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Industry-specific specialization in venture capitalists' internationalization decisions

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Abstract

This study considers the impact of venture capitalists' industry specialization on cross-border investment decisions. The article argues that specialized venture capitalists' liability of foreignness is lower in specific international markets as assessments of the market and the behaviour of market participants are facilitated through industry-specific learning effects. Specialization leads to lower risk in cross-border investments from a venture capitalist's point of view. With increasing deal-specificity, the support and value enhancement of a foreign portfolio company are ensured in international markets due to the investor's specialization. A multilevel investigation of 46,525 worldwide venture capital deals from 2001 to 2019 in 69 countries shows a positive relationship between venture capitalists' industry specialization and internationality. The results show that the likelihood of a cross-border deal increases with higher levels of industry specialization. Furthermore, this effect is moderated by determinants at the institutional and portfolio company levels, reflecting the degree of information asymmetry between the venture capital firm and the portfolio company.

Keywords Venture capital · Internationalization · Specialization · Industry experience · Learning

JEL Classification G11 · G24 · M13 · M16 · O34

1 Introduction

The investment behaviour of venture capitalists is an increasingly international phenomenon (Devigne et al. 2018). As venture capital firms generally invest in young companies operating in aspiring markets, these investments are characterized by

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high levels of asymmetric information and uncertainty (Stuart et al. 1999; Ueda 2004; Vanacker and Manigart 2010). Investors face institutional, geographical, cultural and legal distance from their own nations (Devigne et al. 2018). This remoteness results in higher information asymmetries, investment risk and costs for the investor if the target company is located abroad. Therefore, the investor must devote more resources to monitoring and managing the business abroad (Pruthi et al. 2003; Mäkelä and Maula 2008; Devigne et al. 2016). The sum of these additional costs that would not occur in a domestic deal is defined as the ‘liability of foreignness’ (Zaheer 1995).

Current literature on international venture capital offers several strategies to compensate for the liability of foreignness in cross-border deals. Studies often address cooperation with other investors through syndication or implementing close monitoring and supporting systems to track foreign portfolio companies’ activities abroad. Moreover, research has underlined the relevance of the accumulation and use of the investor’s own experience in international investments (Meuleman and Wright 2011; Li et al. 2014). Investment experience can be acquired in domestic markets as well as when investing abroad (Schertler and Tykvová 2012). According to Li et al. (2014), the intensity and outcomes of learning through prior investments, however, differ. Through investment experience gained in their home countries, investors can improve their understanding of the investment process from the initial screening of portfolio companies until the companies’ exits. Additionally, Guler and Guillen (2010) found evidence that venture capitalists with high social status in the domestic market can transfer it to the international market. Additionally, they are more likely to invest abroad with increased domestic experience.

International experience acquired through investments in various foreign countries mitigates unfamiliarity and enhances venture capitalists’ awareness, tolerance and sensitivity to unexpected behaviours and practices in local institutions and cultural environments (De Clercq and Dimov 2008), particularly if the investor already has prior experience in a country (Li et al. 2014). In addition to domestic and international experience, this paper investigates the role of investors’ experience within specific industries, which will be defined as the investors’ industry specialization. During an investment’s holding period, monitoring and adding value to a target company are some of the major goals of venture capital investors (Gupta and Sapienza 1992; Bertoni et al. 2011). Thus, one can assume that the positive development of a portfolio company is more likely when the investor is familiar with business models in the specific industry of investment, particularly for international investments. Regarding the importance of industry-specific rather than general experience, Gompers et al. (2008) found that industry-specific experience is especially critical to identifying good investment opportunities and adding value to companies. In that information asymmetry and the overall risk of foreign investments are considered to be higher for international rather than domestic investments (Devigne et al. 2018), an investor’s industry specialization may be particularly important in international investment decisions.

Therefore, this paper highlights a firm’s expertise within an industry as a crucial characteristic that may influence its internationalization decisions. A central role is assigned to tacit knowledge, which organizations continuously acquire

through their activities (Itami and Roehl 1991; Hart 1995). By investing several times in one industry, investors gain a precise understanding of industry-specific products and business models. This comprehension is essential for offering value-added services to a portfolio company and increasing the portfolio company's value. Therefore, an investor's industry-specific expertise may play a central role in the successful management of foreign investments and is likely to influence investment decisions.

In addition to domestic and international knowledge, industry-specific knowledge—a firm's specialization in an industry—may be a relevant competence for guiding portfolio companies and may attenuate a firm's liability of foreignness. An investor's industry specialization will likely determine how effectively the investor can advise his target company, as business processes within an industry are similar and recurring. Thus, with each additional investment in and support for a portfolio company within an industry, knowledge about how to support the portfolio company most efficiently increases, and successful practices are established. Furthermore, with increasing levels of industry specialization, the number of suitable investment opportunities in the domestic market matching an investor's specialization may decrease. Specialized investors may, therefore, increasingly be forced to search abroad for suitable investment opportunities. Even though firms' industry specializations may affect venture capitalists' internationalization decisions due to different competencies and knowledge resulting from specialization and fewer opportunities in the domestic market, this is disregarded in the literature on international venture capital. The additional risks associated with an investment abroad may vary depending on a deal's specificity. Consequently, there is a research gap regarding the fit between a target company's business and a venture capitalist's industry specialization and how this fit affects the likelihood of investing abroad. In an increasingly internationalized venture capital market, investigating this omission in the literature is important for understanding firms' investment decisions based on their learning effects from previous deals.

Contrasting with the prevailing view that diversification lowers the risk of a portfolio, Bygrave (1987); Bygrave (1988) offered the first theoretical views on specialization in venture capitalists' portfolios. In a survey of 98 venture capital investors, Norton and Tenenbaum (1993) maintained that to reduce investment risk, venture capitalists should specialize and enhance their technical and product expertise. Most venture capitalists have invested according to a specialization strategy rather than diversifying their investments among various industries. Gupta and Sapienza (1992) also demonstrated that venture capital firms prefer less industry diversity when investing in early-stage companies. Based on a US sample of 169 venture capital firms from California, Massachusetts and Texas, the authors found that small venture capital firms are less likely to invest in different industries. Regarding the link between industry specialization and the scope of an investor's investments, Cumming and Dai (2010) studied a sample of US investments and found a negative relationship between industry specialization in tech industries and the geographic scope of investments. However, their results do not reveal any findings about other industries, as they only account for specialization in tech industries, and the findings are also not generalizable to the international market.

Given the assumption that industry specialization is relevant for successful investments, especially under the difficult conditions of cross-border investment, the role of industry specialization should be addressed more specifically. This paper provides more nuanced findings about the extent to which industry specialization affects firms' decisions to invest abroad, incorporating their level of specialization over time.

Existing research highlights how institutional target market characteristics play a major role in attracting international venture capital. Thus, it can be expected that the institutional view and a firm's internal view are not independent of each other. Therefore, institutional characteristics are included as potential moderators for the impact of industry specialization on the likelihood of investing abroad. Regarding institutional characteristics, this paper focuses on the role of start-up hubs in the context of industry specialization and internationalization. Literature on urban economics highlights the role of start-up and venture capital clusters and density in fostering innovation and entrepreneurship (Florida and Mellander 2016). These clusters are characterized by evolved entrepreneurial ecosystems consisting of dense networks connecting research to commercial products and services, high levels of entrepreneurial activity, and high availability of venture funding sources (Chen et al. 2010). Investors and portfolio companies often locate themselves in start-up hubs, where they can benefit from the network. However, due to start-up hubs' network- and value-enhancing impacts on portfolio companies, investors' specializations and advice may be less needed. In addition, from a venture capitalist's point of view, investing in a portfolio company located in a start-up hub may be accompanied by higher costs due to higher rents or wages. Furthermore, in start-up hub regions, competition for attractive investment opportunities may be higher. Considering these costs, it is questionable whether specialized investors, in particular, are inclined to follow the trend of investing in start-up hubs, especially as they are less dependent on the supporting effect of these hubs.

Furthermore, portfolio companies' attributes are likely to impact venture capitalists' investment decisions. One strategy used by venture capitalists to decrease investment risks when investing abroad includes selecting portfolio companies with lower ex-ante information asymmetries (Devigne et al. 2018). This may be possible for investments in a later round (Schertler and Tykvová 2012), in companies that have received higher funding or with the increasing age of the portfolio company. Accordingly, these three portfolio company characteristics are included as moderators in the analyses.

To examine these issues, this study uses a data set containing detailed information about venture capital firms and corresponding portfolio companies at the deal level from 2001 to 2019. The data set includes 46,525 initial investment decisions into a portfolio company with a global scope. The data are evaluated at the level of the firms' investment level, considering the individual decisions made in different firms' portfolios within a 5-year rolling window. The effects of venture capitalists' industry specializations are measured in a binomial logistic regression model.

This study shows that venture capitalists with higher levels of industry specialization have a significantly higher probability of investing cross-border than venture capitalists with lower levels of industry specialization. Moreover, this effect

is negatively moderated by the portfolio company being located in a start-up hub, and for companies with higher funding to date, which may reduce the importance of venture capitalists' capabilities in international investment decisions. The effect is positively moderated by the age of the portfolio company.

The study makes several contributions to the understanding of venture capital firms' international investment behaviours. By examining the role of firms' industry specialization in international investments, the study explains firm behaviour at the micro level. In contrast to studies drawing on network theory (Patzelt et al. 2009; De Pijcker et al. 2012; Vedula and Matusik 2017), which describe firm characteristics depending on the firm's partners, this paper offers alternative explanations for investors' behaviours by focusing primarily on the investors' own capabilities and their development through learning effects and specialization. Thus, the results add to the literature on international venture capital that refers to firm-level determinants (e.g., Cumming and Dai 2010; Gupta and Sapienza 1992; Cumming and Dai 2010; Vedula and Matusik 2017) of cross-border investments.

By interacting firm-specific characteristics with institutional-level and company-level characteristics, this study also provides insight into the interplay of firm-specific and external criteria, as they may not operate independently (Vanacker et al. 2014; Devigne et al. 2018). This allows for more precise conclusions about the investors' circumstances, including internal and external determinants, and how they affect investment decision behaviours in international markets. Lastly, this study uses a global data set and therefore provides indications about investors' behaviours on a global level.

The remainder of this study is organized as follows. Section 2 describes theoretical considerations and develops the hypotheses, and Sect. 3 details the data set and variables. Section 4 presents the results of the descriptive and multivariate analyses, Sect. 5 discusses the results and Sect. 6 provides the conclusions.

2 Theoretical considerations and development of hypotheses

2.1 Institutional drivers of international venture capital investments

Previous research examines several drivers of venture capital's cross-border capital flows. These drivers mainly relate to the characteristics of the institutional environment and the country in which the investment is made. Investors prefer to invest in countries with highly developed institutional environments since, from an investor's point of view, this implies greater market transparency and regulatory stability (Groh et al. 2010; Guler and Guillen 2010; Aizenman and Kendall 2012). In particular, the literature mentions that strong legal, financial, and political institutions facilitate cross-border venture capital flows (Devigne et al. 2018). Previous literature also reports that venture capitalists prefer investing in countries with cultural similarities to their own countries (Li et al. 2014; Dai and Nahata 2016). These similarities may include a common language, colonial ties (Aizenman and Kendall 2012), or economic integration between the countries (for example, the European Union) (Alhorri et al. 2008). With increasing cultural similarities, communication

and trust between the participating parties—in this case, the investor and the portfolio company—increase (Sorenson and Stuart 2001). Hence, the investor's liability of foreignness decreases when investing in a country with cultural similarities to the investor's own country.

Furthermore, studies have found that the economic growth of the target market is a driver of international venture capital (Groh et al. 2010; Schertler and Tykvová 2011; Aizenman and Kendall 2012). Economic growth within a country can be represented by a dynamic development of entrepreneurial ecosystems, which may foster the creation of new companies (Neck et al. 2004). An entrepreneurial ecosystem is a system of interactions between individuals and organizations—for example, financial intermediaries, research institutions, suppliers, customers, and the government (Colombo et al. 2019a, b). It thus comprises the area in which start-ups are established. From the perspective of a foreign investor, this leads to attractive investment opportunities, particularly due to the framework created by a strong institutional environment for investors (Mack and Mayer 2016). In addition, constant low interest rates in global markets may have led to an increase in the popularity of venture capital as an asset class. This may have resulted in increased competition for interesting and promising investment opportunities, encouraging investors to explore international markets. Further, the amount of 'dry powder', defined as venture capitalists' committed but unallocated capital on hand, has increased in the last years, which may have forced investors to seek investment opportunities beyond their national borders.

2.2 Firm-specific drivers and the importance of industry specialization

Despite the aforementioned drivers of international venture capital investments, comprising strong institutions and commonalities between countries, it is nevertheless argued that compared to domestic deals, international venture capital deals are characterized by higher information asymmetries and additional risks. These risks arise from the geographical, cultural, and institutional distance between the investor and the portfolio company (Lockett and Wright 2002; Pruthi et al. 2003; Wright et al. 2005; Devigne et al. 2016; Devigne et al. 2018). These risks are described as the liability of foreignness, which captures all additional costs arising for the investor that would not occur in a domestic deal (Zaheer 1995). This perspective, however, tends to focus on the institution-based view (Peng 2002). Likewise, the drivers of international venture capital flows mainly relate to institutional differences. At this point, the supplementary view focusing on the characteristics and capabilities of investors, following the resource-based view by Wernerfelt (1984), is missing. Under the circumstances of an international investment with high information asymmetries, an investor's firm-specific knowledge can represent a competitive advantage relative to other investors who do not possess these characteristics.

Some previous findings examine the probability of investing abroad according to investor type. For example, some studies show that corporate venture capitalists exhibit a broader geographic scope, as they invest in companies from which their corporation can derive a strategic advantage. Such target companies require a certain

fit with the parent company's product and service offerings so the corporate investor can access the target's technologies and knowledge. From a strategic point of view, limiting investment opportunities to the domestic market would reduce the number of target companies that fit the investor's product (Gupta and Sapienza 1992; Bertoni et al. 2015).

Furthermore, existing literature describes the decision on whether to internationalize from the perspective of an optimal portfolio allocation. Investing in different countries leads to geographic portfolio diversification and therefore may reduce an investor's overall investment risk (Knill 2009; Humphery-Jenner and Suchard 2013).

In addition, several studies consider the characteristics of an investor's human capital (De Prijcker et al. 2012; Devigne et al. 2018). Regarding the international investment expertise of venture capitalists' investment managers, there is evidence that more experienced managers are more likely to invest abroad (Schertler and Tykvová 2011). This is substantiated by their superior knowledge of the institutional environment and better access to networks (Devigne et al. 2018). In terms of an investor's social capital (e.g., networks), research shows that venture capitalists' social networks impact their international investment behaviours. To share the risks accompanying international investments, venture capitalists often decide not to invest in stand-alone deals rather than syndicates (Tykvová and Schertler 2014; Chemmanur et al. 2016). This practice enables venture capitalists to pool resources for monitoring, supporting and exiting their portfolio companies in international markets. In this context, local investors play a special role, as they are not affected by the liability of foreignness, and they know the local markets and behaviours. Hence, venture capitalists syndicating with local investors can solve problems arising abroad with the help of local partners (Sorenson and Stuart 2001; Cumming and Dai 2010; Vedula and Matusik 2017).

Rather than addressing the capabilities of external partners, this paper presents the firm-specific characteristics that influence internationalization decisions. This focus is meaningful because firms' characteristics determine their success in enhancing their portfolio companies' value and internal efficiency (Mahoney and Pandian 1992; Hart 1995; Abell and Nisar 2007). These characteristics include the investors' level of industry-specific knowledge on technological product development and access to key resources like personnel, raw materials, and distribution channels—what could be considered their level of industry specialization (Gupta and Sapienza 1992). Industry specialization is not static; rather, organizations acquire it through experience and practice in the form of tacit knowledge (Itami and Roehl 1991; Hart 1995). Firms can learn directly from their investment experience and thus develop specialized knowledge (Gupta and Sapienza 1992; Liu and Maula 2016). From venture capitalists' point of view, the provision of industry- and product-specific support and advice to portfolio companies is likely to be facilitated if firms have already developed their industry specialization in the past (Zhang and Pezeshkan 2016). Specialization development may help investors learn about the characteristics and behaviours of markets and their participants in a specific field of business, which is not limited to the domestic market but can also be applied globally. On the one hand, a higher level of specialization likely attenuates an investor's liability of foreignness as the benefits of specialization in the market exceed the risks

of cross-border investment. Through a high degree of industry specialization, the insecurity linked to investment abroad may be reduced by industry-specific expertise accumulated through similar previous investments. Therefore, it is assumed that industry specialization facilitates investments abroad. On the other hand, one could also argue that investors with increasing levels of industry specialization face fewer investment opportunities in their home markets if they want to continue investing in similar business models. Investment opportunities matching an investor's industry specialization may not be available in the domestic market, resulting in a push effect to invest abroad. In summary, industry specialization may be a vehicle for reducing the liability of foreignness and facilitating investments abroad. In addition, international investments may result from an investor's industry specialization. Consequently, the first hypothesis is as follows:

Hypothesis 1: Venture capitalists' degree of specialization is positively related to the probability of internationalization.

2.3 Market-level and portfolio company-level determinants influencing venture capitalists' decisions to invest abroad

Beyond venture capitalists' industry specialization, a considerable body of research examines the mechanisms for overcoming information asymmetries within foreign markets. One strategy is observing and interpreting the determinants of the market and the portfolio company (Valliere 2012).

Regarding the determinants of the target market, the concept of the entrepreneurial ecosystem is widely used to represent increased entrepreneurship and growth in a certain region (Cohen 2006; Stam 2015; Spigel 2017). Entrepreneurial ecosystems are networks of social, cultural, political and economic elements in a region that contribute to the competitiveness and success of new ventures within the system (Dubini 1989; Spigel 2017). This is because favourable institutional conditions for growth are created in a developed entrepreneurial ecosystem: ease of firm communication and cooperation (Gertler 2003), wide social networks that create pathways for knowledge spillover (Powell et al. 2005), and strong connections between founders and founding sources (Powell et al. 2002). Evolved entrepreneurial ecosystems are present in start-up hubs, where the density of innovative companies, networks, and venture funding sources is high. From a venture capital investor's point of view, the risk of a cross-border deal may be evaluated as lower if the investment occurs in an evolved entrepreneurial ecosystem. Thus, an evolved entrepreneurial ecosystem may act as a quality signal for the target market. Thereby reducing information asymmetries. In such regions, the value and success stories of other investors already exist, which venture capital firms can draw on in their decision-making. This ecosystem is missing in regions where only a few deals have been executed.

In sum, I assume that due to entrepreneurial ecosystems' supporting and assisting effects, an investor's industry specialization is less essential because it is locally available. Therefore, investors are not compelled to rely only on their own expertise. Under the assumption that venture capitalists assess an entrepreneurial ecosystem as highly developed, it may be that less specialized investors are more

inclined to invest in start-up hubs than specialized investors, as less specialized investors are necessarily dependent on the assisting effect of start-up hubs. Thus, the second hypothesis is as follows:

Hypothesis 2a: If the portfolio company is located in an evolved entrepreneurial ecosystem, this negatively moderates the relationship between specialization and internationalization.

Another determinant influencing venture capital investors' international investment decisions may be whether the portfolio company under consideration has a previous financing history. New venture financing usually proceeds in several rounds in which portfolio companies must reach milestones and demonstrate progress in their business activities (Gompers 1995). Each additional round carries certification effects from previous rounds, and an investment decision made in a later round is thus made with less uncertainty than decisions made in the first round (Ruhnka and Young 1987; Gompers 1995; Wang and Zhou 2004). Portfolio companies with longer financing histories are also likely to enter a more advanced stage of the life cycle; accordingly, investors may be faced with fewer investment risks, as the portfolio company's first operational challenges have been solved by other investors who were already involved. Consequently, the information asymmetries for investors decrease with each additional round from which information about the portfolio company's past performance is available. Therefore, previous financing rounds could mitigate new investors' insecurities due to the skill sets, experiences, and networks of the investors who are already involved (Schertler and Tykvová 2012; Devigne et al. 2013). Hence, one can argue that a firm's industry specialization is less important when an investment is made in a later round. Accordingly, the third hypothesis is as follows:

Hypothesis 2b: If the firm initially invests in a later round, this negatively moderates the relationship between specialization and internationalization.

The literature also relates differences in the amount of entrepreneurial funding to the characteristics of start-ups (Hsu 2007). If a foreign portfolio company has already received a higher amount of funding, a potential investor may consider this a sign of security. The more equity a company has already received from other parties, the higher potential investors rate the quality of the company. Furthermore, investors already involved in the portfolio company have an incentive not to lose their invested capital, as they would incur financial and reputational damage (Walter 2013). It can be assumed that to prevent losses, previous investors have already contributed to improving the portfolio company's products and processes. Consequently, the company's development has likely progressed further with higher financing. The existing information asymmetries are thus reduced for new investors. Regarding the necessity of specialized knowledge, additional technical support from a specialized investor may then be less necessary, as this support has already been provided. Therefore, I suspect that the funding a company has already received negatively moderates the effect of industry specialization on the probability of a cross-border deal. Thus, the fourth hypothesis is as follows:

Hypothesis 2c: The higher the portfolio company's funding, the lower the influence of industry specialization on the probability of a cross-border deal.

Another proxy reducing information asymmetries between the portfolio company and the venture capital investor might be the portfolio company's age. Particularly young ventures imply a higher risk associated with investment than older companies, and venture capitalists may be affected by this risk in their investment decisions (Zhang and Pezeshkan 2016). The age of the portfolio company indicates how long a company has been established on the market so far. Hence, the older a company is, the more trust it conveys towards investors. Furthermore, the availability of information about the company and its operations is higher for older companies, since they have a track record that investors can use to assess the performance of the company. Information asymmetries are thus lower for older companies.

Older companies are also more likely to have established business processes, a developed product and a customer base generating revenues. New investors can draw on these existing assets and do not have to build up the business from scratch. Regarding industry specialization, investors can access an already existing pool of knowledge, skills and resources. Their specialization is therefore unnecessary to the same extent as is the case with younger companies that still have little investment in their product development and the establishment of processes and customer generation. Thus, the fifth hypothesis states as follows:

Hypothesis 2d: The older the portfolio company, the lower the influence of industry specialization on the probability of a cross-border deal.

3 Data and methodology

3.1 Data on venture capitalists' investment decisions

The main data set is taken from the Refinitiv database Eikon (formerly Thomson Financial), powered by VentureXpert. The data contain detailed information about independent venture capitalists' internationalization decisions at the deal level. Information is included on the corresponding venture capital firms and referring portfolio companies for the last 2 decades (2001–2019). This period includes several global economic events such as the global financial crisis, which may have affected internationality and investment decisions in the venture capital industry. Some variables and further information on the institutional characteristics of the target markets were taken from the websites of Rafael La Porta and the Entrepreneurship and Development Institute, as well as from the International Monetary Fund. The data are analyzed in terms of each internationalization decision to initially invest in a company. A detailed overview and explanations of the variables are provided in Table 1.

Every observation contains information about the investing venture capital firm's characteristics and the corresponding portfolio company into which the firm invested. Data at the institutional and cultural levels were collected separately from the investment deal information and merged into the main data set. Table 2 shows

Table 1 Summary of variables used in the regressions

Variables	Description
Dependent variable	
Cross-border deal	A binary variable, equaling one if the deal under consideration is a cross-border deal and zero otherwise
Independent variables	
Industryspecialization_rw_5y	A ratio variable, reflecting the proportional experience of a venture capital firm within an industry, measured against all its previous investments, calculated on a five-year rolling window. Industry specialization can take on values of 0 if no experience has yet taken place within the industry whose deal is being investigated. Industry specialization can take a maximal value of 1 if all deals a firm has made can be assigned to the industry of the deal under consideration to date. The year of the deal is not included in the calculation. The first five years of the data set as well as the first five years of every firm are also not included in the regression analysis
Start-up hub dummy	A dummy variable, equaling one if the portfolio company is located in a start-up hub and zero otherwise calculated annually. Start-up hubs were identified based on the number of deals per city of all venture capital deals listed in the Refinitiv database. Cities were classified as hubs if the number of venture capital deals within a city is above the 75 per cent quantile of all cities in the year of the deal
Funding round	Variable indicating the financing round in which the deal under consideration takes place. Only initial investments of firms into portfolio companies are included
Log (Company funding to date)	Logarithm of the amount of financing in US-dollars received by a portfolio company up to the respective investment date
Log (age portfolio company)	Logarithm of the age of the portfolio company in years
Local demand	Number of venture capital deals in the industry of the deal under consideration in the home country of the VC firm in t-1
Log (domestic investment experience)	Logarithm of the number of domestic deals a firm has made until the year before the respective deal
Log (internat. investment experience)	Logarithm of the number of cross-border deals a firm has made until the year before the respective deal
Log (age of firm)	Logarithm of the age of the investment firm in years
Log (size of firm)	Logarithm of the size of the investment firm in dollar
Global entrepreneurship score (target market)	Global entrepreneurship score provided by the Global Entrepreneurship and Development Institute (GEDI) measuring the health of the entrepreneurship ecosystem annually. GEDI collects data on entrepreneurial attitudes, abilities, and aspirations of the local population and weights these against the prevailing social and economic infrastructure of a country. Data was downloaded from the website of GEDI at https://thegedi.org/
Efficiency legal system (target market)	Efficiency and integrity of the legal system produced by the country risk rating agency Business International Corp. Efficiency of the legal system can take values from zero to ten, whereas lower scores indicate low efficiency. Data was downloaded from the website of Rafael La Porta at https://faculty.tuck.dartmouth.edu/rafael-laporta/research-publications/

Table 1 (continued)

Variables	Description
Financial openness (target market)	Chinn-Ito index, measuring a country's degree of capital account openness. Chinn-Ito index is calculated on binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). Financial openness can take values from zero to one. Data was downloaded at http://web.pdx.edu/~ito/Chinn-Ito_website.htm
Same religion dummy	Dummy equaling one if the majority of the investment firms and target nations' population belongs to the same denomination and zero otherwise. This applies to the Buddhism, Christianity, Hinduism, and Islam denominations. Data concerning countries' denominations was taken from the CIA World Factbook
Same language dummy	Dummy equaling one if firm nation and target nation have the same official language and zero otherwise. This applies to the languages Arab, English, French, German, Spanish, and Portuguese. Data concerning countries' official languages was taken from the CIA World Factbook
Legal classification effects (target market)	Legal classification fixed effects. The variable contains the legal classification of the target nation country based on the "Legal Classification of Investment Nation" by La Porta et al. (1998). Countries are classified as French, English, German, Scandinavian, or Socialist
Year effects	Investment year fixed effects

Variables used in the regression models

the descriptive statistics of the sample, which consists of 46,525 investments made by 2125 venture capital firms into 21,804 portfolio companies. An overview of the geographical distribution of venture capital firms and portfolio companies is presented in Table 3.

Only venture capitalists' initial decisions to invest in a portfolio company are analyzed. These can occur in the first round or later rounds. Concerning follow-on investments in the same portfolio company, these choices are no longer decisions to internationalize in the sense that the portfolio company and its environment are no longer afflicted with uncertainty. As firms already gain information about the processes, stakeholders and business environment of the company in the first investment round, initial investment decisions and follow-on investments may differ substantially. There is likely a different intention behind the first investment in a company compared to that of a follow-on investment. For example, the dilution of the investor's share may need to be protected if additional investors enter, and further capital may be required to achieve company-specific goals. Therefore, in a follow-on investment, the decision to internationalize is not new, nor is the addition of a new company to the portfolio. However, since firms

Table 2 Descriptive statistics

Variables	Obs	Mean	Std. dev	Min	Max
Cross-border deal	46,525	0.190	0.393	0	1
Industryspecialization_rw_5y	46,525	0.286	0.247	0	1
Start-up hub dummy	46,525	0.293	0.455	0	1
Funding round	46,525	1.932	1.701	1	27
Log (company funding to date)	42,532	16.746	1.760	4.605	23.213
Log (age portfolio company)	34,011	1.260	0.886	0	5.537
Local demand	46,525	0.208	0.133	0	1
Log (domestic investment experience)	46,525	3.597	1.907	0	8.601
Log (internat. investment experience)	46,525	1.680	1.622	0	6.956
Log (age of firm)	46,525	2.403	0.908	0	5.130
Log (size of firm)	46,525	19.466	1.926	9.105	25.324
Global entrepreneurship score (target market)	46,525	74.681	14.152	11.800	90.231
Efficiency legal system (target market)	46,525	9.637	0.970	2.500	10
Financial openness (target market)	46,525	0.954	0.179	0	1
Same religion dummy	46,525	0.924	0.265	0	1
Same language dummy	46,525	0.834	0.372	0	1
Legal classification effects					
Year effects					

Summary statistics of variables used in the regression models

Summary statistics of all variables used in the regression models except the fixed effects variables. Displayed values refer to the observations used in the base model. Summary statistics of the moderator variables are taken from the respective interaction models. The number of observations for Log (company funding to date) and Log (age portfolio company) are lower than in the base model due to the limited availability of these variables

realize industry-specific learning effects by investing in the same company multiple times, these investments are counted as further industry specialization.

3.2 Dependent variable

The dependent variable cross-border deal is a binary variable indicating the internationalization decision of the venture capital firm under consideration. Cross-border deal equals zero if the deal is domestic and one if the deal is international.

3.3 Independent variables

The main independent variable, industry specialization, is a ratio variable reflecting the proportional deal experience of a venture capital firm within an industry

Table 3 Geographical distribution of VC-firms and portfolio companies

Nation	VC-firm nation	Investment nation	Nation	VC-firm nation	Investment nation
Argentina		25	Lebanon	71	25
Australia	353	350	Luxembourg	124	
Austria	82	70	Malaysia	32	43
Bangladesh		5	Mauritius	131	
Belgium	181	168	Mexico	29	53
Bermuda	9		Morocco	8	10
Brazil	150	263	Netherlands	366	289
Bulgaria	4		New Zealand	4	
Canada	1186	1599	Nigeria	3	35
Cayman Islands	14		Norway	273	132
Chile	1	10	Pakistan	4	7
China	369		Peru		2
Colombia	3	23	Philippines	2	23
Costa Rica	6	3	Poland	24	
Cyprus	2	11	Portugal	66	64
Czech Republic	14		Republic of Ireland	206	244
Denmark	191	184	Russian Federation	143	
Ecuador	3	4	Singapore	330	333
Egypt	25	32	South Africa	24	32
Estonia	13	32	South Korea	452	447
Finland	251	302	Spain	316	321
France	1450	1570	Sri Lanka	6	7
Germany	790	950	Sweden	362	472
Ghana		5	Switzerland	369	324
Greece	6	7	Taiwan	74	
Guatemala	1	2	Tanzania		4
Hong Kong	186	90	Thailand		24
Hungary	9		Tunisia		5
Iceland	5	8	Turkey	1	21
India	812	1627	United Arab Emirates	35	84
Indonesia	37	140	United Kingdom	2044	2124
Israel	653	810	United States of America	33,388	32,282
Italy	137	160	Uruguay	34	4
Japan	613	604	Vietnam	4	
Jordan	17	19	Zambia		2
Kenya	4	28	Others	5	10
Kuwait	18	1			
			Total	46,525	46,525

This table shows the geographical distribution of venture capital deals in the sample used in the base model

measured against its previous investments before the deal under consideration. The measure is calculated using a 5-year rolling window as the timespan and, therefore, the number of deals increases over time. Since new investment firms entering the sample will have no experience at all due to their missing history in the sample. Therefore, the first 5 years of the data set and the first 5 years of a venture capital firm's lifetime are not included in the analyses. Industry specialization equals zero if a firm has no experience in the industry of the deal being investigated. Industry specialization can take a maximal value of one if all deals a firm has made within the timespan of the rolling window can be assigned to the industry of the deal under consideration to date. The measurement of Industry specialization incorporates learning effects by assuming that with each additional deal within an industry, a firm's experience increases through successfully supporting companies in that industry in the market. Therefore, for the first deal in a portfolio, the variable industry specialization always equals zero, as no learning effects can occur until a firm's first investment.

Industry classification within the sample was conducted by Refinitiv Eikon Industry Minor Classification, and this classification has been adopted by this study. The specialization categories include biotechnology, communication and media, computer hardware, computer software and services, consumer-related, industrial/energy, internet-specific, medical/health, other products, and semiconductors.

Four different moderators referring to the portfolio company and the corresponding target market are considered. All moderators should illustrate the strength of the information asymmetries between the venture capital firm and the portfolio company. The first moderator is a Start-up hub dummy, which measures whether the region of the portfolio company's headquarters is known for supporting the creation and growth of new ventures. Start-up hub dummy equals one if the portfolio company is located in a start-up hub and zero otherwise. Start-up hotspots were identified based on a data set of all tracked venture capital deals in the Refinitiv Eikon platform from 2001 to 2019. Cities with the most start-up companies in the corresponding year were labelled as start-up hotspots. For this purpose, the companies per city and year were counted, and those cities with values above the 75 percent quartile were marked as hotspots.

In addition to examining institutional factors, the study also examines known indicators of portfolio companies' financing histories that may moderate the influence of industry specialization on decisions to invest abroad. The round in which the investment takes place (funding round) takes the value of the respective investment round. Log (company funding to date) is the logarithm of the financing in US dollars received by a portfolio company from all investors up to the respective investment date. Lastly, the age of the portfolio company Log (Age of portfolio company), is included in the models. The age of the portfolio company is measured as the logarithm of the difference between the founding year and the year of the investment decision.

3.4 Control variables

Several control variables are included in the multivariate analyses. It is likely that in addition to industry specialization, knowledge of other institutional environments and cultures is also necessary; thus, the international investment experience is controlled for (Gupta and Sapienza 1992; Cumming and Dai 2010). International investment experience influences investment decisions because experienced investors are more familiar with foreign institutional and legal environments and have better access to international networks (Schertler and Tykvová 2011; De Prijcker et al. 2012; Devigne et al. 2018). In addition to knowledge of the particularities of international markets, the investors' experience in domestic markets also influences their investment decisions. For example, through experience in domestic markets, investors gain skills in structuring deals and monitoring investments (Gompers et al. 2009; Wang and Wang 2011). Both international and domestic experience are measured by the logarithm of the number of deals a firm made prior to the year of the deal under consideration. Furthermore, the age of the firm (age of firm) as well as the size of the firm (firm size), based on the venture capital firm's assets under management, are included as control variables. Age of firm is measured as the logarithmic value of the difference between the date of the establishment of the firm and the date of the investment. Particularly young ventures imply a higher risk associated with investment than older companies, and venture capitalists may be affected by this risk in their investment decisions (Zhang and Pezeshkan 2016).

In addition to the characteristics of investment firms and portfolio companies, the study also includes other structural and institutional characteristics of the target market.

In addition to the company's industry specialization, the availability of promising investment alternatives in the investor's home country could also play a role in an investor's decision to internationalize. Thus, I add a control variable which considers this factor. The variable Local demand measures the number of venture capital deals in the industry of the deal under consideration in the home country of the venture capital firm prior to the year before the respective deal.

The efficiency of the legal system (efficiency legal system) impacts venture capital investments through more assertive mechanisms for solving agency and control problems (Cumming et al. 2010). The analyses in this study use the index created by Porta et al. (1998) to illustrate legal efficiency. Efficiency legal system can take values from zero to ten, with low scores indicating low efficiency.

Beyond the aforementioned formal institutions, investment behaviours are also likely to be influenced by informal institutions such as cultural heritage (Bruton et al. 2005; Gantenbein et al. 2019). People speaking the same language or sharing the same religion often share similar values (Gantenbein et al. 2019); therefore, some authors have used a country's language and religion as proxies for culture (Grinblatt and Keloharju 2000; Guiso et al. 2006). To control for cultural differences between the investment nation and the nation of the portfolio company, two dummy variables that equal one if the two countries share the same language or religion are included in the models. The variables cover cultural differences among the main languages and religions of the data set. The main official languages of firm nations and

target nations are Arab, English, French, German, Spanish, and Portuguese. Data about countries' official languages are taken from the CIA World Factbook. The religion dummy variable covers Buddhism, Christianity, Hinduism, and Islam. Data on countries' denominations are also taken from the CIA World Factbook. Since languages or beliefs that are only represented in one country act as a fixed effect for that country, these could not be integrated. To further control for country-specific cultural peculiarities, in particular, those related to entrepreneurship and financing, the global entrepreneurship score developed by Acs et al. (2017) is included in the models. The global entrepreneurship score measures the health of the entrepreneurship ecosystem annually and is provided by the global entrepreneurship development institute (GEDI). GEDI collects data on the entrepreneurial attitudes, abilities, and aspirations of local populations and weights these against the prevailing social and economic infrastructure of a country. The score consists of various components, for example, the average of a population's willingness to take risks, the quality of a country's human capital, and a country's financial openness.

Year and legal effects are also included in the analyses. Legal classification fixed effects capture the legal classification of the target nation based on the 'Legal Classification of Investment Nation' by Porta et al. (1998). Countries are classified as French, English, German, Scandinavian or Socialist.

3.5 Descriptive statistics

In the sample, 8855 deals are labelled cross-border deals, and 37,670 are labelled domestic deals. Therefore, almost 20% of all deals in the sample are characterized as cross-border deals.

On average, the firms' industry specialization is 0.286, meaning that on average, 28.6% of the firms' portfolio investments at the time of the investment decision can be assigned to the industry of the company in which the investment is made. Therefore, on average, firms do not invest in a company without any prior industry experience. The maximum industry specialization in the sample is 1, and the minimum value is no industry specialization at all. Most deals can be classified into the categories of computer software and services (33.99%), internet-specific (26.7%), biotechnology (8.91%), and medical/health (8.16%). The communications and media category has the fewest deals (2.67%). A detailed overview of the firms' industry specializations is displayed in Table 4.

Slightly less than 30% of the deals included in the sample are located in a start-up hotspot (mean=0.293). The average funding a portfolio company received (measured in logarithmic values) at the date of the investment of the firm under consideration is 16.746 US dollars (SD=1.76). Firms are on average 2.403 years old and at most 5.13 years old at the time of the investments (also measured in logarithmic values). The average logarithmic age of the portfolio companies is 1.26 years and the maximum age is 5.537 years. The earliest investments into portfolio companies occur in the year of establishment. On average, investments into portfolio companies occurred after two rounds (SD=1.701). The mean of the number of investment rounds seems relatively small. However, this may be because the data set only

Table 4 Industry specialization

Variable	Industry specialization option	Frequency	Percent
Industry specialization			
	Biotechnology	4145	8.91
	Communication and media	1243	2.67
	Computer hardware	1364	2.93
	Computer software and service	15,814	33.99
	Consumer related	1681	3.61
	Industrial/Energy	2019	4.34
	Internet specific	12,423	26.70
	Medical/Health	3796	8.16
	Other products	2413	5.19
	Semiconductors	1627	3.50
	Total	46,525	100.00

Industries in which firms under consideration invest and by which the industry specialization variable is measured on the basis of previous investments within the industry to which the deal under consideration is allocated using a 5-year-rolling-window. Frequency and percentage indicate in which category investments were made in the used data set. Industry classification is done by Refinitiv Eikon Industry Minor Classification

includes initial investments in companies and does not include follow-on investments in later rounds. Before the investments, venture capital firms had executed an average of 2.69 deals in their home countries and 1.68 deals abroad. The local demand for venture capital financing in the specific industry under consideration in the investor's home market is on average 0.208. This means, that in the investors' home country, on average 20.8% of the deals in the previous year were made in the sector of the deal under observation.

Most deals occur in countries with legal systems that are considered efficient (mean=9.64). The lowest efficiency score for a legal system is 2.5 points and the highest is 10 points, the maximum efficiency. Similar patterns can also be observed regarding the financial openness of the target markets. The average financial openness of the target markets is 0.954 points, with 1 as the maximum score and 0 as the lowest score. Investment deals primarily occur in countries with the same official language (mean=0.834) and the same religious orientation (mean=0.924). Deals also mainly occur in countries with high global entrepreneurship scores (mean=74.681). The countries with the lowest global entrepreneurship are assigned a score of 11.8, while some countries reach maximum scores of 90.23.

3.6 Model specification

Within the framework of multivariate analysis, this paper examines if and to what extent a firm's industry specialization impacts its international investment decisions. Furthermore, this work analyzes the extent to which characteristics of the portfolio company and the corresponding target market influence the relationship between a

firm's industry specialization and the decision to invest abroad. Binomial logistic regression models are conducted to investigate the relationship between a firm's industry specialization and internationalization decisions. Therefore, the dependent variable P (Cross-border deal = 1) indicates the probability of a cross-border deal. The base model specification, investigating the isolated effect of a firm's industry specialization on the probability of investing abroad, is:

$$\begin{aligned}
 P(\text{Cross} - \text{border deal} = 1)_i = & \beta_0 + \beta_1 \text{Industry specialization} + \beta_2 \text{Local demand} \\
 & + \beta_3 \text{Log(Domestic experience)} + \beta_4 \text{Log(International experience)} \\
 & + \beta_5 \text{Log(Age of firm)} + \beta_6 \text{Log(Size of firm)} \\
 & + \beta_7 \text{Global entrepreneurship score} + \beta_8 \text{Efficiency legal system} \\
 & + \beta_9 \text{Financial openness} + \beta_{10} \text{Same religion dummy} \\
 & + \beta_{11} \text{Same language dummy} + \text{Legal effects} + \text{Year effects} + \epsilon_i
 \end{aligned} \quad (1)$$

where investment decisions are indexed by i .

To avoid biased regression estimates, all regression models control for possible cross-correlation effects arising from unobserved individual firm effects among all deals made by a respective firm. Therefore, clustered standard errors are used. Pearson correlations of all variables included in the models are displayed in Table 5. As variance inflation factors (VIFs) do not exceed values of 6.11 (see also Table 5), there is no evidence of multicollinearity.

The models analyzing the interaction effects have the same model specification, including the respective additional interaction effect. All interaction effects relate to characteristics reflecting informational asymmetries between the venture capital firm and the portfolio company, which I expect to moderate the impact that industry specialization has on the investor's internationalization decision.

Model 2 includes the moderating effect of the portfolio company being located in a start-up hub on the impact that industry specialization has on the probability a firm invests abroad. The model specification is the following:

$$\begin{aligned}
 P(\text{Cross} - \text{border deal} = 1)_i = & \beta_0 + \beta_1 \text{Industry specialization} + \beta_2 \text{Startup hub} \\
 & + \beta_3 \text{Industry specialization} \times \text{Startup hub} + \delta \text{Controls}_i \\
 & + \text{Legal effects} + \text{Year effects} + \epsilon_i
 \end{aligned} \quad (2)$$

Model 3 analyzes the moderating effect of the funding round on the impact that industry specialization has on the probability a firm invests abroad. The model specification is as follows:

$$\begin{aligned}
 P(\text{Cross} - \text{border deal} = 1)_i = & \beta_0 + \beta_1 \text{Industry specialization} \\
 & + \beta_2 \text{Funding round} + \beta_3 \text{Industry specialization} \\
 & \times \text{Funding round} + \delta \text{Controls}_i + \text{Legal effects} \\
 & + \text{Year effects} + \epsilon_i
 \end{aligned} \quad (3)$$

Table 5 Pairwise correlations and variance inflation factors

Variables	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Cross-border deal		1.000											
(2) Industry specialization _{rw_5y}	1.22	0.014*	1.000										
(3) Local demand	1.41	0.022*	0.408*	1.000									
(4) Log(Domestic investment experience)	2.76	-0.139*	0.059*	0.011*	1.000								
(5) Log(Internat. investment experience)	2.00	0.282*	0.032*	0.054*	0.563*	1.000							
(6) Log(Age of firm)	1.96	0.022*	-0.021*	-0.035*	0.663*	0.508*	1.000						
(7) Log(Size of firm)	1.79	0.033*	0.016*	-0.008*	0.588*	0.543*	0.422*	1.000					
(8) Global entrepreneurship score (target market)	6.11	-0.337*	0.065*	0.014*	0.165*	-0.084*	0.019*	0.055*	1.000				
(9) Efficiency legal system (target market)	4.12	-0.251*	0.040*	-0.013*	0.134*	-0.038*	0.036*	0.084*	0.759*	1.000			
(10) Financial openness (target market)	4.50	-0.234*	0.018*	-0.041*	0.095*	-0.066*	0.034*	0.011*	0.780*	0.618*	1.000		
(11) Same religion dummy	1.64	-0.515*	0.011*	-0.032*	0.095*	-0.180*	-0.023*	-0.039*	0.384*	0.181*	0.316*	1.000	
(12) Same language dummy	2.20	-0.552*	0.035*	0.017*	0.210*	-0.148*	-0.010*	0.079*	0.407*	0.325*	0.142*	0.391*	1.000
Mean VIF	2.71												

This table shows variance inflation factors (VIFs) and pairwise correlations for the variables used in the base model. Significance is marked by * at 5%

Model 4 analyzes the moderating effect of the portfolio company's funding on the impact that industry specialization has on the probability that a firm invests abroad. The model specification is as follows:

$$\begin{aligned}
 P(\text{Cross} - \text{border deal} = 1)_i = & \beta_0 + \beta_1 \text{Industry specialization} \\
 & + \beta_2 \text{Log}(\text{Company funding to date}) \\
 & + \beta_3 \text{Industry specialization} \\
 & \times \text{Log}(\text{Company funding to date}) + \delta \text{Controls}_i \\
 & + \text{Legal effects} + \text{Year effects} + \varepsilon_i
 \end{aligned} \tag{4}$$

Model 5 analyzes the moderating effect of the portfolio company's age on the impact that industry specialization has on the probability a firm invests abroad. The model specification is as follows:

$$\begin{aligned}
 P(\text{Cross} - \text{border deal} = 1)_i = & \beta_0 + \beta_1 \text{Industry specialization} \\
 & + \beta_2 \text{Log}(\text{Age of portfolio company}) \\
 & + \beta_3 \text{Industry specialization} \\
 & \times \text{Log}(\text{Age of portfolio company}) + \delta \text{Controls}_i \\
 & + \text{Legal effects} + \text{Year effects} + \varepsilon_i
 \end{aligned} \tag{5}$$

4 Empirical results

The results show a significant positive relationship between venture capitalists' industry specialization and the probability of investing abroad (see Table 6). Since the logit regression model is nonlinear, the effect of industry specialization on the probability of a cross-border deal is not the same at every level of industry specialization (see Fig. 1). Hence, to better understand the main effect, the probability of a cross-border deal depending on the level of industry specialization is calculated for the mean of industry specialization, as well as the mean of industry specialization plus/minus one standard deviation, while all other independent variables of the model are held at means. If the venture capitalist's industry specialization increases by about one standard deviation from the mean, the probability that the venture capital investor will decide on a cross-border deal increases by about 1.6%. In comparison, the probability of a venture capital firm executing a cross-border deal with a specialization value of the mean minus one standard deviation decreases by about 1.4% from the mean. These findings underline the assumption that the higher the investor's industry specialization, the more likely investors' perceived insecurity linked to a cross-border investment may be reduced. Therefore, the first hypothesis saying that the venture capital firm's degree of specialization is positively related to the probability of internationalization can be confirmed.

Regarding the control variables, results indicate that venture capital investors are less likely to invest abroad the higher the demand for venture capital financing

Table 6 Logistic regression using robust standard errors

Probability of a cross-border deal	Model 1	Model 2	Model 3	Model 4	Model 5
Independent variable					
Industry specialization_rw_5y	0.614*** (0.098)	0.736*** (0.107) 0.0891 (0.088) – 0.608*** (0.173)	0.647*** (0.125)	2.909*** (0.785)	0.396** (0.157)
Start-up hub dummy					
Industry specialization_rw_5y * Start-up hub dummy					
Funding round			0.115*** (0.0163) – 0.030 (0.036)		
Industry specialization_rw_5y * Funding round				0.156*** (0.022) – 0.137*** (0.0459)	
Log (Company funding to date)					0.186** (0.092) 5.346*** (1.043)
Industry specialization_rw_5y * Log (company funding to date)					
Log (Age portfolio company)					
Industry specialization_rw_5y * Log (age portfolio company)					
Control variables					
Local demand	– 1.020*** (0.205)	– 0.971*** (0.207) – 0.449*** (0.034)	– 0.975*** (0.205) – 0.439*** (0.034)	– 1.016*** (0.218) – 0.437*** (0.035)	– 0.813*** (0.213) – 0.437*** (0.036)
Log (Domestic investment experience)	– 0.451*** (0.034)				
Log (Internat. investment experience)	0.686*** (0.038)	0.687*** (0.038) – 0.090* (0.051)	0.687*** (0.038) – 0.107** (0.052)	0.671*** (0.039) – 0.092* (0.054)	0.695*** (0.039) – 0.135** (0.055)
Log (Age of firm)	– 0.087* (0.051)				

Table 6 (continued)

Probability of a cross-border deal	Model 1	Model 2	Model 3	Model 4	Model 5
Log (Size of firm)	0.073*** (0.025)	0.073*** (0.025)	0.063** (0.025)	0.038 (0.025)	0.073*** (0.027)
Global entrepreneurship score (target market)	0.011 (0.008)	0.011 (0.008)	0.009 (0.008)	0.010 (0.009)	0.008 (0.008)
Efficiency legal system (target market)	-0.416*** (0.097)	-0.414*** (0.097)	-0.412*** (0.097)	-0.521*** (0.111)	-0.462*** (0.104)
Financial openness (target market)	-0.196 (0.502)	-0.205 (0.501)	-0.159 (0.501)	-0.038 (0.554)	0.162 (0.546)
Same religion dummy	-2.777*** (0.332)	-2.769*** (0.330)	-2.792*** (0.330)	-2.717*** (0.337)	-2.712*** (0.335)
Same language dummy	-2.727*** (0.194)	-2.732*** (0.195)	-2.721*** (0.195)	-2.885*** (0.199)	-2.790*** (0.192)
Legal effects (target market)	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
Intercept	5.139*** (0.973)	5.080*** (0.967)	5.197*** (0.967)	4.274*** (1.056)	5.346*** (1.043)
Number of observations	46,525	46,525	46,525	42,532	34,011
Pseudo R-squared	0.4441	0.4454	0.4469	0.4567	0.4430

Binomial logistic regression results: The impact of industry specialization of venture capital investments on the probability of investing abroad in a worldwide sample of venture capital deals from 2001 to 2019

Results show a binomial logistic regression with the probability of investing domestic or cross-border as the dependent variable. As the independent variable, firm's proportional industry specialization as measured by its past investments within a 5-year-rolling-window and their industry classifications is used. Values can therefore range from 0 to 1. Interactions are performed with variables that are expected, indicating the degree of information asymmetries between the portfolio company and the investment firm. As other independent variables, several measures referring to the institutional environment of the investment and the experience of the investing firms were included. Heteroscedasticity robust standard errors are in parentheses. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively. Standard errors are clustered by venture capital firms

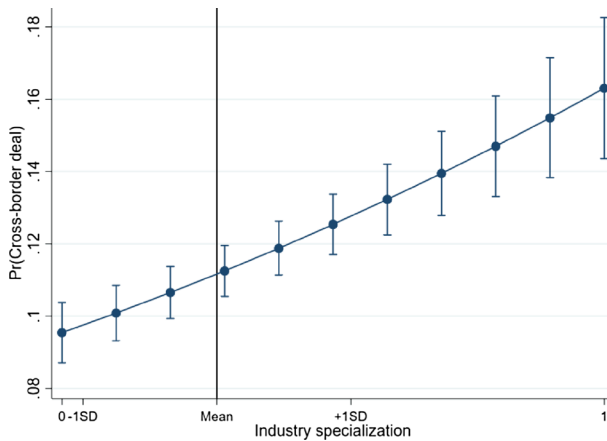


Fig. 1 Effect of industry specialization on the probability of a cross-border investment. Note: figure presents the calculated predictions of Model 1 (Table 6). I show predictive margins with 95% confidence intervals

in their home countries. Local demand is significantly negative correlated with the probability of a cross-border deal. In line with previous literature, it can be seen that the international investment experience of the investor has a positive influence on the decision to invest abroad. On the opposite, the likelihood of a cross-border deal decreases with higher experience in the domestic market. Larger investment firms are also more likely to invest abroad. It is also apparent that older investment companies are more likely to invest domestically.

Referring to the characteristics of the target market, results show that the probability of a cross-border deal decreases with the increasing efficiency of the legal system abroad. The financial openness of the target country has no significant impact on the likelihood of investing abroad. In addition, the entrepreneurship index of the target market indicates a positive but insignificant correlation with the likelihood of investing abroad. Investing in a country with the same language or religion is negatively correlated with the probability of a cross-border deal.

Regarding the moderation effects, as hypothesized in H2a, the assumption can also be confirmed that the probability of a cross-border deal depending on a firm's industry specialization is attenuated by the portfolio company being located in a start-up hotspot. To aid interpretation, the effect of industry specialization on the likelihood of a cross-border deal is illustrated graphically (see Fig. 2a). Figure 2a compares the interaction effect of the start-up hub dummy on the relationship between industry specialization and the probability of a cross-border deal while keeping all other variables at means among the two possible scenarios of the dummy variable. The red curve shows the effect of industry specialization on $\Pr(\text{cross-border investment}) = 1$ for investments where the portfolio company under consideration is located in a start-up hub. The blue curve shows the effect of industry specialization on $\Pr(\text{cross-border investment}) = 1$ for investments in which the portfolio company under consideration is not located in a start-up hub. For the cases where

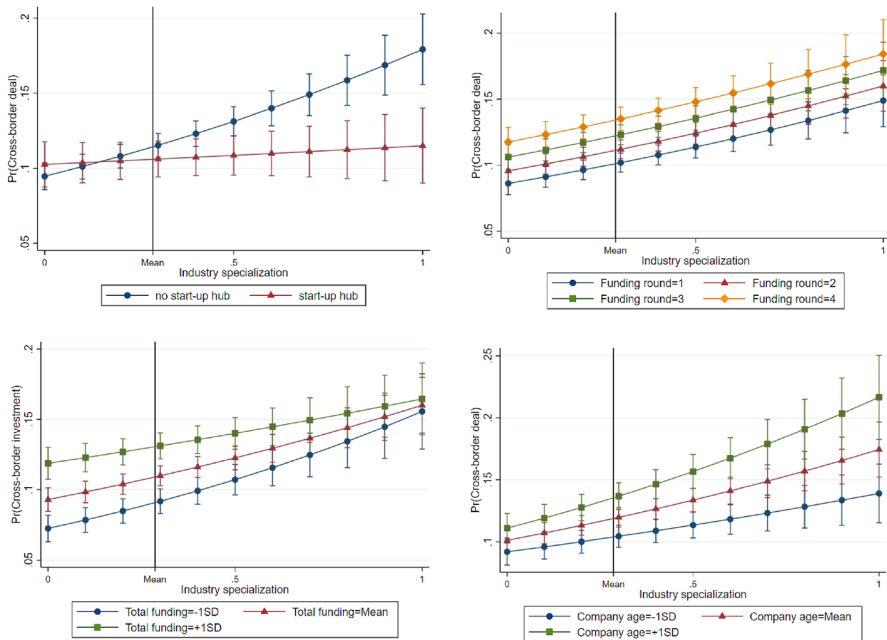


Fig. 2 **a** Moderating effect of start-up hub dummy on the relationship between industry specialization and the probability of investing cross-border. **b** Moderating effect of funding round on the relationship between industry specialization and the probability of investing cross-border. **c** Moderating effect of company's funding to date on the relationship between industry specialization and the probability of investing cross-border. **d** Moderating effect of the portfolio company's age on the relationship between industry specialization and the probability of investing cross-border. Note: Figure **a–d** present the calculated predictions of the moderation effects displayed in Model 2 to Model 5 (Table 6). I show predictive margins with 95% confidence intervals for industry specialization, respectively, depending on the values of **a** the portfolio company's location, **b** the funding round, **c** total funding the portfolio company has received to date, **d** the portfolio company's age

the portfolio company under consideration is located in a start-up hub, the slope of the curve is flatter compared to the blue curve.

I find that the effect of industry specialization on the probability of a cross-border deal is weakened if the portfolio company is located in a start-up hub. It can be seen graphically that investors with lower levels of specialization tend to invest in supporting start-up hubs abroad, whereas with increasing levels of industry specialization, cross-border deals are made in regions that are not labelled as start-up hubs. However, it must be added, that only the effect for investors with high levels of industry specialization is significant in the graph, as the confidence intervals of both graphs overlap for lower values of industry specialization.

No significant moderating effect of the number of funding rounds on the relationship between industry specialization and internationalization was found (Model 3). The curves comparing initial investment decisions in funding rounds 1, 2, 3 or 4, keeping all other variables at means, are almost parallel (see Fig. 2b). Therefore, I reject hypothesis 2b assuming that if a firm initially invests in a later

round, this negatively moderates the relationship between specialization and internationalization.

The results regarding the moderation effect of total funding on the relationship between industry specialization and internationalization show that total funding has a weakening effect on the relationship between industry specialization and cross-border deals. The plot illustrates that with increasing levels of funding to date, the slopes of the curves flatten out. Holding all variables at means, the moderating effect of total funding, shown for the total funding at different values (mean of total funding, mean of total funding \pm 1 SD), on the relationship between industry specialization and the probability of a cross-border deal is displayed in Fig. 2c. For investors with lower values of industry specialization, the probability of investing abroad is higher if the portfolio company under consideration has received higher amounts of funding so far. This effect decreases for more specialized investors. Thus, hypothesis 2c, which assumes that the higher the portfolio company's funding, the lower the influence of industry specialization on the probability of a cross-border deal, can also be confirmed.

Contrary to hypothesis 2d, I found that the portfolio company's age positively moderates the relationship between industry specialization and internationalization. Figure 2d shows that for older companies the curves are steeper. The effect is shown for different values of portfolio company age (mean of portfolio company age, mean of portfolio company age \pm 1 SD). This means, that for older portfolio companies, the positive effect of industry specialization on the likelihood to invest abroad is stronger. Hence, I must reject hypothesis 2d, stating that the older the portfolio company, the lower the influence of industry specialization on the probability of a cross-border deal.

4.1 Robustness check

The venture capital industry is mainly located in the North American market, including the United States and Canada (Tykvová 2018). This is reflected in the sample: 72.83% of all deals refer to the North American market. Therefore, it may be questionable whether the results from the entire global data set can be generalized as they are dominated by the North American market. For this reason, a robustness check excluding the North American market was conducted. The models for the reduced data set were calculated in the same way as they were for the entire sample.

As shown in Table 7, the results are largely robust to changes in the data set. Again, industry specialization has a positive impact on the probability of a cross-border deal. However, the moderating effect of the financing round and the portfolio company's age show no statistical significance. One possible reason for this could be that the certification effects associated with later rounds are less meaningful to investors outside the North American market. Harrison and Mason (2019) describe the European market as being inferior to the American market in terms of the conditions for entrepreneurial growth. Portfolio companies' employees are less trained in growth and innovation and the corresponding leadership capacity is also less present in companies (Harrison and Mason 2019). Investors, therefore, must increasingly

Table 7 Robustness check—excluding the North American market

Probability of a cross-border deal	Model 1	Model 2	Model 3	Model 4	Model 5
Industry specialization_rw_5y	0.804*** (0.157)	0.948*** (0.166)	0.675*** (0.214)	4.042*** (1.258)	0.762*** (0.250)
Start-up hub dummy		0.709*** (0.149)			
Industry specialization_rw_5y * Start-up hub dummy		− 0.898*** (0.331)			
Funding round			0.219*** (0.037)		
Industry specialization_rw_5y * Funding round			0.062 (0.082)		
Log (Company funding to date)				0.338*** (0.033)	
Industry specialization_rw_5y * Log (company funding to date)				− 0.199*** (0.076)	
Log (Age portfolio company)					0.0060 (0.056)
Industry specialization_rw_5y * Log (age portfolio company)					0.083 (0.120)
Control variables					
Local demand	− 0.874*** (0.273)	− 0.985*** (0.275)	− 0.849*** (0.277)	− 0.964*** (0.299)	− 0.865*** (0.291)
Log (Domestic investment experience)	− 0.042 (0.057)	− 0.044 (0.056)	− 0.037 (0.058)	0.036 (0.062)	− 0.047 (0.058)
Log (Internal. investment experience)	0.374*** (0.063)	0.372*** (0.063)	0.369*** (0.063)	0.297*** (0.064)	0.365*** (0.064)
Log (Age of firm)	− 0.244*** (0.107)	− 0.240*** (0.107)	− 0.238*** (0.109)	− 0.245*** (0.120)	− 0.223*** (0.111)

Table 7 (continued)

Probability of a cross-border deal	Model 1	Model 2	Model 3	Model 4	Model 5
Log (Size of firm)	0.273*** (0.053)	0.269*** (0.053)	0.263*** (0.052)	0.208*** (0.053)	0.271*** (0.056)
Global entrepreneurship score (target market)	0.0365*** (0.008)	0.0338*** (0.008)	0.0346*** (0.008)	0.0392*** (0.009)	0.0403*** (0.009)
Efficiency legal system (target market)	-0.174** (0.080)	-0.165** (0.080)	-0.174** (0.079)	-0.213** (0.086)	-0.200** (0.083)
Financial openness (target market)	-1.259*** (0.399)	-1.288*** (0.398)	-1.220*** (0.397)	-1.402*** (0.432)	-1.240*** (0.422)
Same religion dummy	-1.888*** (0.309)	-1.951*** (0.305)	-1.903*** (0.307)	-1.803*** (0.325)	-1.877*** (0.315)
Same language dummy	-2.003*** (0.228)	-2.005*** (0.228)	-2.001*** (0.229)	-2.165*** (0.237)	-2.084*** (0.228)
Legal effects (target market)	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
Intercept	-2.884** (1.218)	-2.811** (1.213)	-2.958** (1.196)	-6.779*** (1.236)	-2.862** (1.298)
Number of observations	12,644	12,644	12,644	10,539	9,374
Pseudo R-squared	0.4734	0.3379	0.3436	0.3545	0.3377

Binomial logistic regression results: The impact of industry specialization of venture capital investments on the probability of investing abroad in a worldwide sample of venture capital deals excluding the North American market from 2001 to 2019

Results show a binomial logistic regression with the probability of investing domestic or cross-border as the dependent variable. As the independent variable, firm's proportional industry specialization as measured by its past investments within a 5-year-rolling-window and their industry classifications is used. Values can therefore range from 0 to 1. Interactions are performed with variables that are expected, indicating the degree of information asymmetries between the portfolio company and the investment firm. As other independent variables, several measures referring to the institutional environment of the investment and the experience of the investing firms were included. Heteroscedasticity robust standard errors are in parentheses. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively. Standard errors are clustered by venture capital firms

engage themselves in companies to drive growth. Industry specialization might therefore be equally important in different financing stages.

Syndication is widely discussed in prior venture capital literature as a strategy to reduce information asymmetries and pooling resources for monitoring and supporting portfolio companies (Dai and Nahata 2016; Liu and Maula 2016) in international deals. It is assumed that syndication thus reduces the investment risk, as the risk can be shared among different investors (Schertler and Tykiová 2012; Devigne et al. 2013). To account for the impact of syndication on the firm's internationalization, I ran all models with and without a syndication-dummy control variable. The results remain robust in both samples with and without the North American market. In that the role of local investors as syndicate partners in internationalization decisions is emphasized in the literature, I also ran the models including a control variable accounting for the number of local partners participating in the deal. Likewise, the results are robust.

5 Discussion

Regarding the question of whether industry specialization in a specific industry impacts the internationalization of venture capitalists, the results show a positive relationship between the two constructs. With higher levels of industry specialization, the likelihood of a cross-border deal increases. This could be explained by the fact that investors with higher industry specialization are familiar with the business activities in certain markets, such as market structure; cooperation partners and their behaviours; and operational processes, such as the procurement of suitable input materials, personnel, advertising and sales, and the selection of suitable supply chains. Hence, a specialized investor may already know how to increase the growth of a specific business model and may be connected to potential customers and business partners. The liability of foreignness associated with international deals may therefore be lower for investors with higher levels of industry specialization. Thus, there is an indication that specialization facilitates investments abroad for similar business models.

Results also show that investors from countries with lower local demand for venture capital financing within the specific industry under consideration are more likely to invest abroad. One could argue that higher levels of industry specialization may force investors to seek suitable investment opportunities outside of their home markets since for more specialized investors, the number of domestic portfolio companies fitting their investment focus decreases with higher levels of industry specialization. From this point of view, industry specialization may also be a push factor that increasingly drives investors to deploy capital abroad.

As expected, venture capital firms with higher international experience are more likely to make a cross-border investment. Those investors might have higher abilities to reduce information asymmetries associated with investing abroad because they are more familiar with the institutional and legal environment in foreign countries and are better connected to other international networks (Gupta and Sapienza 1992; Cumming and Dai 2010; Devigne et al. 2018). On the contrary, investors with

higher domestic investment experience have a lower probability to invest outside of their home countries. One reason for this could be that investors with more national experience are more likely to have a competitive advantage in their home market compared to investors with a high level of international experience. This relationship might also apply to older venture capital firms, which I found are more likely to invest in the domestic market. As older firms have a larger track record in the domestic market, they may be better able to compete in the domestic market even though only a few promising portfolio companies are present there.

In line with the literature, results indicate that larger firms have a higher probability of investing abroad (Gupta and Sapienza 1992; Cumming and Dai 2010). The more capital an investment firm has at its disposal, the more likely it is that more funds will be distributed to foreign companies. This pattern might be driven by the low-interest phase, when comparatively large amounts of capital which had to be invested, were allocated to the private markets.

Higher financial openness of the target market has no significant impact on the probability of investing abroad. However, financial openness may become of greater importance in later stages of financing, for example, if an IPO is planned. At this stage, venture capitalists should invest in a country with a well-functioning banking system and transparent and credible accounting standards.

A higher entrepreneurship ecosystem index is also positively but not significantly correlated with the probability of cross-border investments. The global entrepreneurship index measures the entrepreneurial attitudes, abilities and aspirations of the target market's local population, which might be associated with promising business ideas and innovative portfolio companies. This factor might explain the positive effect on the likelihood of investing abroad since investors' confidence in the abilities of the entrepreneurs might be higher. On the other hand, different investors may have divergent perceptions of the quality of a country's entrepreneurship ecosystem. Furthermore, investors from diverse cultural backgrounds may also have varying opinions about the significance of individual components of the index.

The likelihood of cross-border investments is higher in countries with less efficient legal systems. This initially contradicts the assumptions that an efficient legal system reduces information asymmetries and signals certainty for investors (Wright et al. 2005; Cumming et al. 2010) and that one would therefore assume that an efficient legal system is positively associated with the probability of a cross-border deal. One reason for a negative relationship could be that the common-law countries, where most investors in the data set are located, are rated as the most efficient in terms of their legal system (Porta et al. 1998). If investors from common-law countries invest in regions where a different legal system prevails, they invest in countries that have a less efficient legal system.

Contrary to the assumption that investments are more likely to be made in countries with the same language and religion, that is, similar cultural conditions (Gantenbein et al. 2019), I also found a negative correlation between the probability of investing abroad and sharing a language and religion. This correlation might be explained due to the majority of cross-border investments being made by English-speaking and, in terms of religion, Christian investors. The global dominance of English-speaking and Christian investors results in primarily English-speaking and

Christian investors investing in non-English-speaking and non-Christian environments where culturally similar investors are outnumbered. A reason for this might be that the availability of equity financing opportunities is still limited in most countries. Venture capital investors are mainly located in financial centres and high-tech regions (Colombo et al. 2019a, b), which are prevalent in English-speaking, Christian countries. Even if portfolio companies from other regions globally would prefer investors from the same cultural background, it might be that there are no such investors available.

Referring to the moderation effects, results indicate that the positive relationship between industry specialization and the probability of a cross-border deal is moderated by the portfolio company's location. If the portfolio company under consideration is located in a start-up hub, the effect of industry specialization on the probability of a cross-border deal is weakened. This impact may stem from the supporting and assisting effects of entrepreneurial ecosystems (Gertler 2003; Powell et al. 2005), which attenuate the need for investors to employ tacit knowledge. Consequently, the decisions of investors to deploy capital are less tied to their industry specialization and former learning. Furthermore, start-up hubs are characterized by a high density of investors, which may reduce the likelihood of foreign investor participation. Specialized investors may be more likely to participate in deals attracting less attention and being located outside of start-up hubs but still fit their industry specialization. On the other hand, an investor's specialization may become more important if supportive conditions in the target company's region are less given, which could explain the reinforcing effect.

I could not find a moderating effect of the number of funding rounds on the relationship between industry specialization and internationality. Although it is known from previous literature that each additional funding round carries certification effects from previous rounds (Ruhnka and Young 1987; Gompers 1995; Wang and Zhou 2004), thus lowering information asymmetries, this might not be true for all business models. This might be especially true for research-intensive products whose development phase is longer and comprises more financing rounds than, for example, consumer goods. It may be that there is still as much expertise needed in later phases, as decisions are equally complex and specific. In addition, if such companies want to grow and expand their operations, high investment sums are required (Aernoudt 2017). The financial risk of investments in later rounds in such cases is high, which also tends to suggest that specific industry knowledge is needed at least to the same extent as in early rounds. Furthermore, investments might become more complex with each additional round. It is likely that the number of other investors already involved in the company, is higher for investments in higher rounds. For the new investor, this results in new information asymmetries including not only the portfolio company itself, but also other stakeholders and their specific goals.

I also found that the positive relation between industry specialization and internationality is weaker if the portfolio company under consideration has received higher amounts of funding before the date of the investment decision. One reason for this effect may be that higher funding indicates a portfolio company's heterogeneity in terms of social capital and associated capabilities (Hsu 2007). If capabilities and specific experience are already present in the portfolio company, the investor's

support in this respect is less necessary. Investors with a lower level of specialization are less likely to invest abroad if the company has received less financing, and it may be that this effect is less meaningful for specialized investors since they want to make a greater contribution to the financing and further development of the company.

Contrary to the assumption that the effect of industry specialization on the probability of investing abroad is less strong for older companies, the results show that the opposite effect occurs. Industry specialization gains more weight the older the portfolio companies are, perhaps due to two reasons. First, older companies are likely to have a more complex business. Products and processes that are already established are more difficult to change or improve. Therefore, more specific experience might be needed to successfully develop older companies and increase their value. Second, companies in later growth phases are also faced with different decisions than companies that are still in a very early financing phase. These decisions might include whether to enter additional markets, introduce new product lines or expand abroad. Industry specialization might be an important success factor in achieving these goals.

6 Conclusion

This paper analyzes the effects of industry specialization on venture capital firms' decisions to invest abroad. Furthermore, the study also investigated the interplay between firms' industry specializations and the characteristics of the target markets, as well as the financing-specific characteristics of portfolio companies.

The results show that the probability of investing abroad increases with higher degrees of industry specialization even though international deals are often associated with higher risk. This relationship illustrates how the liability of foreignness has a varying influence on an investor's investment decision depending on the investor's specialization in the specific industry to which the deal is assigned. Thus, the results contribute to previous research on strategies to compensate for the liability of foreignness (Devigne et al. 2018).

The study provides new insights into the decision-making behaviours of venture capital firms. First, there is evidence that in addition to the frequently studied country-level or network determinants (De Prijcker et al. 2012; Vedula and Matusik 2017), firm-level determinants such as industry specialization also play a role in investment decisions. Therefore, the literature is enriched by analyzing firms primarily based on their own capabilities.

Second, by interacting the firm-level characteristic of industry specialization with country- and company-level characteristics, this study adds to the literature by examining the interplay of firm-level determinants, target market determinants and portfolio company-level determinants in investment decisions, as these may not operate independently (Vanacker et al. 2014; Devigne et al. 2018). If ex ante information asymmetries are lower—for instance, due to an evolved entrepreneurial ecosystem or when investing in companies that received higher funding to date—the importance of a company's specialization for internationalization decisions decreases.

Therefore, these findings refine the investigation of factors influencing the decision-making behaviours of venture capital investors in an international context.

This study is subject to some limitations. Within this framework, industry specialization is considered to be equally relevant in all industries. However, it may be that industry specialization is more important, for example, in research-intensive industries or for complex business models than for accessible business models. Furthermore, such a finding would mean that investors' specialization processes are slower in more complex industries than others. Therefore, it might be useful to score the provided industry specializations differently according to their complexity. In addition, this study assumes that the structure of a venture capital firm does not change during the period under consideration. However, investment decisions may also be driven by personnel changes, specific knowledge about industries and markets or ties to a foreign country.

It would also be interesting to investigate whether venture capital firms have local offices in the target countries from which they could more easily contact the target company and intensify their relationship with the specific country. Local offices are also likely to positively influence investors' internationalization decisions. Likewise, it would be interesting to further examine syndication in the context of internationalization and industry specialization. As various partners in the syndicate bring different skills and capabilities to the table, it might be worth exploring which skills complement each other to what extent and how different skills and their composition in the syndicate affect firms' internationalization decisions.

From a deal flow perspective, investors with higher levels of specialization may be more likely to identify specific deals that intersect with their specializations in foreign markets due to more choices of investment opportunities on an international scale. Specialized investors may have a more dispersed global network due to the high specificity of their investment focus. These investors might also have to search more intensively for suitable deals, and the only investment opportunities available may be in foreign countries. Hence, it would be interesting to investigate whether a venture capital investor had other investment options in addition to the chosen international deal. Furthermore, it is likely that the number of other interested investors in the deal under consideration also plays a role. One could investigate the competitive situation faced by venture capitalists in their decision-making processes. Further research is needed to address these points and more specifically examine venture capital firms' industry specializations in the context of international investment decisions.

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Code availability I used Stata SE 15 to conduct the analyses. Stata code is available upon request.

Declarations

Conflict of interest There are no relevant financial or non-financial interests to disclose.

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