

Monetary policy and venture capital markets

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Abstract

We assess the impact of monetary policy (i.e., central bank interest rates) on the activity of venture capitalists (VC). Using data from 31 countries from 2004 to 2019, we find that VC firms' fundraising activity increases when interest rates become negative. We explain this finding by referring to the principal-agent relationship between general and limited partners of VC firms in combination with behavioral finance arguments. Specifically, we identify three channels pertaining to a legal motivation (i.e., legislative hurdles and litigation risks), a liquidity motivation (i.e., substitution effect relative to other asset classes), and behavioral biases (i.e., mental accounting, conservatism, disposition effect, or prospect theory).

JEL codes: G24; L26; O17; E1.

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1. Introduction

Entrepreneurial ventures increase an economy's capacity for wealth creation, job growth, and competitiveness (e.g., Chowdhury et al., 2019). Venture capital (VC) contributes to economic prosperity by financing such entrepreneurial ventures (e.g., Gompers and Lerner, 2001). For example, VC is considered a key enabler behind the rise of vibrant industrial sectors of the global economy over the past decades, such as biotech, semiconductors, or information technology (e.g., Baum and Silverman, 2004; Colombo et al., 2019).

An important research stream shows that the development of VC markets is linked to macroeconomic factors such as GDP, labor market development, and stock market performance (e.g., Gompers and Lerner, 2000). An overlooked macroeconomic lever is monetary policy and, in particular, the level of interest rates set by central banks. Prior research in monetary economics shows that central bank rates affect consumption and asset prices (e.g., Gilchrist and Leahy, 2002), as well as entrepreneurship and economic growth (e.g., King and Levine, 1993; Shane, 1996). However, despite the direct association between interest rates and the cost of capital, entrepreneurial finance studies rarely consider monetary policies.

The aftermath of the global financial crisis (2008/09) was characterized by low economic growth and inflation. Thus, central banks began to implement unconventional and unprecedented monetary policies such as negative interests by charging, rather than paying, interest rates on the reserves that commercial banks hold. The aim is to stimulate the economy by reducing lending rates and increasing credit supply (e.g., Bouncinha and Burlon, 2020; European Central Bank (ECB), 2020; Molyneux et al., 2019). While negative central bank rates have been used in the European Union, Switzerland, and Japan, they are discussed controversially and their translation to the real economy is unclear (e.g., Dell'Araccia et al., 2018; Heider et al., 2019). Due to the phenomenon's recency, negative policy rates represent theoretically and empirically "unchartered territory" (Heider et al., 2019: 3731), with "no agreement in the

economics profession on the effectiveness of negative interest rate policies” (Altavilla et al., 2021: 1). Specifically, we are not aware of any studies that investigate the provision of early-stage finance when interest rates become negative. This lack of understanding about the link between the cost of capital and VC markets is a strong limitation, especially in light of the extreme monetary policies of the last few years.

We combine two veins of scholarship, namely monetary policy and entrepreneurial finance, that have rarely been connected. We examine VC markets when interest rates break through the zero lower bound and find that when interest rates become negative, the fundraising activity of VC firms increases while the demand for VC funding by entrepreneurial firms decreases. We identify three channels to explain this finding. First (*legal explanation*), as the remuneration of retail deposits passes the zero line, banks might experience significant outflows of deposits from large investors, which are typically the limited partners in VC funds. Second (*liquidity explanation*), the abundance of “cheap money” induced by negative interest rates might lead VC general partners to tap the opportunity. Central banks manage interest rates to curb economic activity, therefore when interest rates are lower, VC markets are more lively because entrepreneurs’ projects increase in value, supporting the demand and supply for VC money. When interest rates increase (become positive), the appeal of VC as an asset class decreases, since other types of investments (e.g., bonds) can deliver high (positive) returns. Third (*behavioral explanation*), negative interest rates can induce a change in behavior among investors as a result of behavioral biases, such as mental accounting (i.e., separating decisions that should in principle be combined), conservatism (i.e., anchoring on the ways things have typically been), a disposition effect (i.e., avoiding realizing paper losses and seek to realize paper gains), or prospect theory (i.e., making investments relative to a reference point rather than to wealth levels).

The contribution of our findings is twofold. First, the bulk of prior research in entrepreneurial finance focuses on the uncertainty-reducing function of VC firms as financial intermediaries and deals with agency problems that occur between VC firms as principals and entrepreneurial ventures as agents (e.g., Baum and Silverman, 2004; Block et al., 2017; Colombo et al., 2019; Rosenbusch et al., 2013). Coherently, prior research comprehensively assesses the determinants and outcomes of VC financing for ventures (e.g., Baum and Silverman, 2004; Rosenbusch et al., 2013) and investors (e.g., Cochrane, 2005). Yet, research on the intersection of finance and law ascertains that a second principal-agent problem might arise between the management of the VC firm (general partners) and other investors (limited partners) (e.g., Balboa and Martí, 2007). To mitigate principal-agent conflicts that might arise between these two types of partners, extensive contractual agreements and complex compensation arrangements are meant to align the behavior of the general partner with the interests of limited partners (Cumming, 2008). We contribute to this research by taking this additional agency problem into account. By assessing the supply relationship between general and limited partners, we provide additional insights on whether and how the relationship between interest rates and VC differs for both channels. By documenting an increased fundraising activity of VC general partners when interest rates are negative, despite a decreasing demand for VC funds by entrepreneurs, our findings highlight the need to treat VC funds and the entities involved therein in a more differentiated way. This is a subject of considerable modeling in the industry (e.g., Meads et al., 2016) and has not attracted enough scholarly attention.

Second, applying the principal-agent theory to the setting of general and limited partners in VC firms yields relevant insights about monetary policies. By connecting the macro-level dimension of interest rates to the (micro-)functioning of VC firms, we apply a micro-foundational lens that enriches and refines our understanding of VC markets. By referring to the agency relationship between general and limited partners, we disentangle the effects of extreme

monetary policies (i.e., negative interest rates) on the intermediary role of VCs. While we document that higher interest rates are associated with higher fundraising activity by VC firms, we find that this relationship changes under extreme monetary policies, which have unintended consequences that affect different parties differently. Negative rates are indeed a domain that differs from “standard” monetary policies both in legal and behavioral terms. Negative interest rates, although associated with decreasing entrepreneurial demand, are associated with a higher fundraising activity of VC firms. We explain this behavior of VC firms using principal-agent and behavioral finance arguments.

The remainder of this study is organized as follows. Section 2 provides the institutional and theoretical background. Section 3 presents our hypotheses. Section 4 describes the sample, variables, and data sources used. Section 5 explains the methods and the results of the empirical analysis, including robustness tests and additional analysis of the entrepreneurial demand for VC funds. Section 6 concludes.

2. Institutional and theoretical background

2.1 The structure of VC firms

VC is a specialized form of financial intermediation, where funding is provided to entrepreneurial ventures by VC funds, which are established and managed by VC firms. The bulk of capital committed to these VC funds, and subsequently invested in entrepreneurial ventures, is raised from outside investors (e.g., Block et al., 2017). Investors in VC funds typically include large institutional investors (e.g., corporate and public pension funds, large banks, insurance companies), university endowments, or wealthy individuals. These institutional investors pursue portfolio diversification into an asset class that is characterized by high risk and the potential for high returns (e.g., Cochrane, 2005; Block et al., 2019).

Most VC funds are legally structured as limited partnerships. This organizational form distinguishes general partners (i.e., VC firms) and limited partners (i.e., other investors) (e.g., Alperovych et al., 2015; Gompers and Lerner, 1999b). As the general partner, the VC firm is responsible for setting up, managing, and liquidating the fund. VC firms are active investors that typically engage in several value-adding activities (e.g., monitoring, coaching) to enhance the prospects of their portfolio ventures (e.g., Colombo et al., 2019; Manigart et al., 1996; Sapienza et al., 1996). Additionally, VC firms provide a small share of the total capital to their VC funds to signal their commitment to the limited partners (e.g., Kaplan and Strömberg, 2009). In contrast to the general partner, limited partners are passive and do not participate in the fund's day-to-day management (e.g., Alperovych et al., 2015). Their role is limited to providing capital, which is used for investments and for paying management fees to general partners (e.g., Gompers and Lerner, 1999b; Keil et al., 2010).

VC funds have a predetermined, finite lifespan of around 10 years (e.g., Andrieu and Groh, 2021; Townsend, 2015; Vanacker et al., 2020). During this period, limited partners have little recourse on the capital committed, making VC funds a rather illiquid asset class (Lerner et al., 2007). After this period, the VC fund is liquidated and the limited partners are paid out. Most VC funds are close-ended, so no additional capital is raised from limited partners after the VC fund is launched (Townsend, 2015). If a VC firm is interested in making further investments, it has to set up a new fund to raise additional capital from limited partners (e.g., Gompers and Lerner, 2001; Vanacker et al., 2020).

2.2 Principal-agent theory and the VC market

VC firms provide funding to ventures in the presence of high uncertainty (e.g., Gompers and Lerner, 2001). This uncertainty is a key characteristic of entrepreneurial finance markets and partially stems from an information asymmetry between better-informed entrepreneurs and

less-informed investors (e.g., Cumming, 2006). Hence, principal-agent problems can arise from conflicts of interest between external investors (principal) and entrepreneurs (agent). VC firms are critical financial intermediaries and enhance the efficiency of the VC market because they mitigate this information asymmetry (Balboa and Martí, 2007). Focusing on this intermediary role, prior research in entrepreneurial finance comprehensively documents that VC firms reduce uncertainty by engaging in specialized activities that include the screening, monitoring, and coaching of their portfolio ventures (e.g., Baum and Silverman, 2004; Colombo et al., 2019; Rosenbusch et al., 2013).

A small research stream describes an additional principal-agent conflict within VC funds, that is, between VC firms (i.e., general partners) and the outside investors (i.e., limited partners) (e.g., Balboa and Martí, 2007). The general partner (agent) actively manages the fund and is responsible for successfully investing in portfolio ventures. However, the financial means that are invested mostly come from the limited partners (principals), who find it difficult to engage in monitoring or coaching to overcome potential agency problems pertaining to the general partner. To mitigate this agency conflict, VC funds typically use a comprehensive partnership agreement, which specifies the VC fund's goals and mode of operation ex-ante. The agreement imposes strong contractual, financial, and reputational constraints on the general partner (e.g., Alperovych et al., 2015; Balboa and Martí, 2007; Cumming and Johan, 2009). Such a partnership agreement typically regulates the fund's management (e.g., the amount invested per firm, co-investments, reinvestments of profits), the activities of the general partners (e.g., investments by the general partner, outside activities of the general partner), and the types of asset that the fund can invest in. Additionally, VC fund managers receive a share of the capital gains ("carried interest" or "carry"), thereby partially aligning the interests of general and limited partners. The potential conflict of interest between general partners and limited partners is also mentioned by Dai (2022), who reviews recent academic studies on the private equity industry

to shed light on some issues that the SEC tries to address, with a focus on empirical evidence on measures of private equity return and risk, performance in comparison to other sectors, return reporting and manipulation, and potential conflicts between limited partners and general partners. Similarly, by focussing on the risk-taking implications of style drifts, Koenig and Burghof (2022) add to the growing literature about agency conflicts between limited and general partners in private equity research. As limited partners have no influence on the investment decisions after their initial capital commitment and therefore have to trust the general partners to act in their best interest, limited and general partners form a classical principal-agent relationship. When general partners drift from their originally expected investment style, limited partners cannot usually withdraw capital to rebalance the risk-return profile of their portfolio, opening up a potential agency conflict.

2.3 Interest rates and the VC market

Central bank interest rates are a core instrument of monetary policy. Reducing central bank interest rates typically intends to stimulate demand in the real economy. This is because lower interest rates reduce the funding costs for banks and, subsequently, borrowers (e.g., Garcia-Teurel and Martinez-Solano, 2007; Heider et al., 2019; Molyneux et al., 2019). Indeed, research in monetary economics shows that interest rates affect a range of critical macroeconomic factors, such as consumption and asset prices (Gilchrist and Leahy, 2002), risk appetite (Ioannidou et al., 2015), the aggregate volume of credit in the economy (e.g., Bernanke and Blinder, 1992; Kashyap and Stein, 2000). Also, interest rates are associated with entrepreneurship and economic growth (e.g., King and Levine, 1993; Shane, 1996). The basic argument is that entrepreneurs' fundraising is a function of the cost of capital.

As an instrument of monetary policy, changes in interest rates typically refer to changes in positive interest rates. From 2012 onwards, however, several economies introduced negative

interest rates, mostly to stimulate economic growth in the aftermath of the global financial crisis (e.g., Boucinha and Burlon, 2020; ECB, 2020; Molyneux et al., 2019). In contrast to positive interest rates, negative interest rates represent a recent and unconventional monetary policy where commercial banks can charge (instead of pay) interest rates on the reserves they hold at the central bank. Negative interest rates are controversial because their translation to the real economy is ambiguous (e.g., Dell’Ariccia et al., 2018; Molyneux et al., 2019). It is unclear whether negative interest rates lead to new market dynamics or merely constitute a situation that is akin to very low interest rates.

Despite the direct association between interest rates and the cost of capital, prior research on the relationship between interest rates and VC markets is scarce. We were able to identify two studies that consider interest rates as determinants of VC supply and demand. First, Gompers and Lerner (1999a) assess the determinants of VC fundraising in the US using data from 1972 through 1994. They find that macroeconomic factors are important determinants of the VC supply. These factors include regulatory changes, capital gains tax rates, GDP growth, and research and development expenditures. As an alternative explanation, Gompers and Lerner (1999a) state that the supply and demand for VC could also depend on the attractiveness of financing alternatives, which is reflected in interest rates. However, their argument is conceptual as they do not include interest rates in empirical models. Second, the working paper by Romain and van Pottelsberghe (2004) compares the development of VC markets across countries using panel data from 16 OECD countries (e.g., Germany, Japan, UK, US) from 1990 to 2000. The authors find that VC supply is positively influenced by macroeconomic factors such as GDP growth, R&D investments, and labor market rigidities. They provide empirical evidence of a positive relationship between interest rates and VC supply, which they measure via a country’s VC intensity, the number of VC investments divided by the gross domestic product. Besides these two studies, both of which use data from 2000 and before, we were unable to

identify further research on the impact of interest rates on the VC market. Specifically, we were unable to identify any research that considers negative interest rates.

3. Hypotheses

3.1 Interest rates and the fundraising activity of VC firms

The fundraising activity of VC firms (i.e., the VC firms' demand for investments from limited partners) is expected to be related to interest rates. For "external" investors such as limited partners, VC investments serve as complements to investments in less risky asset classes, such as bonds, loans, or other types of debt securities. To commit capital to VC funds, institutional investors demand a risk premium. The magnitude of this risk premium depends on the attractiveness of investments in other asset classes (Cochrane, 2005). If the risk premium is not large enough, for example, because of the possibility to receive similar expected returns from less risky asset classes, institutional investors will not invest in VC firms. As such, the attractiveness of committing capital is partly shaped by the interest rate.

Since VC funds anticipate the increased demand for VC by entrepreneurial ventures if interest rates increase (Gompers and Lerner, 1999a), they increase their fundraising activity to meet the increased demand and exploit the lower risk premiums relative to other asset classes. Thus, we hypothesize:

H1: Higher interest rates are associated with a higher fundraising activity of VC firms.

3.2 Negative interest rates and the fundraising activity of VC firms

As outlined in the motivation of Hypothesis 1, corporate finance theory suggests that lower interest rates lead to a decrease in VC demand by entrepreneurs. This implies that the demand for VC should further decrease in periods of negative interest rates because, theoretically, it would be possible for entrepreneurs to borrow money at very low costs. Everything else equal,

considering the two-sided nature of the intermediary function of VC firms, a similar impact on VC fundraising activity seems likely. That is, VC funds fundraising activity should decrease with negative rates because VC funds anticipate lower VC demand by entrepreneurs.

However, the nascent research on negative interest rates in finance and monetary economics suggests that a negative interest rate environment differs from a low but positive interest rate environment (e.g., Heider et al., 2019; Molyneux et al., 2019). Hence, the extension of mechanisms derived in an environment of positive interest rates to a negative interest rate environment is not straightforward because new mechanisms affect the behavior of market participants in the territory of negative interest rates (e.g., Heider et al., 2019). Applied to VC, we similarly argue that negative interest rates will affect VC fundraising activity differently than low interest rates. Our rationale is threefold.

First, a *legal motivation* differentiates the decrease in interest rates, once below zero. Retail deposits tend to not carry negative rates, either because of legislative hurdles and litigation risks or because of concerns about deposit withdrawals (Altavilla et al., 2021). Legislators and courts have so far maintained a legal framework that poses a series of legal constraints and litigation risks related to the application of negative deposit rates (e.g., Molyneux et al., 2019). However, the transmission of negative rates to corporate deposits is not subject to legal constraints in most countries and is indeed a relatively widespread phenomenon with an increasing prevalence (e.g., Alatavilla et al., 2021; Boucinha and Burlon, 2020; Molyneux et al., 2019). As the remuneration of retail deposits passes the zero line, banks might experience significant outflows of deposits from large investors, that are typically the limited partners in VC funds. Therefore, the effect of decreasing interest rates applies differently to the trade-off between VC and other investments because general partners of VC firms realize that the basin of potential limited partners might increase, which is generally expected when the return of low-risk secu-

rities like investment-grade bonds is low. We acknowledge, however, that institutional investors, which are among the limited partners in the VC industry, are often conditioned in their choice related to deposits and liquidity by supervisors and internal rules. This might reduce the elasticity of the demand for bank deposits with respect to negative interest rates.

Second, we identify a *liquidity motivation*, with a substitution effect. Relative to other asset classes the lower bound of zero for interest rates would imply a leakage of liquidity away from debt towards equity investments. This creates an abundance of “cheap money”, which tempts VC general partners to tap the opportunity and increase their fundraising activities. When interest rates are negative, investors might rebalance their portfolios towards longer-term or riskier assets. Indeed, a very lax monetary environment has been accused of increasing the risk preferences of financial intermediaries, so that the relationship between monetary policy and macro-prudential management becomes so convoluted that it is considered among the root causes of financial crises (e.g., Bernanke and Reinhart, 2004). With no (or very limited) returns achievable from other investments, investors will invest more in alternative asset classes (such as venture capital) that have the potential to offer higher returns (the so-called “search-for-yield”, De Nicolò et al, 2010). At the very least, negative rates will increase investors’ stakes in portfolio diversification. General partners would therefore increase their fundraising activity, with the prospect for limited partners to achieve higher (i.e., positive) returns. In other words, negative interest rates mean that investors lose money in traditional asset classes and, therefore, tend to avoid them. This increases the amount of investable money in the economy, which leads to a supply surplus. The supply surplus then means that the price (i.e. the expected return) decreases, which makes it attractive for VCs to raise more funds.

Third, we consider *behavioral biases*. Negative interest rates can induce a change in behavior among investors as a result of behavioral bias. In a standard neoclassical framework, managers of firms (including VC firms) are modeled as rational agents who make decisions on

behalf of rational principals. Yet, the corporate finance literature shows that financing decisions are shaped by market timing considerations. For instance, the window of opportunity theory shows that market timing is relevant in equity issuance decisions (e.g., Graham and Harvey, 2001; Loughran and Ritter, 1995). Behavioral finance posits that the presence of behavioral investors is exploited by rational managers to opportunistically profit from mispricing by investing capital, issuing securities, or divesting assets (Ritter, 2003). Cognitive psychology is the building block of behavioral finance that focuses on psychological biases in how people think when making investment and financing decisions. Some of these biases, such as mental accounting (i.e., separating decisions that should in principle be combined), conservatism (i.e., anchoring on the ways things have typically been), disposition effect (i.e., avoiding realizing paper losses and seeking to realize paper gains), or prospect theory (i.e., making investments relative to a reference point rather than to wealth levels) might lead investors to consider negative rates differently from low but positive rates. Applying these arguments to the general partners of VC firms rationally exploiting limited partners, we would expect them to increase their fundraising activity to exploit the uniqueness of negative rates.

In light of the three channels pertaining to a legal motivation (i.e., legislative hurdles and litigation risks), a liquidity motivation (i.e., substitution effect relative to other asset classes), and behavioral biases (i.e., mental accounting, conservatism, disposition effect, or prospect theory), we hypothesize:

H2: Negative interest rates are associated with a higher fundraising activity of VC firms.

3.3 The fading impact of negative interest rates

Above, we argue that interest rates, and in particular negative interest rates, have an impact on the behavior of economic participants such as VC firms and entrepreneurs. However, the absolute value of interest rates is not the only factor that affects behavior. The perception of

interest rates is relative and varies across time and countries. This means that the effect of the change in interest rates does not last for an indefinite amount of time. Until a few years ago, negative rates were not considered a viable option. The zero lower bound has been considered the theoretical limit for an interest rate that, supposedly, could not be lowered to negative levels (McCallum, 2000). In 2020, when a few countries already had negative interest rates, the Chairman of the US central bank, Jerome Powell, argued that “negative interest rates probably [are] not an appropriate or useful policy for us here in the United States” (McCandless Farmer, 2020). Nowadays, although still controversial, negative interest rates gained acceptance. However, we argue that the effect of negative interest rates fades over time.

The longer the new (negative) interest rate is in place, the less effect it will have on economic participants’ behavior. After a certain amount of time, most investors that were motivated by the change in interest rate will have already made their investments and VC firms raised large amounts of capital. Similarly, as time goes by, investors are expected to consider interest rates less exceptional and be less prone to pursue new investments. Therefore, we argue that the longer negative interest rates are in place, the more “normal” they will be perceived. We hypothesize:

H3: The longer negative interest rates are in place, the lower their impact on the fundraising activity of VC firms.

4. Data and variables

4.1 Data sources and sample

Our main data source is Thomson Reuter’s Refinitiv Eikon database, which is commonly used for financial information in recent research (e.g., Jank et al., 2021). We retrieved all VC investments made by VC firms between January 2004 and December 2019. We start our sample in 2004 to avoid any confounding effects of the dot-com bubble. Simultaneously, we limit our

data to December 2019 to avoid turbulences caused by the COVID-19 pandemic.

Due to data limitations, we were forced to exclude observations from several countries. Our final sample concentrates on VC firms and portfolio ventures located in 31 countries: Argentina, Australia, Austria, Belgium, Canada, Chile, Colombia, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, South Africa, South Korea, Spain, Sweden, Switzerland, United Kingdom, and the United States. These countries attract the vast majority of VC investments worldwide. Based on the information included in Refinitiv Eikon, we focus on investments characterized as “venture capital”. All our measures are at the country level and our unit of analysis is country-month. In total, our sample comprises 2,762 observations. However, due to missing variables, our main models use a lower number of observations. We extend this data with additional data from various sources, such as Google Searches, information, the Bank of International Settlements, and the OECD.

4.2 Variables

4.2.1 Dependent variable

Our dependent variable captures the fundraising activity of VC firms (*VC fundraising*) in a given country over the following 12 months (in million USD, log-transformed). The data comes from Refinitiv Eikon. We use the one-period forward measure for the dependent variable. With this method, all our independent variables and controls predict the next 12 months’ fundraising, alleviating concerns of reverse causality. The location of the fundraising is determined by the data provider.

4.2.2 Independent variables

To test H1, we use the central bank interest rates published on the Bank of International Settlements (BIS) website.¹ We use central bank interest rates for several reasons. First, they are widely known by the public and investors. For example, central bank meetings and their results are widely covered by the media and, therefore, are likely to impact the psychology and behavior of industry participants. Second, central bank data is available over a long period of time and across many countries in a harmonized and comparable way. Third, most financial decisions and financial instruments depend on the decisions of the central bank (e.g., mortgage rates, lending rates) and they are thus commonly used in prior research (e.g., Heider et al., 2019). We use nominal rates because VCs, like other investors, make decisions based on nominal rates (Eggertsson et al, 2019) and their performance is eventually benchmarked to a hurdle rate, which expresses the VC's required rate of return. Our study is focused on whether and how their behavior changes when nominal rates become negative. We anyway include inflation among our controls (Chari et al., 1995).

To test H2, we use the dummy variable *negative interest rates*. The variable takes a value of 1 when central bank interest rates are negative in the respective month and country, and 0 otherwise. The dummy variable is constructed from BIS central bank interest rates. To test H3, we construct another variable (*time from negative rates*) that measures the number of months it took interest rates in a given country to turn from negative to positive again (if ever). For example, if central bank rates became negative in December 2012 and stayed negative until February 2013 this variable takes a value of 0 in November 2012, 1 in December 2012, 2 in January 2013, and 3 in February 2013. In March 2013 the variable would take a value of 0.

Table 1 reports the countries and periods with interest rates at 0% or negative. According

¹ A list of how the central bank rate of each country has been coded can be found here: https://www.bis.org/statistics/cbpol/cbpol_doc.pdf. Website last accessed in April 2021.

to the BIS, the Euro area (ten countries), Japan and Sweden experienced interest rates at 0% over the last few years. More specifically, Denmark, Japan, Sweden, and Switzerland experienced negative central bank interest rates. Figure 1 illustrates the relationship between interest rates (right axis) and VC fundraised (left axis) for those countries with negative interest rates, starting from 2011, the year before the first negative interest rate was implemented. The figure shows that, after rates turn negative, there is a short-medium term increase in VC fundraising.

- Please insert Table 1 and Figure 1 about here -

4.2.3 Control variables

Following prior research, we control for a large number of macroeconomic factors that could affect our dependent variables (e.g., Gompers and Lerner, 1999a; Groh et al., 2010) and which are available across countries and time. This data comes from the World Bank, the OECD, and The Economist.

Countries with larger and faster-growing economies will experience more VC activity. Therefore, we control for *GDP growth* (in percent) and *GDP* levels at current USD (in hundreds of billions). We also control for the level of *self-employment* and *unemployment* as a percentage of total employment, *taxes* on income, capital gains, and profits as a percentage of revenues (World Bank data). We include the *credit spread* between the central bank rates and the corporate lending interest rate, as measured by The Economist. This measure controls for spikes in credit spread that might affect the demand and supply of VC. To control for public markets' health, we include the national *stock market returns* over the previous month, and the number of companies listed in the national stock market (*listed companies*; we scale this number by 100 to provide meaningful coefficients (data from Thompson Reuters Refinitiv Eikon). The health of the public finances might also impact VC dynamics, and therefore we control for

government deficit (The Economist data). In addition to changing the policy rate, central banks can also alter the monetary supply. Therefore, we control for *money supply* change, measured by The Economist as the percentage change in M1 plus quasi-money at the end-period, over the previous year. We also control for the GDP percentage invested in R&D (*R&D investments*), as measured by the OECD. Gross domestic spending on R&D is defined as the total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, universities, and government laboratories in a country. The measure includes R&D funded from abroad but excludes domestic funds for R&D performed outside the domestic economy.

Further, to study the relationship between interest rates and the fundraising activity of VC funds, we consider the demand side of VC markets and add a variable that captures entrepreneurial ventures' demand for VC. To measure *VC demand*, we collect worldwide Google searches from January 2004 to December 2019 for the keywords "venture capital". The rationale is that a higher number of Google searches indicates demand for VC (Bellavitis et al., 2020). We average these daily searches per month per country. The measure can range from 0 to 100 and is relative to the top of the period of interest as well as to the US, which we use as a country of reference. We couldn't use more fine-grained keyword searches such as "raise venture capital" because there is not enough data for Google to calculate the index for all countries, and because the word "venture capital" is language agnostic, while "raise" is English. However, investigating the US market only, we find that there is a correlation of $r = 0.40$ between the US searches of "venture capital" and "raise venture capital". Another potential weakness of this measure is that, although "venture capital" is an international term, local terms such as "Risikokapital" in Germany, might be used locally. Therefore, we checked the correlation between these terms and "venture capital" and generally found high correlations. For example, in the case of "risikokapital" (German) it is 57%. However, the amount of data available for

these words is significantly smaller than for “venture capital”. Therefore, we think that our measure, with its own limitations, offers a reasonable overview of the level of VC demand in each location.

In addition, we control for *private sector credit* as a percentage of GDP (World Bank data), as an alternative source of finance. We also include corporate governance measures such as the *extent of disclosure index* and the *extent of liability index*. Both measures come from the World Bank database and can take values from 1 to 10. Along the same lines, we also include the *minimum capital* that an entrepreneur needs to have to start a new company, as a percentage of income per capita (World Bank data). Finally, we control for consumer price *inflation* percentage change from the previous year (The Economist data). It is important to note that not all data sources are available on a monthly basis. If data is only available quarterly, we use the quarterly value for each month in the respective quarter. Table 2 describes our variables.

- Please insert Table 2 about here -

5. Method and results

5.1 Estimation method

To investigate the effect of interest rates on VC fundraising, we run a panel regression model (*xtreg* in Stata) where the dependent variable is *VC fundraising* in the country where the VC firms are headquartered, proxied by the next twelve months’ amount of VC US dollars fund-raised. This empirical strategy is also useful to attenuate endogeneity issues because negative rates are set by central banks concerned about deteriorating economic conditions or lack of inflationary pressure. We log transform the dependent variable to account for non-linearity. We include country fixed effects in all models to control for unobserved heterogeneity at the country level.

5.2 Main results

Table 3 presents summary statistics and correlations. On average, USD 148M was raised capital in each 12 months-period and country. We find that negative rates appeared in 5% of the country-month, and they lasted a maximum of 67 months. GDP growth averaged approximately 2.18% per year, on average. In terms of correlations, we find some interesting patterns. For example, the level of GDP and the number of listed companies are positively correlated with VC firms' fundraising activity. This suggests that larger countries with larger stock markets are associated with more VC. We also find that monetary supply, another form of central bank policy, is strongly correlated with VC fundraising. In addition, self-employment, unemployment, and VC demand are correlated with VC fundraising, suggesting that demand for VC is an important factor in fundraising activity.

- Please insert Table 3 about here -

Before analyzing our main results, Table 4 shows the yearly progression of our main variables interest rates, VC fundraising, and VC demand over our sample period. In Table 5, we also compare fundraising levels when interest rates are below or above 4% via univariate analyses. When it is below 4%, VC fundraising is equal to USD 164M, while when interest rates rise above 4%, it is USD 83M ($p = 0.000$). If we compare means when interest rates are below or above 2%, our results show USD 162M and USD 119M respectively ($p = 0.001$). Comparing VC fundraising when interest rates are negative or positive, shows that, at negative rates, fundraising is equal to USD 70M, while at positive rates fundraising is equal to \$152M ($p = 0.000$). In sum, while we find that higher interest rates lead to lower fundraising, we also find that negative rates are associated with lower fundraising. However, considering the many

factors are associated with interest rates (e.g., GDP growth, unemployment, asset prices, investments), it is important to run multivariate regressions.

- Please insert Tables 4 and 5 about here -

Table 6 shows the results of our regression analysis regarding the impact of interest rates on *VC fundraising*. Model 1 includes the control variables. We find that higher self-employment and VC demand lead to higher fundraising activity. This implies that VCs are attentive to potential investment opportunities when fundraising. We also find that the number of listed companies, a measure of stock market size, leads to higher fundraising. Surprisingly, we find that R&D spending leads to lower VC fundraising. One explanation is that R&D takes a long time to lead to profits so our window of 12 months might not capture this effect. Another potential factor could be reverse causality. When there are limited investments in R&D, VCs can invest more and reap a larger amount of profits.

Model 2 includes the independent variable *interest rates*. In line with H1, we find that higher interest rates lead to more VC fundraising activities ($p = 0.019$). To evaluate the economic significance of these changes, we calculate marginal effects. We find that when interest rates are at 0%, VC fundraising is USD 145M, while at the average interest rate of 2.27% VC fundraising amounts to USD 164M (i.e., a 12% increase), and when interest rates are one standard deviation above the mean (i.e., 5.56%), VC fundraising is USD 197M, 20% higher compared to average interest rates. This supports H1 and shows a strong economic impact. Model 3 includes the independent variable *negative rates*. In line with our expectations, we find that negative rates lead to more VC funds fundraising ($p = 0.000$). Our marginal effects show that negative interest rates increase fundraising by 102% to USD 324M. This is a very strong effect, supporting H2.

Model 4 includes four dummy variables that allow us to see the effect of different levels of interest rates. This equates to a discontinuity model. The base level of interest rates is 0-2%, so the various coefficients compare to that level. We find that negative interest rates lead to significantly more VC fundraising compared to 0-2% (expected fundraising of USD 282M). Similarly, higher rates (2-4% and >4%) also lead to more VC fundraising (approximately USD 185M). This model further supports H1. Figure 2 depicts the effect of the various levels of interest rates on VC fundraising.

- Please insert Table 6 and Figure 2 about here -

In Table 7, to test the fading effect of *time from negative rates*, we include both the linear (Model 2) and quadratic terms (Model 3) of *time from negative rates*, as in Bellavitis et al. (2020). We find that the linear term is positive and significant ($p = 0.000$), and the interaction is negative and significant ($p = 0.000$). This lends support to our third hypothesis.

- Please insert Table 7 about here -

Considering that the interpretation of the curvilinear relationships is challenging, we follow Hoetker's (2007) recommendation of reporting marginal effects at meaningful values of our key independent variable. Figure 3 illustrates the marginal effects of *time from negative rates* on *VC fundraising*. We find that the negative effect fades over time. We find that the effect of negative rates is increasingly positive for up to 20 months, after which it starts to have a negative impact. In the first month with negative interest rates, VC fundraising is equal to USD 159M. VC fundraising increases up to 20 months, where it reaches USD 660M, and then

declines at 24 months to USD 597M. This suggests that negative interest rates affect VC fundraising. However, the effect fades over time and can eventually become counterproductive if kept in place for too long. This further supports H3.

- Please insert Figure 3 about here -

5.4 Additional analyses

The demand for VC is determined by entrepreneurial ventures that seek to raise funds. In general, entrepreneurial ventures can raise capital in the form of debt (e.g., bank loans) or equity (e.g., VC injection). Capital structure theory asserts that entrepreneurial ventures generally prefer debt financing over equity financing (e.g., Myers, 1984; Myers and Majluf, 1984). This is because the adverse selection risk premium demanded by equity investors is higher than the risk premium demanded by debt investors, making debt financing comparably cheaper for entrepreneurial ventures. Also, taking on equity investments implies the partial loss of control of the venture. Both arguments explain why entrepreneurial ventures typically view equity financing as a last resort (e.g., Myers, 1984; Frank and Goyal, 2003).

Entrepreneurial ventures' demand for early-stage finance depends on a variety of factors, including interest rates. Since interest rates determine the costs of debt financing (e.g., Cumming and MacIntosh, 2006; Gompers and Lerner, 1999a; Mason and Harrison, 2002), when interest rates are high, debt financing is more costly because banks will charge higher interest rates from entrepreneurs. In turn, VC is comparably cheaper and becomes a more attractive financing alternative. In contrast, low interest rates are associated with lower demand for VC because debt financing becomes cheaper and is thus more attractive to entrepreneurial ventures (Gompers and Lerner, 1999a; Romain and van Pottelsberghe, 2004). In sum, the demand for VC by entrepreneurial ventures will thus increase when interest rates are higher.

To investigate the effect of interest rates on VC demand, we run a longitudinal linear regression (*xtreg* in Stata). Our dependent variable is *VC demand* over the following 12 months. This variable is continuous and normally distributed and therefore a longitudinal regression is appropriate. Table 8 shows the results of our regression analysis regarding *VC demand*. Model 1 includes the control variables reported in our main analyses and our dependent variables. In model 2 we add the variable *interest rates*. We find that higher interest rates are associated with a higher demand for VC ($p = 0.000$). This suggests that entrepreneurs consider alternative sources of finance, such as debt, when interest rates are lower, and prefer VC when interest rates increase. Model 4 includes the variable *negative rates*. Negative rates are associated with lower demand for VC, further reinforcing the previous findings. In model 5 we include the interest rates dummy variables. We find that the higher the interest rates, the higher the VC demand. Finally, Model 6 adds the base and squared *time from negative rates*. We find that the base coefficient is negative and significant, while the squared coefficient is positive and significant. This suggests that, in the short term, negative rates lead to lower VC demand, but, in the medium term, this effect tends to fade away, but does not invert. Figures 4 and 5 depict these relationships.

- Please insert Table 8 and Figures 4 and 5 about here -

5.5 Robustness tests

To ensure the robustness of our results, we run several alternative tests. First, our main analyses use a forward-looking VC fundraising specification over 12 months. We re-run our analyses using a one and six-months forward window, using a one-month fundraising activity (rather than 12 months). Our results remain robust. We further test the robustness of our results using

the number of VC funds fundraising over the following 12 months, and the results do not change, although we find an increase in the number of funds at very high interest rates.

Second, the United States Federal Reserve Bank (FED) is considered the most important central bank in the world. To ensure that our results are not influenced by any particular country or monetary policy, we re-run our analyses with the exclusion of the United States. The results hold.

Third, we test the sensitivity of our results to alternative thresholds of negative interest rates using -0.05% and -0.1%. Again, the results are consistent and significant ($p = 0.000$ and $p = 0.026$).

Fourth, our models use four dummy variables up to interest rates higher than 4%. It could be argued that, historically, 4% is a low upper bound. Hence, we re-run our models with the addition of another dummy variable to take into consideration even higher levels of interest rates (i.e., above 6%). In addition, the four dummy variables' thresholds could be perceived as subjective. In another test, we use 12 dummy variables incorporating a 1% range each from negative to higher than 10%. The results are consistent and show that negative as well as higher interest rates lead to more fundraising by VC firms.

6. Conclusion

6.1 Summary of the main findings

This study contributes to the limited theoretical and empirical understanding of whether and how interest rates play a role in early-stage finance markets. Our starting point is that the fundraising activity of VC firms is positively associated with interest rates. Vice versa, the fundraising activity of VC firms should decrease with lower interest rates. However, we posit that these expectations derived from “standard times” might change when interest rates become

negative. Conceptually, we combine insights from principal-agent theory applied to the relationship between general and limited partners of VC firms and from behavioral finance. Based on these insights, we posit that the transition to negative rates comes with transiently increased fundraising activity by VC firms. Using data from 31 countries from 2004 to 2019, we find evidence consistent with our hypotheses.

6.2 Discussion and contributions

Our study contributes to research in entrepreneurial finance by taking the agency problem between VC firms (general partners) and their investors (limited partners) into account (e.g., Balboa and Martí, 2007). In contrast to research on the agency problem between entrepreneurs and VCs (e.g., Baum and Silverman, 2004; Colombo et al., 2019; Rosenbusch et al., 2013), this agency problem has received scant attention in prior research. We leverage this agency problem and show that the agency conflict leads to a differential impact of negative interest rates on the supply of capital in the VC market. This finding highlights the need to more carefully distinguish general and limited partners involved in VC funds, which is a subject of considerable practical relevance (e.g., Meads et al., 2016). These findings also call for more work to gain a better understanding of how the nature of delegation in VC firms affects their investment and financing decisions.

Second, we connect the macro-level dimension of interest rates to the (micro-)functioning of VC firms. That is, we apply a micro-foundational lens to VC markets that enables a more advanced understanding of the industry's dynamics. By considering the dynamics between general and limited partners in connection with interest rates, our study provides a comprehensive understanding of the interplay between interest rates and the VC market. So far, only a few studies (e.g., Gompers and Lerner, 1999a; Romain and van Pottelsberghe, 2004) have examined the impact of interest rates on VC investments. Our study contributes to this line of

research by adding an empirical model tested on a multi-country sample that explicitly considers the effect of negative interest rates. Both Gompers and Lerner (1999a) and Romain and van Pottelsberghe (2004) use data from before 2000, a period in which negative rates were nonexistent. In general, our findings suggest that interest rates are important environmental framework conditions that future research on the industrial dynamics of the VC sector should consider.

Third, our focus on negative interest rates provides novel and current insights into the relationship between interest rates and VC market dynamics. Specifically, we show that negative interest rates can have unintended consequences that affect different parties (i.e., general and limited partners) differently and in contrast to expectations based on supply arguments. We identify three channels to explain this finding. These pertain (1) to a legal motivation (i.e., legislative hurdles and litigation risks), (2) a liquidity motivation (i.e., substitution effect relative to other asset classes), and (3) behavioral biases (i.e., mental accounting, conservatism, disposition effect, or prospect theory). An understanding of how negative interest rates shape the VC market is critical for future research because the prevalence of negative interest rates will likely increase in the future. In this sense, our findings are also connected to research on negative interest rates in the fields of finance and monetary economics (e.g., Dell’Ariccia et al., 2018; Heider et al., 2019; Molyneux et al., 2019).

6.3 Practical implications

Our study has important implications for the actors of VC markets. Most existing studies on VC markets take the perspective of entrepreneurship (or corporate finance), by focusing for instance on the treatment effect of VC investments on the performance of portfolio companies (e.g. Bertoni et al., 2011; Vanacker et al., 2014), or the investors’ perspective, for instance by quantifying the return on VC investments (e.g., Cochrane, 2005; Manigart et al., 2002). The

evidence that we present calls for nuanced attention to the activity of limited partners. When interest rates become negative the fundraising activity of VC firms increases. We explain this by using principal-agent and behavioral finance arguments that should, in particular, inform the general partners of VC firms, which serve as residual claimants of VC deals. Investors' search for yield in a negative interest rate environment should factor in the agency opportunities of general partners.

Negative interest rates are an ill-explored topic in entrepreneurial finance. This reflects the conceptualization of policy intervention. Policymakers have often been concerned with the consolidation of the entrepreneurial finance ecosystem, especially in VC markets. Supply-side policies, seeking to increase the supply of financing to entrepreneurial ventures, include the set up of governmental VC funds aimed at fostering the development of a private VC industry and alleviating the equity capital gap of young innovative firms (Colombo et al., 2016). Our evidence suggests that a particular concern for policymakers may be the functioning of VC funds (and relatedly, VC availability for entrepreneurship) in times of extreme monetary policies.

6.4 Limitations and avenues for future research

This study has some limitations that are worth considering and that may open up important avenues for future research. First, our measurements of the supply dynamics in the VC industry are relatively crude in the sense that it is unclear how they translate to actual investments that lead to entrepreneurship and economic growth. While we do measure VC firms' fundraising activity, it is unclear whether and how the funds collected are invested into portfolio ventures. For example, it could be that VC firms simply fundraise in terms of negative interest rates to grab money from institutional investors but only intend to pass on these investments to portfolio ventures much later. Future research could assess the multifaceted phenomenon with more immediate measures, such as the number of newly established VC-financed ventures.

Second, negative interest rates are an instrument of monetary policy that has been introduced recently. A major catalyst for the implementation of negative interest rates was the economic downturn of the global financial crisis (e.g., ECB, 2020). As of 2021, the next world economy suffers from the next global crisis due to COVID-19. While the scale of the crisis is difficult to foresee as of 2022, the economic consequences of the COVID-19 crisis will likely surpass those of prior crises like the tech bubble or the global financial crisis (e.g., International Monetary Fund, 2020). Economies worldwide might intensify their usage of negative interest rates to combat the COVID-19 crisis and stimulate economic growth. This opens many avenues for future research. In particular, future research in entrepreneurial finance can assess whether the period of negative interest rates after the global financial crisis is different from the period after the COVID-19 crisis with regard to its impact on the VC market. Initial studies document a pronounced decline in VC investments in response to the spread of COVID-19 (e.g., Bellavitis et al., 2022; Howell et al., 2020) and it will be interesting to see whether negative policy rates prove an effective mechanism to stimulate the industry again.

Third, we focus on the relationship between equity investments in portfolio ventures and interest rates. However, some companies might combine equity financing with other financing mechanisms, such as debt funding. While portfolio ventures are typically solely equity-financed in the US, prior research suggests that the combination of equity and debt financing is more common in other countries, such as Europe or Canada (e.g., Cumming, 2005; Cumming and Johan, 2008). Hence, the demand for VC by portfolio ventures might partially depend on the financing instruments that are typically used in a country. Thus, future research could extend our preliminary findings by exploring the combination of financing instruments typically used in a country in more detail.

Fourth, there could be some confounding geographical effects. It could happen that, for example, a VC fund located in South Africa fundraises from limited partners located in the

United Kingdom, where interest rates are much lower. Unfortunately, our data do not allow us to track the origin of the limited partner, but only the fundraising activity of the VC firms located in a given country. Researchers with access to more fine-grained data could investigate whether the effect of interest rates varies depending on the location of the limited or general partners.

Finally, because of their novelty, the long-term consequences of negative interest are unclear. Our findings suggest that the impact of negative interest fades over time but this effect is derived from a relatively small number of observations. As time goes on, more data become available that will allow a much more substantiated analysis of the effect of negative interest rates on the VC market.

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Tables

Table 1. Countries with interest rates at 0% or negative.

Country	Interest rates at 0%	Negative interest rates
Denmark	-	Jul 2012 - Mar 2014 and Sep 2014 - end of data
Euro area	March 2016 - end of data	-
Japan	Sep 2006 (beginning of Japan data) - Jun 2006	Sep 2016 - end of data
Sweden	Oct 2014 - Jan 2015	Feb 2015 - Dec 2019
Switzerland	-	Dec 2014 - end of data

Note: Euro area include the following countries: Austria, Belgium, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain. The study covers the period between January 2004 and December 2019.

Table 2. Variables, definitions, and data sources.

Variable	Definition	Source
<i>Dependent variables</i>		
VC fundraising	Fundraising activity of VC firms in a given country over the following 12 months (in million USD, log transformed).	Refinitiv Eikon
<i>Independent variables</i>		
Interest rates	Nominal central bank interest rates.	BIS
Negative rates	Dummy variable equal to 1 when central bank interest rates are negative in the respective month and country, and 0 otherwise.	Authors' calculation
Four dummies interests	Categorical measure associated with interest rates. Value of 1 if interest rates are <0%, of 2 if 0-2%, of 3 if 2-4% and 4 if interest rates are >4%.	Authors' calculation
Time from negative rates	Number of months it took interest rates in a given country to turn from negative to positive again (if ever).	Authors' calculation
<i>Control variables</i>		
GDP growth	Annual percentage growth rate of GDP at market prices based on constant local currency.	World Bank
GDP	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. billion of dollars. Dollar figures for GDP are converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used.	World Bank
Self-employment	Self-employed workers as a percentage of total employment. Self-employed are those workers who, working on their own account or with one or a few partners or in cooperative, hold the type of jobs defined as a "self-employment jobs."	World Bank
Unemployment	Unemployment refers to the share of the labor force that is without work but available for and seeking employment. Definitions of labor force and unemployment differ by country.	World Bank

Taxes	Taxes on income, profits, and capital gains are levied on the actual or presumptive net income of individuals, on the profits of corporations and enterprises, and on capital gains, whether realized or not, on land, securities, and other assets. Intragovernmental payments are eliminated in consolidation.	World Bank
Credit spread	Credit spread between the central bank rates and the corporate lending interest rate	The Economist
Stock market returns	Stock market returns over the previous month, in percentage.	Refinitiv Eikon
Listed companies	Number of companies listed in the national stock market. Divided by 100.	Refinitiv Eikon
Money supply	Percentage change in M1 plus quasi-money at end-period, over previous year.	The Economist
Government deficit	General government receipts minus general government outlays, as a percentage of GDP.	The Economist
R&D investments	GDP percentage invested in R&D. Gross domestic spending on R&D is defined as the total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, universities, and government laboratories in a country. It includes R&D funded from abroad but excludes domestic funds for R&D performed outside the domestic economy.	OECD
VC demand	Worldwide Google searches for the keyword “venture capital”.	Google
Private sector credit	Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, that establish a claim for repayment. For some countries these claims include credit to public enterprises.	World Bank
Extent of disclosure index	Disclosure index measures the extent to which investors are protected through disclosure of ownership and financial information. The index ranges from 0 to 10, with higher values indicating more disclosure.	World Bank
Extent of liability index	Disclosure index measures the extent to which investors are protected through disclosure of ownership and financial information. The index ranges from 0 to 10, with higher values indicating more disclosure.	World Bank
Minimum capital	Paid-in minimum capital requirement for a small- to medium-size limited liability company to start up and formally operate in each economy’s largest business city.	World Bank
Inflation	Percentage change in consumer price index in local currency (period average), over previous year.	The Economist
Stock market volatility	Stock market volatility is the average of the 360-day volatility of the national stock market index.	Bloomberg

Table 3. Descriptive statistics and correlations.

Variable	Obs.	Mean	S. D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1 VC fundraising	4391	5.00	2.58	0.00	11.22																							
2 Interest rates	4331	2.27	3.29	-0.75	83.26	-0.15*																						
3 Negative rates	4331	0.05	0.23	0.00	1.00	-0.07*	-0.20*																					
4 Four dummies interests	4331	2.48	0.85	1.00	4.00	-0.06*	0.74*	-0.43*																				
5 Time from negative rates	4398	1.55	7.60	0.00	67.00	-0.05*	-0.17*	0.84*	-0.36*																			
6 GDP growth	4224	2.18	2.61	-7.79	25.16	-0.06*	0.13*	-0.03	0.21*	-0.03																		
7 GDP	4224	19.69	34.23	1.03	213.74	0.55*	-0.11*	-0.04*	-0.08*	-0.05*	-0.09*																	
8 Self-employment	4224	15.65	6.84	6.22	53.54	-0.34*	0.18*	-0.17*	0.22*	-0.14*	0.11*	-0.31*																
9 Unemployment	4398	7.39	4.65	1.90	30.10	-0.17*	0.10*	-0.17*	0.13*	-0.15*	-0.07*	-0.12*	0.18*															
10 Taxes	3965	32.78	14.66	1.37	66.28	0.35*	-0.11*	0.00	0.02	-0.02	-0.00	0.31*	-0.06*	-0.04*														
11 Credit spread	4331	2.61	1.24	-5.21	8.42	-0.17*	-0.16*	0.05*	-0.10*	0.03*	-0.04*	-0.01	0.22*	0.21*	0.16*													
12 Stock market returns	4388	0.00	0.06	-0.55	0.35	0.01	-0.08*	0.01	-0.04*	0.01	0.02	-0.00	-0.01	0.00	0.01	0.02												
13 Listed companies	3809	14.04	16.29	0.00	69.88	0.58*	-0.18*	0.01	-0.12*	-0.02	-0.10*	0.70*	-0.22*	-0.04*	0.55*	-0.03*	-0.01											
14 Money supply	4398	7.10	6.38	-5.08	40.58	-0.07*	0.50*	-0.10*	0.46*	-0.09*	0.28*	-0.09*	0.09*	-0.05*	-0.14*	-0.17*	0.03	-0.12*										
15 Government deficit	4398	-1.95	5.19	-41.17	18.62	-0.04*	0.13*	0.07*	0.15*	0.06*	0.22*	-0.17*	-0.14*	-0.34*	-0.05*	-0.16*	0.01	-0.20*	0.20*									
16 R&D investments	4398	2.12	0.99	0.18	4.94	0.30*	-0.37*	0.27*	-0.38*	0.23*	-0.05*	0.18*	-0.38*	-0.40*	0.03*	-0.13*	0.01	0.17*	-0.20*	0.04*								
17 VC demand	4398	0.59	0.38	0.00	4.00	0.31*	0.13*	-0.12*	0.22*	-0.09*	0.16*	0.17*	-0.14*	0.04*	0.17*	0.10*	0.05*	0.16*	0.14*	0.00	0.22*							
18 Private sector credit	3950	112.96	44.13	9.68	206.67	0.42*	-0.31*	0.24*	-0.25*	0.18*	-0.27*	0.41*	-0.26*	-0.08*	0.53*	0.13*	-0.01	0.63*	-0.28*	-0.08*	0.30*	0.15*						
19 Extent of disclosure index	3819	6.75	2.21	0.00	10.00	0.08*	0.09*	-0.17*	0.14*	-0.19*	0.07*	0.10*	0.06*	0.16*	0.41*	0.24*	-0.01	0.25*	0.02	-0.15*	-0.18*	0.12*	0.02					
20 Extent of liability index	3819	5.40	2.10	0.00	9.00	0.34*	-0.21*	-0.05*	-0.15*	-0.05*	0.04*	0.29*	-0.17*	0.07*	0.46*	0.21*	0.02	0.39*	-0.16*	-0.14*	0.23*	0.44*	0.33*	0.27*				
21 Minimum capital	4398	94.77	11.89	13.07	100.00	0.10*	-0.08*	0.03*	-0.15*	0.03	-0.11*	0.13*	-0.32*	0.04*	0.23*	0.05*	-0.03	0.15*	-0.07*	-0.07*	0.01	-0.09*	0.10*	0.23*	0.22*			
22 Inflation	4398	2.13	2.93	-6.55	54.48	-0.13*	0.82*	-0.13*	0.50*	-0.10*	0.05*	-0.05*	0.11*	0.06*	-0.18*	-0.14*	-0.10*	-0.12*	0.42*	0.09*	-0.33*	0.04*	-0.28*	0.07*	-0.20*	-0.02		
23 Stock market volatility	4398	19.42	7.96	7.46	64.18	-0.10*	0.17*	-0.08*	0.07*	-0.09*	-0.33*	-0.05*	-0.00	0.17*	-0.32*	-0.05*	-0.02	-0.08*	0.14	-0.16*	-0.10*	0.03	-0.10*	-0.07*	-0.26*	-0.10*	0.18*	

Absolute correlations with * significant at $p < 0.005$.

Table 4. Yearly changes of interest rates, VC raised and VC demand for the average country

Year	Interest rates	VC raised (\$M)	VC demand
2004	3.86	68.5	0.95
2005	3.95	149.6	0.90
2006	4.43	189.1	0.89
2007	5.20	282.3	0.83
2008	5.23	331.3	0.84
2009	2.23	212.5	0.81
2010	2.44	111.4	0.78
2011	2.80	91.1	0.72
2012	2.53	101.7	0.65
2013	2.16	100.1	0.61
2014	2.29	82.2	0.62
2015	2.37	87.6	0.58
2016	1.96	150.0	0.56
2017	1.59	158.4	0.58
2018	1.95	113.1	0.56
2019	2.13	109.1	0.55

Table 5. Univariate comparison of funding raised for different levels of interest rates (mean values).

Funding raised	Interest rates $\leq 4\%$ USD 164M	Interest rates $> 4\%$ USD 83M	p-value 0.000
Funding raised	Interest rates $\leq 2\%$ USD 162M	Interest rates $> 2\%$ USD 119M	p-value 0.000
Funding raised	Interest rates $< 0\%$ USD 70M	Interest rates $\geq 0\%$ USD 152M	p-value 0.000

Table 6. The impact of interest rates on VC fundraising

	Model 1	Model 2	Model 3	Model 4
GDP growth	-0.011 [0.013]	-0.008 [0.013]	-0.012 [0.013]	-0.015 [0.013]
GDP	0.007 [0.004]	0.007 [0.004]	0.008† [0.004]	0.008† [0.004]
Self-employment	0.211*** [0.033]	0.196*** [0.034]	0.222*** [0.034]	0.225*** [0.034]
Unemployment	-0.062*** [0.014]	-0.065*** [0.014]	-0.061*** [0.014]	-0.058*** [0.015]
Taxes	0.032* [0.013]	0.025† [0.014]	0.021 [0.014]	0.024† [0.013]
Credit spread	0.022 [0.038]	0.064 [0.042]	0.046 [0.042]	0.04 [0.040]
Stock market returns	-0.117 [0.382]	-0.072 [0.382]	-0.087 [0.381]	-0.099 [0.381]
Listed companies	0.020** [0.008]	0.020** [0.008]	0.019* [0.008]	0.020** [0.008]
Money supply	0.012* [0.006]	0.011† [0.006]	0.012* [0.006]	0.010† [0.006]
Government deficit	0.021** [0.008]	0.019* [0.008]	0.018* [0.008]	0.017* [0.008]
R&D investments	-0.424** [0.164]	-0.335* [0.169]	-0.406* [0.169]	-0.336† [0.173]
VC demand	0.408** [0.125]	0.387** [0.125]	0.437*** [0.126]	0.435*** [0.126]
Private sector credit	-0.002 [0.002]	-0.003 [0.002]	-0.004† [0.002]	-0.004† [0.002]
Extent of disclosure index	-0.306*** [0.049]	-0.296*** [0.050]	-0.339*** [0.050]	-0.323*** [0.051]
Extent of liability index	-0.051 [0.116]	-0.084 [0.117]	-0.033 [0.117]	-0.002 [0.117]
Minimum capital	-0.006 [0.004]	-0.007† [0.004]	-0.004 [0.004]	-0.006 [0.004]
Inflation	0.028† [0.016]	0.003 [0.019]	-0.002 [0.019]	0.016 [0.017]
Stock market volatility	0.006 [0.004]	0.006 [0.004]	0.006 [0.004]	0.008† [0.004]
Interest rates		0.056* [0.024]	0.063** [0.024]	
Negative rates			0.704*** [0.171]	
<0% rates				0.655*** [0.171]
2-4% rates				0.270** [0.085]
>4% rates				0.217† [0.113]
Constant	4.390*** [1.236]	4.737*** [1.244]	4.465*** [1.242]	4.034** [1.237]
Observations	2,762	2,762	2,762	2,762
R-squared	0.128	0.129	0.135	0.136
Number of Countries	31	31	31	31

All models fit a panel linear regression (xtreg). We include country fixed effects to account for unobserved heterogeneity. The dependent is the amount of VC fundraised over the following 12 months. Standard errors are reported in parenthesis. *** p < 0.001, ** p < 0.01, * p < 0.05 and † p < 0.10 (two tailed tests).

Table 7. The impact of time from negative interest rates on VC fundraising

	Model 1	Model 2	Model 3
GDP growth	-0.011 [0.013]	-0.013 [0.013]	-0.017 [0.013]
GDP	0.007 [0.004]	0.008† [0.004]	0.009* [0.004]
Self-employment	0.211*** [0.033]	0.233*** [0.034]	0.251*** [0.034]
Unemployment	-0.062*** [0.014]	-0.057*** [0.014]	-0.056*** [0.014]
Taxes	0.032* [0.013]	0.029* [0.013]	0.027* [0.013]
Credit spread	0.022 [0.038]	0.003 [0.038]	-0.010 [0.038]
Stock market returns	-0.117 [0.382]	-0.134 [0.381]	-0.155 [0.379]
Listed companies	0.020** [0.008]	0.019* [0.008]	0.020** [0.008]
Money supply	0.012* [0.006]	0.012* [0.006]	0.013* [0.006]
Government deficit	0.021** [0.008]	0.021** [0.007]	0.019* [0.007]
R&D investments	-0.424** [0.164]	-0.489** [0.165]	-0.559*** [0.164]
VC demand	0.408** [0.125]	0.453*** [0.125]	0.482*** [0.125]
Private sector credit	-0.002 [0.002]	-0.003 [0.002]	-0.003 [0.002]
Extent of disclosure index	-0.306*** [0.049]	-0.354*** [0.050]	-0.359*** [0.050]
Extent of liability index	-0.051 [0.116]	-0.002 [0.116]	0.027 [0.116]
Minimum capital	-0.006 [0.004]	-0.004 [0.004]	-0.003 [0.004]
Inflation	0.028† [0.016]	0.024 [0.016]	0.025 [0.016]
Stock market volatility	0.006 [0.004]	0.007† [0.004]	0.006 [0.004]
Time from negative rates		0.035*** [0.008]	0.149*** [0.024]
Time from negative rates squared			-0.004*** [0.001]
Constant	4.390*** [1.236]	4.197*** [1.233]	3.934** [1.229]
Observations	2,762	2,762	2,762
R-squared	31	0.134	0.142
Number of Countries	0.128	31	31

All models fit a panel linear regression (xtreg). We include country fixed effects to account for unobserved heterogeneity. The dependent is the amount of VC fundraised over the following 12 months. Standard errors are reported in parenthesis. *** p < 0.001, ** p < 0.01, * p < 0.05 and † p < 0.10 (two tailed tests).

Table 8. The impact of negative rates and time from negative interest rates on VC demand

	Model 1	Model 2	Model 3	Model 4	Model 5
VC fundraising	0.007*** [0.002]	0.006** [0.002]	0.007*** [0.002]	0.007*** [0.002]	0.008*** [0.002]
GDP growth	0.007*** [0.001]	0.007*** [0.001]	0.008*** [0.001]	0.007*** [0.001]	0.007*** [0.001]
GDP	0.002*** [0.000]	0.002*** [0.000]	0.002*** [0.000]	0.002*** [0.000]	0.002*** [0.000]
Self-employment	0.023*** [0.003]	0.021*** [0.004]	0.016*** [0.004]	0.015*** [0.004]	0.017*** [0.004]
Unemployment	0.014*** [0.001]	0.014*** [0.001]	0.013*** [0.001]	0.013*** [0.001]	0.013*** [0.001]
Taxes	0.004** [0.001]	0.003† [0.001]	0.003* [0.001]	0.003* [0.001]	0.004** [0.001]
Credit spread	0.010* [0.004]	0.016*** [0.004]	0.019*** [0.004]	0.021*** [0.004]	0.014*** [0.004]
Stock market returns	0.044 [0.039]	0.05 [0.039]	0.052 [0.039]	0.059 [0.039]	0.048 [0.039]
Listed companies	0.000 [0.001]	0.000 [0.001]	0.000 [0.001]	0.000 [0.001]	0.000 [0.001]
Money supply	0.004*** [0.001]	0.004*** [0.001]	0.004*** [0.001]	0.004*** [0.001]	0.004*** [0.001]
Government deficit	0.002** [0.001]	0.002* [0.001]	0.002** [0.001]	0.002* [0.001]	0.002** [0.001]
R&D investments	-0.141*** [0.017]	-0.128*** [0.017]	-0.115*** [0.017]	-0.105*** [0.018]	-0.124*** [0.017]
Private sector credit	0.002*** [0.000]	0.002*** [0.000]	0.002*** [0.000]	0.002*** [0.000]	0.002*** [0.000]
Extent of disclosure index	-0.015** [0.005]	-0.014** [0.005]	-0.006 [0.005]	-0.004 [0.005]	-0.007 [0.005]
Extent of liability index	-0.102*** [0.012]	-0.106*** [0.012]	-0.114*** [0.012]	-0.113*** [0.012]	-0.111*** [0.012]
Minimum capital	-0.000 [0.000]	-0.000 [0.000]	-0.001 [0.000]	-0.001 [0.000]	-0.000 [0.000]
Inflation	0.019*** [0.002]	0.015*** [0.002]	0.016*** [0.002]	0.017*** [0.002]	0.019*** [0.002]
Stock market volatility	0.004*** [0.000]	0.004*** [0.000]	0.004*** [0.000]	0.004*** [0.000]	0.004*** [0.000]
Interest rates		0.008** [0.002]	0.006** [0.002]		
Negative rates			-0.124*** [0.018]		
<0% rates				-0.130*** [0.017]	
2-4% rates				0.034*** [0.009]	
>4% rates				0.051*** [0.012]	
Time from negative rates					-0.014*** [0.002]
Time from negative rates squared					0.000*** [0.000]
Constant	0.501*** [0.128]	0.550*** [0.129]	0.588*** [0.128]	0.565*** [0.127]	0.538*** [0.127]
Observations	2,762	2,762	2,762	2,762	2,762
R-squared	0.347	0.350	0.362	0.365	0.360
Number of Countries	31	31	31	31	31

All models fit a panel linear regression (xtreg). We include country fixed effects to account for unobserved heterogeneity. The dependent is VC demand over the following 12 months. Standard errors are reported in parenthesis. *** p < 0.001, ** p < 0.01, * p < 0.05 and † p < 0.10 (two tailed tests).

Figures

Figure 1. Relationship between interest rates and VC fundraised for countries with negative interest rates.

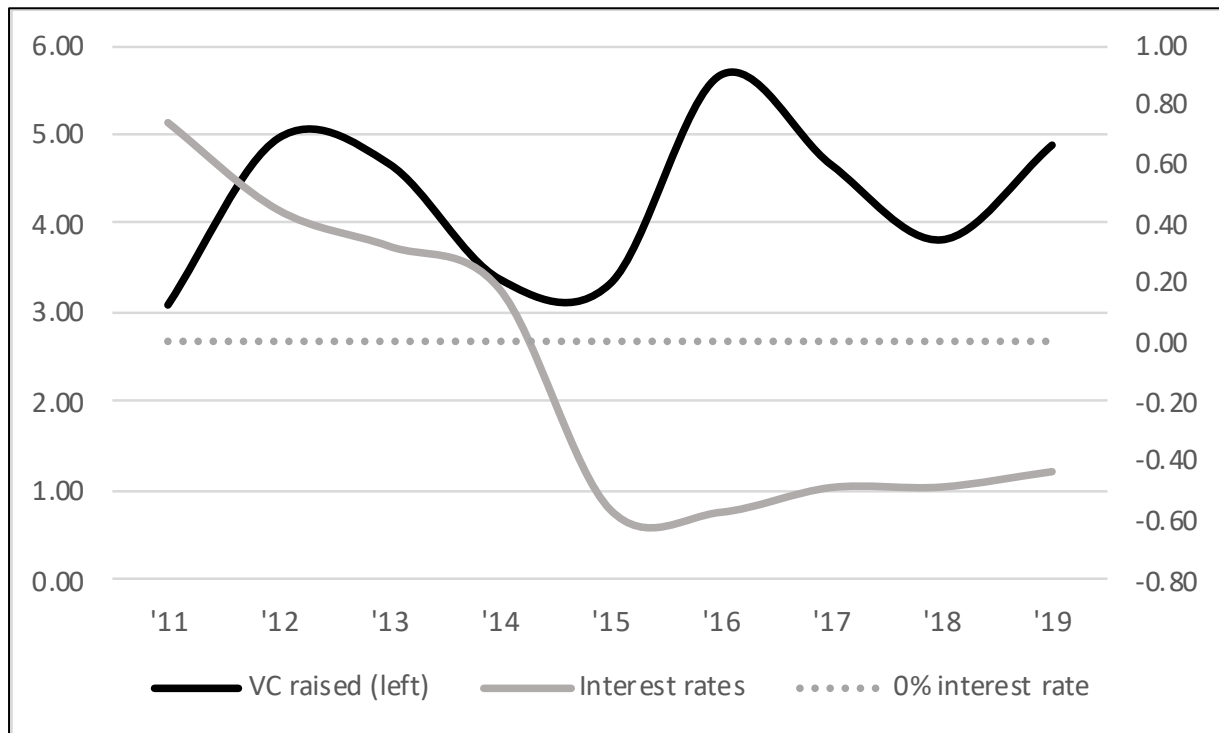


Figure 2. Marginal effects of interest rates on VC fundraising.

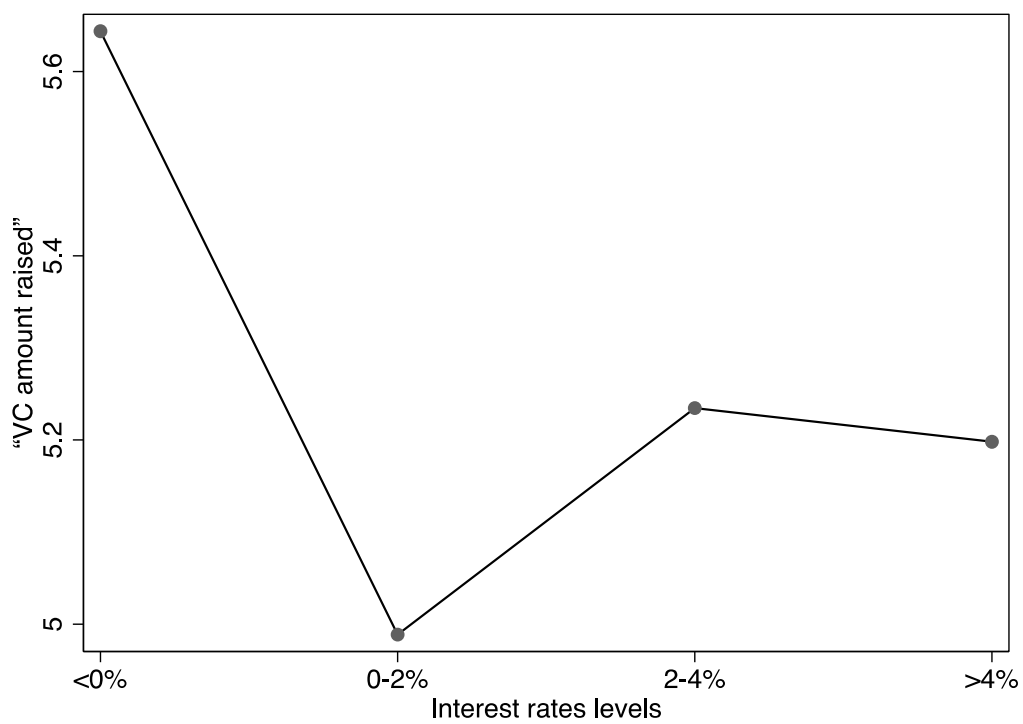


Figure 3. Marginal effects of time from negative rates on VC fundraising.

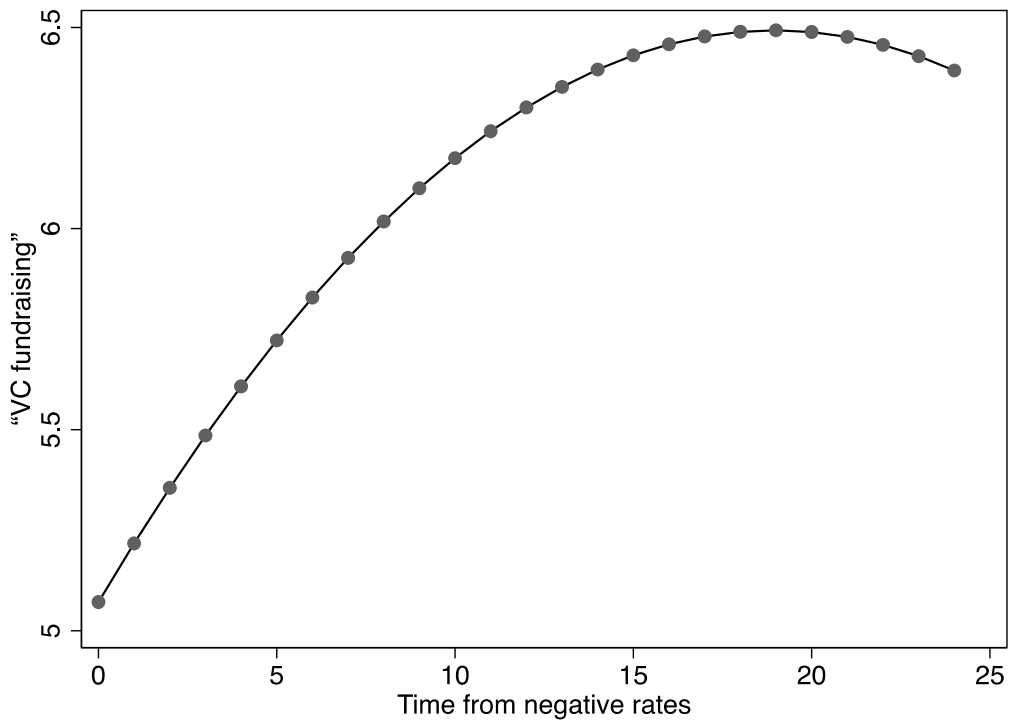


Figure 4. Marginal effects of interest rates on VC demand.

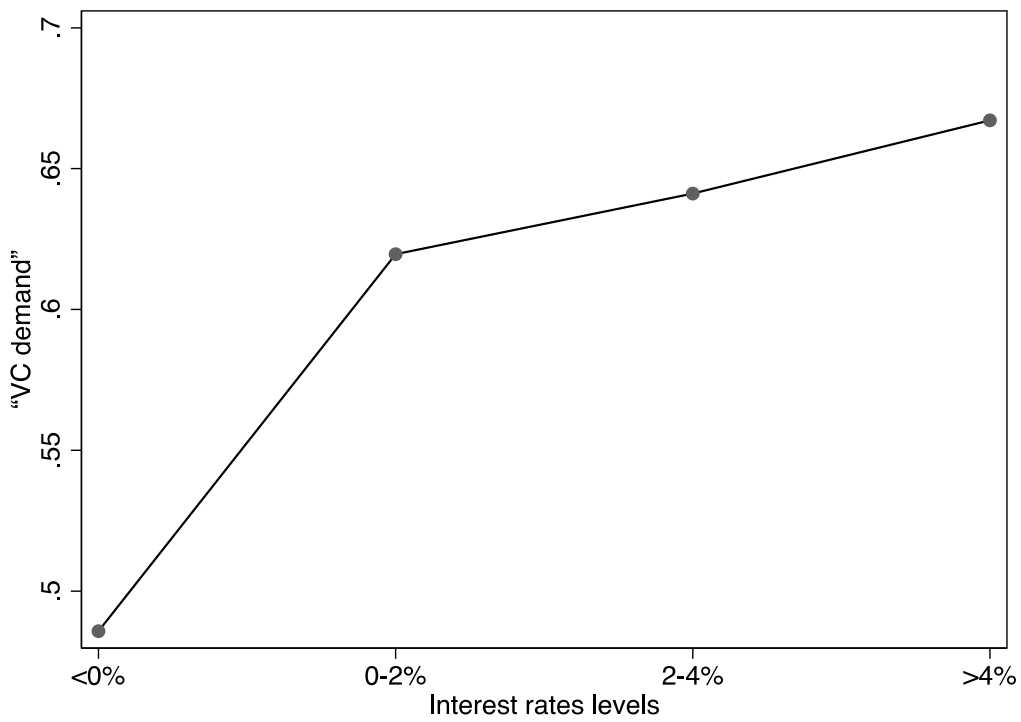


Figure 5. Marginal effects of time from negative rates on VC demand.

