aligned with the newly emerging technological environment by investing in disruptive technologies (Kolokas et al., 2020) and pivoting on the market disruptions. Policy makers should provide strong ICT infrastructure, promote ICT skills, stimulate the use of ICT in both the private and the public sectors, and promote digital entrepreneurship. When financial development is weak, a digital economy generates a substantial demand for VC. On the other hand, digital economy prefers bank credit when it is readily available.

In future, there is a need to further examine the FinTech data to comprehend a direct relationship between those aspects of the digital revolution that interact with entrepreneurial financing. ICT and FinTechs may have an impact on fundraising as well as exit of VC investments and how these relationships interact with innovation and institutions. Mechanisms identified in this study warrant further scrutiny using firm-level and national data including how ICT has improved the efficiency of VC processes of deal origination, selection, and monitoring. It is also worth examining how digitization influences decisions of fund managers to make cross-border investments. Finally, it would be interesting to study how ICT is impacting the inclusion of rural communities in entrepreneurial finance within an individual country, similar to the work of Cumming and Johan (2010) on geographically remote internet communities.

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Appendix 1: Data Sources and Descriptions

	Variable	Description	Data Source
VC investment	Early-stage VC* investment	The sum of seed capital and start-up capital. *Seed capital* is the "Funding provided before the investee company has started mass production/distribution with the aim to complete research, product definition or product design, also including market tests and creating prototypes. This funding will not be used to start mass production/distribution.". *Start-up capital* is the "Funding provided to companies, once the product or service is fully developed, to start mass production/distribution and to cover initial marketing". The amount has been adjusted to total GDP in percentage terms.	Invest Europe
	Later-stage VC investment	"Financing provided for an operating company, which may or may not be profitable. Later-stage venture tends to be financing into companies already backed by VCs. Typically, in C or D rounds." Later-stage investment has been scaled to total GDP in percentage terms.	Invest Europe
	Total VC investment	Both early-stage (i.e., seed and start-up) and later-stage VC. Total VC has been scaled to total GDP.	Invest Europe
Private equity (PE) investment	PE investment	The sum of all stages of privately held equity investments, which includes start-up, later-stage venture, growth capital, rescue/turnaround, replacement capital, buyout. PE investment has been adjusted to total GDP in percentage terms.	Invest Europe
	Government PE investment**	Investments made by government VC funds scaled to GDP.	Invest Europe
Financial development	Financial development index	A composite index measuring the overall financial system of a country, which covers access, depth and efficiency of financial markets and financial institutions.	IMF
	Financial market depth	Stock market capitalization to GDP, stocks traded to GDP, international debt securities of government to GDP, BIS debt securities database, total debt securities of financial corporations to GDP, dealogic corporate debt database, total debt securities of nonfinancial corporations to GDP, and dealogic corporate debt database.	IMF
	Bank credit	Domestic bank credit provided to private sector as % of GDP is the financial resources provided to the private sector by financial corporations.	World Bank
ICT penetration	Internet use	Number of individuals who have used the internet in the last 3 months per 100 population.	World Bank
	Fixed broadband subscriptions	Number of fixed subscriptions (per 100 people) to high-speed access to the public internet at downstream speeds equal to, or greater than, 256 kbit/s.	World Bank
	Use of computers at workplace	Number of persons employed in businesses with 10 or more employees using a computer with internet access as % of total workforce in these businesses.	OECD
	High-technology exports	Exports of products with high R&D intensity, such as aerospace products, computers, pharmaceuticals, scientific instruments, and electrical machinery. High-technology exports have been adjusted to total manufactured exports in percentage terms.	World Bank

Digital economy	ICT sector	Total ICT sector (including ICT manufacturing and ICT services) scaled to GDP in percentage terms.	Eurostat ICT Data
	Employment in ICT sector	Percentage of ICT personnel in the ICT sector (including ICT manufacturing and ICT services) to total employment in the country.	Eurostat ICT Data
	Employment in ICT-based SMEs	Total number of employees in ICT-based SMEs (i.e., firms employing 1-249 persons) as % of total employment in the SME sector except financial and insurance activities.	OECD
	ICT-based enterprises	Total number of ICT-based enterprises as % of total enterprises in a country except financial and insurance related enterprises.	OECD
	ICT-based SMEs	Total number of ICT-based SMEs as % of total SMEs in a country.	OECD
	Equity crowdfunding (rounds)	Equity crowdfunding platforms allow individual users to invest in companies in exchange for equity. Total number of rounds has been scaled to population.	Crunchbase
	Equity crowdfunding (amount)	Annual crowdfunding raised, adjusted to GDP.	Crunchbase
Control Variables	GDP growth	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 US dollars.	World Bank
	Foreign direct investment (FDI), net outflows	The sum of equity capital, reinvestment of earnings, and other capital that flows from the reporting economy to the rest of the world. The amount is GDP-adjusted.	World Bank
	Unemployment	Percentage of individuals without work to total labor force of the country.	World Bank
	New business density	Number of new business registrations per 1,000 people aged 15-64.	World Bank
	Number of employers	Employers are those workers who work on their own account or with one or a few partners or hold the type of jobs defined as "self-employment jobs". The variable is the percentage of total employment.	World Bank
	Ease of doing business	This is measured through time required to start a business (days). It is the number of calendar days needed to complete the procedures to legally operate a business.	World Bank
	Gross capital formation	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. The data has been scaled to total GDP.	World Bank
	Patents	Number of worldwide patent applications filed through the Patent Cooperation Treaty, covering applications by both residents and non-residents. The variable has been adjusted to total population.	World Bank

Notes: The description/definitions of the data have been taken from the source documents/sites of the data with no or very few changes.

*The aggregation of the figures of all stages of VC and PE is according to the country in which the investee company is based, regardless of the location of the private equity fund.

** The aggregation of the figures of government PE consists of industry statistics that represent investments according to the country of the private equity firm rather than country of the portfolio company.