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The signaling effect of founders' human capital: how it compensates for the risk of radical innovation in venture capital investments

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"*Faber est suae quisque fortunae*."

("*Every man is the master of his own destiny*")

Sallustio

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Abstract (English)

The relationship between venture capital investors (VCs) and new ventures is characterised by high uncertainty and the presence of strong information asymmetries, which may lead to adverse selection problems. In this setting, the quality of the venture is often not directly observable. However, VCs may rely on some observable characteristics, which are supposed to co-vary with the venture's underlying quality, serving as signals of quality. These signals play a crucial role in VCs' decision-making processes.

This Thesis provides a novel contribution to the literature about signaling theory in entrepreneurial contexts. It focuses on the signaling effect of the human capital features of ventures' founding teams and investigates whether it may compensate for the risk of radical innovation in venture capital investments.

Radical inventions are generally characterised by a controversial nature. On the one hand, they constitute very attractive investments thanks to their high returns' potentials. On the other hand, they are accompanied by a massive component of risk since the likelihood of achieving commercialization and benefiting from these returns is uncertain. Hence, when faced with radical inventions, for the deal to take place, VC investors are likely to feel the necessity to share this risk and reduce the likelihood of failure through syndication.

However, this need for risk-sharing and, thus, this tendency towards syndication may be affected (i.e., either be reinforced or reduced) as a result of the signaling effect of the human capital endowment of the founding team. This consideration constitutes the backbone of this Thesis. Using a sample of 40.636 dyads venture-investor, several multinomial logit models have been run, providing empirical evidence that the effect of radicalness on syndication is (i) reduced by the signaling effect of founders' managerial competencies and (ii) enhanced by the signaling effect of founders' scientific competencies.

Keywords: venture capital; syndication; radical innovation; signals; human capital.

Abstract (Italian)

Il rapporto tra start-up ed investitori in venture capital (VC) è caratterizzato da elevata incertezza e dalla presenza di forti asimmetrie informative, che possono comportare problemi di selezione avversa. In questo contesto, il potenziale dell'impresa non è direttamente osservabile; tuttavia, gli investitori fanno riferimento ad alcune caratteristiche, correlate alla qualità sottostante l'impresa, le quali fanno da segnali di qualità per la stessa. Tali segnali svolgono un ruolo chiave nei processi decisionali dei VC.

Questa Tesi offre un contributo innovativo alla letteratura sulla teoria dei segnali applicata a contesti imprenditoriali. Concentrandosi sull'effetto segnaletico del capitale umano dei fondatori di una start-up, si interroga sulla relativa capacità di compensare eventuali rischi derivanti da innovazioni radicali proposte dalla start-up stessa.

Le innovazioni radicali hanno una natura piuttosto controversa. Da un lato, dato il loro notevole potenziale per alti ritorni, costituiscono un investimento attraente. Dall'altro, tuttavia, sono caratterizzate da una forte componente di rischio in quanto la probabilità di raggiungere la commercializzazione e, dunque, di godere dei suddetti ritorni è incerta. Pertanto, in questi contesti, i VC sentono il bisogno di condividere il rischio e dunque di riunirsi in un sindacato per poter investire.

Questa tendenza alla sindacazione in presenza di innovazioni radicali potrebbe tuttavia essere alterata (incrementata o ridotta) dall'effetto segnaletico del capitale umano dei fondatori della start-up. Tale considerazione costituisce l'elemento portante di questa Tesi. Sulla base di un campione di 40.636 diadi impresa-investitore, sono stati analizzati una serie di modelli m-logit, i quali hanno offerto prove empiriche del fatto che l'effetto di innovazioni radicali sui sindacati di VC è (i) ridotto dall'effetto segnaletico delle competenze manageriali dei fondatori e (ii) incrementato da quello delle loro competenze scientifiche.

Parole-chiave: venture capital; sindacato; innovazione radicale; segnali; capitale umano

Executive Summary

Venture Capital firms (VCs) are financial intermediaries specialised in investing in new ventures with high growth potential (Gompers and Lerner, 1999). Among the most attractive investment targets for VCs, new technology-based firms (NTBFs), i.e., young, fast-growing and knowledge-based ventures, particularly stand out. As agreed by the extant economic literature, new firms and especially new technology-based firms (NTBFs) are key drivers of economic development and powerful engines of growth. They provide new jobs, favour the static and dynamic efficiency of the economic system and foster innovation (Audretsch, 1995).

Nevertheless, the willingness of VC investors to finance NTBFs can be limited by the level of uncertainty associated to the venture. Recalling the words of Holmstrom and Tirole (1989) innovation is known as "full of uncertainties and with a high probability of failure". Hence, not all the NTBFs are going to achieve successful outcomes and it is extremely hard for an external investor to distinguish the most promising ones since there are no observable attributes of quality on which the assessment can be based. These firms possess almost exclusively intangible assets (which are hard to evaluate) and, since they have less restrictive disclosure requirements, they tend to provide few information about their underlying technology with the scope of protecting the property as much as possible (Hall, 2018). Moreover, they do not have any track record and, being far from commercialization, their projected cash flows are scarcely reliable (Baum and Silverman, 2004). Therefore, the relationship between VC investors and NTBFs is characterised by strong information asymmetries that hinder an effective assessment of the venture's potential.

Among the NTBFs, those belonging to knowledge-intensive industries (e.g. biotech) are particularly attractive for VCs thanks to their high return potentials. Nevertheless, being extremely innovative, these ventures are associated to a higher level of uncertainty, which might further hamper VCs' decision-making processes. In case of biotech NTBFs, the

novelty of the developed product (and thus its commercialization potential) is closely related to the basic R&D research behind it (Zucker, Darby and Brewer, 1998). Thus, an assessment of the quality of the venture requires a careful evaluation of the scientific legitimacy and newness of the idea. Because VCs do not possess an adequately advanced scientific knowledge (Junkunc, 2007), they perceive investments in biotech ventures even more uncertain. In other words, in knowledge-intensive ventures (and specifically biotech) the information asymmetry problem between the venture and the VC investor becomes even stronger.

Signaling theory, anchored to the seminal work of Spence (1973) represents a powerful response to information asymmetry problems. In general, information asymmetries can arise both when dealing with information about quality (i.e., adverse selection problem) or information about intent (i.e., moral hazard problem) (Stiglitz, 2000), but signaling theory addresses only the former case. In particular, it examines the deliberate communication of positive information by the more informed party towards the uninformed one, in order to convey a positive image. In order to serve as a quality signal, a certain attribute must fulfil two main characteristics: (i) it must be observable by the uninformed party and (ii) it must be costly (Connelly *et al.*, 2011). Moreover, the key mechanism behind signaling is the achievement of a separating equilibrium. A separating equilibrium is identified when every difference in signaller state is reflected by a difference in the signal sent. Hence, at this equilibrium, the receiver can exactly infer the signaller's quality from the signal sent (Bergstrom, Számadó and Lachmann, 2002). For separating equilibrium to occur, it is necessary that the cost of signaling is inversely proportional to the quality of the signaller (i.e., the signaling cost is higher for low-quality signallers and discourages them to invest in the signal) (Connelly *et al.*, 2011; Bergh *et al.*, 2014).

Signaling theory perfectly applies as a response to the strong information asymmetries existing between NTBFs and VC investors. The quality of these ventures is not directly observable by VCs. Therefore, to evaluate the firm's potential they mainly rely on other observable attributes and characteristics, which are supposed to co-vary with its quality.

In that context, any feature or information able to alter the investor's probability distribution of unobserved variables can be defined as "signal" (Hsu and Ziedonis, 2013). Signals play a crucial role in any relationship between VCs and NTBFs, but especially in cases where information asymmetries are particularly strong, such as biotech (and other knowledge-intensive) ventures. When investing in biotech NTBFs, VCs tend to rely as much as possible on observable features and use them as signals of quality. In this sense, biotech industry represents a particularly interesting context of study.

All NTBFs generally possess a portfolio of attributes that may serve as signals. Within this portfolio, a leading role is played by patents. Patents have an important value themselves as they ensure monopolistic rights on the developed technology and appropriability of the derived returns. Besides that, they are also acknowledged as powerful Spencian signals of quality for NTBFs. Filing a patent application is a long and costly process, which firms decide to undertake only when they are confident about the potential of their idea. In that sense, patents do have a differential cost which is higher for low-quality ventures (i.e., they lead to a separating equilibrium) (Hsu and Ziedonis, 2013). Moreover, the disposal of granted or pending patents application is an easily and objectively observable attribute of a NTBF. Hence, they undoubtedly serve as signals and, indeed, particularly reliable signals as they result from a standard and regulated process (Janney and Folta, 2003).

Therefore, in order to attract VC investments, founders are incentivised to file patent applications once they are confident about the potential of their technology, and they tend to do it soon. Although the extant literature agrees on the positive signaling effect of patents, little attention has been paid to patents' information content and possible dark-sides hidden in it. This Thesis sheds a new light on that, focusing on the effect that information about the *radicalness* of the underlying technology, extracted from the patent's data, may have on VCs' decision making.

The degree of radicalness of an invention refers to the extent to which it differs from previously existing products and processes (Verhoeven, Bakker and Veugelers, 2016). An invention is considered radical if it leads to a technological paradigm shift (Dosi, 1982). In other words, if it is able to disrupt the industry conventions and change customers'

expectations in a positive way (Deffains-Crapsky and Sudolska, 2014). For a long time, radical innovations have been identified only ex-post. Nevertheless, a number of recent studies have linked radical innovations to the characteristics of their underlying technology, using patents as a source of data (Verhoeven, Bakker and Veugelers, 2016). Several indicators of radicalness have been defined, entirely based on pieces of information contained in the patent documentations (Ahuja and Lampert, 2001; Rosenkopf and Nerkar, 2001; Shane, 2001; Nerkar, 2003; Dahlin and Behrens, 2005). Hence, going through the patent's information content, VCs can infer the level of radicalness of the venture's underlying technology.

The first contribution of this Thesis consists in investigating the effect of radicalness on VCs decision making. On one hand, VC investors are attracted by radical innovations due to their high-return potential. On the other hand, radical innovations require long-lasting and expensive R&D activity and, because they introduce completely new solutions, their future success is extremely uncertain (Deffains-Crapsky and Sudolska, 2014). Thus, despite being particularly attractive, radicalness introduces a massive component of risk. In the light of that, it is reasonable to argue that in the presence of radical innovation (i.e., when the patented invention is assessed as radical), the risk to bear gets too high and, for the deal to take place, investors need to share this risk through syndication. In other words, radicalness leads to syndicated deals.

Starting from such consideration, this Thesis goes further introducing into the analysis the effect of a second major signal of quality for NTBFs: the human capital features of the founding team. In particular, the second contribution of this Thesis consists in investigating how the different characteristics of founders' human capital may influence the effect of radicalness on syndicated deals, working as risk-mitigators or risk-enhancers. Human capital can be defined as "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2007). Human capital endowment of the founding team of a venture is widely acknowledged in literature as a powerful Spencian signal of quality (Zacharakis and Meyer, 2000; Prabhu and Stewart, 2001; Hoenig and Henkel, 2015). Nevertheless, as

it emerges from its definition, many different features can be included in the broad notion of *human capital.* In particular, this work focuses on two main attributes of human capital: *managerial* competencies and *scientific* competencies. They both serve as signals, as well as radical patents. When more signals are sent by same signaller (i.e., the same venture) they are going to interact, either reinforcing or neutralizing each other (Bergh *et al.*, 2014).

Assumed that radicalness increases the perceived risk and drives VCs to syndicate, this effect may change (i.e., be reinforced or reduced) when the founding team presents advanced managerial competencies or advanced scientific competencies. In this regard, the two human capital signals tend to have opposite effects. When the founding team presents high managerial competencies (i.e., they have completed an MBA, they have worked in a C-level role, or they have already founded other start-ups), VC investors tend to be more confident about the survival chances and financial returns of the venture (Muzyka, Birley and Leleux, 1996; Zacharakis and Meyer, 2000; Colombo and Grilli, 2005). Hence, in the presence of radical patents, advanced managerial competencies within the founding team are likely to compensate for the risk of radical innovation and reduce VCs' inclination towards syndication. On the other hand, when founders possess advanced scientific competencies (i.e., they are faculty researchers, professors, or have worked in the R&D department), VCs tend to be more uncertain about the venture's future outcomes. The associated ventures, indeed, are often rooted in advanced scientific research (i.e., they are hard to assess without adequate scientific knowledge) and they are often at a low level of maturity (i.e., they are far from commercialization) (Sorescu, Chandy and Prabhu, 2003; Munari and Toschi, 2011). Hence, when a venture presents both radical patents and founders with advanced scientific competencies, the two signals are likely to reinforce each other and increase the risk and uncertainty associated to the venture. These arguments are at the core of this Thesis, which provides empirical evidence that the effect of radicalness on syndication is (i) reduced by the signaling effect of founders' managerial competencies and (ii) enhanced by the signaling effect of founders' scientific competencies.

Finally, for a comprehensive assessment of the joint signaling effect of radical patents and founders' human capital features on syndication, it is interesting to distinguish for different types of VC investors (i.e., more or less experienced). Different signal's receivers, due to their diverse nature, may respond differently to the same signal (or group of signals). Specifically, experienced VCs (i.e., those venture capitalists with a high number of realised deals) are likely to be less risk-averse and to have a better gut in judging start-ups, especially in the presence of strong information asymmetries (Cumming, 2010). From what stated so far, it emerges that the two signals about radicalness and scientific competencies reinforce each other and increase the risk associated to the venture. Hence, in such highly uncertain condition, if VCs decide to invest, they do it in a syndicate with the scope of sharing the risk of the investment. In this regard, the third and last contribution of this Thesis consists in introducing the consideration about expert VCs, and argues that when both signals (i.e., radicalness and scientific competencies) are in place, VCs are more prone to syndication if an experienced VC takes part in the syndicate.

In order to address the above-mentioned arguments, it has been used a sample of 672 NTBFs registered in the VICO dataset, all operating in the biotech industry and endowed with at least one patent application (either granted or pending). The analysis has been limited to the biotech industry because it represents a particularly interesting context of study as it is characterised by exceptionally strong information asymmetries and by a very close relationship between patents and marketable products. Being all the firms VC-backed, in order to understand the reasoning driving VCs' decision-making process, a matching model has been built, associating each venture with all the alternative VC firms, controlling for their existence at the year of foundation. The 40.636 dyads venture-investor, resulting from the matching model, constituted the actual units of analysis for the study conducted. For each dyad venture-VC, the type of deal occurring between the two has been registered through a categorical variable (i.e., 0=no deal, 1=standalone deal and 2=syndicated deal), which has been used as dependent variable in all the econometrics models defined.

The results of the multivariate and logit regression analyses run on the sample confirm that in the presence of radical patents the probability of opting for a syndicated deal increases, meaning that radicalness actually leads to syndication. Moreover, when considering the interaction between radicalness and managerial capabilities, radicalness' impulse towards syndication becomes non-significant. In other words, founders' endowment with advanced managerial capabilities counterbalances the positive effect of radicalness in syndicated deals. On the other hand, when interacting radicalness with scientific competencies, it emerges that when both signals occur, then the probability of syndicating becomes positive and significant. This corroborates the hypothesis that, in the presence of radicalness, high scientific competencies increase further the uncertainty perceived by VCs in their investment decision. Finally, keeping the focus on this last highly uncertain context (i.e., when both radicalness and high scientific competencies are in place), the results of the m-logit model corroborate the hypothesis that the marginal probability of syndication is even higher when an experienced VC joins the syndicate.

1. Introduction

Europe's prospering economies, the singular growth of the European tech industry and the region's availability of experienced fund managers has led to an accelerated growth of the European VC industry. According to Invest Europe data, European VC investment totals have increased each year for the last five years, reaching the value of € 6.4 billion in 2017. Europe hosts the world's largest single market with an open economy, stable political system, a proud history of innovation and a highly educated workforce (Invest Europe, 2017).

As a consequence of its growing relevance within the European landscape, scholars and policy-makers have increased their attention towards European VC market. A high number of works have analysed the main actors involved in the VC market, in order to understand the grounding principles and inner dynamics of this industry. This Thesis contributes to this stream of research and focuses the attention on the mechanisms affecting VCs' investment decisions. In order to fully grasp the scope of this work and its relevance within the literature about VC investments, it is important to have a comprehensive understanding of the nature of the relationship between VC investors and the new venture.

A VC investor is a financial intermediary that provides equity capital to relatively young and risky entrepreneurial ventures, favouring them with particular strategies and practices (Gompers and Lerner, 1998) (**Figure 1**).

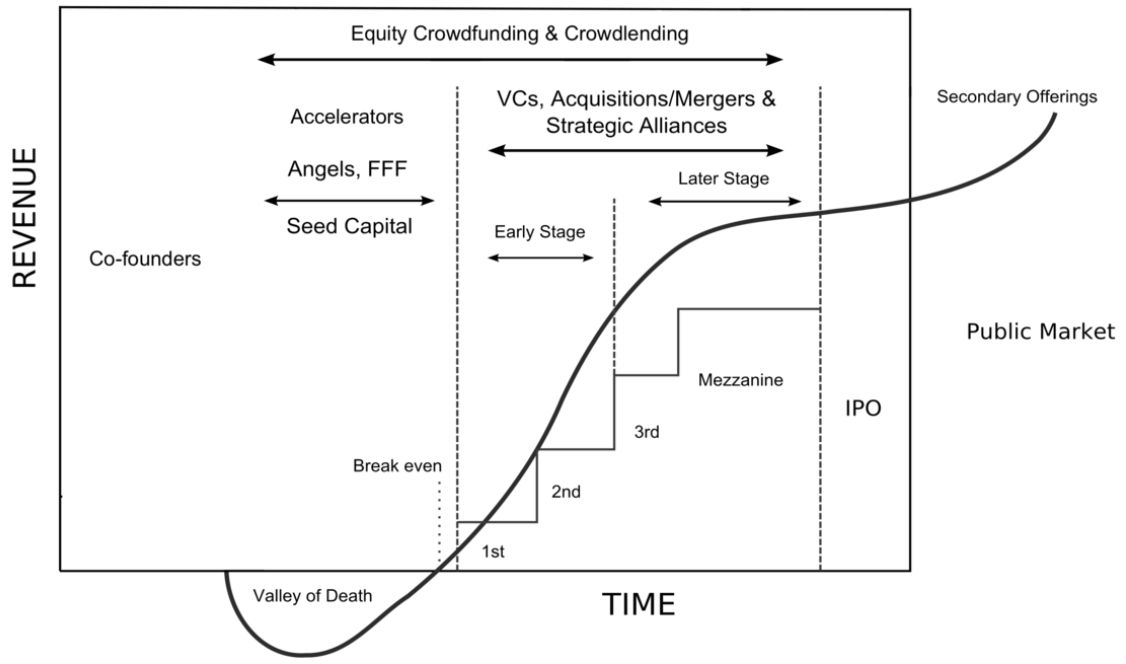

Figure 1*: Ventures financing cycle (Cardullo, 1999)*

Young, fast-growing and knowledge-based ventures (namely *New Technology Based Firms or NTBFs*) constitute a privileged investment target for VCs. NTBFs are widely recognised as important drivers for the development of countries' economy. Their key feature consists in the ability of providing a quick response to the changing needs and preferences of society and they contribute to the evolution of processes and to the creation of new jobs (Burżacka and Gąsiorowska, 2016). They are drivers of innovation, which in turn is the primary instrument of competition for many firms (Schumpeter, 1934). If on one hand NTBFs are associated to high risks, on the other hand they are characterised by exceptionally high-growth and high-returns potentials (Czarnitzkiabc and Delanoteab, 2012). Being prone to innovate, they tend to gain market share, create new product markets, and use resources more productively (NRC, 1996).

Although it is widely recognised by scholars that VC-backed NTBFs are likely to outperform their non-VC-backed counterparts, this phenomenon is associated to two distinct mechanisms (Gompers and Lerner, 2001). On one hand, VCs may have better *scout* capabilities, in the sense that they are more able to identify, in the pre-investment phase, those ventures that have higher-growth prospects (i.e., picking winners). Related

to this first mechanism, since other resource holders recognize that VCs are good at identifying promising firms, a VC investment facilitates the venture's access to other financial sources (Stuart, Hoang and Hybels, 1999). On the other hand, VCs may provide portfolio firms with additional post-investment competences, resources and connections which can foster venture's growth (i.e., building winners) , thus exerting a *coach* function (Baum and Silverman, 2004; Colombo and Grilli, 2010). In other words, VCs can affect selection by acting as a *scout* able to identify potential and as a *coach* (Hellmann, 2000) that can help realize it. Both roles result positively associated with the subsequent performance of the venture and there is no sufficient evidence of one prevailing over the other.

As far as VCs' scouting role is concerned, it entails selecting the most promising investment targets among a number of potential ventures. This task is not smooth at all since the potential of a new venture is never directly observable for an external investor (Stuart, Hoang and Hybels, 1999). NTBFs, due to their nature, are subject to strong uncertainties in terms of survival chances, probability of success of the developed products (and associated technology) and extent of this success (Sorescu, Chandy and Prabhu, 2003).

It stands out that VC market is an imperfect market. Strong information asymmetries exist between entrepreneurial ventures and VC investors, which may hinder the capability of the latter to *scout* the most promising firms. In order to overcome this information gap and be selected by VCs, entrepreneurs need to communicate the quality of their venture through appropriate signals (Colombo, Meoli and Vismara, 2018). VC investors, relying on these observable characteristics, are able to infer the quality of the venture and its future potential in terms of growth and returns. In that sense, signaling theory has largely been applied to the entrepreneurial context, and specifically as a response to the adverse selection problem occurring in the context of VCs' decision-making process.

In this regard, this Thesis finds inspiration from the extant literature about the role of signals in VCs' investment decisions. It focuses on one specific signal, founders' human capital endowment, and investigates its effect as risk-enhancer or risk-mitigator in

response to the uncertainty introduced by a radical invention. In other words, starting from the assumption that radical inventions make ventures more uncertain, this work wonders whether this higher perceived risk may result mitigated or rather enhanced by the signaling effect of certain human capital features of the founding team.

The Thesis proceeds as follows. The next section provides an overview of the theoretical and empirical literature regarding (i) the main features of the VC industry, (ii) the key concepts of information asymmetries and signaling theory applied to the context of NTBFs and specifically biotech ventures, (iii) the signaling effect of patents in NTBFs and (iv) the signaling effect of human capital in NTBFs. In Chapter 3, after an analysis of the literature gap, the research question and the research hypotheses are formulated. Next, Chapter 4 presents the descriptive statistics of the dataset, firstly at the individual level (i.e., statistics regarding the features of the founders associated to the companies of the sample) and then at company level. Chapter 5, instead, illustrates the specification of the econometric models, together with the description of the dependent, explanatory and control variables. The results of the econometric estimates are then presented in Chapter 6 and precede an extensive discussion of the main findings, performed in Chapter 7. Finally, Chapter 8, illustrating final remarks, work's limitations and directions for future research, concludes the Thesis.

2. Literature Review

This Chapter presents the theoretical background of the Thesis. It deals with the main theories and principles constituting the backbone of all the arguments treated. It starts with an overview of the VC industry and of the dynamics characterising the relationship between VC investors and new ventures. Next, it presents the key concepts about signaling theory, with a focus on the entrepreneurial context. Then, it shows theoretical and empirical evidences of the signaling role of patents and of the human capital endowment of ventures' founding teams.

2.1 Overview of the VC industry

This section illustrates the main activities and scopes of VC firms. It also describes VCs according to their organizational structure, distinguishing between independent and captive VCs. Finally, it provides several insights about syndicates of VCs are and the main benefits associated to them.

2.1.1 The activity and scope of VCs

Venture capital is generally assessed as one of the most suitable financing modes for early and later stage entrepreneurial ventures to raise external capital (Gompers and Lerner, 2001). VCs' typical activity consists in pooling capital from institutional investors (e.g., pension funds, university endowments) and making investments with it, linking their compensation to the returns of those investments. Since the VC manages only a small share of his capital, the institutional investor faces a relatively contained risk exposure. Due to the nature of this agreement, VCs are prone to invest in risky ventures that can potentially ensure extremely high returns, maximising their own compensation and that of the institutional investor (Zider, 1998).

When investing in those firms, the final objective of VC investors is to *exit* after few years by liquidating the equity stakes at a much higher value with respect to the original purchasing price, thus realising high capital gains in few time (Cumming, Fleming and Suchard, 2005).

Most exit studies focus on the type of exit. First, promising ventures which achieved significant profitability and solid track record can be quoted on a stock exchange through an Initial Public Offering (IPO). In this case the firm may issue new shares and sell them to both retail and institutional investors, or rather sell existing shares to the public allowing existing investors (i.e., the VC) to cash-out their stakes. A second exit strategy consists in being acquired by another company. In this case, however, VCs' returns are expected to be lower than what they would be in the IPO case (Da Rin, Hellmann and Puri, 2011). IPOs and acquisitions are interpreted as successful events, while it is considered a failure if the company closes down or remains alive after many years (the so-called *living dead*).

2.1.2 Organizational structure of VCs

VC investors differ along several dimensions, among which the most important is the type of ownership and governance (Bertoni, Colombo and Quas, 2015), since it strongly influences VCs' objectives and investment decisions as well as the competences and resources added to portfolio firms (Colombo and Murtinu, 2014).

Different configurations of ownership characterise different typologies of VCs. The first distinction can be made between *independent* VCs (i.e., *IVCs*) and *captive* VCs. The former is the most familiar typology and consists in investors acting as limited partners who invest money on behalf of institutional investors and wealthy individuals (Sahlman, 1990). Captive VCs, on the other hand, are structured as investment vehicles or as business units of a parent company and can be distinguished into three main sub-typologies: (i) *corporate* VCs, (ii) *bank-affiliated* VCs and (iii) *government-affiliated* VCs (Bertoni, Colombo and Quas, 2015).

Corporate venture capitalists (CVCs) are non-financial corporations that make venture capital investments, either directly or through a wholly owned subsidiary (Da Rin, Hellmann and Puri, 2011). The parent company is responsible for the investment decisions and provides both the financial and non-financial capital (e.g., Intel Capital, division of Intel Corporation). While seeking financial gains, CVCs are also interested in strategic benefits that may arise from synergies with their core activities. They are aware of their perfect technology partner and have a stronger incentive with respect to IVCs to invest in younger and riskier ventures operating in R&D intensive industries (Chemmanur, Loutskina and Tian, 2014). Looking at the deal from the venture's perspective, however, a model developed by Hellmann (2002) claims that also the entrepreneur's choice between being financed by an IVC or a CVC depends on synergistic perspectives. If the venture is developing a technology that is complementary to the CVC's core activities, then the entrepreneur would opt for the CVC as it is likely to provide a more effective support. Contrarily, if the venture's technology is a substitute for the CVC's core assets, then there is a trade-off. On the one hand, the CVC would offer a higher amount of money, while the IVC would provide more valuable support. In general, if the technology represents a mild threat, the optimal choice for the entrepreneur is to choose an IVC, while if it is a strong threat, then IVCs and CVCs are likely to syndicate the deal.

Bank-affiliated venture capitalists (BVCs) are VC investment vehicles owned by a bank or other financial institutions (e.g., City Venture Capital International, owned by Citigroup). While CVCs actively influence and monitor their portfolio ventures, BVCs act as passive investors providing almost exclusively financial resources. Furthermore, BVCs invest more in companies operating in industries with higher debt and leverage levels since the main strategic objective is increasing further their demand of debt (Da Rin, Hellmann and Puri, 2011). They tend to pick later-stage ventures and ventures operating in countries with more developed financial markets and stricter accounting disclosure requirements (Cumming and Murtinu, 2017). In general, BVC-backed ventures are more likely to receive debt capital from banks (and to receive it at lower rates) with respect to non-BVC-backed

ones, especially if they show low default risk and solid operating performances (Hellmann, Lindsey and Puri, 2008).

Government-affiliated venture capitalists (GVC) are governmental entities that either own venture capital funds to finance local entrepreneurial ventures, or favour entrepreneurial ventures' financing through indirect programs and policy measures (Gompers and Lerner, 2004). Differently from the other VC typologies, GVCs do not only seek financial returns, but they are also more concerned with political objectives, such as reducing unemployment, investing in local economy and boosting the development of national or regional technological hubs (Lerner, 2009).

2.1.3 Syndicated deals in the VC industry

A remarkable feature of VC financing is that investments are often syndicated, which means that two or more VCs jointly finance a certain venture (Brander, Amit and Antweiler, 2002). A formal definition of the term is provided by Wright and Lockett (2003), who describe a VC syndicate as "a form of inter-firm alliance in which two or more venture capital firms co-invest in an investee firm and share a joint pay-off".

Syndication is a concept that does not apply only to the VC context, but rather occurs also with other kinds of investments. VC syndication is just one example of a general phenomenon (in which one party of a project brings in other partners), which is gaining popularity in the business landscape as a response to a growing dynamism and competition (Mowery, Oxley and Silverman, 1996). For example, equity joint ventures are, to some extent, similar to VC syndicates.

Syndication is a widespread phenomenon in the VC industry. The reasons leading to syndication may vary from case to case. It is frequent, for instance, that syndicates originate even though the venture's capitalization requirements are modest with respect to the resources owned by any of the VCs (Brander, Amit and Antweiler, 2002). However, given the magnitude of the phenomenon, scholars have tried to categorize the main motives that induce VCs to syndicate.

The first is a *finance* motive, that is composed of two main arguments: (i) for a small VC firm, syndication is a way to fund projects with high capital requirements without unbalancing the portfolio, (ii) syndicated investments allow VCs to invest in more ventures and experience stronger diversification benefits (Lockett and Wright, 2001; Checkley, 2009). Second, being the VC market characterised by strong information asymmetries, syndication represents for VC firms a means to better judge entrepreneurial ventures and limit the adverse selection problem (i.e., *improved selection* motive) (De Clercq and Dimov, 2010). Third, through syndication, VCs can join their complementary competences, resources and connections and offer them to the venture, resulting in a more effective treatment effect (i.e., *value-adding* motive) (Brander, Amit and Antweiler, 2002). Fourth, having a solid syndication network strengthens the status and the visibility of the VC, increasing the likelihood of being invited into the next syndicated investment (i.e., *deal flow* motive) (Lerner, 1994). Along with the most popular motives listed above, many others (more case-specific) can be identified, such as importance of reputation building or protection for a certain VC firm.

All the members of the syndicate are supposed to have an equity stake in the venture, but they are not necessarily required to invest the same amount of money. Furthermore, syndication generally occurs after the first VC investment. According to the work of Brander, Amit and Antweiler (2002), overall, three alternative patterns for syndication can be identified. First, one VC (namely, the *lead investor*) invests in the venture when it is in the early-stage and, shortly after (or simultaneously) syndication takes place. This is the most common pattern. In fact, among all the ventures backed by more than one VC, about 70% received an investment from a second VC within the same calendar year as the initial investment. Alternatively, the lead investor makes a seed or early-stage investment and syndication occurs in a later stage. In this case, the future of the venture principally depends on the experience of the lead investor. Specifically, if the lead investor experiences a poor outcome at the initial stages the venture is likely to fail. In the third (and least common) pattern, VCs syndicate at the seed or start-up stage. Nevertheless, a

common characteristic of all the patterns is that the lead investor is the one deciding whether to syndicate or not.

Brander, Amit and Antweiler (2002) also performed a pioneering analysis on the relationship between syndication and performance. In particular, the results of their models suggested that syndicated deals tend to lead to higher returns. They justified this outcome through the *value-adding hypothesis*, according to which the treatment effect of a syndicate of VCs is more effective as they benefit from the integration of complementary skills. Several papers further developed this theory, supporting the idea that syndicated deals perform better. Tian (2011), for instance, claimed that they are more likely to experience a successful exit, benefit from higher IPO valuations and are less under-priced at IPOs.

2.2 Signaling theory

This section aims at providing a comprehensive overview of signaling theory as a response to information asymmetries. The main concepts behind the theory are presented and applied to the relationship between new ventures and VC investors. At the end of the Chapter, the role of signals is investigated in the biotech industry, a very uncertain context characterised by particularly strong information asymmetries.

2.2.1 Key concepts in signaling

Signaling theory is fundamentally concerned with reducing information asymmetry between two parties (Spence, 2002). The origins of signaling theory go back to Spence's (1973) seminal work on labour economics, where information asymmetries were introduced into economic models of decision making. In this work, the author illustrated through a hypothetical labour market problem the utility of signaling theory for achieving optimizing solutions for both the signaller and the receiver.

In the labour market information asymmetries between job applicants and employers hamper the selection ability of the latter. Employers take time to assess and learn the

productive capabilities of job applicants since they are not known beforehand. This makes the hiring process an investment decision and puts it under uncertainty. In that sense, hiring can be considered as purchasing a lottery, where the employer pays to the employee the monetary equivalent of the lottery in terms of wage. In turn, assuming risk-neutrality, wage corresponds to the marginal contribution of the employee to the hiring organization. In this context, the author demonstrated that employees can reduce this information gap by engaging in specific behaviours. In particular, high-quality employees can signal to employers their quality and distinguish themselves from low-quality ones, for instance through the costly signal of a certification of rigorous education. Although the employer cannot directly observe the marginal productivity of a worker beforehand, he does observe characteristics of the individual (i.e., education, previous work, race, sex and others), on which he bases his assessment. Of those observable attributes, some are immutably fixed while others are alterable. Each individual can leverage on those alterable attributes to invest in their own image and signal their quality to the employer.

Going more in details, three main concepts constitute the pillars of signaling theory: (i) information asymmetry, (ii) the signal, (iii) the receiver and the signaller.

Information asymmetries arise when "different people know different things" (Stiglitz, 2002) and they affect decision-making processes in a wide range of fields. In general, individuals make decisions on the basis of both public information (freely available) and private information (available only to a part of the public). Being some information private, asymmetries originate when one party holds the information and the other does not, but could potentially make better decisions by having it. For more than a century, information asymmetries were neglected and economic models of decision-making processes were assuming perfect information. These models were developed under the assumption that markets with minor imperfections would behave substantially the same as markets with perfect information (Stiglitz, 2000). Various economists subsequently studied the influence of information asymmetries in decision-making processes. Among them, George Akerlof, Michael Spence and Joseph Stiglitz received the 2001 Nobel Prize in Economics for their work in information economics.

Information asymmetry is particularly critical when dealing with two main typologies of information: (i) information about quality and (ii) information about intent (Stiglitz, 2000). Hidden quality problem, also known as *adverse selection problem,* arise when one party lacks information on the characteristics and attributes of the other party (Akerlof, 1970). On the other hand, hidden intent problem, also known as *moral hazard problem,* is important when one party ignores the other party's behaviour or behavioural intentions (Elitzur and Gavious, 2003). In this respect, signaling theory is studied only as a response to the first typology of information asymmetry, which is addressed by the majority of management studies about signaling theory (Connelly *et al.*, 2011).

In imperfect information contexts, the most informed party is endowed with both positive and negative information and must decide whether to communicate this information to the less informed one. Signaling theory investigates mainly the deliberate communication of positive private information to outsiders in order to convey a positive image. The signaller could potentially communicate to the uninformed party a big number of observable attributes, but not all of them are useful as a signal. Specifically, in order to constitute an efficacious signal, the attribute should present two imperative characteristics: (i) observability and (ii) cost (Connelly et al., 2011). Observability refers to the capability of the receiver to notice the signal. Cost, on the other hand, refers to the condition that the cost of signaling must be lower for high-quality signallers (Hoenig and Henkel, 2015). Signal cost is sometimes referred to as a separated theory, namely *theory of costly signaling* (Bird and Smith, 2005). If a signaller is low-quality but perceives that the benefits of signaling are higher than the cost of producing the signal, then he/she may be tempted to produce a false signal. Therefore, in order to discourage the emission of false signals and maintain effectiveness, the costs of credible signals must be inversely related to the quality of the sender. In other words, low-quality signallers must invest at a much higher level than high-quality signallers to convey the same signal of quality (Connelly *et al.*, 2011; Bergh *et al.*, 2014).

Receivers (uninformed party) and signallers (more informed party) represent the last key elements of signaling theory. Signaling takes place only if, thanks to the signal, the signaller

can benefit from some actions from the receiver, that the receiver would not otherwise have done. In other words, signaling should have a strategic effect and usually involves a selection of the signaller in favour of several alternatives (Connelly *et al.*, 2011).

Signals can be evaluated on the basis of different attributes that jointly assess the effectiveness of the interaction between signaller and receiver. First, a signal can be defined as *strong* or *weak.* In literature the concept of signal strength has been principally associated to its observability in absence of environment or receiver distortion (e.g., Gulati and Higgins, 2003). Many management scholars have shared this view, although they used related terms such as signal clarity, intensity or quality (Connelly *et al.*, 2011). A second relevant aspect is signal *fit*, which assesses the correlation between the signal and the signaller's unobservable quality (Busenitz, Fiet and Moesel, 2005). Third, signal *frequency* represents a key aspect. A signal communicates the signaller's unobservable quality in a specific point in time. Therefore, the signaling process becomes more effective if the signaller sends the same signal repetitively or, even better, if he sends different signals to communicate the same quality (Janney and Folta, 2003; Balboa and Marti, 2007). Finally, this concept is related to signal *consistency*, which describes the alignment or contradictions between different signals sent by the same signaller. Keeping signals consistent among each other is crucial since conflicting signals can confuse the receiver and make the signaling process inefficient (Fischer and Reuber, 2007).

2.2.2 Separating equilibrium in signaling games

To fully apply signaling theory in a study, however, it is necessary to develop and test for the presence of a *separating equilibrium*. It represents the key mechanism behind signaling theory (Bergh *et al.*, 2014). A separating equilibrium is identified when every difference in signaller state is reflected by a difference in the signal sent. Hence, at this equilibrium, the receiver can exactly infer the signaller's quality from the signal sent (Bergstrom, Számadó and Lachmann, 2002).

As Spence (1973) illustrated in his work, a separating equilibrium arises from the differential signal cost for high-quality versus low-quality signallers. Going back to

Spence's example of labour market, assuming that employees and employers are rational, a high-quality employee will become certified while a low-quality employee will not. Indeed, the cost for gaining the certification (signal of quality) is higher for a low-quality worker rather than for a high-quality worker. These differences in signaling constitute the basis for employees' selection process in which they use the signal to select a signaller from a larger set. When a high-quality worker meets employer's post-hiring expectations and receives his/her compensation, then the equilibrium is reached. Specifically, in this case the equilibrium is Pareto optimal, since there is no alternative solution that could not make any party better off without making the other party worse off (Spence, 1973).

In sum, a separating equilibrium occurs when the following four conditions are met: (i) there are information asymmetries, (ii) the signal is costly and the costs is inversely related to the quality of the signaller, (iii) Pareto optimizing logic is implemented by signallers and receivers to derive expectations and rewards, (iv) signal is confirmed through subsequent data and experience (Bergh *et al.*, 2014).

Nevertheless, an alternative way of creating a separating equilibrium would be involving in the signaling process a third party (i.e., a prestigious affiliate or an intermediary). This third party must be more informed than the receiver about the signaller's quality and must be willing to sustain the signal cost (Pollock, Porac and Wade, 2004). An example can be found in the entrepreneurial field. Investors' decision to fund new ventures represents a very uncertain context, entailing strong information asymmetries. This information gap proves to be reduced when a venture is backed by a prestigious venture capitalist (VC). Indeed, in this case the investor (i.e., the signal receiver) is more willing to invest, mainly on the basis of two main arguments. First, prestigious VCs tend to have better scouting capabilities. They have presumably achieved their prestige through a series of prudent decisions, and the affiliation with this additional venture is likely to be one more of such decision. Second, prestigious VCs are aware of the high value of their reputation. In front of the wide set of potential affiliations they are only willing to sign those deals that are likely to reinforce rather than hamper their prestige (Stuart, Hoang and Hybels, 1999). In that sense, this third party creates a separating equilibrium since investors (i.e., receivers)

invest in high-quality ventures by trusting the affiliation decision of prestigious VCs (Bergh *et al.*, 2014).

2.2.3 Information asymmetries between NTBFs and external investors

Starting from the seminal work of Spence (1973) an enormous volume of literature, belonging to a wide range of fields, has invoked signaling theory. Applying signaling theory as developed by Spence to real-world contexts, and specifically to the context of companies, has been particularly challenging because different actors may have different abilities to interpret signals and because it is difficult to agree on the signaling value of a certain action (Haeussler, Harhoff and Mueller, 2014). For instance, a study of Zhang and Wiersema (2009) illustrates that CEOs signal the quality of their firms to potential investors through the quality of their financial statements. Studies concerning diversity demonstrate that firms signal to external stakeholders their adherence to social values through heterogeneous boards (Miller and Triana, 2009). Nevertheless, among the various applications of signaling theory, the entrepreneurial field is of particular relevance.

Signaling theory, indeed, is frequently invoked inside the entrepreneurial literature. Among the various contexts of study, particular attention must be paid to the signaling process occurring between NTBFs and VCs. Being backed by VCs is crucial for NTBFs for several reasons. VCs constitute the main source of funds for NTBFs (Gompers and Lerner, 2004). Also, they have a signaling value themselves to attract further investments and benefit from more successful IPOs (Stuart, Hoang and Hybels, 1999; Elitzur and Gavious, 2003).

Signaling theory perfectly applies to the relationship between ventures' founders and VCs since strong information asymmetries exist between the two parties. As previously discussed, VCs generally invest in start-ups when they are in their early- or later- stage of growth. At this phase, it is very hard for an external investor to capture the potential of the venture as there are no observable characteristics on which the evaluation can be based. First, their assets are almost entirely intangible (i.e., new ideas and inventions), which makes the venture's evaluation extremely hard (Hall, 2018). Second, early-stage ventures

have less restrictive requirements as concerning disclosure of accounting information and strategic objectives, they are not assessed by external auditors and, usually, they are not required to register to national regulatory agencies. In some cases, entrepreneurs may exploit this lack of regulations and oversell the quality and the viability of the technology in order to get a more favourable access to financial resources (Arthurs and Busenitz, 2003). Also, being absent from capital markets, NTBFs are exempt from the evaluation of expert investors, generally reflected in the stock price (Berger and Udell, 1998). NTBFs lack proper track records and their projected financial statements are generally scarcely reliable. Indeed, given the young age of the firm and the high uncertainty characterising new technologies, entrepreneurs find it difficult to make objective estimations of projected cash flows. They also tend to be over optimistic about their business ideas and often over-state the value of their venture (Baum and Silverman, 2004).

Moreover, being characterised by a strong technological component, they are subject to additional hazards. Undeveloped markets may experience unexpected turns, hyped technologies can disappear or become rapidly obsolete. Also, due to their young age, they usually lack adequate employee commitment, knowledge about the environment, network and connections (Baum and Silverman, 2004). Moreover, being inexpert and small, they may be unable to sustain a period of poor performance and are thus vulnerable to the so-called *liability of newness* (Hannan and Freeman, 1984).

From the above-mentioned arguments, it stands out that (i) NTBFs are risky firms, characterised by strong uncertainties about financial projections and survival chances and (ii) NTBFs' quality cannot be observed directly. It is an imperfect market characterised by an adverse selection problem, where VCs mainly rely on observable attributes and characteristics (which are supposed to co-vary with the underlying quality) and take them as a basis for drawing conclusions about the venture's quality. Hence, VCs assess the value of a venture by estimating the conditional probability that it will succeed, given a set of observable characteristics (Stuart, Hoang and Hybels, 1999). In that context, a quality signal can be defined as information able to alter an observer's probability distribution of unobserved variables (Hsu and Ziedonis, 2013). And that is the reason why VCs put a lot

of effort in seeking and assessing venture's observable features as signals of quality and potential (Hoenig and Henkel, 2015).

At the same time, from the entrepreneur's point of view, being noticed and selected by VCs is challenging and is substantially a matter of sending the right signals (Colombo, Meoli and Vismara, 2018). The literature has largely investigated how entrepreneurs communicate quality to venture capitalists (VCs) and several signals of quality have been identified. First, founder ownership is an effective signal since the founder is the one who possesses more information than anyone else about the quality of the venture (Busenitz, Fiet and Moesel, 2005). Second, the characteristics of the board of directors (Certo, 2003) and of the top management team of the firm (Lester *et al.*, 2006; Zhang and Wiersema, 2009) are also an important means to signal the quality of the venture. Third, the human capital (i.e., education and previous work experiences) of the founders also represent a signal of quality (Burton, Sørensen and Beckman, 2002). Fourth, granted patents and patent applications may allow entrepreneurs to communicate the quality of their underlying technologies to investors (Hsu and Ziedonis, 2013).

2.2.4 A special focus on biotechnology ventures

Among the NTBFs, a particularly attractive industry for VCs is biotechnology. (Zucker, Darby and Brewer, 1998). In 1992 the Convention on Biological Diversity (CBD) defined biotechnology as "any technical application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use". The history of biotechnology can be traced from the beginning of scientific agriculture and fermentation and for centuries the principles of biotechnology were restricted to agriculture. Then, throughout the 19th century, biotech industry experienced a rapid growth, thanks to significant scientific advancements in related fields (i.e., discovery of micro-organisms, Mendel's studies of genetics, innovative works on fermentation and microbial processes, discovery of penicillin by Fleming). In the second half of the 20th century, the growth of biotech industry was boosted by breakthrough discoveries (i.e., the 3D structure of DNA, the development of biotech-derived drugs and vaccines against

cancer or hepatitis, the completion of human genome sequence), and has been soaring over the last decades (Christensen *et al.*, 2002). The industry is characterised by the presence of two categories of players: giants on one hand (e.g., Amgen, Biogen, Gilead Sciences), and thousands of small and dynamic firms on the other.

Thanks to their potential for high returns, biotech ventures are a very interesting investment target for VC firms, which have already invested large amounts in the industry (Gompers and Lerner, 2001; Baum and Silverman, 2004). Nevertheless, these high returns are accompanied by an exceptionally risky nature. Those companies are likely to face particularly complex scientific hazards caused by long research cycles and challenging legal environments (DiMasi and Grabowski, 2007).

Due to their nature, biotech NTBFs pose specific challenges to VC investors. This industry is characterised by a very close relationship between basic R&D and the novelty of the products, which, in turn, is a fundamental requirement for commercial success. Although it is crucial for VCs to be confident about the scientific quality of the venture (Zucker, Darby and Brewer, 1998), they usually do not have the proper knowledge to assess it (Junkunc, 2007). Regarding that, the fact that all NTBFs are reluctant to disclose information about their underlying technologies worsen this information gap (Janney and Folta, 2003). Hence, due to the industry nature, when investing in biotech firms, VCs are faced with the highest level of information asymmetries. As a consequence, they tend to rely as much as possible on observable characteristics, assess them and use them as a signal of quality. In this sense, biotech industry constitutes the perfect context to study the role of signals in NTBFs.

In particular, among the portfolio of signals owned by a venture, patent applications (both granted and pending) are one of the most influential ones (Hoenen *et al.*, 2014), especially in knowledge-intensive industries. In this regard, evidence suggests that the weight that VCs attribute to patents is much higher when they decide to invest in biotech ventures compared to any other high-tech industry, perhaps reflecting the strong relationship between innovation and patents in biotech industry (Arundel and Kabla, 1998).

2.3 The signaling effect of patents in NTBFs

Among the portfolio of signals owned by NTBFs, patents play a crucial role especially in knowledge-intensive industries. Moreover, thanks to their rich information content, patents can provide insightful information about the features of a venture's underlying invention. In this regard, this section provides a broad description of patents and explores the literature supporting their role as signals, both in theoretical and empirical terms. Furthermore, it illustrates how patents' information content can be used as precious source of data to assess the radicalness of the patented invention.

2.3.1 Main features of patents

Along with copyrights, trademarks and trading secrets, patents represent one of the means that a company has to protect its intellectual property. Auerbach, in his work *Patent Law Principles & Strategies* (2006), illustrates the main features of patents and patenting processes. In particular, patents are defined as the broadest form of intellectual property protection, which allow to protect the product or process invented as well as all the variants of those products or processes employing the underlying invention.

Patents can be classified as *utility* or *design* patents. The former is used to protect the functional aspects of the invention, while the latter focuses on the ornamental features of the invention. Analogously to the deeds of real property, governments require patents to specify the boundaries of the property claimed as involved in the invention. Differently from real property, however, defining the boundaries of an invention is much less obvious and precise. Therefore, patents often come with a set of claims that move from a broad description of the intellectual property, towards a much more detailed one.

A patent cannot protect the underlying invention forever, but it rather holds for a limited number of years. During this period, it can exclude others from making, selling, using or importing the invention. In particular, the rights associated to a utility patent hold up to the 20th year from the patent's filing date (or the 17th year from the patent's issue date, if filled before the 8th of June 1995). The duration of a design patent, on the other hand, is 14

years from the patent's issue date. The precise term of a utility patent, however, may vary significantly according to various factors.

Patents are granted by governmental authorities (i.e., patent offices) such as the European Patent Office (EPO), United States Patent and Trademark Office (USPTO) and others. The choice of a specific patent office is extremely relevant since a patent can be enforceable only in the country that granted it. The scope and the content are carefully examined by the Patent Examiner and the final version results from a negotiation process he carries out with the patent applicant and the patent counsel. Nevertheless, it is worth to highlight that patents do not confer to the owner an affirmative right to practice the underlying invention. It rather entails the right to exclude others from making, using, selling or importing the invention. In fact, the possibility to fully practice the invention may be constrained by other patents.

An invention is patentable only if it meets three criteria: (i) *utility*, (ii) *novelty* and (iii) *non-obviousness* (or *inventive step*).

As far as it concerns utility, two independent tests are provided by the patent statutes to assess whether a certain idea meets this criterion or not. First, the idea must be describable as a process, machine, manufacture, composition of matter or an advancement of those classes of ideas. Any invention that does not belong to one of these classes cannot be protected by a patent (e.g., mathematical expressions, physical laws). Second, it must be useful, namely it has to entail a certain use. Any invention or idea which that does not have any concrete use or that is inoperable (e.g., methods for synthesizing an organic compound without a known function) are excluded from patents.

Novelty, on the other hand, can be defined with respect to the date of invention or to the date upon which the applicant filed for the patent application. The European patent convention privileges the latter, meaning that it precludes patentability if the invention has become publicly available in any way (i.e., it has already been patented, described in a printed publication, publicly used or sold) before the date of application. In the USA the attribute of novelty is defined by seven complex definitions, all of which has to be met

separately. Some of them define novelty with respect to the date of invention (i.e., the initial mental conception of the idea) while others refer to the date of filing the patent application. The interplay of those definitions provides a one-year *grace period*. Namely, in the USA the inventor can freely publish the invention without compromising its patentability. However, this rule only applies for the USA. If an inventor does so, his/her invention is no more patentable in Europe and many other countries.

Lastly, the invention is required to be non-obvious. Regarding this criterion, while the US regulation only requires non-obviousness, the European convention provides a stricter interpretation of this term. According to European rules, a patent application is asked to involve an inventive step. Specifically, an invented step is involved if the invention it is able to solve a technical problem in a non-obvious way. In other words, the invention has to (i) solve a problem and (ii) that problem must be technical.

2.3.2 Patents as a signal of quality in NTBFs

Being associated to high risks and uncertainties, when VCs invest in NTBFs they put even more effort in assessing observable features as signals of quality. As a new technology is proposed and intangible assets (i.e., the idea) are substantially the only resources available, a key role is played by patents. Patents have an important value themselves, as they offer the firm a series of benefits such as monopolistic market rights, protection from competitors and higher negotiation power (Hoenen *et al.*, 2014). Besides that, granted patents and pending patent applications also act as powerful signals of the potential of the venture for VC investors (Hall, 2018).

Up until the 2000s, patents have been considered as a relevant, but not very important, selection criterion for VCs and only in the last decades they have attracted scholars' attention. Since then, a long stream of research has demonstrated the positive effects that patents have on VCs' investment decision in case of NTBFs. One obvious reason why an investor prefers a patented idea compared to an unpatented one is that the expected profitability is higher since the returns deriving from commercialization are easy to appropriate. Also, the presence of patents allows to increase the value of the firm in case

of failure of exit, thus limiting losses (Hall, 2018). Besides the usual appropriability and salvage value functions, patents also play a significant role in reducing the information gap between the entrepreneur and the VC and signaling the quality of the entrepreneurial idea. By the time an entrepreneur fills a patent application, indeed, he signals that the venture has matured enough to invest in the protection of the underlying technology (Long, 2002). For VCs, patents are the evidence that the firm is well-managed, that the research is proceeding quickly, that it has achieved a certain development stage and that it has targeted a specific market niche (Lemley, 2001). In other words, they constitute a Spencian signal of the quality of technology developed by a NTBF.

Patents, indeed, conform to Spence's criteria for quality signals. First, they are freely available and thus observable. Second, filling a patent has a cost for the venture and, specifically, a differential cost which is a decreasing function of the quality of the underlying technology. Third, patent applications constitute a vehicle to sort companies and, in that sense, they favour the achievement of a separating equilibrium (Long, 2002; Hsu and Ziedonis, 2013).

In order to patent an invention, the entrepreneur must demonstrate its novelty, originality and its potential in industrial applications. Undertaking the patenting process is costly in terms of effort, time and money. On the one hand, it requires to follow strict guidelines and to provide detailed technical information. On the other hand, the entrepreneur has to pay a number of fees (including the fees of patent lawyers) and the translation costs. Being those costs inversely proportional to the quality of the technology developed, patents can be interpreted by VCs as a signal to distinguish high-quality from low-quality inventions, playing the same role as education in Spence's model (1973). The signaling role of patents remains effective as long as they are correlated to the actual quality of the venture.

Furthermore, an important role in the signaling process of patents is played by the patent office. The patent office provides the VC with reliable information about the quality of the venture's patent over an extended time horizon. The VC relies on this information to get insights about the available patent documents and to assess the patent portfolios of potential investment targets (with the help of external experts) (Haeussler, Harhoff and

Mueller, 2014). The fact that the patent office strictly governs the patent application procedure makes the signaling effect of patents even more reliable. Indeed, scholars agree that signals governed by reliable institutions and thus conform to specific criteria and requirements tend to increase in value (Janney and Folta, 2003).

The strong signaling effect of patents explains why entrepreneurs start filing patent applications in earlier stages. Ventures' founders are aware that patents represent a strong signal of quality for VC investors and that, at the same time, VCs are often under considerable time pressure to make investment decisions. Therefore, although postponing the filling of patent applications would allow to benefit from the legal protection longer, they are prone to start earlier because VC investors might be negatively affected by postponements (Hsu and Ziedonis, 2013). To reduce the time to financing further, however, the patent application should also guarantee the generation of good news at and from the patent office (Hoenen *et al.*, 2014).

2.3.3 Empirical evidences of the signaling effect of patents in NTBFs

In line with the theoretical expectation that patents have a signaling effect on VCs, empirical evidence demonstrates that patents do serve this function, especially in case of knowledge-intensive ventures.

Hoenen *et al.* (2014), using a sample of biotech firms, demonstrated that patent applications have a positive correlation with VC investments during the first round of financing but not in the second. Considering only the productive value of patents on VC investment, the effect would theoretically increase in later founds thanks to higher synergies with other resources. Therefore, the fact that the positive correlation decreases over time, was interpreted by the authors as an evidence that the signaling value (versus productive value) of patents exists and is strong. This interpretation is based on the idea that as firms mature, information asymmetries between them and VCs result contained (i.e., the commercial value of the business idea has been proved, track records are available). Hence, the signaling value of patents decreases and does not play any role in the second round of VC investment. The authors also argued that pending patent

applications have an even stronger effect compared to granted patent applications, because VCs see more opportunities in the former. A final remark of Hoenen *et al.*'s work (2014) highlights that the amount invested by VCs is also affected by characteristics of the VCs themselves, such as size, syndication and proximity.

Conti, Thursby and Othaermel (2013) examined a sample of (mainly) information technology ventures from an incubator at Georgia Institute of Technology and discovered that the number of patents filed by a venture positively affects the likelihood of receiving a VC investment as well as the amount invested. Similarly, Cao and Hsu (2011) considered a pool of U.S.-based VC-backed ventures and demonstrated that the higher the number of filed patent applications, the larger the amount invested and the lower the probability of failure. A comparable outcome has been reached by Engel and Keilbach (2007), who, from the analysis of several German ventures, found that VC-backed firms hold more numerous patent applications at pre-funding stage compared to non-VC-backed firms.

Moreover, several empirical evidences prove that the role of patents as signals is particularly effective under certain conditions and within certain industries. Hsu and Ziedonis (2013), through a study conducted in the semiconductor industry, claim that (i) patents are a particularly influential signal when the new venture lacks alternative means for communicate its quality to external investors, (ii) patents favours VCs' assessments in early stage of financing and (iii) conditioned to an IPO exit, patents allow to cover the information gap in absence of prestigious VC investors.

In terms of industries, a number of empirical studies demonstrate that the signaling effect of patents gains even more relevance in case of emerging firms in knowledge-intensive industries, where information asymmetries are particularly strong. Indeed, firms in these industries, such as biotechnology, suffer from stronger uncertainties as they are faced with technical, scientific and regulatory obstacles that cannot be predicted ex-ante and are not easy to handle ex-post (Harhoff, 2011). Baum and Silverman (2004) demonstrated that knowledge-intensive NTBFs (in particular biotech NTBFs) possessing granted patents or pending patent applications are more likely to attract prominent VCs, prompt VCs to invest faster and with higher amounts. Similarly, Häussler, Harhoff and Müller (2012) showed

that biotech ventures tend to be backed by VCs earlier in case of existing patent applications and, particularly, if those patents are assessed as high quality.

2.3.4 Using patents to measure innovation's radicalness

As far as it concerns patents, an important feature to discuss is their *quality.* It is argued that high-quality patents allow to reduce the uncertainty characterising new ventures, foster innovation and promote ventures' success, with beneficial effects for entrepreneurship, employment and growth (OECD, 2015). Most scholars agree that the quality of a patented invention varies from patent to patent and that the probability of patenting an high-quality invention depends both on the firm and on the industry (Scherer, 1965). Nevertheless, there is no a unique interpretation of the concept of patent quality. In fact, it has been associated to numerous meanings and definitions, which are nor uncorrelated, neither overlapping. One of the drivers associated to patents' quality is the radicalness of the underlying technology. In other words, the capability of the patent to introduce a major invention rather than an incremental one (OECD, 2015).

The radicalness of an innovation refers to the extent to which it differs from previously existing products and processes (Verhoeven, Bakker and Veugelers, 2016). Incremental innovations generally involve only a minor change from (or adjustment to) existing practices. On the other hand, radical innovations (or *breakthrough innovations*) provide something new by uprooting industry conventions and changing customer expectations in a positive way (Deffains-Crapsky and Sudolska, 2014). It is worth to say that the bulk of radical innovations in the economy relies on young entrepreneurial ventures. Indeed, NTBFs offer two and a half times more innovations per employee compared to large firms (Acs and Audretsch, 2003).

Radical innovations have a very strong potential. They generally lead to paradigm shifts that are able to interrupt the predictable trajectories of traditional technologies, introducing completely new approaches (Dosi, 1982). In that sense, radical innovation may have a disruptive effect in re-shaping industries and markets. They may introduce the necessity of new competencies and drive existing players out of competition.

Besides their strong potential, they are also associated to a very high risk. They entail strong uncertainties since not all of them will result in successful technological breakthrough and, even when they do, they require extremely long processes with slow acceptance and diffusion (Fleming, 2001).

In most empirical studies, radical innovations have been identified ex-post, on the basis of their impact on product performance or on the market structure. Nevertheless, being able to characterise them ex-ante would allow to improve the awareness over their origins and effects, and thus exploit them at the most. To serve this scope, a number of recent researches have studied radical inventions in terms of the characteristics of their underlying technology, using patents as a source of data (Verhoeven, Bakker and Veugelers, 2016). In particular, the extant literature proposes several indicators of radicalness, which rely entirely on pieces of information contained in the patent documents. These measures allow to control for any field-specific shock (OECD, 2015). Furthermore, they are grounded on homogeneous information and apply for patents filed in any jurisdiction, meaning they are suitable for cross-country analysis (Verhoeven, Bakker and Veugelers, 2016).

Great part of the empirical studies conducted (and of the related indicators) mainly rely on patents' backward citation information. Authors such as Ahuja and Lampert (2001) looked at the number of citations, claiming that innovations whose patents does not possess any backward citation can be considered as radical. However, this measurement neglects those inventions that employ principles that, despite being already in place, belonged to unrelated technologies. Further studies focused on the role of citations, although they considered other aspects rather than the number. Among them, the work of Shane (2001) particularly stands out. He measured radicalness looking at how the citations are spread among the fields. Specifically, he linked radicalness to a time-invariant count of the number of technological classes to which the cited patents belong, excluding the ones in which the patent itself is classified. In this way, radicalness is associated to the extent to which the patent differs from other patents it has cited. Similar approaches have been used by other authors such as Rosenkopf and Nerkar (2001) or Nerkar (2003), who,

instead, considered the spread in age of the cited patents as a measure of technological novelty. The main drawback of these approaches, however, is that they fail to consider whether the patent is also unique compared to contemporaneous inventions (i.e., other patents filed in the same period in the analogous technological domain) (Verhoeven, Bakker and Veugelers, 2016). The indicator proposed by Dahlin and Behrens (2005) covered this gap. They assessed an invention's radicalness on the basis of its novelty, uniqueness and impact on technological development. In practical terms, they studied the citation trends before, during and after the patent application. The main weakness of this indicator is that it is binary in nature. OECD, however, is currently working to improve this measurement and transform it into a continuous variable.

Along with citations, other pieces of information appearing in patent documents have been used in literature as an ex-ante measure of radicalness. Fleming (2007), for instance, looked at the technological classifications assigned to the patent. In particular, he considered all the pairwise combinations of technology classes and assessed the previous existence of the pair within the list of patents filed before the application year of the concerned patent. In other words, he looked at how often and how recently a certain component or combination of components has been used before. A further contribution has been provided by the work of Verhoeven, Bakker and Veugelers (2016), who provided a more comprehensive measure of radicalness. Inspired by the study of Arthur (2007), they measured technological radicalness referring to three (related) dimensions: (i) novelty in *technological knowledge origins* and (ii) novelty in *scientific knowledge origins* and (iii) novelty in *recombination*. The three measures result correlated, but each of them conveys a specific information. Specifically, (i) and (ii) take into consideration the research questions pertaining to the sources of knowledge applied in the invention. The indicators measuring novelty in knowledge are mainly inspired to the work of Shane (2001). Novelty in recombination, on the other hand, is particularly relevant when the focus is on the elements and principles related to the functioning of the invention. In this case, the indicators proposed mainly recall the studies of Fleming (2007), analysing the originality of pairwise combinations of technology classes.

2.4 The signaling effect of founders' human capital in NTBFs

The human capital endowment of a venture's founding team constitutes another extremely powerful signal of quality for NTBFs. This section provides an overview of the concept of *human capital* and of its evolution over time. Moreover, it explores the literature concerning the signaling role of human capital in NTBFs, supporting this view through a number of empirical evidences.

2.4.1 Human Capital theory and its evolution

Progress and evolution have brought significant improvements to the society, among which improved health, a wider diffusion of education and greater levels of training. The knowledge that people gain through education and the skills they develop through training and previous experiences represent a form of capital, namely *human capital*. Human capital can be defined as "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2007). Hence, it entails the idea that investments can also be made in people (e.g., education, training, health) and that those investments can increase the individual's productivity with strong effect in the economy and society in general.

The notion of human capital is hard to pin on one person and its acceptance and diffusion has been quite controversial among the economists. The idea behind it goes back at least to Adam Smith. In his book *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776) he described the concept of fixed capital dividing it into four main components, where the fourth was the acquired and useful abilities of all the inhabitants or members of the society. Specifically, he noted: "The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship, always costs a real expense, which is a capital fixed and realized, as it were, in his person."(Smith, 1776). Over the years, several other exponents, such as Irving Fisher (1897), expressed similar ideas.

However, there was virtually no use of the term *human capital* in the English language until the late 1950s (**Figure 2**), when it became more popular thanks to the works of

Theodore Shultz (1961) and Gary Becker (1964). Shultz (1961) defines human capital as all the skills and knowledge that are principally a product of a deliberate investment. According to him, much of what is defined as consumption constitutes an investment in human capital. Some examples include investments in education, internal migration to benefit from better job opportunities, or the earnings foregone by mature students and trainees. Becker, in the first edition of his book *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education* (1964), defines the notion as the knowledge, skills, and abilities residing within and utilized by individuals. He then updates this definition further in the following editions of the book, up to the final conception of "investment in education, training, skills, health, and other values that cannot be separated from the individual." (Becker, 1993).

However, it is worth noting that at the early stage of development of the concept, there was some resistance from several scholars who claimed that free people should not be equated with property and marketable assets as it would imply slavery (Shultz, 1961). Indeed, Gary Becker in his work *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education* (1964) claims that he hesitated to use the term *human capital* in the title and that he added a long subtitle to prevent criticisms (Becker, 1964). However, a wider acceptance was then gained by the term in the following decades and the notion has progressively received more and more attention.

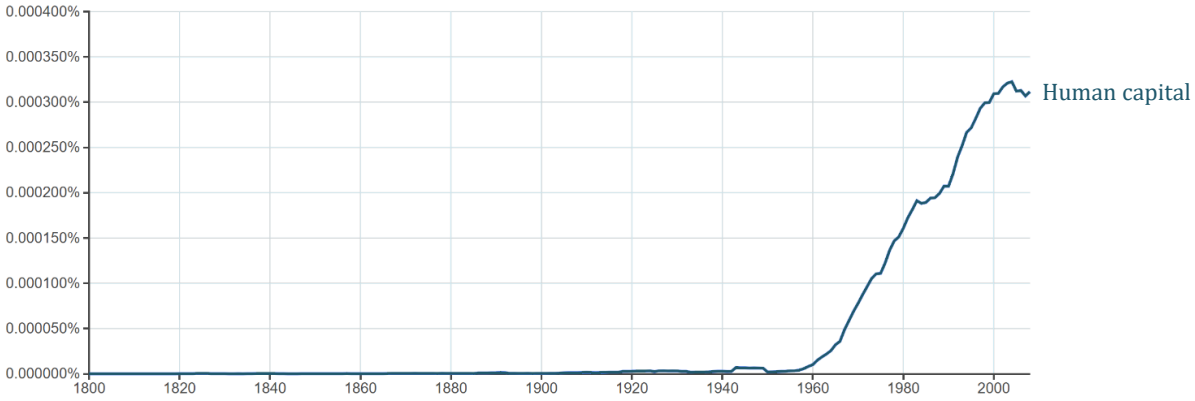

Figure 2: *A Google "N-Gram" of the term "human capital" from 1800 to 201*

2.4.2 Human capital in entrepreneurial literature: the competence-based view

Education and experience are key concepts within the notion of human capital. Experience entails work experience, practical learning originating from the place on the job and non-formal education (i.e., training). Human capital theory originally focused in investigating the economic value of education and experience. However, over the last two decades, the concept has been increasingly applied also to the field of entrepreneurship, exploring the relationship between human capital attributes and entrepreneurial success (Unger *et al.*, 2011).

Competence-based theories of the firm, inspired by the works of Knight (1921) and Schumpeter (1934), claim that firms are bundles of unique, difficult-to-imitate capabilities that are the main source of their sustainable competitive advantages (e.g., Grant, 1996). Those distinctive capabilities are strictly related to knowledge and skills of the founders, hence to their human capital endowment (Cooper and Bruno, 1977; Colombo and Grilli, 2005). They allow to justify the growth differentials among different firms, especially in case of new technology-based firms (NTBFs) (Colombo and Grilli, 2010).

According to the competence-based view, human capital features prove to be significantly important for NTBFs in several respects. First, founder's human capital fosters the scouting and generation of entrepreneurial opportunities, especially in very uncertain business environments (Hodgson, 1998; Alvarez and Barney, 2007). In addition, in case of prior experience in the focal industry, entrepreneurs are likely to possess more specialised knowledge (Colombo and Grilli, 2010), easier access to customers and suppliers (Gimeno *et al.*, 1997) and industry-specific skills to quickly grasp and exploit opportunities (Feeser and Willard, 1990). Also, more experienced founders are more effective in problem-solving, have better entrepreneurial judgment and benefit from broader network connections which may support the development of the venture (Hsu, 2007). Thus, they are better off in seizing neglected business opportunities, mitigating the venture's liability of newness and taking effective strategic decisions (Haynes and Hillman, 2010).

2.4.3 Founders' human capital as a signal of quality in NTBFs

While the competence-based view claims that there is a direct positive effect of founders' human capital on firm growth, further studies in entrepreneurial finance contend that higher human capital founders have an indirect effect on firm's growth, mediated by VC-backing.

This second view starts from the assumption that the potential associated with founders' capabilities may remain unexploited (at least partially) in case of lack of adequate financial and other resources. Thus, it argues that new ventures created by high human capital entrepreneurs are more likely to achieve a higher growth because they are more able to attract VC's investments (Baum and Silverman, 2004). The reason why high human capital entrepreneurs enjoy an advantage in attracting VCs lies in signaling theory. When it comes to evaluate the potential of a NTBF, VCs tend to observe human capital characteristics of the founding team as a signal of quality, especially when complex technological advancements play a critical role in the venture (Beckman *et al.*, 2012).

The extant literature supports this view arguing that aspects related to the human capital of founders are among the top three evaluation criteria taken into account by VCs when assessing a new venture (Zacharakis and Meyer, 2000). Popular sayings within the VC industry back up this theory claiming that ''nothing is more important than people'' and that "VCs would rather invest in a grade A team with a grade B idea than in a grade B team with a grade A idea" (Bygrave, 1997).

Indeed, human capital features of a venture's founders (i.e., prior education, prior working experience in the same field, prior managerial experience, prior self-employment experience) perfectly meet the signals' criteria set by Spence (1973). Firstly, they are easily accessible and observable. Moreover, these attributes are strongly correlated with the unobservable quality of the venture (i.e., high signal fit) (Prabhu and Stewart, 2001). Finally, the cost differential for assembling an experienced start-up team is high (even higher than the cost of filling a patent application or obtaining a patent grant) and leads to

a separating equilibrium (Hoenig and Henkel, 2015). In sum, along with patents, founders' human capital attributes serve as a key quality signal in VCs' assessment of NTBFs.

2.4.4 Empirical evidences of the signaling effect of founders' human capital in NTBFs

A number of empirical evidences have corroborated the theory that the identity and background of ventures' founders are influential signals of a start-up's future potential. Depending on the study, several different human capital variables have been taken into consideration.

As to education, Zucker, Darby and Brewer (1998) demonstrated that the successful launch of biotech ventures is strictly correlated to the number of *star scientists,* meaning that founders' education experience is a crucial aspect in entrepreneurship and, especially, in the biotech field. In this regard, Audretsch and Lehmann (2004) analysed 341 German start-ups and found that the number of members of ventures' top management teams with a PhD degree has no influence in VC investment. However, subsequent studies stated the opposite and supported the view of Zucker, Darby and Brewer. Hsu (2007), for instance, argued that, under some circumstances, the founding teams' prior education (i.e., a PhD degree) constitute a signal of quality, as may foregoing high-value alternatives.

Another interesting aspect is founders' prior managerial experience. Several authors such as Tyebjee and Bruno (1981) and Muzyka, Birley and Leleux (1996) conducted early studies entirely based on surveys or interviews with VCs and demonstrated that prior managerial competencies are influential selection criteria for those investors. More recently, Baum and Silverman (2004) analysed a sample of Canadian biotech start-ups and provided evidence that the amount of VC financing obtained in the early pre-IPO period is positively correlated with the managerial competencies of the firm's president. They also argued that biotech firms whose presidents are, at the same time, also presidents for other biotech start-ups, gained more VC financing. In the same year, Kaplan and Strömberg (2004) studied the investment memoranda from 11 VC partnerships for investments in 67 ventures and found that the quality of the management team emerges remarkably.

Moreover, further studies in subsequent years (i.e., Behrens *et al.* (2012)) supported this evidence and stated that prior managerial education and experience serve as signals of managerial competence to investors. Furthermore, MacMillan, Siegel and Subba Narasimha (1985) and Shepherd, Ettenson and Crouch (2000) demonstrate that a prior managerial experience in the same industry constitute a strong signaling element for VCs.

Conflicting viewpoints can be found in literature regarding the influence of prior entrepreneurial experience. Baum and Silverman (2004), in the study described above, demonstrated that the pre-IPO amount of VC financing obtained by the ventures is negatively correlated to founders' entrepreneurial experience. Contrarily, Burton, Sørensen and Beckman (2002) analysed a sample of Silicon Valley start-ups across several industries and found that the presence of a serial entrepreneur within the founding team increases the probability of obtaining external financing in its early stage. More recently, further studies (e.g., Gompers, Kovner and Lerner, 2009) supported this view and demonstrated the existence of a positive relationship between prior entrepreneurial experience and VCs' investment decision.

3. Theoretical Framework

Starting from the extant literature about signaling theory in entrepreneurial ventures, this Thesis provides a novel contribution concerning the signaling effect of the human capital features of a venture's founding team in the presence of radical inventions. This Chapter aims at describing this contribution in further details, illustrating the research question and the hypothesis addressed by the Thesis.

3.1 The literature gap and the research question

As it emerges from the studies presented above, signaling theory has been extensively applied to the entrepreneurial field. Specifically, the extant literature has investigated a number of different observable attributes that new ventures can use to signal their quality to VC investors (Burton, Sørensen and Beckman, 2002; Certo, 2003; Lester *et al.*, 2006; Hsu and Ziedonis, 2013). Among them, a relevant role has been acknowledged to patents (both granted patents and patent applications), as powerful means to communicate to external investors the potential of the venture's underlying technology.

Although numerous studies have highlighted the bright-side of patents, to the best of our knowledge, no prior study has examined possible dark-sides hidden within patents' information content. Indeed, patents are endowed with a rich set of information which may affect and disturb their pure signaling power. Information about the invention's radicalness fall into this category.

As previously explained, data and details contained in the patent documentation may represent the source to measure the level of radicalness of the venture's underlying invention (Verhoeven, Bakker and Veugelers, 2016). Radical inventions generally constitute investments with high growth- and returns- potential, at the expenses of an extremely high uncertainty. In particular, ventures involved in radical innovation face

both an unknown probability and an unknown extent of their products' success (Sorescu, Chandy and Prabhu, 2003). Sticking with the definition of *risk* as the "uncertainty associated with a course of action" (Singh, 1986), the risk associated to a radical patent is definitely higher than the risk associated to a non-radical patent. In that sense, information about high radicalness constitutes a dark-side of the patent as it introduces a massive component of risk.

It is agreed that granted patents and pending patents applications work as Spencian signals of quality for the venture, thus attracting VC financing. Nevertheless, because radical inventions are perceived as high-risk investments, the positive signaling role of a patent may result disturbed when the patent information content suggests high radicalness. Yet, no prior work has (i) recognised the possible presence of dark sides within the patenting information and (ii) analysed how these dark sides may influence the positive signaling power of patents. The first contribution of this Thesis consists in covering this gap through two main arguments: (i) information about radicalness represents a dark-side of patents as it introduces a strong risk component and (ii) this dark-side may affect the positive signaling effect of patents on VCs' investment decisions.

Given that the presence of a radical patent rises the perceived risk for the investor, this Thesis goes further and wonders whether another signal of quality (specifically, the human capital characteristics of the founding team) may mitigate the risk associated to a radical patent. It starts from the awareness (i) that each venture possesses a portfolio of signals through which it can communicate to investors its underlying potential and (ii) that when the same signaller sends multiple signals, they are going to interact with each other, either enhancing or diminishing the signaling process (Connelly *et al.*, 2011). Hence, the second contribution of this Thesis consists in shedding a new light on the interaction of two major signals, i.e., radical patents and founders' human capital, to analyse whether the latter may be able to moderate the high risk associated to the former.

Nevertheless, a comprehensive assessment of the joint signaling effect of radical patents and founders' human capital features, ought to consider possible different outcomes depending on different types of VC investors (i.e., more or less experienced). This idea

builds on the acknowledgment that different signal's receivers may respond differently to the same signal, according to their different ability to recognise and interpret the signal itself (Vanacker and Forbes, 2016). Thus, the third and last contribution of this Thesis consists in considering the typology of VC investor when assessing (i) the risk perceived in case of radical innovation and (ii) the mitigation effect of founders' human capital features.

The main contributions of this Thesis, lead to the following research question.

RQ: *Does the signaling effect of founders' human capital compensate for the risk of radical innovation in venture capital investments?*

3.2 Hypotheses formulation

This section presents all the hypotheses addressed in the Thesis, supporting them with theoretical arguments. In particular, this work aims at testing four different hypotheses. The first one is related to the effect of radical innovations in VCs' investment decisions. The second and the third, instead, deal with the alteration of the effect of radicalness as a result of the signaling effect of founders' human capital features. Finally, the last hypotheses, includes into the analysis differences in the type of investors (i.e., differences in signals' receivers), distinguishing between experienced and non-experienced investors.

3.2.1 Effect of radicalness on VC's investment decision

The extant literature largely agrees on the idea that patents serve as quality signals in NTBFs (Long, 2002; Hsu and Ziedonis, 2013). The patenting process is costly and its cost increases as the quality of the underlying technology decreases. Only those ventures which are confident about the potential of their technology decide to sustain this cost and undertake the patenting process. Because the presence of patents constitutes a distinctive feature of high-quality technologies, VC investors tend to invest more and more rapidly in NTBFs endowed with patents (Engel and Keilbach, 2007; Cao and Hsu, 2011; Conti, Thursby and Othaermel, 2013).

Nevertheless, when pursuing the patenting process the venture is required to provide detailed information about the underlying technology. In fact, patents are endowed with an extremely rich information content (Auerbach, 2006). On the one hand, this transparency and rigorousness reinforces the effectiveness of the signal and makes it more reliable (Janney and Folta, 2003). On the other hand, not all the information emerging from patents' documentation have a positive impact on VC investment decision. A dark-side of the patent may be hidden within its information content and may disturb its positive signaling effect on VCs' investment decisions.

Information about the radicalness of the patented invention may constitute a major example of patents' dark-side. As claimed in Chapter 2.3.4, from the information contained in a patent it is possible to extract a measure of the radicalness of the underlying technology. Radical innovations are often proposed by NTBFs (Acs and Audretsch, 2003) and represent a peculiar type of investment. Because they may be able to introduce shifts in technological paradigms and disruptive changes in existing markets, they have an exceptionally high potential in terms of growth and returns. In that sense, they may constitute an attractive investment for VCs. On the other hand, radical innovations are traditionally associated to an extremely high level of uncertainty. They often require a long-term development time and massive initial investments. These technologies are frequently far from commercialization and it may happen that after a long and expensive R&D activity, they do not lead to any attractive product for the market (Deffains-Crapsky and Sudolska, 2014). Thus, if investing in NTBF is always risky for VC investors, investing in a NTBF with a radical patent is even riskier.

Starting from the assumption that a patent per se constitutes a quality signal and attracts VC investments, in the specific case of a radical patent, VCs are likely to have a dual reaction. On one hand, the attraction towards the venture is enhanced as they see high potential returns. On the other hand, the perceived risk increases significantly. Since the rise of the perceived risk has an inverse effect in the investor's willingness to invest, it is worth to investigate how VCs' investment decisions change in the presence of radical patents.

Being the investment so attractive, it is unlikely that VCs decide to forego the possibility of such high returns. However, being the investment so risky, it is reasonable to think that they may be willing to share this risk. In other words, it is plausible that in the presence of radical patents VC investors (i) still decide to invest to benefit from the high-returns potential, but (ii) opt to syndicate in order to share the high risk associated to radicalness. In accordance with this view, the following hypothesis is derived.

HP1: *Radicalness leads to syndicated deals.*

3.2.2 Effect of human capital features

In Chapter 3.2.1 it has been highlighted that, besides the overall positive signaling value of patents, when the patented invention is radical the risk perceived by VCs tends to increase. Nevertheless, it is important to stress that patents are not the only observable feature through which VCs can assess the potential of a new venture. In fact, there are a number of characteristics that may serve as signals of quality for NTBFs. In other words, NTBFs possess a portfolio of signals, which interact with each other either enhancing or weakening the signaled message (Bergh *et al.*, 2014).

Along with patents, a major signaling role is played by human capital characteristics of the founding team. The extant literature agrees that prior education and experiences of the venture's founders are carefully evaluated by VCs when assessing the potential of the firm (Bygrave, 1988; Zacharakis and Meyer, 2000). In particular, human capital features can be distinguished between *managerial competencies* and *scientific competencies*, which are likely to have divergent effects on VCs' investment decisions. The endowment of managerial competencies can be assessed through several proxies such has having completed an MBA program, having worked as CEO (or as any other C-role), having founded other ventures before (i.e., being a serial entrepreneur). On the other hand, an individual's scientific competencies can be evaluated taking into account other attributes such as the attainment of a PhD degree or of the title of *professor* in a scientific field. As illustrated in Chapter 2.4.3, all those features meet the Specian definition of *signal*.

Nevertheless, when interacting with the signal of radicalness, the two categories of human capital signals are expected to have an opposite effect.

On the one hand, founders' managerial competencies are likely to mitigate the risk associated to radical innovations. Numerous works have already agreed that managerial skills are an important criterion for VCs' decision making (Zacharakis and Meyer, 2000), and Muzyka, Birley and Leleux (1996) found that they are actually the first criterion used by VCs. Similarly, Colombo and Grilli (2005) demonstrated that managerial education and managerial experience present a large indirect effect on NTBFs and that VCs place a high importance on managerial education and expertise when selecting NTBFs investments. In other words, when the founding team boasts high managerial competencies, VCs are more likely to invest because they perceive the venture as less uncertain and are more confident about its survival and growth potential. Acknowledged a positive signaling effect of founders' managerial competencies, it is interesting to analyse how this second signal may affect VCs' investment decision in the presence of radical patents. It is a matter of examining the interaction between two signals: (i) radical patents and (ii) managerial competencies of the founding team. The former increases the risk perceived by VCs, while the latter decreases this risk. The first hypothesis formulated in this Thesis (i.e., *HP1*) argues that, because the perceived risk increases, in the presence of radical patents VC investors may feel the necessity to share the risk and, thus, to syndicate. Nevertheless, this incentive for syndication may decline when other signals of quality compensate VCs for the risk of radicalness. Specifically, as founders' managerial competencies endowment constitutes a major signal of quality in early-stage ventures, it can mitigate the risk perceived by VCs and thus reduce their impulse towards syndication. From this consideration, the following hypothesis has been derived.

HP2a: *High founders' managerial competencies counterbalance the effect of radicalness in syndicated deals.*

Moving to scientific competencies of the founding team, they are another important component of human capital and are likely to have a different impact on VCs' decision making. First, individuals with high scientific competencies tend to develop ideas that are

rooted in advanced scientific research and are characterised by a particularly low level of maturity (Munari and Toschi, 2011). Hence, when the scientific competencies of founders are particularly advanced, it is likely that the venture's underlying technology requires specialised scientific knowledge to be adequately assessed, meaning that the information gap between VC investors and the venture is particularly strong. Moreover, being these technologies particularly far from commercialization, there is great uncertainty about the probability of products' success (i.e., likelihood of extracting cash flows from the products) and about the extent of products' success (i.e., the expected magnitude of future cash flows) (Sorescu, Chandy and Prabhu, 2003). Furthermore, among founders with advanced scientific competencies, faculty researchers, PhD students and professors particularly stand out. These categories of founders tend to have no or little awareness of the commercialization potential of their research. And when they are aware, they may be less motivated to pursue commercialization opportunities for several reasons (i.e., they are more committed to pursue basic research as a more effective driver of prestige, they are more risk-averse and prefer to avoid the stigma of failure in their professional career) (Radinger-peer, Sedlacek and Goldstein, 2016). This limited experience and propensity towards commercialization makes the investment even more uncertain from the VCs perspective. As a consequence of that, it is reasonable to think that when a venture presents a radical-patent and its founding team is mainly composed by scientists and researchers, the risk perceived by VCs is even higher and they are even more keen to syndicate. This last argument is expressed by the following hypothesis.

HP2b: *High founders' scientific competencies reinforce the effect of radicalness in syndicated deals.*

3.2.3 Effect of experienced VCs

The arguments stated in the previous sections focus on the effect of radicalness and founders' human capital features on VCs' investment decisions. Nevertheless, not all VCs are likely to react in the same way to a certain signal (or combination of signals). As stated by Vanacker and Forbes (2016) different receivers may respond differently to the same

signal, according to their own ability to recognise and interpret the signal itself. In that sense, a distinction can be made between experienced VCs and non-experienced VCs. A certain venture capitalist is considered experienced if it has already realised a high number of deals (Cumming, 2010). In general, experienced VCs are less risk-averse than non-experienced ones and are acknowledged for having a particularly good gut in selecting ventures. Also, because preserving and enhancing reputation is important for VC investors, it is reasonable to think that reputable VCs are more likely to invest in better ventures, characterised by a greater potential to succeed (Cumming, 2010).

Thanks to their nature, experienced VCs are likely to respond differently to signals (Cumming, 2012), and particular to the signal about radicalness. The high uncertainty characterising radical innovation is a much stronger limit for unexperienced VCs rather than for the experienced ones, as the latter are willing to bear a higher risk compared to the former. This argument becomes even stronger in the case in which both the signals about radicalness and advanced scientific competencies take place. In this condition, the level of uncertainty may be so high to lead unexperienced investors to retrieve from syndicated deals. However, the outcome may change if an experienced investor takes part in the syndicate. Thanks to the reputation effect, the fact that experienced VCs participate in the deal constitutes a signal of quality itself and facilitates the attraction of other investors, and thus the establishment of the syndicate.

HP2b argues that the joint occurrence of radicalness and high founders' scientific competencies (high-risk scenario), leads to syndication even more than in presence of radicalness alone. Building on that, it can be stated that the probability of going towards syndication is further favoured by the participation of an experienced VC in the deal. This last argument leads to the following hypothesis.

HP3: *The experience of VC investors reinforces the effect of founders' managerial competencies and radicalness in syndicated deals.*

4. The Dataset

In order to address the research question, this Thesis has worked on a sample of VC-backed companies, endowed with at least one patent in the portfolio and operating in the biotech sector. This Section aims at providing a detailed presentation of the dataset, enriched by a series of descriptive statistics at broad level, at individual level and, finally, at company level.

4.1 Overview of the sample

This section aims at offering an overview of the sample. It provides a brief description of the companies included in the analysis as well as several information about the VICO dataset from which they were extracted. Several descriptive statistics are offered, remaining at a broad level of detail.

4.1.1 Sample companies and the VICO dataset

In order to pursue the analyses introduced in the previous sections, this Thesis has taken advantage of a pool of 672 VC-backed firms owning at least one patent in their portfolio. Sample companies were established in 1998 or later, were independent at founding time and operate in the biotech sector.

The analysis has been limited to biotech industry as it has been considered a particularly interesting context of study. Indeed, it is a knowledge-intensive industry where innovation (and, often, radical innovation) is lifeblood. As explained in Chapter 2.3.4, due to their nature. biotech ventures are affected by particularly strong information asymmetries and, thus, constitute the perfect field to test the effect of signals. Findings from biotech field may have implications for other knowledge-intensive and innovation-based industries.

The firms included in the sample are registered in the VICO dataset. The VICO 4.0 database represents the final output of a research project funded by the 7th Framework Programme of the European Commission. It includes information on new high-tech ventures in thirty countries (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom). The dataset, which is developed within the VICO project, is constantly updated by the project RISIS (Research Infrastructure for Research and Innovation Policy Studies), again funded by the 7th Framework Programme of the European Commission. During the years, it has been used by many researchers and it is a well-known and reliable source. It contains a wide variety of information ranging from geographical to industrial on companies dating back to 1998, which have received at least a VC or angel investment. The overall number of companies is about 24000 ventures.

4.1.2 General descriptive statistics of the sample

Once the sample was extracted from the VICO dataset together with other companies' data, the development of the database went through a series of steps. The first cluster of variables aims at providing information on the companies as entities.

In particular, the first dimension of analysis is the country of foundation of the companies. The distribution of the companies by their nation is presented in **Figure 3**.

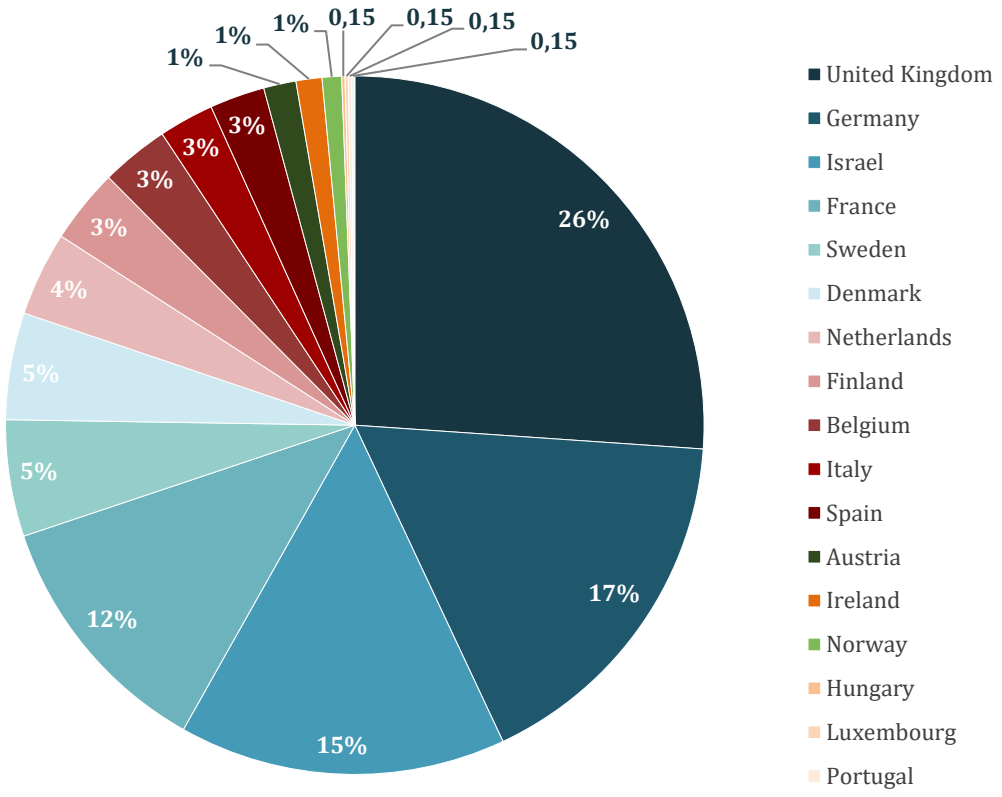

Figure 3: *Portion of companies by country*

Most of the companies included in the database are from United Kingdom, Germany and Israel (26%, 17% and 15%, respectively), followed by France (12%). Looking at the sample from a macro point of view, the sum of those countries comprises the great majority of the companies with a significant 70 % of the entire sample.

As shown in **Figure 4,** in absolute terms, there are 174 English firms, 113 German firms, 101 Israel firms and 78 France firms out of 672 in the whole sample. The Scandinavian countries (Sweden and Denmark) and Finland firms complete the bigger portion of the sample (5,5%, 5 % and 3,5% respectively) and they represent a significant centre of biotech research and innovation. All the others countries together account for 16% (**Figure 3**).

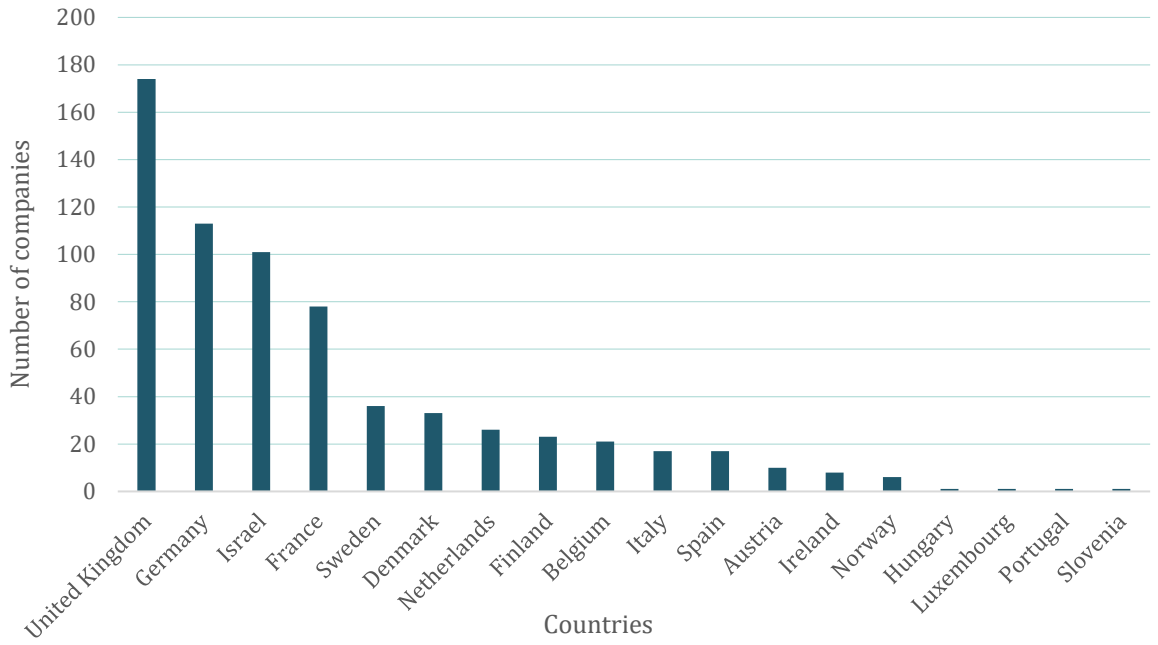

Figure 4: *Number of companies by country.*

The database provides also information about the age of the companies which is intended as the age of the company when it received its first round of financing. It was computed as the difference between the year in which it received its first investment and the company's foundation. Including 137 missings (21 %), the sample shows that almost a third of the firms (32 %) had less than 2 years when they received their first round of financing, while the remaining portion (47 %) is equally distributed between firms with an age of 2 - 5 years and more than 5 years from the foundation date (22 % and 25 %, respectively) (**Figure 5**).

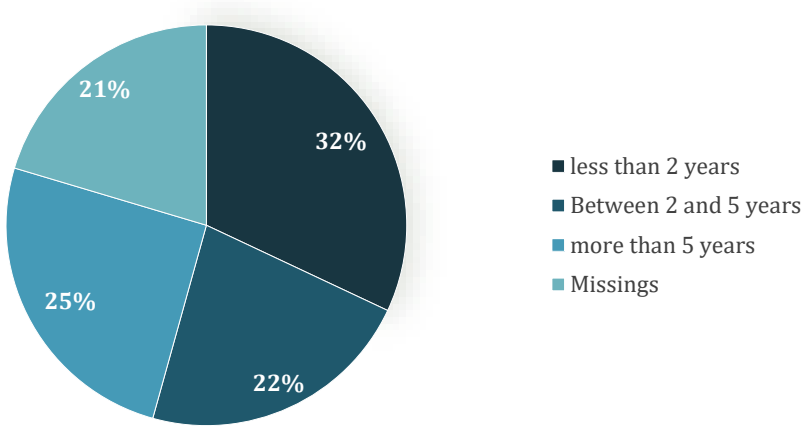

***Figure 5**: Portion of companies by age.*

Figure 6 illustrates the number of companies founded in each year of the timespan under analysis (i.e., from 1998 to 2015). As a matter of fact, the amount of new companies through the years follows a fluctuating trend. In this scenario, it is interesting to highlight that the years 2006-2007 and 2010-2011 experienced significant positive peaks.

***Figure 6:** Number of companies by foundation year.*

In addition, a set of variables, linked to companies' biotech researches, aim at modelling firms' portfolio of patents up to the investment date. The first variable of this group classifies the companies by the number of patent applications submitted before the first round of VC financing. The sample is divided among four classes, which represent the possible combinations of number of patent applications for each company. Of the whole sample, 52 % of the companies are characterized by having between 1 and 3 patent

applications; 4-5 patents category displays a significant 22 %, while only the 14 % of the sample has more than 5 patent applications (**Figure 7**).

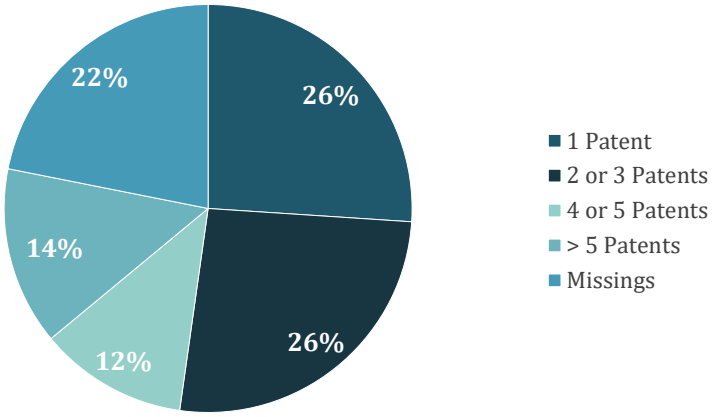

***Figure 7**: Number of companies by number of patent applications before the first VC round of financing.*

The second variable of this cluster categorizes the sample on the presence of companies with at least one granted patent. According to the data, 188 firms (28 %) has at least one granted patent, whereas 337 companies - which represent the 50 % of the sample – did not register any patent. The 147 missings are treated as such in this particular case (**Figure 8**).

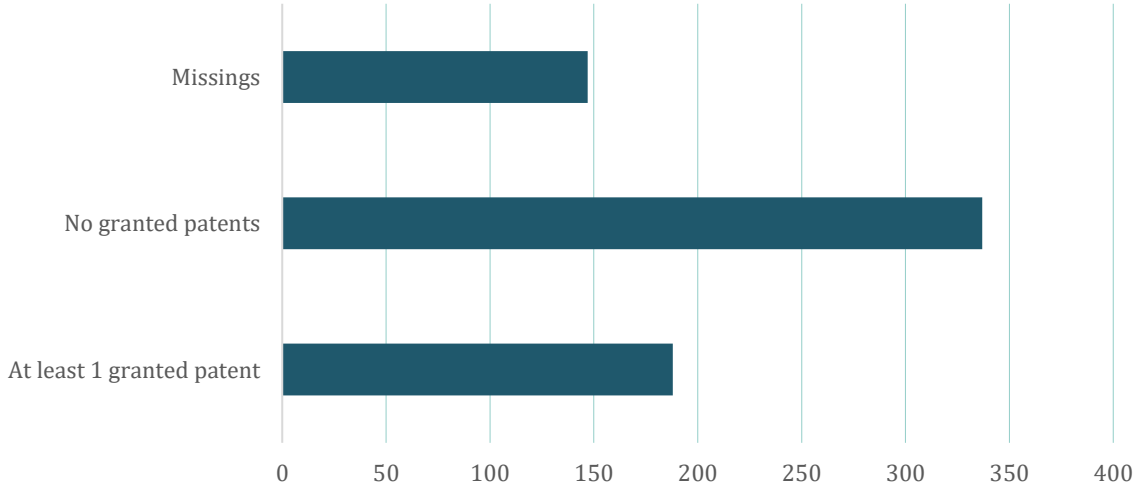

***Figure 8:** Number of companies according to the presence of a granted patent before the first round of VC financing.*

Lastly, the sample companies have been distinguished according to the presence of a radical patent family in their portfolio. Beside 147 missings, the majority of the sample (i.e., 415 companies, which accounts for 62% of the pool) has no radical patent family, while roughly 110 firms filied at least one radical patent prior to the first round of financing (**Figure 9**).

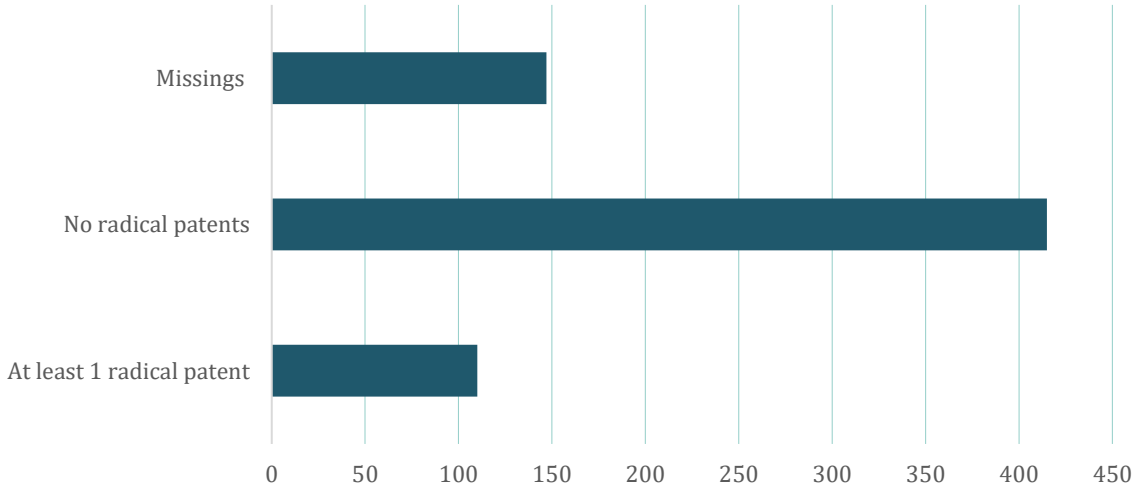

Figure 9: *Number of companies according to the presence of a radical patent family before the first round of VC financing.*

4.2 Methodology

The process towards the dataset completion went through several phases. The most time-consuming one was the collection of information about the founding teams (i.e., number of members, names and human capital features) of the ventures included in the sample. For several ventures no founders have been found, so they were treated as missings. This section describes the entire process followed to obtain the final dataset on which multinomial logit regressions were run, with a special focus on founders' name collection.

4.2.1 Overview of the process towards dataset completion

This section illustrates the process aimed at the construction of the final database through a series of subsequent steps. First of all it is important to stress that, in order to address

the research question of this Thesis, the dataset needs to contain information concerning (i) human capital features of the founding team, (ii) the patent portfolio and (iii) the features of VC investors. While patent-related and investor-related data were already available, information concerning the human capital of the founding teams needed to be collected.

Therefore, the first phase of the process dealt with the collection of information about ventures' founders. Firstly, the names of founders were researched for the 672 companies in the sample. Secondly, the human capital characteristics of these founders were collected. In both cases, the initial approach to fill the dataset was to integrate the data with other proprietary datasets (Crunchbase, Orbis and Zephyr). Furthermore, a cross-sources research was performed on platforms such as LinkedIn, companies' webpages and past press releases in order to fill the remaining gaps and further enrich the dataset whether possible. Given the fragmentation and potential incompleteness of the single sources, a careful screening and cross-check process was required in order to find consistency among the different sources and to ensure a reasonable degree of confidence about the completeness and correctness of the data.

After having collected, for each identified founder, all the human capital features, these human capital data at individual level were aggregated and fully integrated at company level. Throughout this process, a relatively smaller selection of individual variables was kept, whereas several new variables have been added to the database in order to consider some dynamics visible only on a more aggregated perspective.

At this point, the database contained, for each venture of the sample, information about the human capital characteristics of their founding teams. Hence, the dataset needed a further, last step to be ready for running the multinomial logit regression analysis the study aims at. For the purpose of studying the interactions between VC investors and companies in the presence of radical innovations, a second database was added and integrated to the first one. This dataset was developed by a research project in collaboration between Polytechnic of Milan and Mannheim Business school. It includes an additional set of variables regarding the radicalness of the innovations which were

developed by the companies in the sample. Moreover, it provides supplementary information on their patents' portfolio, especially on its variety and size. Along with this new information at the company side, the dataset also comprises critical data about VCs investors (i.e., type of investors, type of deal, etc.). This last piece is extremely important in the context of creating a self-explanatory model which would be able to integrate the investment decisions of the VCs with each single element of the sample, without the effects of spurious correlations or the omission of relevant variables.

At this stage the dataset was endowed with a comprehensive set of information. Nevertheless, because the research question entails investigating the effect of radicalness and founders' human capital on investment decision, the fact that all the companies in the sample are VC-backed may be a limitation. Hence, a matching model was developed, associating each venture of the sample to all the potential VCs existing at its year of founding. The resulting 40.363 dyads venture-investor constituted the sample of analysis for all the econometric models run. For each dyad venture-investor, the typology of deal occurring between the two was defined (i.e., no deal, standalone deal or syndicated deal), as the aim of the econometric analyses is to model the probability of occurrence of each type of deal with respect to no deal (i.e., the baseline scenario).

4.2.2 Collection of founders' names

Regarding the very first step of the process (i.e., collection of founders' names), the total number of founders, which constitute the first base of analysis, amounts to 1075 names over a total of 672 companies. Nevertheless, of the whole founders' sample, 175 are missings (**Table 1**).

# Founders with a master degree		
	Frequency	**Percent (%)**
No Missings	900	83,72
Yes Missings	175	16,28
Total	1075	100

***Table 1**: Number and portion of missing founders' names in the sample.*

As highlighted in previous sections, the extant literature largely agrees that founders' human capital has a key role in driving VCs' investment decisions (Bygrave, 1997; Zacharakis and Meyer, 2000; Baum and Silverman, 2004; Beckman *et al.*, 2012). Therefore, it is reasonable to argue that the difficulties in finding information about company's founders or their background is a negative signal for an external investor. In order to consider this implicit signal embedded into the existence of missing information, it was decided not to strip them out of the analysed sample. The names were treated as missings, whereas their missing information as zeroes.

Overall, the sample is quite large, and it exhibits considerable heterogeneity. As will be shown in the following sections, the human capital information is fine-grained and quite exhaustive.

4.3 Descriptive statistics of human capital variables at individual level

This section focuses on the data about the human capital features of the founders of the ventures. It provides a list of all the variables defined for each founder, along with several descriptive statistics of these variables at founders' level.

4.3.1 Main human capital variables at individual level

The table below (**Table 2**) shows the list of all human capital variables collected at the founder level and, for each one of them, provides a brief definition.

Variable	Description
CompanyID	VICO company ID
MSc_SiNo	Founder with a Master degree
PHD_SiNo	Founder with a PHD
PHD Technical	Founder with a PHD in a technical field: engineering, physics, math.
PHD Life Science	Founder with a PHD in a life science: chemistry, biochemistry, biology, medicine etc
PHD_PrestigiousUni	Founder with a PHD from a Top30-World university or a Top50-European University
MBA_SiNo	Founder with a MBA
MBA_PrestigiousUni	Founder with a MBA from 2010 MBA - QS World ranking
TechnicalRole	Founder with a working experience in a technical role
CommercialeRole	Founder with a working experience in a commercial role
FinanceRole	Founder with a working experience in a finance role
ManagerialRole	Founder with a working experience in a managerial role
CEO_SiNo	Founder with experience as CEO
Clevel_SiNo	Founder with experience in any C-Level role such as CEO, CFO, CSO, CTO, COO etc
Entrepreneur_SiNo	Founder with at least one previous successful entrepreneurial experience
Professor_SiNo	Founder with an experience as university professor
BigPharma	Founder with experience in a company top 30 in sales in the pharmaceutical sector
Exp Biotech	Founder with experience in biotech sector or related (pharmaceutical, medical devices etc)

Table 2: *Description of the main human capital variables.*

As previously stated, the human capital data were collected, refined and analysed at the individual level, then aggregated at the company level and eventually merged with the other information regarding companies and VC investors. Human capital information can be clustered in two main groups: (i) education background and (ii) previous work experiences.

4.3.2 Education

The education attainments of the founders in the sample, concerning both graduate (i.e., MSc) and post-graduate (i.e., PhD and MBA) education, have been considered. In order to obtain a more fine-grained dataset, the education section has been further broken down into three categories in order to capture the distinct marginal effects of the different education fields. On this regard, it was distinguished among technical, life science and managerial studies to disentangle the relative explanatory power of each field of application.

In the sample, 874 founders out of 1075 have at least one master degree, which accounts for 81,3 % of the pool (**Table 3**). Given the 175 missings in the pool out of 201 founders with No-MSc, a great portion of the sample obtained a degree before the founding stage. Due to the high percentage of founders holding a MsC, this information is not considered significant and will be neglected at company level.

# Founders with a master degree		
	Frequency	**Percent (%)**
No MSc	201	18,7
Yes MSc	874	81,3

***Table 3**: Number and portion of founders with a master degree*

Considering the post-graduate education, more than 50 % of the founders has at least a PhD degree, which equals to 548 founders. The remaining 527 founders without a doctoral education include also the 175 missings (**Table 4**).

# Founders with a PHD education		
	Frequency	**Percent (%)**
No PHD	527	49,02
Yes PHD	548	50,98

***Table 4:** Number and portion of founders with a PhD degree.*

Figure 10 points out that the vast majority of the PhDs are in life science with a leading share of nearly 80 % of the total PhDs (432 out of 548). The remaining part (i.e., 111 PhDs) is mostly in technical studies, while the managerial section accounts for only 5 elements. This preliminary result suggests that the managerial class is likely not to have a significant impact on the analysis and therefore it will be cut out at company level.

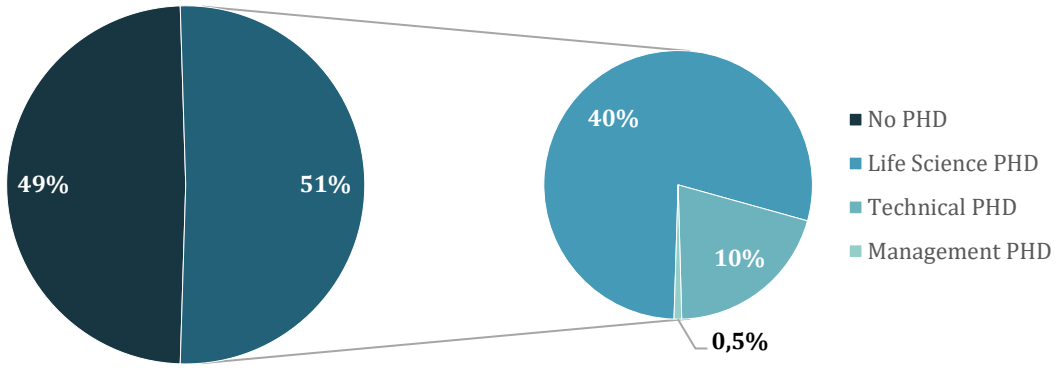

Figure 10: *Portion of founders with a PhD degree and portions of different PhD fields.*

When analysing PhD education, the issuing University was also taken into consideration, distinguishing those PhDs coming from prestigious universities. Specifically, a university has been considered prestigious if it is included in the top30 World ranking or in the top40 European ranking of *The Times Higher Education University Rankings 2010-2011* (**Annex A**). Going through the actual numbers, 211 founding members got a doctoral degree from a prestigious university, which represent almost the 20 % of the total founders' sample (**Table 5**)**.** If the percentage is computed against the actual number of PHD (548) in the sample, the result reaches the significant value of just over 38 %.

# Founders with a PHD from a prestigious university		
	Frequency	**Percent (%)**
No prestigious PHD	864	80,37
Yes prestigious PHD	211	19,63

Table 5: *Number and portion of founders with a PhD from a prestigious university.*

Moreover, keeping the focus on post-graduate education, as shown by **Table 6**, 119 founders have attained an MBA (i.e., just over the 11 % of the total founders) before the first round of funding of the company.

# Founders with an MBA		
	Frequency	**Percent (%)**
No MBA	956	88,93
Yes MBA	119	11,07

Table 6: *Number and portion of funders with an MBA.*

Again, a further distinction was applied whether the MBA was taken from a prestigious university. The prestige of a university was determined by the position in the 2010 *MBA QS World ranking* since only the top 30 was counted (**Annex B**). As expected, the great majority of the MBAs (i.e., 95 out of 119) were from prestigious universities due to the nature itself of the MBA education as deliver of a signal of prestige, reputation and network. Given this minimal difference, this distinction will be neglected at company level.

4.3.3 Prior work experience

The second section concerns the work experiences of the founders. First, the database decomposes industry-specific working experience in five classes according to the role held by the founder: (i) technical, (ii) commercial, (iii) finance and (iv) managerial. The former captures the context-specific knowledge and skills of founders in R&D, process design, engineering and production. In this respect there are 240 founders with a technical working experience which represents about the 22 % of the sample (**Table 7**).

# Founders with a technical working experience		
	Frequency	**Percent (%)**
No Technical Role	835	77,67
Yes Technical Role	240	22,33

Table 7: *Number and portion of founders with a prior work experience in a technical function.*

Then, commercial roles relate to marketing, sale, and customer care activities, while finance roles include all those positions with responsibilities in the finance function. The data show that 59 and 21 founders, respectively, had previous experience in those two roles (**Table 8**; **Table 9**). Due to the relatively small portion of founders included in this segmentation, they are expected to have a limited impact as signals. Consequently, both have been excluded from the analysis at company level.

# Founders with a commercial working experience		
	Frequency	**Percent (%)**
No Commercial Role	1.016	94,51
Yes Commercial Role	59	5,49

Table 8: *Number and portion of founders with a prior work experience in a commercial function.*

# Founders with a finance working experience		
	Frequency	**Percent (%)**
No Finance Role	1.054	98.05
Yes Finance Role	21	1.95

Table 9: *Number and portion of founders with a prior work experience in a financial function.*

Lastly, as shown in **Table 10**, founders with a prior experience in a managerial role are 421, about the 39 % of the sample.

# Founders with a managerial working experience		
	Frequency	**Percent (%)**
No Managerial Role	654	60,84
Yes Managerial Role	421	39,16

Table 10: *Number and portion of founders with a prior managerial experience.*

Given the importance of the managerial capabilities, a further division is provided on the basis of the extent of managerial experience of the founders. In the sample 195 founders (i.e., just over the 18 % of the sample) has a prior experience in a C-level role (e.g., COO, CFO, CTO or CEO), while 152 founders out of the 192 with a C-Level position had a CEO experience (**Table 11**; **Table 12**).

# Founders with a C-Level Role experience		
	Frequency	**Percent (%)**
No C-Level Role	880	81,86
Yes C-Level Role	195	18,14

Table 11: *Number and portion of founders with a prior experience in a C-level role.*

# Founders with a CEO Role experience		
	Frequency	**Percent (%)**
No CEO Role	923	85,86
Yes CEO Role	152	14,14

Table 12: *Number and portion of founders with a prior experience as CEO.*

As a matter of fact, the majority of C-Level positions of the pool were CEOs (**Figure 11**, thus a high correlation between the two variables is expected.

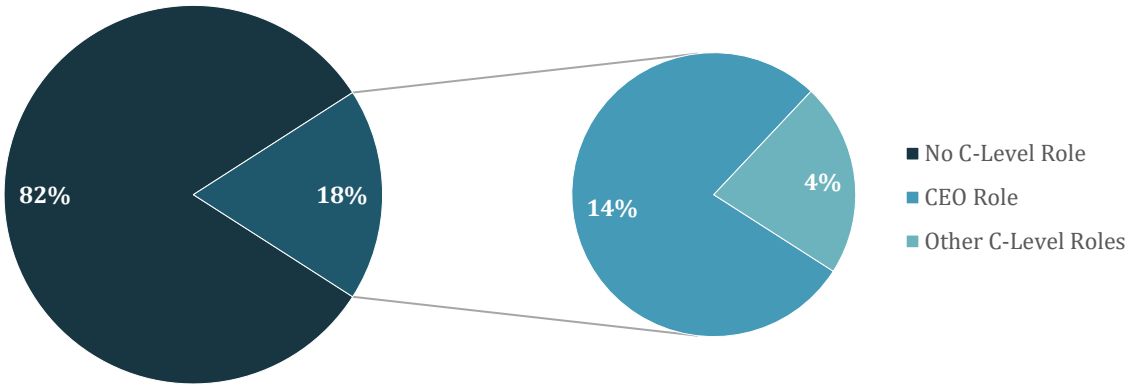

Figure 11: *Portion of founders with a prior experience in a C-level role, with a focus on prior experience as CEO.*

Another important proxy of managerial competencies are prior entrepreneurial experiences. Specifically, in the sample, 188 founders had already funded at least another company before the first round of financing of the company in the pool under analysis. This number is quite significant as it represents over the 17 % of the total (**Table 13**).

# Founders with a entrepreneurial experience		
	Frequency	**Percent (%)**
No entrepreneurial experience	887	82,51
Yes entrepreneurial experience	188	17,49

Table 13: *Number and portion of founders with a prior self-employment experience.*

Along with the variables measuring founders' managerial competencies, there was also the intent to measure the scientific competencies of the founding team. In this regard, it was interesting to consider founders' prior experiences as faculty professors. The founders with a previous professor experience are 196 (i.e., over 18 % of the sample) (**Table 14**).

# Founders with a professor experience		
	Frequency	**Percent (%)**
No professor experience	878	81,75
Yes professor experience	196	18,25

Table 14: *Number and portion of founders with prior experience as professor.*

Furthermore, keeping the attention on prior work experiences, two additional dummy variables (i.e., BigPharma and biotech experience) have been designed to take into consideration the impact of previous experience in the sector. The biotech experience variable measures the portion of the founders with at least one experience in a biotech or biotech-related (e.g., medical devices, chemistry, medical or pharmaceutical) company. **Table 15** illustrates that 467 founders (i.e., the 44 % of the sample) had a previous working experience in a biotech or biotech-related sector.

# Founders with a biotech experience		
	Frequency	**Percent (%)**
No biotech experience	608	56,56
Yes biotech experience	467	43,44

Table 15: *Number and portion of founders with a prior experience in the biotech industry.*

In this regard, it was also established whether the prior biotech experience was in a big pharmaceutical company. The firms included in the top30 of 2010 ranking of pharmaceutical companies by revenues (downloaded from Orbis database) was used as selection criterion (**Annex C**). Among all the founders of the sample, 82 had a previous work experience in a Big Pharma, which accounts for just over 7,5 % of the sample (**Table 16**).

# Founders with a Big Pharma experience		
	Frequency	**Percent (%)**
No Big Pharma experience	993	92,37
Yes Big Pharma experience	82	7,63

Table 16: *Number and portion of founders with a prior experience in a big pharmaceutical company.*

For the sake of clarity and transparency, it is worth to remember that the sample includes 175 missing elements at individual level, which turns into 145 missings once the sample is aggregated at company level. As previously explained, the missings have been treated as zeros in the analysis. In other words, the founders whose names were not found or whose certain human capital characteristics were not possible to be determined with a sufficient degree of comfort were recorded as if they did not exist.

4.3.4 Correlation among human capital variables at individual level

The following table (**Table 17**) shows the correlation among all human capital variables at individual level. The only correlation which turns out to be particularly high is the one between prior experience in a C-Level role and prior experience as CEO. Indeed, the latter variable is included in the definition of the former. Because of that, when aggregating at company level, only the variable *CEO_SiNo* will be kept in the analysis.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**PHD Technical**	10000																
2	**PHD LifeScience**	-0,2785	10000															
3	**PHD Management**	0,0023	-0,0546	10000														
4	**Prestigious_ Uni**	0,1016	0,4164	0,0831	10000													
5	**MBA_SiNo**	-0,0029	-0,102	0,0001	-0,0551	10000												
6	**Msc_SiNo**	0,1629	0,3936	0,0441	0,2373	0,1466	10000											
7	**PHD_SiNo**	0,3265	0,7961	0,0901	0,4798	-0,1051	0,4898	10000										
8	**Professor_ SiNo**	0,093	0,3646	-0,0434	0,1971	-0,1361	0,2267	0,4099	10000									
9	**BigPharma**	-0,0515	0,0859	0,012	0,0167	0,1331	0,111	0,0502	-0,0995	10000								
10	**ExpBiotech**	-0,0448	0,1423	0,0224	0,1099	0,1571	0,3342	0,1154	-0,1324	0,3207	10000							
11	**CEO_ SiNo**	-0,015	-0,0607	0,0213	-0,026	0,1545	0,1332	-0,0618	-0,1296	0,0844	0,312	10000						
12	**Clevel_SiNo**	-0,0092	-0,076	0,0362	-0,0566	0,1415	0,1517	-0,07	-0,1538	0,0829	0,3616	0,8621	10000					
13	**Technical Role**	0,0602	0,0614	-0,0003	0,1173	0,0528	0,2116	0,1008	-0,1493	0,2161	0,3726	-0,0447	-0,0265	10000				
14	**Commercial Role**	-0,055	-0,0728	0,0227	-0,0472	0,1362	0,0738	-0,1153	-0,1033	0,1153	0,1595	0,16	0,1409	0,008	10000			
15	**Finance Role**	-0,0259	-0,1158	0,0608	-0,036	0,0787	0,0678	-0,1172	-0,0667	-0,0406	0,066	0,1356	0,1952	-0,0112	-0,0045	10000		
16	**Managerial Role**	0,0031	-0,0597	0,0099	-0,0562	0,2695	0,2777	-0,0527	-0,2214	0,2144	0,5884	0,5002	0,5619	0,1553	0,2249	0,1483	10000	
17	**Entrepreneur_ SiNo**	0,0126	-0,0231	-0,0155	0,0436	0,0325	0,1519	-0,0094	-0,0273	-0,0309	0,3522	0,3542	0,3932	0,0235	0,0502	0,0588	0,3127	10000

Table 17: *Correlation among the main human capital variables.*

4.4 Descriptive statistics of human capital variables at company level

This section maintains the focus on human capital data of the dataset, but shifts the attention from the individual level to the company level. Indeed, the third step of the process towards the dataset's completion consists in aggregating the individual human capital features at company level. This section aims at describing the main features of the resulting dataset, along with several descriptive statistics.

In this new database structure, the sample presents 144 missing companies out of the overall 672 companies (**Table 18**). As mentioned above, the missing values of human capital variables will be treated as zeroes in the analysis.

# Missing companies in the sample		
	Frequency	**Percent (%)**
No Missings	526	78,27
Yes Missings	144	21,43

Table 18: *Number ad portion of missing companies in the sample.*

4.4.1 Main human capital variables at company level

Table 19 presents the list of all the variables defined at company level and a brief description of each. Again, companies' human capital information can be clustered in two main groups: (i) education background and (ii) previous work experiences.

Variable	Description
CompanyID	VICO company ID
Company_PHD	Company with at least one founder with a PHD
Company_Prestigious_PHD	Company with at least one founder with a PHD from Top30-World university or Top50-European University
Company_PHDTecnico Scientifico	Company with at least one founder with a PHD in a technical field: engineering, physics, math.
Company_PHDLifeScience	Company with at least one founder with a PHD in a life science: chemistry, biochemistry, biology, medicine etc
Company_SumPHDFields	The sum of the different PHD fields that the company's founders obtained
Company_MBa	Company with at least one founder with a MBA
Company_CEO_Role	Company with at least one founder with experience as CEO
Company_FounderStartup	Company with at least one founder who founded one or more companies
Company_BiotechExp	Company with at least one founder with experience in a company top 30 in sales in the pharmaceutical sector
Company_BigPharmaExp	Company with at least one founder with experience in the biotech sector or related (e.g. pharma, medical devices)
Company_ProfessorExp	Company with at least one founder with experience as university professor
Company_N_Roles	Sum of the different working roles the company's founders perfomed in the past

Table 19: *Description of the main variables at company level.*

4.4.2 Education

Starting from post-graduate education, 55 % of companies (in absolute terms, 367 companies) have at least one founder with a PhD (**Table 20**). Among them, the 43 % (158 elements) have been released from a prestigious university (**Table 21**). The criteria to determine whether the PhD was from a prestigious university is the same as the one used at individual level (i.e., Chapter 4.3.2).

# Companies with a founder with a PHD		
	Frequency	**Percent (%)**
No PHD	303	45,22
Yes PHD	367	54,78

Table 20: *Number and portion of companies with at least one founder with a PhD degree.*

# Companies with a PHD from a prestigious university		
	Frequency	**Percent (%)**
No prestigious PHD	512	76,42
Yes prestigious PHD	158	23,58

Table 21*: Number and portion of companies with at least one founder with a PhD degree from a prestigious university.*

Focusing on PhD field, Among the total amount of companies with a PhD, 94 firms have a founder with PhD in technical studies, while 293 have a PhD in a life science field. Moreover, looking at **Figure 12**, It is relevant to note that the majority of companies (i.e., 51,5 % of the whole) can count on just one type of doctoral expertise in its founding team, while a relatively small number of firms (i.e., 3,5 % or 22 firms, in absolute terms) has a post graduate education in two distinct fields. The remaining portion, except for 2 firms with all three fields of education covered (technical, life science and managerial), has none of the fields.

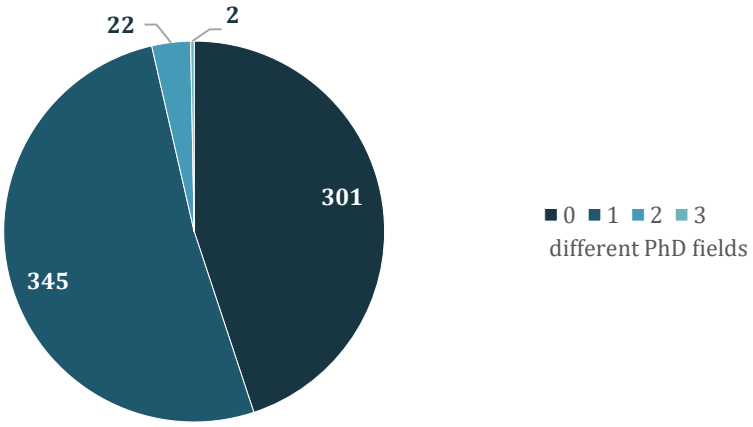

Figure 12: *Companies arranged by number of different PhD fields covered by the founding team.*

The last interesting education feature assessed at company level, is the possession of at least one founder with an MBA. In this regard, a significant portion of the sample (i.e., 108 companies, which represent the 16 % of the whole) has at least one member with an MBA among their founders (**Table 22**).

# Companies with a founder with an MBA		
	Frequency	**Percent (%)**
No MBA	562	83,88
Yes MBA	108	16,12

Table 22: *Number and portion of companies with at least one founder with an MBA.*

4.4.3 Prior work experience

Moving to work experiences, as far as managerial experiences are concerned, a prior experience as CEOs was considered as the most significant proxy. In this sample, 139 companies, which represent almost the 21 % of the total, have at least one founder who has been chief executive officer of a company in the precedent years (**Table 23**).

# Companies with a founder with a CEO experience		
	Frequency	**Percent (%)**
No CEO Role	531	79,25
Yes CEO Role	139	20,75

Table 23: *Number and portion of companies with at least one founder with a prior experience as CEO.*

Another important variable when assessing human capital at company level is prior entrepreneurial experience. Specifically, 61 companies, which represent the 24 % of the sample, have at least one member within their founding team with a prior entrepreneurial experience (**Table 24**).

# Companies with a founder with an entrepreneurial experience		
	Frequency	**Percent (%)**
No entrepreneurial experience	509	75,97
Yes entrepreneurial experience	161	24,03

Table 24: *Number and portion of companies with at least one founder with a prior self-employment experience.*

For what concerns industry-specific work experiences, instead, 335 companies (i.e., the 50% of the pool) have at least on founder with a prior experience in the biotech industry (**Table 25**). Furthermore, 66 companies (i.e., the 20 % of the companies with biotech experience and almost 10 % of the whole sample) have a member of the founding team who has previously worked in a Big Pharma (**Table 26**).

# Companies with a biotech experience		
	Frequency	**Percent (%)**
No biotech experience	335	50
Yes biotech experience	335	50

Table 25: *Number and portion of companies with at least one founder with a prior experience in the biotech industry.*

# Companies with a founder with a Big Pharma experience		
	Frequency	**Percent (%)**
No Big Pharma experience	604	90,15
Yes Big Pharma experience	66	9,85

***Table 26**: Number and portion of companies with at least one founder with a prior experience in a big pharmaceutical company.*

It was also measured the heterogeneity of previous working roles of a firm's founding team before the first round of financing. As explained in the individual section, the roles have been clustered in four categories: (i) technical, (ii) commercial, (iii) finance and (iv) managerial. Even though the results include 145 missings, the absence of previous professional experience in 289 companies remains a significant statistic. Additionally, almost a third of the sample (i.e., 206 companies) has a founding team with experience in one of the roles, while the 22 % has founders who worked in two different functions. Lastly, a relatively small portion (i.e., 4 % of the sample, which is equal to 28 companies) can count on founders with very variegated professional background having worked in 3 out of 4 potential roles (**Figure 13**).

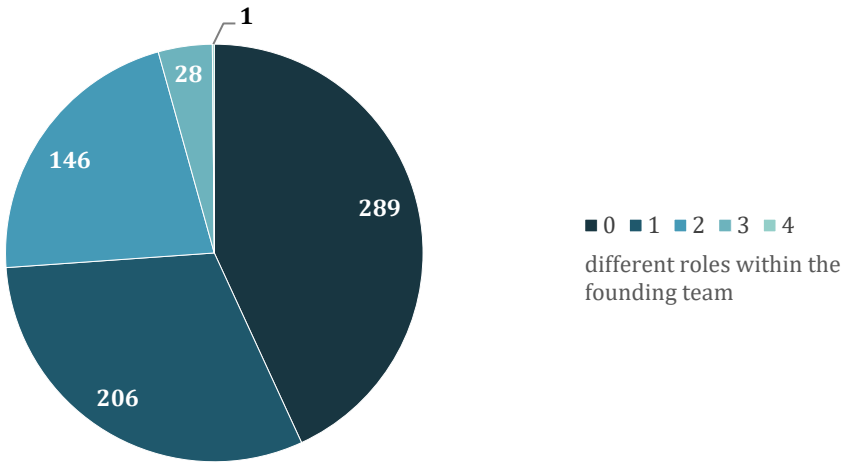

***Figure 13**: Companies arranged by the number of different prior roles experienced by the founding team.*

Lastly, moving to founders' scientific expertise, **Table 27** highlights that 159 companies in the sample (i.e., almost the 24 % of the whole pool) present at least one university professor within the founding team.

# Companies with a founder with a professor experience		
	Frequency	**Percent (%)**
No professor experience	511	76,27
Yes professor experience	159	23,73

Table 27: *Number and portion of companies with at least one founder with a prior experience as professor.*

4.4.4 Correlation among human capital variables at company level

Table 28 shows the correlation among all the human capital variables at company level. *Company_PHD* and *Company_SumPHDFields* are strongly correlated at 0,92 due to the way they have been defined. Apart from them, overall the correlation across human capital variables is low, suggesting the absence of any relevant problem of multicollinearity.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	**Company_PHD**	10000												
2	**Company_ Prestigious_PHD**	0,4977	10000											
3	**Company_ PHDTechnical**	0,3584	0,14	10000										
4	**Company_ PHDLifeScience**	0,7889	0,4175	-0,1742	10000									
5	**Company_MBa**	0,0558	0,0338	0,0567	0,0063	10000								
6	**Company_ BiotechExp**	0,3089	0,225	0,0172	0,3099	0,2192	10000							
7	**Company_ ProfessorExp**	0,4787	0,2934	0,1484	0,4559	-0,0442	0,0596	10000						
8	**Company_ BigPharmaExp**	0,1394	0,0995	-0,0326	0,1932	0,1684	0,3306	0,0157	10000					
9	**Company_ SumPHDFields**	0,9231	0,4674	0,4714	0,766	0,045	0,2851	0,4812	0,15	10000				
10	**Company_ N_Roles**	0,2127	0,1941	0,1085	0,1392	0,3038	0,6319	-0,0236	0,2846	0,2016	10000			
11	**Company_ CEO_Role**	0,0729	0,0366	0,0053	0,0609	0,1561	0,357	-0,0431	0,115	0,0648	0,426	10000		
12	**Company_ FounderStartup**	0,125	0,1566	0,0746	0,0746	0,0955	0,4017	0,0886	0,0251	0,1229	0,3453	0,3928	10000	
13	**Company_ ManagerialCapabilities**	0,1947	0,1458	0,0836	0,1357	0,527	0,5161	0,0569	0,1529	0,178	0,5193	0,6151	0,6761	10000

Table 28: *Correlation among the main human capital variables at company level.*

5. The Econometric Model

For all the companies of the sample, the process illustrated in Chapter 4 has led to the definition of a dataset containing information about (i) the human capital features of the ventures' founding teams, (i) the patent portfolio and (iii) the VC investors characteristics. This dataset, has been used to run several multinomial logit regressions aimed at addressing the research question of this Thesis. This Chapter presents an extensive description of the variables, starting from the dependent variable (i.e., deal type), moving to independent variables and, finally, control variables. It concludes with the specification of the econometric model.

5.1 Overview of the variables

This section provides general information about all the variables included in the econometric analysis. The aim of the analysis is to study VCs' investment choices in case of radical innovation and how these choices may vary as a response to the signaling effect of founders' human capital.

This research question was addressed through the estimation of an econometric model which relates the dealtype (i.e., no deal, standalone deal or syndicated deal) to a set of independent variables and control variables. In this respect, **Table 29** presents the list of all the variables included in the econometric model, accompanied by a brief description of each.

Variable	Description
dealtype	Dummy variable that equals 1 for standalone realized ties, 2 for syndicated realized ties, 0 for unrealized ties
nb_ipc_mean	Average number of IPC classes of patents in the company's portfolio
familysize_mean	Average family size of patents in the company's portfolio
nb_grant_mean	N. of company's granted patents
d_radical	Dummy variable that equals 1 for companies with at least one radical patent
Company_PHD	Company with at least one founder with a PHD
Company_Prestigious_PHD	Company with at least one founder with a PHD from Top30-World university or Top50-European University
Company_PHDTecnicoScientifico	Company with at least one founder with a PHD in a technical field: engineering, physics, math.
Company_PHDLifeScience	Company with at least one founder with a PHD in a life science: chemistry, biochemistry, biology, medicine etc
Company_SumPHDFields	The sum of the different PHD fields that the company's founders obtained
Company_MBa	Company with at least one founder with a MBA
Company_CEO_Role	Company with at least one founder with experience as CEO
Company_FounderStartup	Company with at least one founder who founded one or more companies
Company_BiotechExp	Company with at least one founder with experience in a company top 30 in sales in the pharmaceutical sector
Company_BigPharmaExp	Company with at least one founder with experience in the biotech sector or related (e.g. pharma, medical devices)
Company_ProfessorExp	Company with at least one founder with experience as university professor
Company_N_Roles	The sum of the different working roles the company's founders performed in the past
expVC	Dummy variable that equals 1 for experienced investors (n_inv_3y greater than its 75th percentile)
CVCi	Dummy variable that equals 1 for CVC investors
GVCi	Dummy variable that equals 1 for GVC investors
log_distance	Logarithm of distance investor – firm
d_industry3d	Categorical variable treated as a vector of 12 industry dummies
d_country	Categorical variable treated as a vector of 19 country dummies
d_period	Categorical variable treated as a vector of 4 period dummies

Table 29: *Description of the variables included in the econometric model.*

Table 30, instead, shows the correlation among all the variables of the model with the exception of the categorical variables to control for industry, country and period for obvious reasons of clarity. The variables do not show any significant correlation, suggesting the absence of problems of multicollinearity.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	**dealtype**	1																								
2	**nb_Pat_preF**	-0,002	1																							
3	**log_distance**	-0,242	0,004	1																						
4	**samecountry**	0,279	-0,013	-0,655	1																					
5	**age**	-0,005	0,165	0,030	0,005	1																				
6	**CVCi**	-0,002	-0,001	0,066	-0,046	0,010	1																			
7	**GVCi**	0,009	-0,004	-0,041	0,006	0,006	-0,127	1																		
8	**other_invi**	-0,001	-0,002	-0,043	0,025	0,010	-0,125	-0,167	1																	
9	**familysize~n**	0,004	-0,052	-0,012	0,004	-0,137	0,002	-0,016	-0,012	1																
10	**nb_citn_mean**	0,005	0,104	0,025	0,004	0,280	0,004	0,008	0,006	-0,016	1															
11	**expVC**	0,006	-0,004	-0,074	0,019	0,002	-0,107	0,187	-0,065	0,004	0,002	1														
12	**d_radical**	0,009	0,247	0,001	0,006	0,165	-0,001	-0,001	-0,007	0,013	0,124	-0,001	1													
13	**Company_PHD**	0,010	-0,037	-0,052	0,021	-0,071	-0,003	0,011	-0,007	0,142	-0,073	0,008	0,001	1												
14	**Company_ Prestigious_PHD**	0,003	0,017	-0,084	0,035	-0,053	0,002	-0,003	-0,006	0,201	-0,081	-0,004	-0,026	0,470	1											
15	**Company_ PHDTechnical**	0,007	-0,050	-0,004	0,021	-0,056	-0,005	0,003	-0,001	-0,109	0,023	-0,001	-0,007	0,367	0,161	1										
16	**Company_ PHDLifeScience**	0,004	-0,010	-0,056	0,008	-0,048	0,003	0,009	-0,005	0,221	-0,124	0,006	-0,013	0,764	0,372	-0,191	1									
17	**Company_ SumPHDFields**	0,011	-0,041	-0,049	0,019	-0,089	0,001	0,007	-0,004	0,112	-0,099	0,005	-0,004	0,911	0,447	0,483	0,742	1								
18	**Company_MBa**	0,012	-0,026	0,024	-0,014	-0,069	0,008	-0,003	-0,002	0,078	-0,020	0,001	-0,001	0,018	0,006	0,026	-0,010	0,014	1							
19	**Company_ CEO_Role**	0,001	0,017	0,008	0,005	-0,103	-0,001	0,002	0,010	0,021	0,051	0,001	-0,060	0,035	0,006	0,006	0,029	0,038	0,172	1						
20	**Company_ ProfessorExp**	0,001	-0,045	-0,039	0,000	-0,052	0,001	-0,001	-0,004	0,079	-0,090	-0,004	-0,055	0,462	0,257	0,159	0,425	0,457	-0,071	-0,049	1					
21	**Company_ FounderStartup**	0,010	0,004	0,018	-0,008	-0,097	-0,011	0,003	0,012	0,040	0,064	0,004	-0,008	0,116	0,143	0,056	0,074	0,114	0,087	0,391	0,069	1				
22	**Company_ BiotechExp**	0,015	0,030	-0,015	0,008	-0,136	0,003	0,011	-0,003	0,144	0,036	0,002	-0,044	0,270	0,189	-0,006	0,290	0,248	0,200	0,329	0,033	0,365	1			
23	**Company_ BigPharmaExp**	0,013	-0,015	-0,067	0,033	-0,121	-0,004	0,003	-0,006	0,146	-0,022	0,004	-0,085	0,133	0,097	-0,036	0,197	0,149	0,151	0,105	0,018	-0,001	0,332	1		
24	**Company_N_Roles**	0,010	-0,033	-0,003	0,006	-0,201	0,005	0,014	0,008	0,001	-0,059	0,004	-0,129	0,185	0,172	0,106	0,114	0,182	0,291	0,407	-0,061	0,312	0,601	0,266	1	
25	**missing_HC**	-0,017	0,018	0,001	-0,013	0,106	-0,003	-0,018	0,004	-0,070	0,074	-0,002	0,103	-0,544	-0,261	-0,206	-0,422	-0,505	-0,184	-0,231	-0,262	-0,254	-0,466	-0,164	-0,450	1

Table 30: *Correlation among the variables included in the econometric model.*

Finally, **Table 31** presents a statistic summary (i.e., mean, standard deviation, minimum and maximum) of the variables of the model, including the dependent one. For the sake of synthesis, the variables which control for the industry, country and period were omitted.

Variable	Mean	Std. Dev.	Min	Max
dealtype	0,0569692	0,32215	0	2
nb_Pat_preF	5,611	20	1	353
log_distance	6,895	1,385	0	9,543
samecountry	0,1477376	0,354844	0	1
age	3,54	3,76	-3	25
CVCi	0,0913588	0,288122	0	1
GVCi	0,1333531	0,33996	0	1
other_invi	0,1521244	0,359146	0	1
familysize~n	9,256687	5,191984	0	37
nb_citn_mean	1,257095	2,717872	0	29
expVC	0,2259812	0,418233	0	1
d_radical	0,2192462	0,413741	0	1
Company_PHD	0,5493841	0,497561	0	1
Company_ Prestigious_PHD	0,2293071	0,420392	0	1
Company_ PHDTechnical	0,1460169	0,353128	0	1
Company_ PHDLifeScience	0,4332371	0,495529	0	1
Company_SumPHDFields	0,5925597	0,573866	0	3
Company_MBa	0,1536942	0,36066	0	1
Company_CEO_Role	0,2090647	0,406646	0	1
Company_ProfessorExp	0,2307882	0,421342	0	1
Company_FounderStartup	0,2400948	0,427146	0	1
Company_BiotechExp	0,4986793	0,500004	0	1
Company_BigPharmaExp	0,1005456	0,30073	0	1
Company_N_Roles	0,8708929	0,896693	0	4
missing_HC	0,2136809	0,409909	0	1

Table 31: *Mean, Standard Deviation, Minimum and Maximum of the variables included in the econometric model.*

5.1 Dependent variable

The dependent variable of the econometric model (i.e., *dealtype*) aims at modelling the three potential conditions in which the venture-investor dyad can turn out. It resulted from the matching process of each company of the sample with all the VC investors actively operating, controlling for the year of foundation. Considering each dyad company-VC, deal type is a categorical variable that equals 0 if there is no tie, at 1 in case of standalone deals and at 2 in case of syndicated deals.

5.2 Explanatory variables

In this section, the explanatory variables of the econometric models are described. They can be subdivided into three main areas of interest: (i) the radicalness of the company's patent portfolio, (ii) human capital variables and (iii) the experience of VC investors.

5.2.1 Radicalness of the company's patent portfolio

The first explanatory variable of this econometric model, *d_radical*, aims at creating an aggregate measure of the radicalness of the patent portfolio and innovation potential of the venture. It is a dummy variable which equals to 1 if within the company's patent portfolio, at investment time, there was one or more patents classified as radical.

Since the concept of radicalness is a key starting point for the analysis, this variable (i.e., *d_radical*) requires a more detailed description. The extant literature has defined several indicators able to define ex-ante the radicalness of a certain invention relying exclusively on patents' information. In this Thesis, a patent is classified as radical if its underlying invention applies a novel combination of components and principles to serve a certain purpose. More specifically the proxy used is the one proposed by Verhoeven, Bakker and Veugelers, (2016). It relies on the group-level IPC codes to which the patent is assigned and for each pair of IPC-Codes it assesses the previous existence of the pair among all the

patents filed before the application year under concern. If that specific pair has not been proposed before, then the associated patent is assessed as radical.

5.2.2 Founders' human capital variables

The second cluster of explanatory variables encompasses proxies for the human capital features of the founders. Considering the research question addressed by this Thesis, this cluster plays a crucial role in the analysis.

The first set of variables contains information about founders' education background, specifically master degree (i.e., *Company_MSc*) and post-graduation education attainments (i.e., *Company_PHD*). In particular, as regards *Company_PHD*, it was broken down into two categories to account for the most common fields of expertise required in biotech industry: technical (*Company_PHDTechnical*) and life-science (*Company_PHDLifeScience*). *Company_PHDTechnical* includes faculties such as engineering, physics, maths and computer science. *Company_PHDLifeScience*, on the other hand, comprises biology, medicine, chemistry and related subjects.

Keeping the focus on PhD education, it was also determined whether the PhD degree was released by a prestigious university (*Company_Prestigious_PHD).* This variable is aligned with what stated by the extant literature regarding affiliation with prestigious universities. Indeed, it is generally agreed that affiliation with prestigious universities has a signaling value for potential investors, making them confident about the scientific quality of the technologies and products the focal company. As claimed by Colombo, Meoli and Vismara (2018), in general, investors are reassured by the endorsement of prestigious universities for two main reasons. On the one hand, they enjoy a solid reputation due to their previous scientific achievements and thus show differential abilities in evaluating the scientific rigor of experiments. On the other hand, because scientific reputation is their critical asset, they put particular effort in screening projects in order not to tarnish their image.

Although all the variables described above (i.e., those about the nature and the level of the education of founders) are generally important drivers of VCs' investment decisions, in this analysis they partly lose their relevance. Indeed, because in the biotech sector the novelty and the success of the developed product is closely dependent on the quality and radicalness of the underlying patent, the signaling effect of patents tends to be much stronger than that of those variables. Nevertheless, as far as the educational attainments reflect the capabilities within the founding teams, these explanatory variables still play an important role in enriching the model and in differentiating the firms by the human capital characteristics of their founders.

Second, prior industry-specific experiences have also been taken into consideration. The competence-based literature suggests that if the business of the new firm (i.e., biotech industry), is similar to the one of the organization in which the founders were previously employed, the capabilities acquired during that experience are crucial for the new company business' success (Colombo and Grilli, 2005). Specifically, the model distinguishes for *Company_BiotechExp* and *Company_BigPharmaExp.* The former is a dummy variable which equals 1 if within the founding team there are one or more members who had a previous professional experience in a firm in the biotech sector or biotech-related sectors (i.e., medical devices, pharmaceutical, chemistry or medicine). The latter is a dummy which equals 1 if one or more company's founders has previously worked in a Big Pharma firm. *Company_BigPharmaExp* measures not only the industry-specific capabilities, but also the benefits of the professional network that the founder was able to create while working in a big pharmaceutical company prior to the foundation of the new firm.

Third, the model also accounts for the roles in which the venture's founders were previously employed. Regarding that, two variables have been taken into consideration: *Company_TechnicalRole* and *Company_N_Roles.* The former indicator defines whether any of the founders has a previous work experience in the R&D, design, engineering or production department of any company. It is worth noting, however, that the vast majority of those with a prior experience in a technical role, held this role in a firm belonging to the

biotech industry. The latter variable, instead, is a measure that aggregates the previous experiences of the founders in the different functions. As explained before, the roles have been clustered in four categories: technical, commercial, finance and managerial. This variable works as a proxy to detect the existence of synergistic gains within the founding team, arising from the heterogeneity of working-related capabilities developed during their previous roles (Colombo and Grilli, 2005).

Fourth, a group of variables provides a measure of the managerial and entrepreneurial capabilities of the founding team. *Company_FounderStartup* aims at modelling the signaling effect of a previous entrepreneurial episode. This variable equal 1 if one or more founders had prior self-employment experience as the foundation of a company. *Company_CEORole* is a dummy variable, which equals 1 if within the founding team there are one or more individuals who had a CEO position in a medium or large company prior to the establishment of the new firm. On this regard, literature presents different theoretical explanations of the possible effect of such signals, but they agree with its positive impact. In most of the cases, managerial and entrepreneurial skills benefit from learning by doing (Colombo and Grilli, 2005), therefore both these variables are expected to play a significant signaling role in the analysis. The last variable of this cluster is *Company_MBa*. It is a dummy which considers founders' attainment of an MBA education. It is expected to have a positive coefficient in the model because of its perception as a strong signal of professional network and superior managerial expertise.

In order to analyse the synergetic gains that may come from the combination of different and complementary managerial capabilities, it was taken into consideration a further variable which aggregates the three managerial competencies' proxies defined above, namely *Company_ManagerialCapabilities*. It is a dummy variable that equals 1 if at least one of the founders has a prior self-employment experience, or a prior experience as CEO or possesses an MBA. In other words, it holds:

$$Company\_ManagerialCapabilities = \max(Company\_FounderStartup, Company\_CEORole, Company\_MBa)$$

Lastly, a further dummy variable, *Company_ProfessorExp*, aims at modelling the scientific competencies of the venture's founders. *Company_ProfessorExp* equals 1 if one of the founders had a previous work experience as university professor and zero otherwise. In this respect, having a professor as founder is considered to be a good proxy to assess whether the company was born as spin-offs from a university project.

5.2.3 Experience of VC investors

The last explanatory variable of the econometric model is the dummy *expVC*. It is introduced in the model in order to account for differences in the signal's receivers, which may affect the interpretation of the signal sent. This variable distinguishes experienced VCs from non-experienced ones. Specifically, it identifies as "experienced VC" those venture capitalists which are located in the highest quartile of a distribution for number of realized deals prior to the financing. It is equal to 1 if the VC is experienced at the time of investment in the company under analysis, while it is equal to 0 otherwise.

5.3 Control variables

Several control variables were included in the model in order to control for additional characteristics of the venture, of their patent portfolio, of VC investors and of the context of investment.

A first cluster of variables controls for aspects related to the patent portfolio of the venture. It comprises three different variables: (i) *nb_ipc_mean* measures the average number of IPC classes of patents' in the company's portfolio, (ii) *familysize_mean* counts the average family size of patents in the company's portfolio, (iii) *nb_grant_mean* measures the number of company's granted patents.

Second, moving to investor-related variables, two dummy variables - *CVCi and GVCi* – account for the investor's organizational structure and distinguish between corporate venture capital investors and governmental venture capital investors, respectively.

Third, two variables control for geographical characteristics which may influence the business interactions between companies and VCs. On one hand, the variable *log_distance* aims at modelling the negative influence that the distance between investor and investee can enforce on VC investment decision process due to the bigger difficulties in the evaluation of the investment opportunity and the monitoring of firm's performances. Given the flattening shape of the logarithm curve, a log function was used to mitigate the impact of long distances on the distribution. Indeed, it is reasonable to assess that the VC risk perception of an investment is not linearly influenced by distance. At the beginning, the negative impact grows exponentially with the distance, and then it experiences a gradual reduction of the marginal effect as the distance becomes longer. On the other hand, a dummy variable (*samecountry*) controls whether VC and firm have their headquarters located in the same country (*samecountry = 1).*

Finally. the last group includes mixed control variables. *Age* controls for the age of the company at investment time. Four *d_period* dummy variables control for the years in which the investor – firm tie took place, while nineteen *d_country* dummy variables were included to differentiate the firms by the country in which they were incorporated. This is supposed to help to control for country-specific factors that may influence venture capitalists. Lastly, twelve *d_industry3d* dummy variables were included in the model to control for industry-specific factors that may have an impact on the VCs' investment decision.

5.4 Specification of the econometric model

This scope of this Chapter is defining the specification of the econometric model. In reality, several different multinomial logit models have been run in order to account for the interaction between radicalness and different human capital features. In the following sections the regression equations of all those models are presented.

5.4.1 Econometric model to test *HP1*

In order to test the first hypotheses of this Thesis (i.e., *HP1*), the above-mentioned variables have been used to define the following multinomial logit model specification:

$$dealtype = \eta_o + \alpha\ d\_radical + \beta_1\ GeneralHC + \beta_2\ ManagerialHC + \beta_3\ Company\_ProfessorExp + \gamma\ expVC + \delta\ Controls + \varepsilon_i \quad (1)$$

The dependent variable *dealtype,* as previously stated, is a categorical variable that can assume the value 0,1 or 2 according to the typology of deal occurring for each specific dyad venture-investor (i.e., no deal, standalone deal or syndicated deal, respectively).

d_radical, *GeneralHC*, *ManagerialHC* and *Company_ProfessorExp*, together, include all the explanatory variable of the model. The dummy *d_radical*, mentioned above, indicates whether the venture possesses at least one radical patent in its portfolio. It plays a major role in the analysis as it is the only variable responsible for the information about radicalness. *GeneralHC*, *ManagerialHC* and *Company_ProfessorExp* bring together all the explanatory variables regarding founders' human capital endowment. *GeneralHC* is a vector containing several information about founders' background education and prior work experience, which are not directly linked to hypotheses *HP2a* and *HP2b* (i.e., the hypotheses about the signaling effect of human capital). The variables (all dummies) included in this vector are: *Company_MSc, Company_PHD, Company_PHDTechnical, Company_PHDLifeScience, Company_Prestigious_PHD, Company_BiotechExp, Company_BigPharmaExp, Company_TechnicalRole* and *Company_N_Roles*. *ManagerialHC*, instead, is a vector that comprises all the dummy variables describing the managerial capabilities of founders. These variables play a key role in addressing hypothesis *HP2a* and comprehend *Company_FounderStartup, Company_CEORole* and *Company_MBa*. Next, the dummy *Company_ProfessorExp* is considered a reasonable proxy for the scientific competencies of the founding team and has a significant relevance in relation to hypothesis *HP2b.* Finally, the dummy *expVC* indicates whether the investor involved in a certain deal is experienced or not and plays a crucial role in testing hypothesis *HP3*.

Controls is a vector composed by all the control variables of the model. Specifically, the vector includes patent-related variables (i.e., *nb_ipc_mean*, *familysize_mean* and *nb_grant_mean*), investor-related variables (i.e., the dummies *CVCi* and *GVCi*, *log_distance* and *samecountry*) and other variables regarding the investment (i.e., A*ge*, *d_period*, *d_country* and *d_industry3d)*. Finally, ε_i is the error term.

5.4.2 Econometric models to test *HP2a*

The second hypothesis formulated in this thesis, requires to analyse the interaction between radicalness and the signal about the managerial competencies of the venture's founders. In order to test *HP2a*, four different models have been developed, starting from the one below.

$$dealtype = \eta_o + \alpha\ d\_radical + \beta_1\ GeneralHC + \beta_2\ ManagerialHC + \beta_3\ Company\_ProfessorExp + \beta_4 d\_radical * Company\_Founder\ Startup + \gamma\ expVC + \delta\ Controls + \varepsilon_i \quad (2.1)$$

Compared to equation (1), this model introduces an interactive term between *d_radical* (i.e., measure of radicalness) and *Company_FounderStartup* (i.e., one of the proxies for founders' managerial competencies). The two models below follow the same principle, but take into consideration the other two dummies expressing managerial competencies (i.e., *Company_CEORole* and *Company_MBa*).

$$dealtype = \eta_o + \alpha\ d\_radical + \beta_1\ GeneralHC + \beta_2\ ManagerialHC + \beta_3\ Company\_ProfessorExp + \beta_4 d\_radical * Company\_CEORole + \gamma\ expVC + \delta\ Controls + \varepsilon_i \quad (2.2)$$

$$dealtype = \eta_o + \alpha\ d\_radical + \beta_1\ GeneralHC + \beta_2\ ManagerialHC + \beta_3\ Company\_ProfessorExp + \beta_4 d\_radical * Company\_MBa + \gamma\ expVC + \delta\ Controls + \varepsilon_i \quad (2.3)$$

Nevertheless, the three models above present a limitation. They analyse the interaction between radicalness and managerial competencies considering each proxy of managerial competencies separately. In this way, in every equation, the interactive effects of the other

two dummies related to managerial competencies are neglected. In order to compensate for this limitation, the vector *ManagerialHC* has been replaced with the dummy *Company_ManagerialCapabilities*. As explained in Chapter 5.2.3, this variable is an aggregate measure of managerial competencies that equal 1 if at least one of the founders has a prior self-employment experience, or a prior experience as CEO or possesses an MBA.

$$dealtype = \eta_o + \alpha\ d\_radical + \beta_1\ GeneralHC + \beta_2 Company\_ManagerialCapabilities + \beta_3 Company\_ProfessorExp + \beta_4 d\_radical * Company\_ManagerialCapabilities + \gamma\ expVC + \delta\ Controls + \varepsilon_i \quad (2.4)$$

5.4.3 Econometric model to test *HP2b*

Hypothesis *HP2b* aims at investigating how the signaling effect of founders' scientific competencies may influence the effect of radicalness in syndicated deals. Hence, similarly to the models presented in the previous section, it requires to include an interactive term composed by *d_radical* (i.e., measure of radicalness) and *Company_ProfessorExp* (i.e., main proxy of founders' scientific competencies).

$$dealtype = \eta_o + \alpha\ d\_radical + \beta_1\ GeneralHC + \beta_2 ManagerialHC + \beta_3 Company\_y\_ProfessorExp + \beta_4 d_{radical} * Company\_ProfessorExp + \gamma\ expVC + \delta\ Controls + \varepsilon_i \quad (2.5)$$

5.4.3 Econometric models to test *HP3*

Finally, the last hypothesis of this Thesis (i.e. *HP3*) aims at analysing whether the joint signaling effect of radicalness and human capital in syndicated deals may result either enhanced or reduced by the presence of experienced VC. Hence, to address this hypothesis, it is necessary to edit the last models presented (i.e., 2.1, 2.2, 2.3, 2.4 and 2.5), by introducing a further interaction with the dummy *expVC.* The following multinomial logit specifications can be derived:

$$dealtype = \eta_o + \alpha\, d\_radical + \beta_1\, GeneralHC + \beta_2 ManagerialHC + \beta_3 Company\_ProfessorExp + \beta_4 d\_radical * Company\_FounderStartup + \gamma_1\, expVC + \gamma_2\, expVC * d\_radical + \gamma_3\, expVC * Company\_FounderStartup + \gamma_4\, expVC * Company\_FounderStartup * d\_radical + \delta Controls + \varepsilon_i \quad (3.1)$$

$$dealtype = \eta_o + \alpha\, d\_radical + \beta_1\, GeneralHC + \beta_2 ManagerialHC + \beta_3 Company\_ProfessorExp + \beta_4 d\_radical * Company\_CEORole + \gamma_1\, expVC + \gamma_2\, expVC * d\_radical + \gamma_3\, expVC * Company\_CEORole + \gamma_4\, expVC * Company\_CEORole * d\_radical + \delta Controls + \varepsilon_i \quad (3.2)$$

$$dealtype = \eta_o + \alpha\, d\_radical + \beta_1\, GeneralHC + \beta_2 ManagerialHC + \beta_3 Company\_ProfessorExp + \beta_4\, d\_radical * Company\_MBa + \gamma_1\, expVC + \gamma_2\, expVC * d\_radical + \gamma_3\, expVC * Company\_MBa + \gamma_4 expVC * Company\_MBa * d\_radical + \delta Controls + \varepsilon_i \quad (3.3)$$

$$dealtype = \eta_o + \alpha\, d\_radical + \beta_1\, GeneralHC + \beta_2 Company\_ManagerialCapabilities + \beta_3 Company\_ProfessorExp + \beta_4 d\_radical * Company\_ManagerialCapabilities + \gamma_1 expVC + \gamma_2\, expVC * d\_radical + \gamma_3\, expVC * Company\_ManagerialCapabilities + \gamma_4\, expVC * Company\_ManagerialCapabilities * d\_radical + \delta Controls + \varepsilon_i \quad (3.4)$$

$$dealtype = \eta_o + \alpha\, d\_radical + \beta_1\, GeneralHC + \beta_2 ManagerialHC + \beta_3 Company\_ProfessorExp + \beta_4 d\_radical * Company\_ProfessorExp + \gamma_1\, expVC + + \gamma_2\, expVC * d\_radical + \gamma_3\, expVC * Company\_ProfessorExp + \gamma_4\, expVC * Company\_ProfessorExp * d\_radical + \delta Controls + \varepsilon_i \quad (3.5)$$

6. Empirical Results

This Chapter aims at presenting the results of all the multinomial logit regressions run, whose specifications have been defined in Chapter 5.

6.1 Results of the multinomial logit regression models

The two tables below illustrate the overall results of the different multinomial logit regressions in case of both standalone (**Table 33**) and syndicated deals (**Table 34**) against the no-deal baseline scenario. The six models (associated to equations 1, 2.1, 2.2, 2.3, 2.4 and 2.5 presented in Chapter 5.4) include all explanatory human capital variables, two independent variables characterising firms' radicalness and VCs' experience and a set of variables to control for companies' patents portfolio, additional VCs features, industry, country and timespan of investment time. With the exception of Model I, interactive terms among a selected human capital feature of founders and a measure of radicalness of the firm are added to the set of explanatory variables in order to evaluate the synergistic effects.

Standalone deals	I	II	III	IV	V	VI
nb_Pat_preF	0,003 **	0,003 *	0,003 **	0,002 *	0,003 *	0,003 *
	(0,002)	(0,001)	(0,001)	(0,001)	(0,001)	(0,001)
log_distance	-0,281 ***	-0,283 ***	-0,283 ***	-0,282 ***	-0,282 ***	-0,278 ***
	(0,051)	(0,051)	(0,051)	(0,051)	(0,051)	(0,051)
samecountry	3,308 ***	3,310 ***	3,310 ***	3,310 ***	3,311 ***	3,312 ***
	(0,262)	(0,263)	(0,262)	(0,262)	(0,262)	(0,262)
age	0,016	0,016	0,016	0,016	0,016	0,019
	(0,016)	(0,016)	(0,016)	(0,016)	(0,016)	(0,016)
CVCi	0,234	0,231	0,231	0,229	0,229	0,299
	(0,267)	(0,267)	(0,267)	(0,267)	(0,267)	(0,265)
GVCi	0,001	0,002	0,000	0,000	-0,001	0,070
	(0,192)	(0,192)	(0,192)	(0,192)	(0,192)	(0,189)
d_radical	-0,006	0,025	-0,058	0,016	0,003	-0,016
	(0,15)	(0,163)	(0,155)	(0,159)	(0,170)	(0,170)
familysize_mean	0,027 **	0,028 **	0,029 **	0,028 **	0,028 ***	0,029 **
	(0,012)	(0,012)	(0,012)	(0,012)	(0,012)	(0,012)
nb_citn_mean	-0,001	0,001	0,001	0,001	0,002	-0,001
	(0,019)	(0,02)	(0,020)	(0,020)	(0,020)	(0,020)
expVC	0,507 ***	0,512 ***	0,513 ***	0,512 ***	0,514 ***	0,533 ***
	(0,163)	(0,162)	(0,163)	(0,163)	(0,163)	(0,163)
company_PHD	0,096	0,097	0,092	0,086	0,103	0,094 *
	(0,3)	(0,31)	(0,311)	(0,308)	(0,308)	(0,308)
Company_Prestigious_PHD	-0,032	-0,038	-0,039 *	-0,045	-0,036	-0,059
	(0,190)	(0,191)	(0,192)	(0,190)	(0,192)	(0,187)
Company_MBa	-0,151	-0,124	-0,136	-0,060	-0,123	
	(0,186)	(0,191)	(0,195)	(0,205)	(0,192)	
Company_SumPHDFields	-0,208	-0,194	-0,205	-0,185	-0,212	-0,177
	(0,243)	(0,253)	(0,255)	(0,253)	(0,253)	(0,253)
Company_ProfessorExp	-0,034	-0,008	0,003	-0,008	0,024	-0,006
	(0,173)	(0,177)	(0,178)	(0,178)	(0,189)	(0,178)
Company_FounderStartup	-0,220	-0,153	-0,201	-0,214	-0,206	
	(0,167)	(0,188)	(0,169)	(0,169)	(0,169)	
Company_CEO_Role	-0,265	-0,151	-0,185	-0,135	-0,151	
	(0,178)	(0,196)	(0,203)	(0,196)	(0,197)	
Company_BiotechExp	0,120	0,171	0,144	0,161	0,149	0,138
	(0,152)	(0,177)	(0,173)	(0,173)	(0,173)	(0,173)
Company_BigPharmaExp	-0,024	-0,083	-0,051	-0,093	-0,063	-0,061
	(0,21)	(0,210)	(0,211)	(0,211)	(0,207)	(0,211)
Company_TechnicalRole	0,273 *	0,412 **	0,415 **	0,416 **	0,407 *	0,454 **
	(0,163)	(0,208)	(0,209)	(0,209)	(0,209)	(0,200)
Company_N_Roles	-0,141	-0,150	-0,141	-0,145	-0,136	-0,174
	(0,134)	(0,136)	(0,134)	(0,134)	(0,134)	(0,136)
missing_HC	0,198	0,145	0,144	0,141	0,144	0,164
	(0,188)	(0,195)	(0,196)	(0,196)	(0,196)	(0,197)
Company_ ManagerialCapabilities						-0,159
						(0,179)
d_radical * Company_FounderStartup		-0,272				
		(0,422)				
d_radical * Company_CEO_Role			0,2358575			
			(0,435)			
d_radical * Company_MBa				-0,329		
				(0,479)		
d_radical * Company_ProfessorExp					-0,163	
					0,3860189	
d_radical * Company_ ManagerialCapabilities						-0,061
						(0,319)
_cons	-5,788 ***	-5,926 ***	-5,890 ***	-5,913 ***	-5,929 ***	-6,101 ***
	(0,563)	(0,591)	(0,585)	(0,589)	(0,589)	(0,573)

Table 32: *Results of the multinomial logit regression models: the effect of radicalness and human capital features on the probability of closing a standalone deal with respect to no deal (i.e., the base case).*
Note: *The table shows coefficients and standard errors of six multinomial logit regressions, whose dependent variable is specified in the first row. Standard errors can be found in brackets. *p-value< .05. **p-value< .01. ***p-value< .001.*

Syndicated deals	I	II	III	IV	V	VI
nb_Pat_preF	-0,0003	0,000	0,000	-0,000122	0,000	-0,001
	(0,002)	(0,002)	(0,002)	(0,002)	(0,002)	(0,002)
log_distance	-0,245 ***	-0,246 ***	-0,247 ***	-0,24596 ***	-0,247 ***	-0,247 ***
	(0,038)	(0,038)	(0,038)	(0,038)	(0,038)	(0,038)
samecountry	2,775 ***	2,774 ***	2,771 ***	2,771 ***	2,773 ***	2,760 ***
	(0,168)	(0,168)	(0,168)	(0,168)	(0,168)	(0,168)
age	-0,012	-0,012	-0,011	-0,0113726	-0,010 *	-0,013
	(0,014)	(0,014)	(0,014)	(0,014)	(0,014)	(0,014)
CVCi	0,175	0,176	0,180	0,1778132	0,185	0,170
	(0,173)	(0,173)	(0,173)	(0,173)	(0,173)	(0,173)
GVCi	0,148	0,148	0,147	0,147211	0,149	0,143
	(0,117)	(0,117)	(0,117)	(0,117)	(0,117)	(0,114)
d_radical	0,257 **	0,345 **	0,359 **	0,2767946 *	0,134	0,378 *
	(0,140)	(0,168)	(0,153)	(0,154)	(0,171)	(0,195)
familysize_mean	0,005	0,004	0,003	0,0050349 *	0,005	0,004
	(0,015)	(0,015)	(0,015)	(0,015)	(0,015)	(0,015)
nb_citn_mean	0,020	0,019	0,020	0,0201381	0,018	0,020
	(0,013)	(0,014)	(0,014)	(0,014)	(0,014)	(0,014)
expVC	-0,008	-0,010	-0,012	-0,0095348	-0,013	-0,001
	(0,105)	(0,104)	(0,104)	(0,104)	(0,104)	(0,104)
company_PHD	-0,085	-0,176	-0,200	-0,1725816	-0,192	-0,192
	(0,308)	(0,315)	(0,315)	(0,318)	(0,316)	(0,323)
Company_Prestigious_PHD	-0,104	-0,094	0,100	-0,0979411	-0,096	-0,067
	(0,152)	(0,150)	(0,150)	(0,150)	(0,148)	(0,148)
Company_MBa	0,245	0,195	0,204	0,1842202	0,177	
	(0,145)	(0,1467)	(0,147)	(0,168)	0,146459	
Company_SumPHDFields	0,136	0,116	0,137	0,1058676	0,134	0,123
	(0,311)	(0,307)	(0,307)	(0,311)	(0,309)	(0,318)
Company_ProfessorExp	0,028	-0,020	-0,019	-0,0128598 *	-0,161 *	-0,005 *
	(0,147)	(0,148)	(0,148)	(0,148)	(0,163)	(0,150)
Company_FounderStartup	0,171 *	0,204 *	0,152 *	0,1536648 *	0,161	
	(0,130)	(0,139)	(0,128)	(0,129)	0,1283636	
Company_CEO_Role	-0,206 **	-0,314 **	-0,228 **	-0,3153705 **	-0,304 **	
	(0,132)	(0,146)	(0,162)	(0,146)	0,1462207	
Company_BiotechExp	0,065	-0,006	-0,015	-0,0278312	-0,036	-0,002 *
	(0,135)	(0,144)	(0,142)	(0,144)	(0,141)	(0,144)
Company_BigPharmaExp	0,161	0,202	0,181	0,2179423	0,207	0,158
	(0,225)	(0,227)	(0,231)	(0,232)	(0,233)	(0,224)
Company_TechnicalRole	-0,259 *	-0,261 *	-0,260 *	-0,2602067 *	-0,250 *	-0,144
	(0,158)	(0,158)	(0,158)	(0,158)	(0,158)	(0,152)
Company_N_Roles	0,091	0,081	0,089	0,0909773	0,092 **	0,019
	(0,092)	(0,093)	(0,093)	(0,092)	(0,090)	(0,089)
missing_HC	-0,498 **	-0,500 **	-0,503 **	-0,4981798 **	-0,479 **	-0,510 **
	(0,200)	(0,200)	(0,200)	(0,200)	(0,201)	(0,202)
Company_ManagerialCapabilities						0,087
						(0,138)
d_radical * Company_FounderStartup		-0,229				
		(0,278)				
d_radical * Company_CEO_Role			-0,464 *			
			(0,331)			
d_radical * Company_MBa				0,0383799		
				(0,334)		
d_radical * Company_ProfessorExp					0,614 **	
					0,2573737	
d_radical * Company_ManagerialCapabilities						-0,191
						(0,263)
_cons	-4,990 ***	-4,764 ***	-4,773 ***	-5 ***	-4,705 ***	-4,781 ***
	(0,512)	(0,530)	(0,527)	(0,527)	(0,524)	(0,529)

Table 33: *Results of the multinomial logit regression models: the effect of radicalness and human capital features on the probability of closing a syndicated deal with respect to no deal (i.e., the base case).*
Note: *The table shows coefficients and standard errors of six multinomial logit regressions, whose dependent variable is specified in the first row. Standard errors can be found in brackets. *p-value< .05. **p-value< .01. ***p-value< .001.*

6.2 General considerations

In order to provide a general overview of the results, two considerations deserve particular attention as they represent the baseline on which to develop the rest of the analysis.

First, looking at the estimated coefficients, it emerges that the experience of VC investors (measured in terms of amount of deals realized in a predetermined period of years) plays an important role in the standalone deals as if a greater practical experience seems to be required to deal with the higher risk of investing alone. In this respect, the coefficient of *expVC* is positive and significant at 99%.

Second, given the nonlinear specification of the multinomial logit model, looking at the significance and the magnitude of the estimated coefficients is not sufficient to assess the impact of the variables of interest and the existence of moderating effects. To ascertain whether the various hypotheses are confirmed a marginal analysis of the interactive terms has to be carried out for each model.

6.3 Effect of radicalness in syndicated deals

The first column shows the results of Model I, the baseline conditions with no-interactions between variables (associated to equation 1, illustrated in Chapter 5.4.1). It stands out that the radicalness of a company as reflected by *d_radical* has a positive effect significant at 95% on syndicated deals. Hence, the likelihood of closing a syndicated deal with respect to no-deal increases with the radicalness of the company's underlying invention. As argued in hypothesis *HP1*, in the presence of a radical innovation, investors do not give up on the high return potentials. Nevertheless, at the same time, they are prone to invest in syndication as a way to share the higher perceived risk owed to the tougher difficulties in translating the companies' innovations into marketable products and therefore profits. In this regard, besides what emerges from the econometric regression, it is interesting to go further and study the marginal effect of radicalness on syndicated deals. The marginal

analysis of *d_radical* in Model I, shown in **Table 34**, illustrates that, in the presence of at least one radical patent in the venture, the probability of concluding a syndicated deal increases by 0,5 % significant at 95 %. The coefficient for standalone deals, though positive, is not significant. Being the probability of syndication around 2,5 %, such change represents a 20 % increase. As the focus of the analysis is on the impact of radicalness on syndication and eventual changes resulting from the signaling effect of human capital features, the analysis will be focused entirely on the syndication part of the regression outputs.

	ME	Std. Err.	Sign.
No-Deal	-0,005	0,002	**
Standalone	0,000	0,001	
Syndicate	0,005	0,003	**

Table 34: *Marginal effect of radicalness based on Model I.*
*(Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

6.3 Signaling effect of founders' managerial competencies

The following sections aim at presenting the results of Models II, III, IV and IV, all including interactive terms between radicalness and proxies of founders' managerial competencies. Specifically, each section treats a different proxy (i.e., prior entrepreneurial experience, prior experience as CEO and attainment of an MBA).

6.3.1 Model II: signaling effect of founders with prior entrepreneurial experience

The estimates of Model II (associated to the equation 2.1, illustrated in Chapter 5.4.2) show that *Company_FounderStartup* has a positive coefficient at conventional confidence levels. From the marginal analysis shown in **Table 35** it emerges that the marginal effect of *d_radical* on syndicated deals is positive and significant at 95 % in case of absence of

founders with prior experience as entrepreneurs; while it is no more significant when at least one founder has previously founded another start-up. In particular, if there are no serial entrepreneurs in the founding team, radicalness increases the probability of syndication by 0,6 %. Being the probability of syndication equal to just 2,5 % of the total potential ties, this represents a 26 % increase. Conversely, the probability of going for syndication turns out not to be affected by radicalness (i.e., radicalness does no more lead to syndication) if the firm has one or more serial entrepreneurs within the founding team. This confirms the contention of Hypothesis *HP2a* that high managerial competencies of the founding team, represented by prior entrepreneurial experiences, counterbalance the effect of radicalness in syndicated deals.

	No Serial Entrepreneur			**Yes Serial Entrepreneur**		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal	-0,006	0,003	**	-0,001	0,004	
Standalone	0,000	0,001		-0,001	0,002	
Syndicate	0,006	0,003	**	0,002	0,005	

Table 35: *Marginal effect of radicalness (based on Model II) in the presence and in the absence of a founder with a prior self-employment experience. (Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

6.3.2 Model III: signaling effect of founders with prior experience as CEOs

Model III (associated to the equation 2.2, illustrated in Chapter 5.4.2) draws the attention to the managerial experiences developed by founders through their past experiences as CEOs. The results of the marginal analysis on the interaction *d_radical * Company_CEO_Role* (**Table 36**) highlight that, when there is no founder with a previous role as CEO, the marginal effect of radicalness increases the probability of syndication by 0,7 %, significant at 95 %. Although the impact might seem marginal in absolute terms, it represents a 28 % increase relatively to the portion of syndicated ties - which are only the 2,5 % of the total potential ones. Contrarily, when at least one founder has a prior experience as CEO, the marginal effect of radicalness on syndication is no more significant.

Thus, it stands out that radicalness leads to syndication only when it is not compensated by high founders' managerial competencies (considering prior experience as CEOs as a proxy of managerial competencies).

	No Previous CEO			Yes, Previous CEO		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal	-0,007	0,003	**	0,000	0,004	
Standalone	-0,001	0,001		0,001	0,003	
Syndicate	0,007	0,003	**	-0,002	0,004	

Table 36: *Marginal effect of radicalness (based on Model III) in the presence and in the absence of a founder with a prior experience as CEO. (Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

6.3.3 Model IV: signaling effect of founders with an MBA

The estimates of Model IV (associated to the equation 2.3, illustrated in Chapter 5.4.2) help to further clarify the role of the managerial competencies in the VCs' investment decision process. Indeed, it was tested whether the attainment of an MBA might play some kind of signaling role in the probability to strike a syndicated deal. If this variable turned out to affect the effect of radicalness in syndicated deals, this would support the claim of Hypothesis *HP2a* that founders' managerial competencies might compensate for the risk of radicalness.

From the marginal analysis of the interactive term between *d_radical* and *Company_MBa* it stands out that in absence of a founder with an MBA, the average marginal effect of radicalness increases the probability of syndication by 0,5 % significant at 95 % (**Table 37**). Given that the portion of syndicated deals in the database reaches barely the 2,5 % of the total, that small increase in absolute terms represents a +20 % if measured relatively to the syndication portion. Conversely, as it is shown by the low level of significance, radicalness stops having a remarkable effect on the probability on syndication in case the company has one or more founders with an MBA. Hence, in accordance with Hypothesis

HP2a, firms established by a founding team with any member who obtained an MBA has a higher probability to strike a syndicated deal.

	No MBA Education			Yes MBA Education		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal	-0,005	0,003	*	-0,005	0,006	
Standalone	0,000	0,001		-0,002	0,002	
Syndicate	0,005	0,003	**	0,007	0,007	

Table 37: *Marginal effect of radicalness (based on Model IV) in the presence and in the absence of a founder with an MBA. (Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

6.3.4 Model VI: signaling effect of overall managerial competencies

All the previous three models support the claim in Hypothesis *HP2a* that the presence of a founder with managerial competencies in a company counterbalances the effect of radicalness in syndicated deals. Nevertheless, the effects of the three signals have been tested one at a time, while it would be of extreme interest to study the complementary signaling effect of an aggregated measure which considers the overall managerial competences of a firm as a single signal.

In order to estimate this overall effect, according to the equation 2.4 (illustrated in Chapter 5.4.2), in Model VI the three managerial competencies variables (*Company_FounderStartup*, *Company_CEO_Role* and *Company_MBa*) were replaced with a new variable *Company_ManagerialCapabilities* which combines them in one variable as if the VCs would receive them as a single signal. The estimates of Model VI help to further strengthen the role of managerial competencies as a positive signal for VC. As **Table 38** illustrates, the marginal effect of radicalness increases the probability to strike a deal in syndication by 0,7 % significant at 95% when the founding team does not possess any managerial competence. In this case, the direct impact relatively only to the portion of ties in syndication would be a + 28% increase. Contrarily, when founders possess one or more

of the three above-mentioned managerial competencies (i.e., *Company_ManagerialCapabilities* = 1), the marginal effect of radicalness becomes not significant. Thus, hypothesis *HP2a* has been once again corroborated.

	No managerial capabilities			Yes managerial capabilities		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal	-0,007	0,004	*	-0,003	0,003	
Standalone	0,000	0,001		-0,001	0,001	
Syndicate	0,007	0,004	**	0,004	0,004	

Table 38: *Marginal effect of radicalness (based on Model VI) in the presence and in the absence of at least one managerial capability. (Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

6.4 Signaling effect of founders' scientific competencies

This section presents the results of Model V, which includes an interactive term between radicalness and the proxy of founders' scientific competencies (i.e., founders' prior experience as professors). From the results it stands out that founders' scientific competencies present an opposite effect with respect to founders' managerial competencies on syndicated deals.

6.4.1 Model V: signaling effect of founders with prior experience as professors

As far as it concerns founders' scientific competences, in Model V the managerial competences' variables were replaced by *Company_ProfessorExp* (according to the correspondent equation 2.5, presented in Chapter 5.4.3). This dummy variable equals 1 if one or more founders were previously university professors. Given the fact that most companies with a professor in their founding team are spin-offs of a university research project, this variable represents a good proxy of the amount of companies in the sample which were created within universities Hub as a result of a research program. At the same

time, professors have generally a profound knowledge in their fields of expertise because of their doctoral studies and the additional researches they developed. This variable draws the focus on the impact of rich founders' scientific competencies on VCs' investment decisions as a sign of quality, but even higher radicalness of the firms' innovation. In other words, although the presence of a professor in the founding team signals a very high potential return, this brings also higher perceived risks due to the higher radicalness and knowledge-intensiveness of the patents.

In accordance with Hypothesis *HP2b*, the presence of a founder with an experience as professor turns out to positively influence the probability of syndication against a no-deal scenario. As a matter of fact, as **Table 33** shows, the interactive term between *d_radical* and *Company_ProfessorExp* has a positive coefficient significant at 95 %. This result which is already very relevant in the overall picture becomes dramatically meaningful once its marginal impact on syndication has been analysed.

As it is illustrated in **Table 39** the output shows that the average marginal effect of radicalness increases syndication probability by 1,55 % which represents in relative terms a stunning 62 % increase of syndication. The result is statistically significant at 99%. Conversely, in case of a company with a professor in its founding team, the effect of radicalness on the probability of syndication seems not to play any relevant role. As claimed by Hypothesis *HP2b*, this indicates that high founders' scientific competencies drastically reinforce the effect of radicalness in syndicated deals.

	No Professor experience			Yes Professor experience		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal	-0,002	0,003		-0,014	0,004	***
Standalone	0,000	0,001		-0,001	0,002	
Syndicate	0,002	0,003		0,015	0,005	***

***Table 39**: Marginal effect of radicalness (based on Model V) in the presence and in the absence of a founder with a prior experience as professor. (Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

Before moving to the next section, it is worth noting that, this analysis has focused on proxies of founders' managerial competencies and of scientific competencies. Nevertheless, other human capital features, including founders' prior work experience either in industry-specific firms or in other sectors, seem not to play a relevant signaling role in the presence of radicalness. The same applies to the education attainments with the exception of *Company_MBa* because of its managerial competence's signal rather than the scientific expertise in itself.

6.5 Effect of experienced VCs

As a second part of the study, given the fact that *expVC* plays an important role in the standalone deals as it was highlighted at the beginning of this section, the interactive term at two variables was replaced by an interactive term at three variables. The new interactive term includes a characteristic of radicalness (*d_radical*), the experience of the VCs (*expVC*) and a human capital variable, different case by case. For comparison purpose, the results of the five additional models (associated to the equations 3.1, 3.2, 3.3, 3.4 and 3.5, illustrated in Chapter 5.4.3) are reported in **Annex D**. Marginal analyses have been computed an all the interactive terms of the five models.

First, for what it concerns the proxies of founders' managerial competencies, the results of the marginal analyses confirm the previous outcomes with an interesting exception. More specifically, the results of the marginal analyses on the variables *Company_FounderStartup* and *Company_CEOrole* (reported in **Annex E**) show that the marginal effect of radicalness on syndicated deals is positive and significant only in the case of absence of one of the proxies of founders' managerial competencies, confirming the precedent results. Nevertheless, quite surprisingly, the marginal analysis of the model which includes *Company_MBa* as human capital variable in the triple interactive term, shows opposite and counterintuitive results to those previously found (**Table 41**). Indeed, the probability of syndicating in the presence of radicalness seems to increase when the presence of one or more founders with an MBA is combined with an experienced VC. Contrarily, the model described in **Table 37** (without the interaction with experienced VCs) was showing that the marginal effect of radicalness becomes non-significant in presence of at least one founder with an MBA.

	Low Experience			**High experience**		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal						
No MBA Education	-0,005	0,003		-0,005	0,004	
Yes MBA Education	0,001	0,006		-0,023	0,012	**
Standalone						
No MBA Education	0,000	0,001		0,001	0,003	
Yes MBA Education	-0,001	0,002		-0,004	0,004	
Syndicate						
No MBA Education	0,005	0,004		0,005	0,004	
Yes MBA Education	0,000	0,007		0,027	0,012	**

***Table 40**: Marginal effect of radicalness (based on Model IV) in the presence and in the absence of a founder with an MBA, distinguishing for the presence or the absence of an experienced VC. (Note: *p-value< .05. **p-value< .01. ***p-value)*

On the other hand, moving to the case involving the variable *Company_ProfessorExp*, proxy of founders' scientific competencies, the marginal analysis (**Table 40**) suggests two

relevant results. On one side, the marginal analysis confirms the previous results since the presence of a professor in the founding team strongly increases the probability of syndication in case of radicalness either the VC is experience or unexperienced. On the other side - and this is the major difference - the marginal effect of radicalness on syndication in the presence of a professor increases significantly when combined with the presence of an experienced VC. Confirming what was claimed in Hypothesis *HP3***,** the result highlights that the marginal increase in the probability of syndication moves up from 1,4 % to 2 % when shifting from no experienced VC to experienced VC. In relative terms, this means that in case of experienced VC the influence of radicalness and professor experience is likely to induce a boost of 80 % in the amount of syndicated deals.

	Low Experience			**High experience**		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal						
No professor experience	-0,001	0,003		-0,005	0,005	
Yes professor experience	-0,013	0,006	**	-0,017	0,008	**
Standalone						
No professor experience	0,000	0,001		0,001	0,003	
Yes professor experience	-0,001	0,002		-0,003	0,004	
Syndicate						
No professor experience	0,002	0,004		0,004	0,005	
Yes professor experience	0,014	0,006	**	0,020	0,008	***

Table 41: *Marginal effect of radicalness (based on Model V) in the presence and in the absence of a founder with a prior experience as professor, distinguishing for the presence or the absence of an experienced VC. (Note: *p-value< .05. **p-value< .01. ***p-value< .001)*

7. Discussion

The scope of the following sections is to interpret the results presented in Chapter 6, in order to answer to the Thesis' research question. First of all, *HP1* is discussed, interpreting the results concerning the effect of radicalness on syndication. Next, *HP2a* and *HP2b* are treated, focusing the attention on the interactive role of the signaling effect of founders' human capital. Finally, *HP3* is addressed, analysing the effect of VCs' experience.

7.1 The effect of radicalness on syndication

This Thesis brings together and integrates several different principles and theories involved in VCs' decision-making processes. It starts from the role that the venture's portfolio of patents plays in VCs' investment decisions. Patents have an extremely important value themselves because they ensure the venture monopolistic rights on the developed technologies and the appropriability of the associated returns. Along with that, a number of prior works demonstrated that they also constitute an effective means to attract financing from VC investors (Engel and Keilbach, 2007; Cao and Hsu, 2011; Conti, Thursby and Othaermel, 2013; Hoenen *et al.*, 2014). Specifically, patents (both granted and pending) are likely to attract VCs not only for their intrinsic value, but also because they work as signals of the quality of the venture and of its underlying technology (Janney and Folta, 2003; Hsu and Ziedonis, 2013). Because the relationship between VC investors and the potential venture is characterised by extremely strong information asymmetries, patents may contribute to reduce the information gap between the two parties and help VCs in distinguishing "high-quality" ventures from "low-quality" ones.

Nevertheless, the extant literature has paid less attention to possible "dark-sides" of patents. Patents documentations follow precise regulations and present a very detailed and rich information content. In this regard, it may be interesting to investigate whether

some of this information may have an additional effect on VCs' decision-making process, that goes beyond the pure signaling effect of patents. More specifically, hypothesis *HP1* of this Thesis focuses on the effect of information about the radicalness of the patented invention. Although the radicalness of an invention is often assessed ex-post, several recent works have defined indicators of radicalness which use patents as a source of data. This study relies on the indicator developed by Verhoeven, Bakker and Veugelers (2016) according to which a patent is considered as radical if its underlying invention applies a novel combination of components and principles to serve a certain purpose.

In this regard, the results of the econometric model corroborate the first hypothesis of this Thesis (i.e., *radicalness leads to syndicated deals*). First, they show that the presence of at least one radical patent in the venture's patent portfolio increases the probability of closing a syndicated deal with respect to no-deal (while nothing can be inferred about the preference between no-deal and standalone deals). The reasoning behind that, lies in the nature of radical inventions. An idea is assessed as radical if it is able to bring something completely new into the market, answering to new needs (sometimes hidden needs) and introducing new competencies and technologies (OECD, 2015). They represent extremely attracting investments because they are characterised by particularly high potential growth rates and returns. Nevertheless, the achievement of these returns is very uncertain. Indeed, a patented radical idea is often far from commercialization, requires a long-term and expensive development activity and, sometimes, it does not lead to any attractive product for the market (Deffains-Crapsky and Sudolska, 2014). Hence, assuming VCs' perspective, on the one hand they tend to be attracted by radical inventions, on the other hand, they feel the burden of an excessively high risk.

However, the risk perceived by a single investor may result mitigated when shared with other VCs in a syndicate. That explains why the probability of going for syndication rather than for no-deal is positively correlated with the presence of a radical invention. In other words, when VCs are faced with a radical invention and have to choose between syndicating or not-investing, they are likely to go for syndication in order to (i) benefit from potentially high returns while (ii) sharing the high associated risk.

Along with that, results show that the marginal effect of radicalness on syndicated deals is positive and significant. In other words, radical inventions incentivize to invest in a syndicate also in absolute terms (not only with respect to no-deal). In the presence of a radical invention the marginal probability of syndicating rises by 0,5 % (i.e., about 20% increase). Hence, the attraction for high returns potential on the one hand, and the uncertainty associated to these returns on the other, contribute to the inclination towards syndication. In this sense, it is verified that radicalness leads to syndication (i.e., hypothesis *HP1* is corroborated).

7.2 The effect of founders' human capital

From the previous section it emerges that radical inventions, despite being attractive, increase the perceived risk and lead to syndication. Therefore, it can be stated that patents may have additional effects on VCs' investment decisions with respect to their pure signaling effect.

Along with this consideration, it is worth to highlight that patents are not the only signal that ventures use to communicate their quality to investors. In general, ventures possess a portfolio of signals among which a key role is played by the human capital endowment of their founding team. Many works have highlighted the absolute signaling effect of founders' human capital features on VCs' investment decisions (Zacharakis and Meyer, 2000; Prabhu and Stewart, 2001; Hoenig and Henkel, 2015). However, the literature provides fewer information on how different signals interact with each other, although it is clear that when more signals are sent by the same signaller they can either enhance or reduce the signaled message (Connelly *et al.*, 2011). This Thesis focuses on radical patents and founders' human capital features and sheds a new light on how the signaling effect of the latter may influence the effect of radical inventions in syndication.

Assumed that radical inventions lead to syndicated deals, hypotheses *HP2a* and *HP2b* aim at investigating whether this effect may be reduced or enhanced as a result of the signaling effect of founders' human capital. Human capital is an extremely broad concept which is

generally defined as "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2007). It includes many different aspects, from background education to work experiences in different fields and in different roles. The human capital features considered in this Thesis mainly refer to prior experiences rather than to background education (i.e., tacit knowledge rather than declarative knowledge). In general, past experiences determine how individuals direct their attention and process critical information. Unexperienced individuals tend to process new knowledge on the basis of surface aspects, whereas experienced ones are able to find analogical patterns and understand deeper causal connections (Tzabbar and Margolis, 2017).

In particular, this work is focused on two main aspects of human capital: managerial competencies and scientific competencies. In practical terms, managerial competencies have been assessed against three proxies: (i) having completed an MBA, (ii) having worked as a CEO or (iii) having founded other companies prior to the establishment of the firm under consideration. On the other hand, the scientific competencies of the founders have been gauged in relation to the possession of the title of university professor.

7.2.1 The effect of managerial competencies

The models presented in Chapter 6.3 (i.e., Model II, III, IV and VI) aim at investigating how the signaling effect of founders' managerial competencies may influence the effect of radicalness on syndication. Firstly, the three different measures of managerial competencies have been studied separately. Afterwards, it has been analysed the effect of an aggregated measure of managerial capabilities.

In Model II (illustrated in Chapter 6.3.1) it has been studied the interaction between radicalness and founder's prior entrepreneurial experience. The results of Model II show that the marginal effect of radicalness on syndication is positive and significant in the absence of prior founding experience, while it is not significant in the presence of prior founding experience. In other words, when there are no serial entrepreneurs in the founding team, radical inventions push VCs towards syndication (for all the reasons

explained above). Contrarily, when there is at least one serial entrepreneur within the founding team, radicalness does no more generate an impulse towards syndication.

This result shows that the signaling effect of serial entrepreneurship is able to compensate for the risk of radical innovation. The relevance of prior founding experience has already been largely investigated in literature and has been supported by numerous empirical evidences. Many scholars have argued that serial entrepreneurship constitutes a signal of quality for ventures and that it is more likely to attract capital from VC investors with greater ease. Gompers, Kovner and Lerner (2009) estimated that in the 1990s in the US, around 10% of all VC-backed founders were serial entrepreneurs. Moreover, Hsu (2004) found that prior start-up founding experience is a significant driver for direct VC financing. Similarly, Hsu (2007) claimed that serial entrepreneurs not only are more likely to obtain VC financing, but they also obtain better valuations. Moreover, it is agreed that prior founding experience can help a new venture identify areas for potential growth. Serial entrepreneurs are more capable to recognise opportunities (e.g., recognise market niches more aligned with industry needs) and procure greater benefits from these opportunities (Ucbasaran, Westhead and Wright, 2009). Hence, the larger the number of founding members with a prior entrepreneurial experience, the more sooner the team will recognise opportunities consistent with this accumulated knowledge and direct future actions (Aldrich and Fiol, 1994).

For all these reasons, when the venture's underlying invention is radical, the presence of a founder with prior entrepreneurial experiences mitigates the risk perceived by VCs, along with their inclination towards syndication. This finding constitutes a first argument in support of Hypothesis *HP2a*, according to which founders' managerial competencies reduce the effect of radicalness in syndicated deals.

Furthermore, Model III (illustrated in Chapter 6.3.2), analyses the effect of founders' prior experience as CEOs. Again, it emerges that the marginal effect of radicalness on syndication is significant only when there are no founders with prior experience as CEOs within the founding team. In the presence of at least one founder with a precedent work experience as CEO, the marginal effect of radicalness on syndication is no more significant.

The argument explaining this finding is similar to the previous one. Individuals who had such a relevant managerial position in another firm are likely to have better entrepreneurial judgment and more specialised knowledge than other individuals (Colombo and Grilli, 2010). They are endowed with a richer network and have better capabilities in finding and exploiting opportunities. In that sense, their signaling effect is strong and it is able to compensate VCs for the risk associated to a venture's radical invention. Hence, in the presence of ex-CEOs within the founding team, VCs willingness to risk-sharing results mitigated and the marginal effect of radicalness on syndication comes out to be not significant. This second finding further corroborates hypothesis *HP2a*.

Model IV (presented in Chapter 6.3.3) expands this analysis taking into consideration a third proxy of managerial capabilities, which has to do with education rather than work experiences. In this model, the effect of radicalness is studied in relation with founders' possession of an MBA. By attaining an MBA degree, an individual can signal his/her innate managerial capabilities as well as increasing skills and knowledge (Peck, 2011). It is broadly considered as a powerful Spencian signal of the managerial competencies of the individual, whose cost is significant and higher for "low-quality" individuals. Hence, similarly to the two models above, the presence of a founder with an MBA mitigates the perceived risk associated to the venture's radical invention and counterbalances the effect of radicalness in syndicated deals. Again, hypothesis *HP2a* results verified.

Along with these three separate measures of managerial capabilities, a further aggregate proxy has been entailed by the variable *Company_ManagerialCapabilities*. Model VI (shown in Chapter 6.3.4) works on the interaction between this variable and radicalness and aims at investigating the effect of a broader idea of managerial competencies. In all the prior models the effects of the three proxies have been investigated separately, as if there was no influence of one over the other. With the introduction of this new variable, these synergies and mutual interactions are taken into consideration. The findings of model VI are totally aligned with all the previous ones and once again demonstrate that the marginal effect of radicalness on syndicated deals (positive and significant), becomes

not significant when the founding team is endowed with any of the three measures of managerial competencies.

In sum, all the models dealing with the interaction between managerial competencies and radicalness are aligned on similar results. They all corroborate Hypothesis *HP2a* and demonstrate that the signaling effect of founders' managerial competencies work as risk-mitigator and does influence the pure effect of radicalness on syndicated deals. Specifically, while a venture's radical inventions increase the risk perceived by VCs and lead to syndication, all the signals of founders' managerial competencies are able to mitigate this risk and neutralize VCs' inclination towards syndication. The signaling effect of founders' managerial competencies reduce the necessity of risk-sharing and counterbalance the effect of radicalness on syndicated deals.

7.2.1 The effect of scientific competencies

The second category of human capital features taken into consideration are the scientific competencies of the founders. Specifically, as a proxy of a founder's scientific competencies endowment it has been assessed whether he/she has previously worked as university professor. Individuals possessing the title of university professors generally have a profound knowledge in their fields of expertise thanks to their doctoral studies and additional research projects.

The results of the multinomial logit model V (presented in Chapter 6.4.1) demonstrate that founders' scientific competencies have an opposite effect with respect to managerial competencies. The marginal analysis conducted on the interactive term of radicalness and scientific competencies shows that the marginal effect of radicalness on syndicated deals is positive and significant only in the case in which there is a professor within the founding team. It is an opposite result compared to those discussed in the previous section since, in this case, founders' scientific competencies constitute the condition under which radicalness has a positive and significant marginal effect on syndication.

This result suggests that when a venture based on a radical invention is founded by professors (i.e., individuals with advanced scientific competencies), the risk perceived by VCs is higher. The reason for that, lies in the nature of these type of ventures. Indeed, most companies with a professor in their founding team are spin-offs of a university research project, which were created within universities Hub as a result of a research program. The inventions proposed by this typology of ventures are often rooted in advanced scientific research, hence they require specialised scientific knowledge to be adequately assessed. Because VCs are not experts in these fields, the information asymmetries between them and the venture result enhanced and they struggle even more in evaluating its quality.

Moreover, these inventions are often the results of basic research and, because of that, they have a low level of maturity (Munari and Toschi, 2011). The fact that they are far from being commercialised increases the uncertainty around their associated future outcomes. The likelihood of deriving cash-flows and the magnitude of these cash-flows becomes something extremely hard to be assessed by external investors. If the venture's underlying idea is radical and is at the very early stages of its development, any investment would be aimed at its further development with high uncertainty about its potential of becoming an actual marketable product (Sorescu, Chandy and Prabhu, 2003). Moreover, when professors become entrepreneurs, they tend to remain more focused in pursuing their basic research rather than in favouring the commercialization of the associated product (Radinger-peer, Sedlacek and Goldstein, 2016). First, they tend to be less aware of the market potential of their ideas. Moreover, they associate their prestige more to the research itself rather than to the returns of the product developed through the research (which is what really matters for VCs). Hence, being aware of professors' low experience and commitment in seeking early and high returns, the risk perceived by VC investors tends to be even higher when professors are part of the founding team.

Therefore, for all the reasons stated above, the presence of professors among the venture's founding team constitutes a source of further risk for VCs, which increases their willingness to syndicate. The results of the econometric Model V corroborate hypothesis

HP2b, providing empirical evidences of the fact that founders' scientific competencies enhance the effect of radicalness on syndicated deals.

7.3 The effect of experienced VCs

The sections above highlighted (i) that radical inventions lead to syndicated deals and (ii) that the signaling effect of founders' scientific competencies increase the risk perceived by VCs and reinforce the effect of radicalness on syndication. Nevertheless, analysing the effect of signals without taking into consideration possible differences in the signal's receivers may be limiting. Specifically, both the effect of radical inventions and of founders' human capital features on VCs' investment decisions may vary according to the characteristics of the VC receiving the signal. Vanacker and Forbes (2016) argue that different receivers may respond differently to the same signal, according to their ability to recognise and interpret the signal. Hence, the outcome of VCs' decision-making process depends on the ability of the specific receiver to successfully acquire and interpret the signals conveyed by the radicalness of the patented invention and the features of founders' human capital.

In particular, this analysis distinguishes for the experience of the VC investors taken into consideration. A certain venture capitalist is considered experienced if it has already closed a high number of deals. Experienced VCs are recognised to have a particularly good gut in selecting new ventures. Moreover, in order to protect and enhance their reputation, they tend to invest in better companies, with higher potential to succeed (Cumming, 2010). Generally, the more experienced the VC, the higher the ability to interpret the signal received (Cumming, 2012).

In this regard, it is interesting to highlight the results obtained from the models presented in Chapter 6.5. They aimed at considering any alterations in the effect of founders' human capital features on syndicated deals, in the presence of radical inventions. The most interesting result involves the triple interaction between experienced VCs, scientific competencies and radicalness. It emerges that the marginal effect of radicalness on

syndicated deals is positive and significant in the presence of at least one professor (i.e., advanced scientific competencies) within the founding team. However, this effect is stronger when experienced VCs take part in the syndicate. In other words, in the presence of radical inventions, the fact that there are professors among the founders always leads to syndication, but more intensively if experienced VCs participate in the syndicate.

To interpret this result, it may be helpful to focus on the features of syndication. One of the main benefits of syndication is information sharing. By the way of bundling signals about the potential outcomes of the venture, VCs can reduce the likelihood of failure (Cumming, 2012). However, as argued by Casamatta and Haritchabalet (2007), the sharing of signals within a syndicate depends heavily on the reputation and experience of the VC investors involved. Thanks to the higher ability of reputable VCs in acquiring and interpreting signals, a syndicate involving experienced VCs leads to a very good joint signal. Because of that, in a particularly uncertain environments (i.e., when the venture presents both radical inventions and professors within the founding team), the inclination towards syndication becomes even stronger if experienced VCs take part in the syndicate. Indeed, they increase the syndicate's joint ability of interpreting signals, thus raising the likelihood of successful investment decisions. This finding corroborates hypothesis *HP3* as it demonstrates that the experience of VC investors increases the effect of founders' scientific competencies and radicalness on syndication (i.e., increases the inclination towards syndication).

Finally, from this analysis, it also emerges that, in most of the models, the experience of VC investors does not alter the joint effect of founders' managerial competencies and radicalness on syndication. Nevertheless, in the case of founders with an MBA, the presence of experienced VCs has a peculiar effect. It stands out that the marginal effect of radical inventions in syndicated deals is positive and significant only when at least one founder has an MBA and an experienced investor participates in the syndicate. It is a quite controversial result as it goes against the previous finding of founders' MBA counterbalancing the risk associated to radical inventions. In this regard, further analyses about the relationship between VC experience and founders' managerial competencies may be helpful to interpret this result and draw a more complete conclusion.

8. Conclusive Remarks

This final Chapter aims at providing a summary of the main findings emerging from the analysis conducted in the Thesis, while suggesting potential future studies.

8.1 Main findings

This Thesis expands the literature on signaling theory applied to entrepreneurial contexts and aims at answering to the following research question: *Does the signaling effect of founders' human capital compensate for the risk of radical innovation in venture capital investments?*

In addressing this research question, it has been considered a sample of 672 VC-backed firms, containing at least one patent in their portfolio and operating in the biotech sector. The choice of focusing the analysis on biotech firms, is due to the peculiar features of the industry which make it a particularly uncertain environment, characterised by strong information asymmetries. For each firm of the sample information about (i) the patent portfolio, (ii) the human capital endowment of the founders and (iii) the characteristics of the associated VC investors have been collected. Being all the firms VC-backed, in order to fully grasp the reasoning driving VCs' decision-making process, a matching model has been built, associating each venture with all the potential VC firms, controlling for their existence at the year of foundation. For each dyad venture-VC it has been defined the typology of the deal occurring between the two, through a categorical variable (i.e., 0=no deal, 1=standalone deal and 2=syndicated deal). The sample of 40.363 dyads venture-investor resulting from the matching model has been used as unit of analysis to run multinomial logit regressions, whose dependent variable was the typology of deal.

The analysis conducted in this work sheds a new light on VCs' investment decision process when faced with radical inventions, with a major focus on the signaling effect of the human

capital features of the ventures' founding teams. In this regard, this Thesis brings three novel contributions.

First, it demonstrates that information about the radicalness of a venture's invention (arising from the patent's information content) constitutes a "dark-side" of the patent itself as it increases the risk perceived by VC investors. As a consequence of this higher uncertainty, radical inventions lead VCs to syndicate in order to share the risk and reduce the likelihood of failure.

Second, the effect of radical inventions on syndicated deals is influenced by the signaling effect of founders' human capital endowment. Specifically, the signaling effect of founders' managerial competencies compensates for the risk of radical innovation and counterbalances the effect of radicalness in syndicated deals. Hence, when the founding team is endowed with high managerial competencies, the risk perceived by VCs results mitigated and their inclination towards syndication reduced. Contrarily, the signaling effect of founders' scientific competencies enhances the risk of radical innovation and reinforces the effect of radicalness in syndicated deals. In other words, when the founding team is composed by professors and scientific experts, VCs are likely to perceive higher uncertainty and are more willing to syndicate.

Last, the experience of VC firms does have an effect on the tendency to syndicate in case of high invention's radicalness and high founders' scientific competencies. Specifically, because reputable investors are more able to interpret signals and have better gut in selecting ventures, in such highly uncertain contexts the presence of experienced VC investors increases the probability of going for syndicated deals.

8.2 Limitations and future work

The findings and limitations of our study open several avenues for future research. First, this Thesis analyses the effect of radical inventions (and related alterations due to the signaling effect of founders' human capital) on the type of deals taking place between the

venture and the VC investor, distinguishing between no-deals, standalone deals and syndicated deals. Scholars may expand the understanding of these effects considering other aspects of the investment process, such as the amount invested by VCs. In this regard, it would be interesting to investigate the effect of radicalness on the amount invested by VCs and eventual changes consequential to the signaling effect of founders' human capital features.

Second, once demonstrated that radicalness leads to syndication, this study investigates how this effect may change as a result of the signaling effect of the human capital endowment of the founding team. Future work might take into consideration the interactive effect of other signals of quality. Valuable alternatives may be the human capital features of the management team or the characteristics of the board of directors. Indeed, both of them have been assessed as powerful signals of quality by the extant literature (Certo, 2003; Lester *et al.*, 2006; Zhang and Wiersema, 2009).

Finally, the analysis presented in this Thesis relies on a sample of ventures extracted exclusively from the biotech sector. This industry is particularly interesting for the topics treated as it is characterised by strong information asymmetries and close relationships between the patented ideas and the commercialised products (from which returns are derived). Thanks to its nature, findings from the biotech field may have implications for other knowledge-intensive and innovation-based industries. Nevertheless, it may be interesting to overcome the limitation associated to this specificity and expand the analysis to further sectors, in order to improve the ability of drawing more general conclusions.

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Annexes

Annex A:

List of prestigious universities according to The Times Higher Education University Rankings.

World Ranking 2010		
	University	**Country**
1	Harvard University	United States
2	California Institute of Technology	United States
3	Massachusetts Institute of Technology	United States
4	Stanford University	United States
5	Princeton University	United States
6	University of Cambridge	United Kingdom
6	University of Oxford	United Kingdom
8	University of California, Berkeley	United States
9	Imperial College London	United Kingdom
10	Yale University	United States
11	University of California, Los Angeles	United States
12	University of Chicago	United States
13	Johns Hopkins University	United States
14	Cornell University	United States
15	ETH Zurich	Switzerland
15	University of Michigan	United States
17	University of Toronto	Canada
18	Columbia University	United States
19	University of Pennsylvania	United States
20	Carnegie Mellon University	United States
21	University of Hong Kong	Hong Kong
22	University College of London	United Kingdom
23	University of Washington	United States
24	Duke University	United States
25	Northwestern University	United States
26	The University of Tokyo	Japan
27	Georgia Institute of Technology	United States
28	Pohang University of Science and Technology	South Korea
29	University of California, Santa Barbara	United States
30	University of British Columbia	Canada

Table 42: *Top30 World ranking of The Times Higher Education University Rankings 2010-2011*

Europe Ranking 2010		
	University	**Country**
1	University of Cambridge	United Kingdom
2	University of Oxford	United Kingdom
3	Imperial College London	United Kingdom
4	ETH Zurich	Switzerland
5	University College London	United Kingdom
6	École Polytechnique	France
7	University of Edinburgh	United Kingdom
8	École Normale Supérieure	France
9	Karolinska Institute	Sweden
10	University of Göttingen	Germany
11	École Polytechnique Fédérale de Lausanne	Switzerland
12	LMU Munich	Germany
13	Trinity College Dublin	Ireland
14	King's College London	United Kingdom
15	University of Sussex	United Kingdom
16	University of York	United Kingdom
17	Heidelberg University	Germany
18	Durham University	United Kingdom
19	London School of Economics and Political Science	United Kingdom
20	University of Manchester	United Kingdom
21	Royal Holloway, University of London	United Kingdom
22	Lund University	Sweden
23	University of Southampton	United Kingdom
24	University of Zurich	Switzerland
25	University College Dublin	Ireland
26	University of Basel	Switzerland
27	École Normale Supérieure de Lyon	France
28	Technical University of Munich	Germany
29	University of Helsinki	Finland
30	University of St Andrews	United Kingdom
31	Eindhoven University of Technology	Netherlands
32	University of Geneva	Switzerland
33	KU Leuven	Belgium
34	Queen Mary University of London	United Kingdom
35	Technical University of Denmark	Denmark
36	Ghent University	Belgium
37	Lancaster University	United Kingdom
38	Leiden University	Netherlands
39	University of Glasgow	United Kingdom
40	Stockholm University	Sweden

Table 43: *Top40 European ranking of The Times Higher Education University Rankings 2010-2011.*

Annex B:

List of prestigious universities according to the MBA QS World Ranking.

MBA -World Ranking 2010		
	University	**Country**
1	Harvard	United States
2	INSEAD	France
3	HEC Paris	France
4	Stanford	United States
5	London Business Schoo	United Kingdom
6	Penn (Wharton)	United States
7	MIT (Sloan)	United States
8	Columbia	United States
9	Oxford (Said)	United Kingdom
10	IE Business School	Spain
11	UC Berkeley (Haas)	United States
12	Chicago (Booth)	United States
13	UCLA (Anderson)	United States
14	Northwestern (Kellogg)	United States
15	Michigan (Ross)	United States
16	Imperial College	United Kingdom
17	ESADE ESADE	Spain
18	Yale	United States
19	Cambridge (Judge)	United Kingdom
19	NYU (Stern)	United States
21	IMD	Switzerland
22	SDA Bocconi	Italy
23	Duke (Fuqua)	United States
24	IESE Business School	Spain
25	Erasmus (RSM)	Netherlands
26	Copenhagen Business School	Denmark
27	ESSEC	France
28	CEIBS	China
29	EDHEC	France
30	Texas (McCombs)	United States

Table 44: *Top30 2010 MBA QS World ranking.*

Annex C:

List of big pharmaceutical companies assessed by yearly revenues.

World Ranking Pharmaceutical Companies by sales	
1	Johnson & johnson
2	Bayer ag
3	Roche holding ag
4	Pfizer inc
5	Novartis ag
6	Sanofi
7	Sinopharm group co., ltd.
8	Glaxosmithkline plc
9	Merck & co., inc.
10	Abbvie inc.
11	Abbott laboratories
12	Teva pharmaceutical industries limited
13	Astrazeneca plc
14	Eli lilly and company
15	China resources pharmaceutical group limited
16	Bristol-myers squibb company
17	Shanghai pharmaceuticals holding company limited
18	Merck kgaa
19	Novo nordisk a/s
20	Akzo nobel nv
21	Janssen pharmaceutica
22	Takeda pharmaceutical co., ltd.
23	Allergan plc
24	Solvay sa
25	Shire plc
26	Sanofi winthrop industrie
27	Celgene corp
28	Merck sharp & dohme international services b.v.
29	Mylan n.v.
30	Astellas pharma inc.

Table 45: *Top30 of 2010 ranking of pharmaceutical companies by revenues (Source: Orbis database.)*

Annex D:

Results of the econometric models with interactions between radicalness, human capital and VC's experience in both standalone and syndicated deals.

Standalone deals	I	II	III	IV	V	
nb_Pat_preF	0,003 **	0,003 *	0,003 *	0,003 *	0,003 **	0,003 *
	(0,002)	(0,001)	(0,001)	(0,001)	(0,002)	(0,002)
log_distance	-0,281 ***	-0,283 ***	-0,284 ***	-0,281 ***	-0,281 ***	-0,282 ***
	(0,051)	(0,051)	(0,051)	(0,051)	(0,051)	(0,052)
samecountry	3,308 ***	3,309 ***	3,305 ***	3,312 ***	3,312 ***	3,308 ***
	(0,262)	(0,263)	(0,263)	(0,264)	(0,263)	(0,264)
age	0,016	0,015	0,016	0,015	0,015	0,017
	(0,016)	(0,016)	(0,016)	(0,016)	(0,016)	(0,016)
CVCi	0,234	0,229	0,230	0,229	0,231	0,232
	(0,267)	(0,267)	(0,267)	(0,268)	(0,268)	(0,267)
GVCi	0,001	-0,001	0,002	-0,003	-0,005	-0,003
	(0,192)	(0,192)	(0,192)	(0,192)	(0,193)	(0,193)
d_radical	-0,006	-0,034 *	-0,147	-0,049	-0,062	-0,096
	(0,15)	(0,226)	(0,223)	(0,226)	(0,237)	(0,226)
familysize_mean	0,027 **	0,027 **	0,029 **	0,027 **	0,028 **	0,029 **
	(0,012)	(0,012)	(0,012)	(0,012)	(0,012)	(0,012)
nb_citn_mean	-0,001	0,001	0,001	0,001	0,002 *	0,000
	(0,019)	(0,020)	(0,020)	(0,020)	(0,020)	(0,021)
expVC	0,507 ***	0,473 **	0,498 **	0,510 ***	0,536 **	0,634 ***
	(0,163)	(0,205)	(0,204)	(0,198)	(0,216)	(0,225)
company_PHD	0,096	0,084	0,104	0,097	0,096	0,103
	(0,3)	(0,310)	(0,310)	(0,310)	(0,308)	(0,309)
Company_Prestigious_PHD	-0,032	-0,038	-0,049	-0,047	-0,036 *	-0,057
	(0,190)	(0,190)	(0,192)	(0,190)	(0,192)	(0,189)
Company_MBa	-0,151	-0,123	-0,135	0,004	-0,122	
	(0,186)	(0,192)	(0,194)	(0,265)	(0,191)	
Company_SumPHDFields	-0,208	-0,195 **	-0,205	-0,189	-0,206	-0,185
	(0,243)	(0,254)	(0,257)	(0,254)	(0,253)	(0,251)
Company_ProfessorExp	-0,034	-0,007	-0,005	-0,011	0,087	0,007
	(0,173)	(0,179)	(0,179)	(0,178)	(0,230)	(0,179)
Company_FounderStartup	-0,220	-0,172	-0,203	-0,214	-0,197	
	(0,167)	(0,247)	(0,170)	(0,170)	(0,170)	
Company_CEO_Role	-0,265	-0,147	-0,158	-0,125	-0,156	
	(0,178)	(0,191)	(0,251)	(0,192)	(0,197)	
Company_BiotechExp	0,120	0,171	0,139	0,161	0,151	0,131
	(0,152)	(0,178)	(0,174)	(0,173)	(0,173)	(0,175)
Company_BigPharmaExp	-0,024	-0,084	-0,053	-0,098	-0,069 *	-0,065
	(0,21)	(0,21)	(0,21)	(0,21)	(0,21)	(0,21)
Company_TechnicalRole	0,273 *	0,415 *	0,418 *	0,419 *	0,413 **	0,466 **
	(0,163)	(0,208)	(0,210)	(0,210)	(0,208)	(0,204)
Company_N_Roles	-0,141	-0,152	-0,139	-0,151	-0,137 *	-0,179
	(0,134)	(0,136)	(0,135)	(0,136)	(0,135)	(0,139)
missing_HC	0,198	0,146	0,143	0,138	0,141	0,156
	(0,188)	(0,196)	(0,196)	(0,197)	(0,196)	(0,198)
Company_ ManagerialCapabilities						-0,021
						(0,223)
d_radical * expVC (II)		0,179				
		(0,402)				
d_radical * Company_FounderStartup		-0,159				
		(0,517)				
expVC * Company_FounderStartup		0,046				
		(0,444)				
d_radical * expVC * Company_FounderStartup		-0,348				
		(0,942)				
d_radical * expVC (III)			0,238			
			(0,390)			
d_radical * Company_CEO_Role			0,471			
			(0,508)			
expVC * Company_CEO_Role			-0,095			
			(0,450)			
d_radical * expVC * Company_CEO_Role			-1,022			
			(1,261)			
d_radical * expVC (IV)				0,178		
				(0,386)		
d_radical * Company_MBa				-0,139		
				(0,539)		
expVC * Company_MBa				-0,205		
				(0,509)		
d_radical * expVC * Company_MBa				-0,676		
				(1,304)		
d_radical * expVC (V)					0,188	
					(0,408)	
d_radical * Company_ProfessorExp					0,014	
					(0,477)	
expVC * Company_ProfessorExp					-0,219	
					(0,409)	
d_radical * expVC * Company_ProfessorExp					-0,482	
					(0,948)	
d_radical * expVC (VI)						0,216
						(0,437)
d_radical * Company_ManagerialCapabilities						0,075
						(0,403)
expVC * Company_ManagerialCapabilities						-0,432
						(0,376)
d_radical * expVC * Company_ManagerialCapabilities						-0,480
						(0,826)
_cons	-5,788 ***	-5,911 ***	-5,874 ***	-5,905 ***	-5,935 ***	-5,997 ***
	(0,563)	(0,599)	(0,596)	(0,596)	(0,600)	(0,597)

Table 46: *Results of the econometric models with interactions between radicalness, human capital and VC's experience in standalone deals.*

Syndicate deals	I	II	III	IV	V	
nb_Pat_preF	-0,0003	0,000	0,000	0,000	0,000	0,000
	(0,002)	(0,002)	(0,002)	(0,002)	(0,002)	(0,002)
log_distance	-0,245 ***	-0,247 ***	-0,248 ***	-0,246 ***	-0,248 ***	-0,248 ***
	(0,038)	(0,038)	(0,038)	(0,038)	(0,038)	(0,038)
samecountry	2,775 ***	2,771 ***	2,770 ***	2,769 ***	2,767 ***	2,757 ***
	(0,168)	(0,167)	(0,168)	(0,167)	(0,167)	(0,167)
age	-0,012	-0,012	-0,011	-0,011	-0,010	-0,013
	(0,014)	(0,014)	(0,014)	(0,014)	(0,013)	(0,014)
CVCi	0,175	0,176	0,183	0,180	0,184	0,173
	(0,173)	(0,173)	(0,173)	(0,173)	(0,173)	(0,172)
GVCi	0,148	0,147 **	0,147	0,149	0,149	0,145
	(0,117)	(0,117)	(0,117)	(0,117)	(0,117)	(0,117)
d_radical	0,257 **	0,296	0,343 *	0,278 *	0,096	0,407 *
	(0,140)	(0,195)	(0,176)	(0,176)	(0,191)	(0,221)
familysize_mean	0,005	0,004	0,003	0,005 *	0,005	0,004 *
	(0,015)	(0,015)	(0,015)	(0,015)	(0,015)	(0,015)
nb_citn_mean	0,020	0,019	0,020	0,020	0,018	0,021
	(0,013)	(0,014)	(0,014)	(0,014)	(0,014)	(0,014)
expVC	-0,008	-0,078	-0,020	-0,044	-0,071	0,060
	(0,105)	(0,152)	(0,140)	(0,134)	(0,146)	(0,168)
company_PHD	-0,085	-0,173	-0,198	-0,170	-0,187	-0,182
	(0,308)	(0,316)	(0,316)	(0,320)	(0,317)	(0,324)
Company_Prestigious_PHD	-0,104	-0,096	-0,097	-0,095	-0,096	-0,068
	(0,152)	(0,150)	(0,150)	(0,150)	(0,148)	(0,148)
Company_MBa	0,245	0,196	0,201	0,201	0,177	
	(0,145)	(0,145)	(0,147)	(0,187)	(0,146)	
Company_SumPHDFields	0,136	0,113	0,132	0,101	0,131	0,114
	(0,311)	(0,308)	(0,308)	(0,312)	(0,309)	(0,319)
Company_ProfessorExp	0,028	-0,022	-0,019	-0,017	-0,172 **	-0,010
	(0,147)	(0,149)	(0,148)	(0,147)	(0,177)	(0,150)
Company_FounderStartup	0,171 *	0,190 *	0,152 *	0,154 *	0,160	
	(0,130)	(0,153)	(0,128)	(0,129)	(0,128)	
Company_CEO_Role	-0,206 **	-0,311 **	-0,193 *	-0,314 **	-0,302 **	
	(0,132)	(0,146)	(0,180)	(0,146)	(0,147)	
Company_BiotechExp	0,065	-0,006	-0,013	-0,026	-0,036	0,000
	(0,135)	(0,144)	(0,143)	(0,144)	(0,141)	(0,143)
Company_BigPharmaExp	0,161	0,204	0,185	0,223	0,209	0,159
	(0,225)	(0,226)	(0,231)	(0,233)	(0,233)	(0,224)
Company_TechnicalRole	-0,259 *	-0,257 *	-0,259 *	-0,258 *	-0,249 *	-0,147
	(0,158)	(0,158)	(0,158)	(0,158)	(0,158)	(0,151)
Company_N_Roles	0,091	0,079	0,085	0,089	0,090	0,018
	(0,092)	(0,092)	(0,092)	(0,092)	(0,09)	(0,088)
missing_HC	-0,498 **	-0,502 **	-0,505 **	-0,499 **	-0,480 **	-0,513 **
	(0,200)	(0,200)	(0,200)	(0,200)	(0,201)	(0,202)
Company_ ManagerialCapabilities						0,142 *
						(0,151)
d_radical * expVC (II)		0,186				
		(0,273)				
d_radical * Company_FounderStartup		-0,238				
		(0,312)				
expVC * Company_FounderStartup		0,063				
		(0,254)				
d_radical * expVC * Company_FounderStartup		0,040				
		(0,471)				
d_radical * expVC (III)			0,053			
			(0,252)			
d_radical * Company_CEO_Role			-0,662 **			
			(0,373)			
expVC * Company_CEO_Role			-0,150			
			(0,288)			
d_radical * expVC * Company_CEO_Role			0,806 *			
			(0,524)			
d_radical * expVC (IV)				-0,010 *		
				(0,258)		
d_radical * Company_MBa				-0,300		
				(0,387)		
expVC * Company_MBa				-0,076		
				(0,325)		
d_radical * expVC * Company_MBa				1,049 **		
				(0,523)		
d_radical * expVC (V)					0,147	
					(0,275)	
d_radical * Company_ProfessorExp					0,576 **	
					(0,317)	
expVC * Company_ProfessorExp					0,047	
					(0,265)	
d_radical * expVC * Company_ProfessorExp					0,094	
					(0,496)	
d_radical * expVC (VI)						-0,136
						(0,312)
d_radical* Company_ManagerialCapabilities						-0,393
						(0,298)
expVC * Company_ManagerialCapabilities						-0,237
						(0,247)
d_radical * expVC * Company_ManagerialCapabilities						0,786 *
						(0,444)
_cons	-4,990 ***	-4,738 ***	-4,767 ***	-4,736 ***	-4,680 ***	-4,796 ***
	(0,512)	(0,531)	(0,526)	(0,529)	(0,526)	(0,529)

***Table 47**:Results of the econometric models with interactions between radicalness, human capital and VC's experience in syndicated deals.*

Annex E:

Results of the marginal analyses based on the models including triple interactions among radicalness, VC experience and proxies of founders' managerial competencies.

	Low Experience			High experience		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal						
No Serial Entrepreneur	0,005	0,004		-0,009	0,005	**
Yes Serial Entrepreneur	0,000	0,005		0,004	0,008	
Standalone						
No Serial Entrepreneur	0,000	0,001		0,001	0,003	
Yes Serial Entrepreneur	0,001	0,002		0,003	0,004	
Syndicate						
No Serial Entrepreneur	0,005	0,004		0,009	0,005	**
Yes Serial Entrepreneur	0,001	0,005		0,006	0,008	

Table 48: *Marginal effect of radicalness (based on Model II) in the presence and in the absence of a founder with a prior experience as entrepreneur, distinguishing for the presence or the absence of an experienced VC. (Note: *p-value< .05. **p-value< .01. ***p-value<.001)*

	Low Experience			High experience		
	ME	**Std. Err.**	**Sign.**	**ME**	**Std. Err.**	**Sign.**
No-Deal						
No Previous CEO	0,006	0,004	*	0,008	0,005	*
Yes Previous CEO	0,002	0,004		0,006	0,009	
Standalone						
No Previous CEO	0,001	0,001		0,000	0,002	
Yes Previous CEO	0,002	0,003		0,003	0,005	
Syndicate						
No Previous CEO	0,007	0,004	**	0,008	0,005	*
Yes Previous CEO	0,004	0,004		0,009	0,008	

Table 49*: Marginal effect of radicalness (based on Model III) in the presence and in the absence of a founder with a prior experience as CEO, distinguishing for the presence or the absence of an experienced VC. (Note: *p-value< .05. **p-value< .01. ***p-value<.001)*