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To patent or not to patent? How patent portfolios impact on venture capitalists' decisions: evidence from European companies

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Summary

This study investigates how venture capitalists evaluate the presence of patents in the portfolio of the companies they decide to finance. In order words, the focus of this research is the signalling effect of patents, i.e. whether the ownership of patents by a company attracts venture financings.

Venture capitalists are professional investors who focus their business on young companies, characterized by high-risk but also high potential returns; they are experts about the industries they choose to invest in, and their mix of financial and technical knowledges allows them to successfully deal with uncertain and risky start-ups.

For these reasons it is natural to think that the venture capitalists' involvement should have positive effects on the performance of companies they choose to finance: the availability of funds should support growth and innovation and the VC's capabilities should conduct to the selection of the most promising strategy for the funded-firm.

There is a wide literature that confirms this intuition demonstrating the existence of a link between the presence of a VC and the performance of a firm; on the contrary, other authors highlight also the potential disadvantages that the venture capitalists' presence could involve for the funded-company. The present study analyses the existence of this link looking at the European context; for the European countries examined, variables from the profit and loss account and from the balance sheet are evaluated as proxies for the performance of each company.

The underlying database is based on information derived from Amadeus, a European database created by Bureau van Dijk Electronic Publishing. The collection data process has been accurate and the final database counts 1196 companies divided in two groups with the same number of companies: the first sample includes only VC-funded companies, while the other group is the control sample which consists of twin firms, i.e. companies with the same age, industry and country of the others but which have not been funded. In this way a one to one comparison has been conducted and only the performance variables have been studied, controlling for all the other external factors.

The analysis has been conducted using a probit regression and results confirm that the VC involvement has a positive and significant impact on the companies' performance. Once the impact of VC funds on performance has been checked, a patent related measure has been included in the analysis to test its significance.

Other studies tried to analyse the existence and the nature of this relationship, but the evidence is controversial. The main problem is the presence of inverse causality: it is not clear if patents, adding value to the owner, attract VCs or, on the contrary, the VC involvement supports innovation through patents.

In the present analysis the selected patent related measure is the cumulated number of patents for a single firm i up to a specific year t. The results of the probit regression highlight the existence of a positive and significant relation between the number of patents owned by a company and its probability of being financed, confirming the signalling effect.

A second investigation has been conducted, and it originates from the work of Caviggioli, Colombelli, De Marco and Paolucci (2017). The study is performed again at a European level, but the previous database has been integrated with additional information about the financing rounds and the patents' characteristics for the VC-backed companies. These complementary data have been gathered from Orbis, another Bureau van Dijk Electronic Publishing product. The main aim of this second research is to verify whether the size and the characteristics of a patent portfolio, such as the number of forward and backward citations and the industry and geographical scopes, are linked with the total amount of VC financing.

Results show that not just the quantity aspect of a patent portfolio is important, but also its quality. In particular, results differ between industries and financing rounds: in sectors characterized by a strong IP regime, the size of a patent portfolio is the most significant measure, followed by the presence of forward citations; in industries with a weak IP regime, a third strongly significant variable is added which is the presence of backward citations. Moreover, while for later stages the most significant variable is the size of the patent portfolios, for the A rounds other two measures are relevant: the number of IPC subclasses associated to each patent family in the portfolio of a company, and its number non-patent citations which are negatively and positively correlated, respectively.

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Chapter 1

1. The Institution of Venture Capital

Kortum and Lerner (2000) define a venture capital as “equity or equity-linked investments in young, privately held companies, where the investor is a financial intermediary who is typically active as a director, an advisor, or even a manager of the firm[1]”. Venture capitalists decide to invest in very young companies that have huge financial needs and a high degree of risk because they expect potential large profits. In fact, such companies have usually a high potential for growth.

When a firm seeks to start a new activity, it needs a considerable amount of capital to launch its business. In most cases the company founder does not have enough funds to finance his projects and he has, therefore, no choice but to seek external financing. One possibility is to look for bank loans or other debt financing, but these sources are not always available. Generally, firms with significant intangible assets are characterize by huge uncertainty and information asymmetries, which make them too risky for traditional sources of financing. An additional risk is due to the fact that this type of firms tends to have negative expected earnings for several years after their foundation. These are just some of the reasons why for many firms venture capital is the only potential source of financing.

As Gompers and Lerner (1998) say, venture capital organizations finance these high-risk, potentially high-reward projects, purchasing equity stakes while the firms are still privately held. The list of the companies that turned out to be very successful and that have been financed by venture capitalists over time is wide; among them there are Apple Computer, Compaq, Cisco Systems, Genentech, Intel, Microsoft, Netscape, Sun Microsystems, Lotus.

[1] Samuel Kortum and Josh Lerner (2000), “Assessing the contribution of venture capital to innovation”

This first chapter is composed of three main sections. The first one focuses on the history and the working principles of venture capital funds; it describes the role played by venture capitalists not just in term of financiers; finally, it illustrates the key-concepts of the venture capital market looking at the demand and supply curves.

The second main section aims attention at the relationship between the venture capitalist involvement and the financed companies: it delineates the potential advantages and disadvantages resulting from the venture presence.

The third section analyses the link between patents and VC funding; it focuses on the possible meanings that patents and their related measures can get, and it inspects whether the presence of patents attracts the venture capitalist presence.

1.1. History of VC

The origins of venture capital in the U.S. date back to 1946, when the American Research and Development (ARD) has been founded. Its creation was made by the MIT President Karl Compton, George F. Doriot a professor at Harvard Business School, and Ralph Flanders President of the Boston branch of the Federal Reserve and trustee at MIT.

The ARD was born right after the end of the World War II to encourage the private sector investing in those emerging companies whose business was based on technologies developed during the conflict. Such companies did not have the possibility to grow because institutional investors were mostly hesitant to invest. In contrast, the ARD was structured as a publicly traded, close-end fund and marketed mostly to individuals (Gompers and Lerner, 1998).

A close-end fund is a mutual fund with indefinite life. It issues a predetermined number of shares, which are purchased by investors as stocks, and this prescribed amount of capital is raised only once through an Initial Public Offering (IPO). Close-end funds are flexible for the investors because permit them to get rid of their investments if they no longer want to hold them. This operation can be easily done by selling the shares on a public exchange to other investors.

This flexibility allowed the ARD to invest in illiquid assets, knowing that they would not need to return investors' capital in an uncertain time frame (Gompers and Lerner, 2001). Even if this type of investment was open to every class of investors, institutional investors still showed little interest in it because of the associated riskiness. Therefore, mainly individuals were involved.

In Europe, similarly, the origins of venture capital funds date back to 1945 with the foundation of the Industrial and Commercial Finance Corporation (ICFC), in the United Kingdom. This company was created by the Bank of England in association with other big British banks to sustain small and medium-sized enterprises over the long run. For such small enterprises was difficult to obtain a bank loan in the post-war era and they were not big enough to raise capital from the public markets; the ICFC helped them to raise long-term investment funding. This company expanded in the following years, becoming the largest provider of growth capital for unquoted firms in the United Kingdom during the 1960s.

In the United States, the successors of the ARD were also structured al close-end funds, up until 1958 when the first venture capital limited partnership was formed. As its predecessors, also the limited partnership form had a finite lifetime which usually was ten years, but extensions were often allowed. This type of fund, though, could raise capital from a smaller set of investors: high-net-worth individual investors and a limited number of institutions. Moreover, investors were limited partners, so they had not to be involved in the day-to-day management of the fund in order to maintain the limited liability (Gompers and Lerner, 1998).

An important aspect regarding the gains associated with the investment changed. Beforehand, venture capitalists had to wait until the funded company went public, sell the investment and then return cash to investors. Whereas, with the limited partnership, they could easily give investors their allocation of shares in the new public company. In this way, was up to the investors to choose if and when to sell their shares to realize the capital gains associated with the investment.

In the years between 1960s and 1970s limited partnerships slowly became more common but the venture capital industry was not very successful yet.

A huge increase in investments occurred between the late 1970s and early 1980s, mostly thanks to the amendment to the *prudent man* rule (Kortum and Lerner, 2000). This modification regarded the types of investments that pension funds were allowed to hold. Previously, they were regulated by the Employee Retirement Income Security Act (ERISA) which prevented pension funds from investing substantial capital in high-risk assets classes, including venture capital. The new amendment removed this constraint and the impact on the venture capital industry has been considerable. As Kortum and Lerner (2000) show, in 1978, $424 million was invested in new venture capital funds; of which 32% were individuals while pension funds supplied just 15%. Eight years later, more than $4 billion was invested, and pension fuds accounted for more than half of all contributions.
However, this growth cannot be attributed just to this legislative change; in fact, at that time, a technological revolution in micro-electronics occurred which created opportunities for technology-based businesses and increased the demand for venture capital.

As depicted in figure 1[2], the commitments to venture capital after the 1980s in the U.S. was subject to several variations. After an initial increase, a drop occurred since 1987 to 1991.

[2] Figure from Paul Gompers and Josh Lerner (2001), "The Venture Capital Revolution"

The reduction in venture capital returns, which discouraged investors to commit their capital, was probably due mainly to two factors: an overinvestment in different industries and the entry of inexperienced venture capitalists (Gompers and Lerner, 2001).

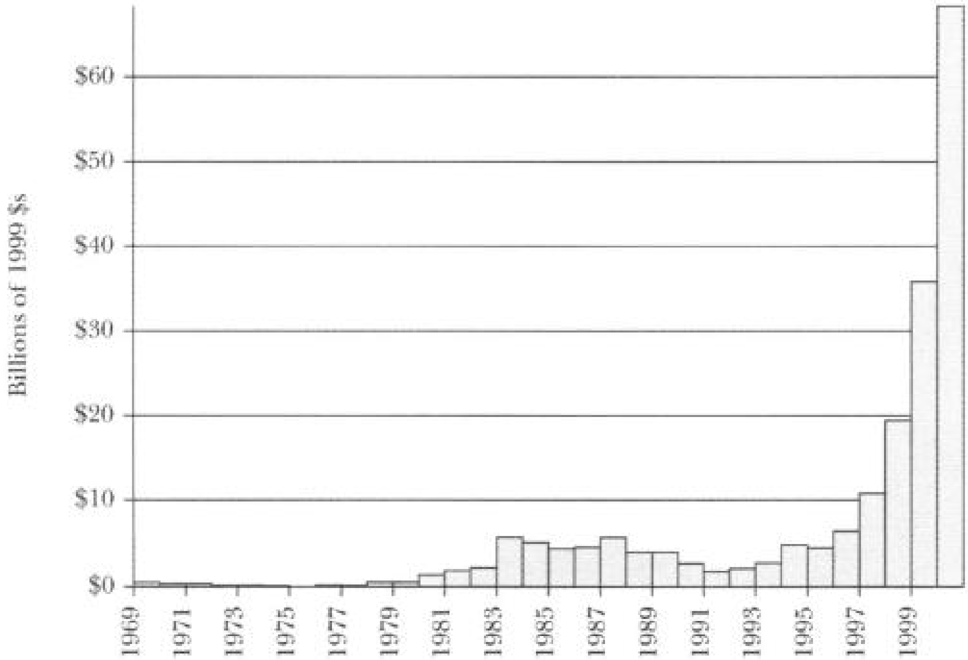


Figure 1. Commitments to the Venture Capital Industry (billions of 1999 dollars)

This pattern, then, reversed dramatically in the 1990s since when the growth in commitments has been rapid and continuous up until the 2000s.
In that span of time, the exit of many inexperienced venture capitalists and the surprising increase in the market for initial public offerings helped to raise again venture capital returns.

One of the factor that definitely fostered the growth was the great diffusion of Internet: companies started to understand the importance and the potential of this new technology and wanted to integrate it into their business. The economic support offered by venture capitalists was therefore necessary.

1.1.1. Venture Investment

In this paragraph will be described the operating principle of a venture fund. In particular, the first section examines why innovative start-ups are usually financed by venture capital rather than by banks or other traditional financial institutions; the second section describes the different financing stages that characterize an investment cycle; finally, the third section deepen all the activities conducted by venture capitalists that add values beyond the simple funding.

1.1.1.1. Why firms choose venture capital instead of banks or other sources?

As already said, young firms, especially in high-technology industries, are characterized by uncertainty and information asymmetries. The presence of information asymmetries could cause several problems, like the moral hazard. Usually, the effort exercised by the entrepreneur cannot be determined with complete confidence: his action is hidden. In such an unclear environment, when a firm raises equity from outside investors, the manager, the party with more information, has the incentive to behave inappropriately. For example, he might engage in wasteful expenditure to take advantage of the resulting benefits without carrying the entire cost of his actions.

Information asymmetries, and the related problems, are especially common for companies in early stages, with intangible assets and based on R&D activity. For these firms it is costly to raise debt or other external financing because it can happen that the entrepreneur, once obtained the funds, invests in projects with high personal return but low payoff to shareholders. These are the reasons why banks and other traditional source of finance are not suitable for innovative start-ups.

In such cases, specialized financial intermediaries, like venture capital funds, can help companies to start their business providing them with the required capital. In fact, such organizations can reduce the information gap thanks to their abilities and knowledges to: analyse firms in-depth, and once they have decided to finance a company, conduct a continuous monitor of its activity.

Obviously, several measures are taken by venture capitalists to deal with risk and protect themselves from potential losses.

The first action is to finance companies in discrete stages over time. Staged investment (which will be discussed in the next paragraph) is used as a control mechanism by venture capital to monitor the activity of the firm over time, and decide, based on the performance, if it is profitable to continue the funding or not. Thus, potential losses are reduced because if venture capitalists expect negative future returns from a project, they just suspend the financing.

Another measure to deal with risk is to syndicate investments with other venture capital firms. Lerner (1994) showed that in the early rounds of investing, venture capitalists tend to associate only with other venture capitalists that have similar experience. This result suggests that the reason why they syndicate is to look for a second opinion about the quality of the investment they are about to finance. This would also explain why venture capitalists syndicate only with other venture capitalists who have similar or better ability: not just to gather more money, but to improve knowledge about the investment in order to limit the risk. The syndicating process can reduce the risk also allowing venture capitalists to diversify investments by investing less money but in a greater number of projects. In this way venture capitalists can diversify the firm-specific risk.

Other two measures are taken by venture capitalists to better monitor the companies and reduce the information asymmetries.

When the need for control is large, venture capitalists often take seats on the firm's board of directors. This position allows them to closely monitor the activity of the firm and give advices.

Moreover, to lessen the harmful consequences of the moral hazard, venture capitalists usually use stock options as part of the manager's compensation. In fact, if managers receive a great amount of their compensation in form of equity or stock options, their interests are better aligned with those of venture capitalists and the moral hazard is reduced: managers and executive officers will focus part of their effort maximizing the market value of the firm which will turn into a profit also for the venture capitalists.

Some security measures are taken by venture capitalists to prevent incorrect behaviour of the entrepreneurs. For example, venture capitalists can impose a minimum amount of time (usually several years) during which entrepreneurs cannot leave the firm and take their shares. In this way entrepreneurs are incentivized to focus on a long-term strategy.

All this knowledge and capabilities are the reasons why organizations like venture capital are capable to deal with such risky investments, while other sources like banks are not. Obviously, the reward associated to such high-risk and uncertain investments is outstanding if the firm turns out to be successful.

The literature highlights the presence of a connection between the VC involvement and the superior performance of the firms financed. In fact, the techniques that venture capitalists employ, and the effort that they exert are two of the key-elements that allow the financed companies to succeed. The characteristics of the relationship between the presence of venture capitalists and the VC-backed firm's performance will be deepen in section 2.

1.1.1.2. Financing stages

As anticipated, the financing process is made of several stages, or rounds; each one of them has a different average amount of money and a different risk level.

The first stage of venture financing is called *seed*. Usually, this is a modest amount of capital, in the order of a few hundred thousand euros (Bottazzi and Da Rin, 2001) used by entrepreneurs to finance the early development of a new product or service. These funds are used to conduct the initial market researches and develop a business plan. At the end of the seed stage, both the entrepreneurs and the venture capitalists will have more information about the feasibility of the project.

When a company is able to begin operations, new financings are required. This is the *start-up* investment. Companies at this stage use funds to develop the product and start the marketing campaign in order to sell their goods. Up to this point, companies do not realize profit yet, but they use more cash than they generate. Both the seed stage and the start-up stage are named early stage investments. Moreover, this is the stage where venture capitalists can actually take part in shaping the corporate strategy of the company.

After these beginning phases, there may be several later stages to provide capital after commercial manufacturing and sales but before any initial public offering; these are the *expansion* stages. At this point companies have already established their products in the marketplace and they are ready to expand; therefore, they need additional capital to develop both their manufacturing and distribution capacities (Jeng and Wells, 2000). Venture capitalists can help the expansion of firms also by providing them with contacts of potential clients and suppliers (Bottazzi and Da Rin, 2001).

As the company become better established, venture capitalists increase the duration of financing and reduce the frequency of revaluation (Gompers and Lerner, 2001). The monitor intensity is reduced with the increase in asset tangibility because the uncertainty decreases.

Overall, early stage investments have higher risks, balanced by higher returns; while later stage financings are characterized by lower risks and lower returns. Returns depend not only on the stages, but also on industry. For example, in Europe the lowest aggregate returns have been registered for early stage and technology specialist funds (OECD 1996).

Usually, venture funds focus their investments just in some stages of a company lifecycle; the size of the various type of funds are different. Since the early-stage investments require less money than those in the later-stage, funds focusing on the first ones are significantly smaller than the others. Gompers found that early-stage investments are half as large as the later-stage investments. While the difference in the amount of financing is considerable, the effort in terms of time and activities (like the analysis of the investments and the monitoring process) that the early and later-stages investments require is similar. This is why early-stage funds are smaller.

Moreover, small funds are usually raised by older and larger venture organizations because they have the necessary experience and knowledge to support them.

1.1.1.3. The venture cycle

The inspection of the firms before the financing process and its monitoring afterward, are just two of the aspects of the whole venture cycle. This cycle includes different phases. It starts when the venture capitalists decide to raise a venture fund; then, there are the financing stages and their monitoring process; afterward, successful projects are completed, and the venture capital firm can exit and return capital to its investors; finally, the venture fund raise additional capital.

A venture fund is composed of venture capitalists, who are the general partners, and investors who, in contrast, are limited partners. Depending on the size and the experience of the fund, the compensation pattern of venture capitalists can differ.

In particular, Gompers and Lerner (1999) found that for older and larger venture capital the compensation is more sensitive to performance. The explanation could be about the capabilities of venture capitalists: in younger funds, the venture capitalist's abilities are not known because they have to learn and build up their own experience. For these reasons, younger venture capitalists do not need a pay-for-performance incentive to put effort in their work. They would work hard anyway to establish a good reputation, select new investments and add value to their portfolio. While, for older venture capitalists the reputation concern is not a problem, therefore a pay-per-performance incentive is needed to work harder.

But the high-powered compensation is just one of the elements that govern the relationship between investors and venture capitalists. There can be other restrictions to limit potential conflicts. For example, venture capitalists may not be allowed to raise new funds until one is already fully invested; or they cannot invest in market where they are not experts.

An important step in the venture-backed firm lifecycle, is the exit of the fund which takes place after the investment stage. Usually, it occurs through an IPO: after a company issues shares to the public, the venture firm does not sell its equity because that would be a negative signal to the market, but it retains most of it. Gompers and Lerner (2001) report that before the IPO, on average, all the venture investors hold about the 34 percent stake and control one-third of the board seats. After the IPO they continue to hold this equity position, and this is an incentive for other investors, like institutional investors, who feel more confident about the investment.

The presence of venture capitalists is not just a commitment device after the IPO, but it also helps the company to reduce its underpricing when it enters the market. Magginson and Weiss (1991) found that the underpricing of venture capital-backed initial public offering is significantly less than the underpricing of non-venture initial public offering. And the explanation is again the presence of venture capitalists who act like a guarantee about the quality of the company.

This is what happen when venture capitalists decide to take a firm public. But which factors affect their decision? How do they decide whether it is time to take a firm public rather than finance it with another round?

One of the factors that definitely impact the decision is the relative valuation of publicly traded securities. Usually, venture capitalists resort to an IPO when there is a market peak, while they prefer another round financing when valuations are lower. But again, the reasons behind this choice differ between young and more experienced funds.

Young venture capital firms usually have the incentive to hasten the process trying to establish a reputation and raise capital for new funds. Taking a firm public is used as a signal to show the ability of the venture capitalists to potential investors. This produces a cost for the fund because the shorter the time the venture capital firm is in the company’s board of direction, the greater is the underpricing of the offering. Moreover, the percentage of equity retained by venture capitalists after the IPO is lower. Gompers (1996), studying a sample of venture-backed IPO between 1978 and 1987, found that the time that young venture capital firms have been on the company's board of directors is 14 months less than the correspondent for older firms. Besides, companies that went public and which were financed by young venture firms are nearly two years younger and more underpriced than the companies backed by older venture capital firms.

Older venture capital firms do not have these concerns; therefore, they are more flexible and have better timing abilities.

1.1.2. Who are venture capitalists?

To examine in depth the differences between venture capital and other sources of financing and understand in which ways venture capital funds add value to the firms they finance, it is necessary to look at the role played by venture capitalists.

Hellmann (2000) defines venture capitalists as "coaches": they provide assistance on everything from the strategy and recruitment to marketing and basic bookkeeping. There is a very close connection between venture capitalists and the firms they choose to finance; this bond is one of the key-element that distinguishes venture capitalists from the other sources.

While banks are concerned only about the financial health of the firm they lend money to, venture capitalists oversee also the strategy and the investment decisions of the company. They are advisors and can even intervene in the firm's operations if necessary because they usually are in the board of directors. They are full-time professional investors (Hellmann and Puri, 2000), who are experts in a specific area and have therefore the competences to evaluate business concepts. They are familiar with technologies and market developments in that area, so they can make an informed investments decision (Hellman and Puri, 2000).

As already said, venture capitalists influence a company's IPO and their presence is seen like a positive signal by other investors in the market. But they also help the process of professionalization of the firm replacing the original founder.

Hellmann and Puri (2002) examined different dimensions, like the recruitment processes, the overall human resource policies, the adoption of stock option plans and the hiring of a vice president of marketing and sales. They found that venture-backed companies are more likely or faster to professionalize along these dimensions. In particular, firms obtaining venture capital financing are more likely to adopt stock option plans and elect a vice president of sales and marketing.

Moreover, the professionalization process is also at the CEO level: in venture-backed companies, the founder is more likely to be replaced by an outsider as CEO and this change takes place very soon (Hellmann and Puri, 2002). Usually, when a new firm is founded, the founders take the leadership position. However, when the company begins to grow, many founders do not have the necessary abilities to manage this change. This is why venture capitalists decide to hire an outside, professional CEO.

The CEO turnover could take place at different times of the company life. Hellmann and Puri identify two important milestones in the development of a firm: the time it brings a product to the market and the time it goes public. Before the first event, a company is more fragile because it has not demonstrated the feasibility of its business plan yet. On the contrary, a company that goes public sends a message about its good quality. If the firm has already achieved these two milestones, venture capitalists are not more likely than other investors to replace the founders with an outside CEO. But in the previous stages, venture capitalists play a significant role in attracting professional CEOs (Hellmann and Puri, 2000).

Therefore, for venture-backed firms, the professionalization process occurs sooner or faster both in the human resource policies and at the top leadership level.

1.1.3. Supply and Demand in Venture Capital

The working principles of the venture capital market is based on the concepts of demand and supply.

The term supply identifies the willingness of investors to provide funds to venture firms. In figure 2[3] the supply curve slopes upward because the availability to invest in venture capital funds increases with the expected rate of return on the future investments, which corresponds to the price. However, this curve is quite flat because close substitutes to this kind of investment exist.

[3] Figure from Paul Gompers and Josh Lerner (1998), "What Drives Venture Capital Fundraising?"

One of the factors that causes its upward slope is the presence of the differential taxes system. Investors with higher tax rate would require a higher expected return on the investment to be incentivized to invest in a venture fund rather than prefer some tax-free investment.

The demand curve, instead, slopes downward. It indicates the number of companies which are looking for financing and that can provide a specific expected rate of return. As the expected rate increases, and thus the price rises as well, the number of firms seeking for financing decreases because there are fewer projects meeting the required threshold of profitability.

The intersection of the two curves identifies the equilibrium. But usually, the supply curve is very elastic, therefore, changes in the equilibrium will affect more quantities than price.

The expected rate of return in the venture capital market is not foreseeable and it is very difficult to have an accurate estimate of it.

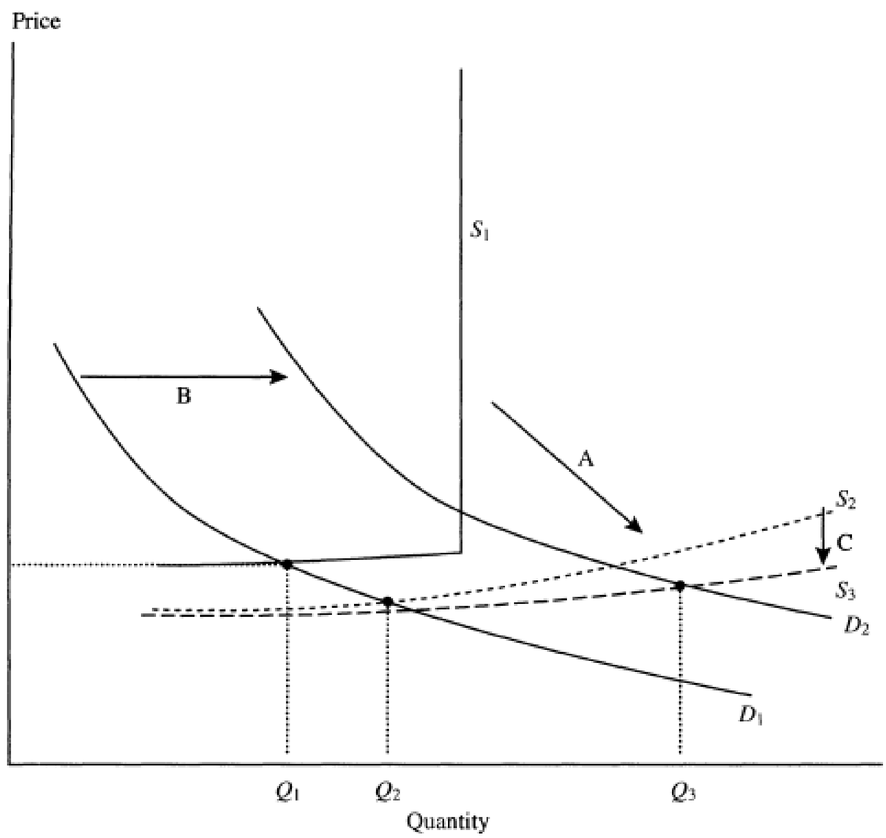


Figure 2. Supply and demand in venture capital. Equilibrium before the clarification of ERISA is represented by Q_1. After ERISA, the supply curve shifts from S_1 down to S_2 (A) and the new equilibrium quantity of venture capital is Q_2. Capital gains tax reductions move both demand to D_2 (B) and supply to S_2 (C) and the equilibrium quantity of venture capital moves to Q_3.

Firms are valued at their cost until they are sold or taken public; therefore, returns from venture capital investments can only be observed several years after the original investment (Gompers and Lerner, 1998).

The slope of the curves, and thus the equilibrium, is affected by several macroeconomic factors. Capital gains tax rate certainly is one of those. Gompers and Lerner find that changes in capital gains tax rate, impact the venture capital supply indirectly through the demand side. If this rate decreases, the impact on the supply curve would not be very pronounced.

Poterba (1989) suggested that a reduction in the capital gains tax rate would lower the required expected pre-tax rate of return on venture investments for taxable investors and this would cause a slight shift downward of the supply curve (Gompers and Lerner, 1998).
The effect of such a change on the demand curve, instead, would be much more significant. If the capital gains tax rate decreases, more managers and entrepreneurs would be willing to start their own company. In fact, most of the compensation from being an entrepreneur derive from the capital appreciation on the equity. Gompers and Lerner confirmed what Poterba suggested: more managers would be induced to become entrepreneurs when the capital gain tax rate declines, the demand for venture capital would increase, the demand curve would shift upward, and the equilibrium quantity would increase.

As far as other macroeconomic variables are concerned, Gompers and Lerner find that real GDP growth has an impact on the commitments to venture funds. An increase in the GDP is a signal for a growing economy and this is an attractive opportunity to start a new company. Once again, this would cause an increase in the demand for venture capital.

The supply side is affected by another factor: the interest rate. As said, there are substitutes to the venture capital investment; thus, if the interest rate increases, investors could lose their interest in supplying venture capital at all prices.

1.2. Venture capital and firm performance

As anticipated in the previous section, different studies highlight the existence of a relationship between the presence of venture capitalists and the performance of the financed company. The following paragraphs show the potential positive and negative effects that VC could have on the firms' performance.

1.2.1. Benefits of the VC involvement

Jain and Kini (1995) found that venture-backed firms in U.S. exhibit superior post-issue operating performance compared to the non-venture backed counterparts. Specifically, venture-backed firms show significantly higher growth rates in the three years immediately following the IPO. Brav and Gompers (1997) found that using equal weighted returns, venture-backed companies outperformed the non-venture-backed over a five-year period in a sample between 1972 and 1992. Brown (2005) examined high-tech U.S. firms that went public between 1980 and 1989. He showed that venture-backed firms raised significantly more funds from the IPO, compared to non-venture-backed companies; they survive longer and have faster growth rate for many years after the IPO, though the two rates slowly converge over time; venture-backed firms have faster growth in R&D spending and superior operating performance; in the decade after the IPO they raise more equity and have higher equity to total assets ratio.

An Italian study by Bertoni et al. (2010) has been conducted on a sample of 538 Italian new technology-based firms. Even though the Italian market is structured and behaves very differently than the U.S. market (Bertoni and Colombo, 2015), the results are very similar: VC investments have a large positive and statistically significant impact on sales and on the growth of employment. This effect is especially evident in the period immediately after the first financing round. Engel (2002) highlights the presence of this relationship also for German companies. Based on empirical evidence he shows that firms receiving venture capital achieve significantly higher growth rates mostly in the short-term period. Venture-backed firms develop faster and have better performance.

Trying to identify the critical success factors that determine the higher performance of VC-backed firms, Jain (2001) highlights three elements:

i. the first one is what he called the VC-manager strategic fit which identifies the connection between the VC expertise and the managerial strategy strength;
ii. the second factor is the long-term commitment of both VC and venture managers;
iii. the last element regards the involvement stage of venture capitalists: their contribution is more effective if they are involved in the early stages of the company life.

These factors are identified by Jain as significant predictors of venture performance.

All these findings seem to confirm the hypothesis that venture capitalists add value to the companies they finance; their guidance and experience are essential to achieve superior performance in the years right after the IPO and they allow to speed up the development of the firms.

In addition to the outstanding capabilities of venture capital described in the previous paragraphs, other factors help explain why venture-backed firms might outperform non-venture-backed firms.

Non-venture-backed firms have more difficulties in finding the necessary sources of financing and this process might require a longer time. Therefore, these companies might be forced to delay some key investment or some crucial project because they do not dispose of the needed funds. Venture-backed firms, on the other hand, have the necessary financing to start new projects when they arise. Non-venture-backed firms could thus be under-funded and have mediocre long-run performance compared to the venture-backed. Brown (2005) found that venture-backed firms engage in more R&D before the IPO which allows them to acquire great intellectual capital that will impact on the performance also after the IPO. This is a difficult competitive disadvantage for non-venture-backed companies.

1.2.2. *Disadvantages of the VC involvement*

Nevertheless, while there is evidence that performance in the year subsequent to the IPO are superior for venture-backed firms, there are reasons to believe that venture involvement could also harm the long-run performance of the firm.

One of those factors has already been explained. It consists in the underpricing caused by young venture funds who want to anticipate the IPO trying to attract more investors. This process is damaging for the long-run performance of the firm because issuing an IPO for a firm that is too young could decrease its future growth rate.

In addition to the underpricing, there is a second problem that involves both young and old venture capital. As already explained, venture capital funds have a finite lifetime, therefore, after some year from the IPO, venture capitalists liquidate their holding either by selling shares in the open market or distributing them directly to the investors. In any case, they can have the incentive to maximize the value of the firm just in the short-run in order to maximize their return, regardless of the effects on the performance of the firm. Brown (2005) states that this short-term period is represented by the first or the second year after the IPO. For example, venture capitalists could be incentivized to delay or even abandon some profitable investment just to increase the current stock price of the firm; in this way its image is improved even if it could be a damage for the long-run performance.

Another cause of the poor performance of a firm could be the consequences of the assumption of outsider CEO and the replacing of the original founders. This process is very common when venture capitalists are involved and could cause a misalignment between the incentive of the entrepreneurs and the success of the firm; the reason is that the entrepreneur is forced to give up a substantial part of his ownership and control over the direction of the firm.

Hellmann and Puri (2000) also state that the presence of venture capitalists could harm the performance of the company because the attention of the entrepreneur is diverted from the important activities of the firm; in fact, he is forced to spend much time meeting and discussing with the venture capitalists.

1.2.3. *Role of innovation*

There seems to be some characteristics that influence the decision of venture capitalists to finance a company. For example, based on a probit regression, Hellmann and Puri (2000) found that firms pursuing an innovator strategy are advantaged in finding venture capital financing. Innovators have some competitive advantage compared to those who pursue an imitator strategy.

One of the element that venture capitalists take into consideration when they analyse a company before investing in it, is its business plan; it contains all the details about the strategy that the company will try to realize. But Hellmann and Puri (2000) found that innovators are more likely to have a business plan at the time they received venture capital than imitators, therefore, it is easier for them to be taken into consideration by venture capitalists.

The evidence that venture capitalists invest in young innovative firms suggest that they are not afraid of the uncertainty that such new companies can entail but rather they are willing to invest in them at a very young age.

Usually, the strategy pursued by innovators is based on the first-mover advantage and, to exploit it, the support given by venture capitalists is crucial. In fact, Hellmann and Puri (2000) found that for innovators, the presence of venture capitalists is associated with a significant reduction in the time taken to bring a product to the market. Venture capital involvement, thus, is associated with faster time to market and allows to secure the first-mover advantage.

These findings suggest that venture capitalists could play different roles depending on the type of firm they decide to finance. Imitators turn to venture capital just to obtain an additional source of financing; on the other hand, innovators, are interested not only in the capital they can obtain, but also in the value that venture capitalists can add thanks to their experience and knowledge.

1.3. *Signalling effect of patenting*

1.3.1. *Patents as a quality measure*

There is a wide literature about the role of patenting in young companies. Usually, they are used as a measure of innovation of a start-up: to overcome problems related to information asymmetries, start-ups can use some types of signal to communicate to external investors information about the quality of their business. In particular, patents are suitable for this because they do not change over time and are costly to obtain in terms of financial costs, effort and time (Graham et al., 2010). Besides, they are less subjective than other measures because to be validated, a patent has to pass different valuations: there are strict guidelines and technical information have to be described in detail. Therefore, companies are willing to support all these costs only if the quality of the new technology is sufficiently high. This is way patents can be considered as a proxy of the underlying firm quality (Haeussler, Harhoff and Mueller, 2014).

In the academic literature, patents are used as a measure also of firm productivity and innovative activity; the number of patents reflect measures that are difficult to obtain otherwise, like the knowledge capital or the productivity of R&D spending. In fact, the correlation between patenting and R&D spending is positive and strong (Long, 2002; Griliches, 1998).

Patents are also used to compare the inventive activity across firms in the same industry: they represent a benchmark that firms use to control the evolution of performance in their industry.

1.3.2. *Intellectual Property regimes*

The role played by patents differs depending on the stage of firm development and on the industry. The rate of patenting varies substantially among industries and even among sectors within the same industry, because of the different appropriation regimes. For example, in the software industry, Mann and Sager (2007) found significant differences from sector to sector, demonstrating that the appropriability of innovation through patenting differs considerably depending on the software development of each firm.

Moreover, the software industry seems to be characterized by a lack of concentrations and thus it is dominated by small firms. In such a context property rights could be important to facilitate an industrial structure where small firms are protected in developing pieces of product assembled by larger companies (Mann and Sager, 2007).

Graham et al. (2010) found that patents help start-ups to compete in the market and this role is more pronounced for biotechnology and hardware companies; while for software firms this function is not important. Confirming the findings of Mann and Sager, Graham et al. show that industries and sectors do matter: biotechnology and medical device industries not only have substantially greater numbers of patents than software and Internet industries, but they also have a significantly larger share of companies with larger patent portfolios (Mann and Sager, 2007). The appropriability regime in the biotechnology industry is particularly strong. The firm that benefit from patents, has the monopoly over the products or processes patented that lasts for several years and is a signal of the star-up's future potential (Baum and Silverman, 2004).

The appropriability strategies used by companies are different depending on the industry as well. Graham et al. highlight that for biotechnology, medical devices and IT hardware (such as semiconductors and communications equipment) firms patenting is the most important appropriability mean; while for software companies, the most important strategy is the first mover advantage whereas patents are the least important one. In general, software firms do not consider their technologies patentable, that is, they do not believe that patents can protect their competitive advantage. Thus, the costs that software firms would have to sustain to obtain a patent is not justified by a real protection.

For these reasons, in seeking patent protection, companies have different purposes. Biotechnology and medical devices firms state that two of the very important objectives are to prevent others from copying products or service and to improve chances of securing investments. On the other hand, for software companies a very important objective, apart from protect from potential imitations, is to enhance the company reputation and the product image.

When looking at the intensity of patents for venture-backed firms, is then necessary to consider also these relevant differences among industries.

1.3.3. *Patents and venture capital*

Based on empirical evidences, some authors suggest the existence of a relationship between the intensity of patents and the presence of venture capital. Others seems to reject this hypothesis. Demonstrating a causal relationship between the presence of venture capital and innovation is a very challenging problem.

One of the main complications, is the inverse causality. It is not clear if patents facilitate progress attracting venture financing or if venture financing facilitates progress through patenting. On one hand, venture capitalists could help the innovation process supporting firms with capital and with management expertise; these competences help the company to apply for patents and speed up the development process. On the other hand, patents, or their prospects, could attract investors.

In the literature there are numerous studies on this topic, and some of them are conflicting. For example, Mann (2005) showed, through a series of interviews to venture capitalists, that the presence of patents has positive effects but just in some stages of the firm lifecycle. Investors affirmed that for companies in the pre-revenue stage they are interested in the management experience and abilities rather than in the intensity of patents. While, for revenue-generating start-ups, investors see the presence of patents as a tool which might provide sustainable differentiation from competitors and also as a symbol of the operational competences of the firm's management. Some data suggest that, while it is not significant to have patents before the first financing, the majority of the firms that obtain patents do so in the early stages after the first venture financing. Mann and Sager (2007) explain this excluding the possibility that the presence of patents has the objective to increase the value of the firm and attract new investors; instead, they suggest that the acquisition of patents is used as a tool to protect the companies from the expropriation by both the investors and larger incumbents. Without patents, in fact, it is possible that potential investors decide to steal the entrepreneur's ideas. In this way, the value of the firm does increase but only because patents reduce the costs of moral hazard and hold-up between entrepreneurs and investors.

1.3.3.1. *VC favors innovation?*

Among the studies that demonstrate the absence of a signalling effect of patents, the analysis by Bertoni et al. (2015) does not find any selection effect of VC investments. In Europe, venture capitalists tend to invest in very young but relatively large firms. VC financing is not a random treatment, but there is no evidence of any impact of the role of patenting of VC. On the contrary, it seems that VC involvement affect positively the subsequent patent activity.

Similarly, Dushnitsky and Lenox (2005) demonstrated that strong corporate venture capital (CVC) involvement is associated with higher future patent citations levels of the financed company. They focused on the impact that CVC financings have on the innovation rate of a company, measured by the count of its forward patent citations. However, this relationship is significant only for firms operating in industry where the intellectual property regime is weak, such as the information technology sector.

To test the existence of a relationship between patenting and venture capital, one approach is to look at regressions across industries and examine whether venture capital has in impact on the number of patents. But this technique can be biased because both venture financing and patenting could be related to others unobservable factors like the arrival of technological opportunities.

To control for this factor, Kortum and Lerner (2000) used R&D expenditures as a control variable. They analysed data between 1965 and 1992 for firms in twenty industries operating in the U.S. market. Using patents issued as the dependent variable, they found that there is a strong association between venture capital and patenting. Even if the results showed that R&D and venture capital are substitutable in generating innovations, they confirmed that venture funding is between 1.5 and 3 times more potent than corporate R&D (Kortum and Lerner, 2000).

Looking at the frequency and extent of patents, and the trade-secret litigation, they found that venture-backed companies received a larger number of patents award and also higher scores of these variables. Kortum and Lerner concluded that venture-backed firms are more innovative because they produce a larger and higher valued stock of patents.

1.3.3.2. Or patents attract VC funds?

In contrast to these findings, other studies seem to demonstrate the inverse relation.

Baum and Silverman (2004) studied a sample of 204 Canadian start-ups in the biotechnology industry between 1991 and 2000. They found that patents played a significant role in obtaining VC financing. In particular, not just the number of patents was important but also having more recent patent applications was an advantage to obtain significantly more VC financing.

Munari and Toschi (2014) give a similar interpretation. Based on a sample of 332 VC-backed companies in the nanotech industry, they analyse the impact of the characteristics of patent portfolios on the amount of financing obtained by VCs. But rather than look at the total number of patents owned by firms, they considered the number of the core technology patents, which are those patents directly related to the core technological capabilities of a target company. They found that it is the type of patents owned by start-ups that matters for the financing decisions of venture capitalists, rather than their quantity. In fact, only the number of patents belonging to the nanotechnology class has a positive and significant effect of VC financing.

Haeussler, Harhoff and Mueller (2014) using a sample of British and German companies, found evidence that firms which applied for patent protection received venture capital financing faster. The number of patents it is not the only measure that influence the VC involvement, but they look also at the quality of the patent portfolio, through the number of citations by large technology followers. They found that the higher this number is (and thus the commercial opportunities for licensing), the faster the process of obtaining VC.

The importance of patents quality has been recognized also by Hoenen et al. (2014). In their study of 1500 U.S. biotechnology firms, they confirmed the importance of patent activity as a signal to attract venture capitalists, and looking at the number of forward patent citations, they found that companies with a higher number of those, attract greater amount of capitals. The signalling effect is due both to the number of patents and to their quality. Anyway, Hoenen et al. underlie that the impact of the patent activity is significant only during the early stage investments, when the information asymmetries are most significant; while after the first round of investment, neither the number of patents nor their quality impact the capital accumulation.

Another study by Engel and Keilbach (2007) analyse the impact of venture capital finance on growth and innovation focusing on young German firms. They focused on firm-level data rather than industry data and in this way they were able to identify the exact moment of the venture involvement, for venture-backed firms, and compare performance before and after the financing. Besides, they compared every single firm with its twin, that is a company with similar characteristics respect to age, size, industry and other variables, but which did not receive venture funding.

Their results showed that venture-backed firms have a significantly larger number of patents than their twins. However, this difference exists even before the venture involvement.

Engel and Keilbach suggested that venture capitalists try to select the most promising firms in their screening process; to evaluate the innovative potential of each company, they look at the number of patent applications. Thus, patents have a signalling role, they communicate to possible investors the great potential of the firm. In this view, patents are considered as signals sent by start-ups to external investors, with the purpose of communicating the quality level of the firm and reducing the information asymmetries (Conti et al. 2013).

Engel and Keilbach found also that venture-backed firms have an average growth rate that is twice as large as their counterparts. The reason why they have such better performance is explained by the authors as the result of the commercialization process. Venture capitalists choose the most promising firms and then support them with management assistance to commercialize the innovations that were already in the firm before the venture funding. In this hypothesis patents have a signalling effect to represent the most innovative firms that are then exploited by venture capitalists to maximize their returns through commercialization. The higher innovativeness of venture-backed firms is due to the selection process.

Chapter 2

2. Development of the VC industry

The venture capital industry shows different characteristics depending on the country it has developed. In the United States, for example, it is oriented to technology-based sectors and it includes different types of investors, like pension funds, private individuals and insurance companies. The European venture capital industry instead, is younger, dominated by banks and it focuses on the mainstreams sectors (the most represented are the industrial products and the manufacturing sectors). The Japanese venture capital market is further different, it is composed of firms which are mostly subsidiaries of financial institutions and that invest in already established firms providing loan and equity finance.

The two key points that distinguish the European venture capital industry from its U.S. counterpart are both the industries in which the investments are conducted and the type of investors. While in the U.S. pension funds are among the main investors, in Europe banks are more significant, with U.K. being the only exception. This difference has some implications also on the nature of the investments because banks tend to have a shorter investment horizon than pension funds and insurance companies. This is one of the reasons why the venture capital market in Europe has developed less than in the United States.

In Europe, up until the 1990s, the most developed venture capital markets were the United Kingdom and the Netherlands. The OECD reports that the U.K. was responsible for the 34% of the total number of deals in 1995 (which accounted for the 42% of the total value).
The venture capital financing was active in more than 20 countries across Europe and it provided between 5000 and 7000 investments every year. More than 50% of all investments were to provide expansion finance but, on average, two start-ups were funded each day (OECD, 1996).

2.1. Global trend

The global venture capital industry has experienced a continuous increase since the beginning of the twentieth century, to the point that its value more tripled between 2006 and 2015. Figure 3 shows this trend: both the total amount raised in venture capital deals and the number of deals has grown considerably.

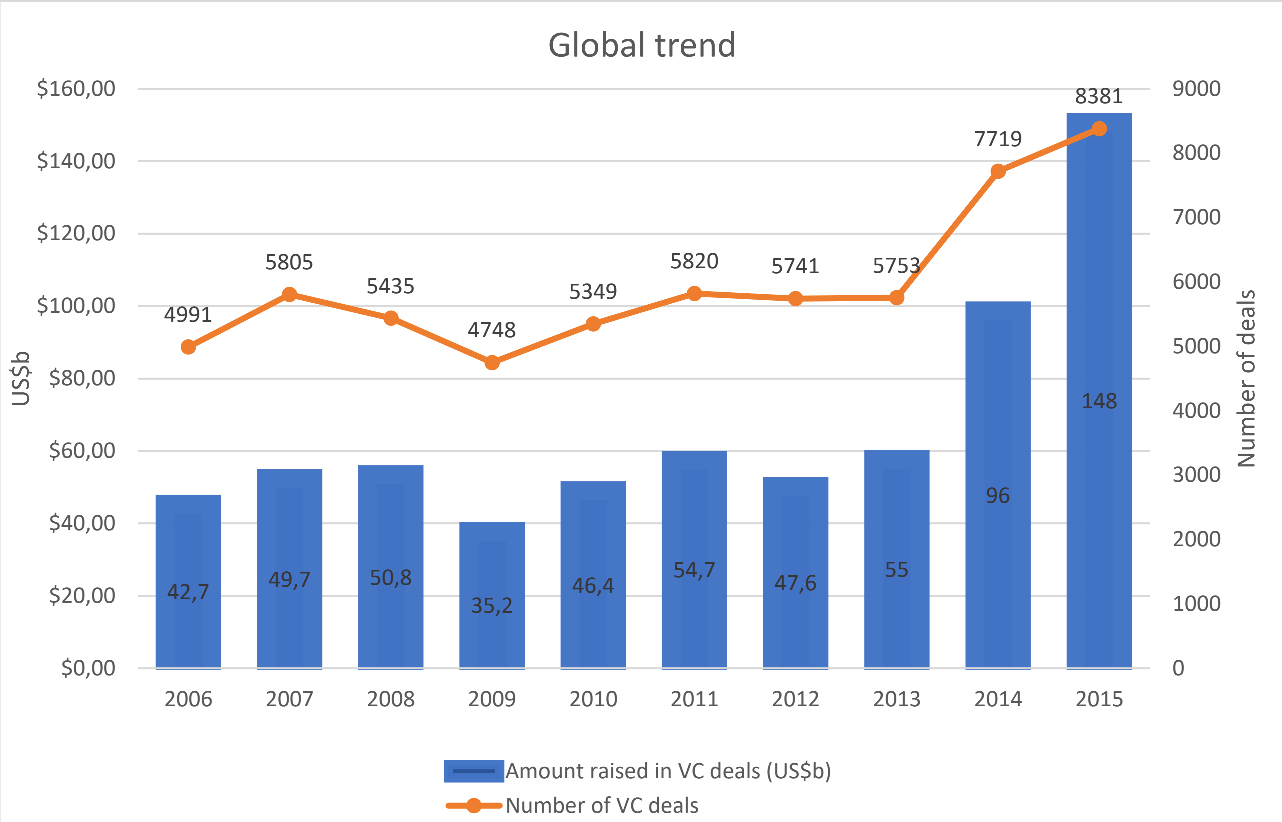


Figure 3. Global trend of VC. Data are in US$b

Only two years are characterized by a downward trend in the amount of VC investment. In 2009, after the worldwide big financial crisis that affected investments all over the world, the amount raised in VC deals dropped by 30.7% reaching US$ 35.2 billion. The United States, that has always been the oldest and most developed market among all, leading the investments of all the other countries, was also one of the most damaged country after 2008, seeing a decline in the amount of VC investment of about 26%. Figure 4 shows the venture capital industry trend for the three main countries between 2006 and 2015.

After that tough year, investments in the venture capital industry begun to increase again reaching a new maximum in 2011. The increase was supported also by a globalization:

although the United States remained the leader country, accounting for 67% of the global VC activity, other emerging markets like China and India begun to develop faster.

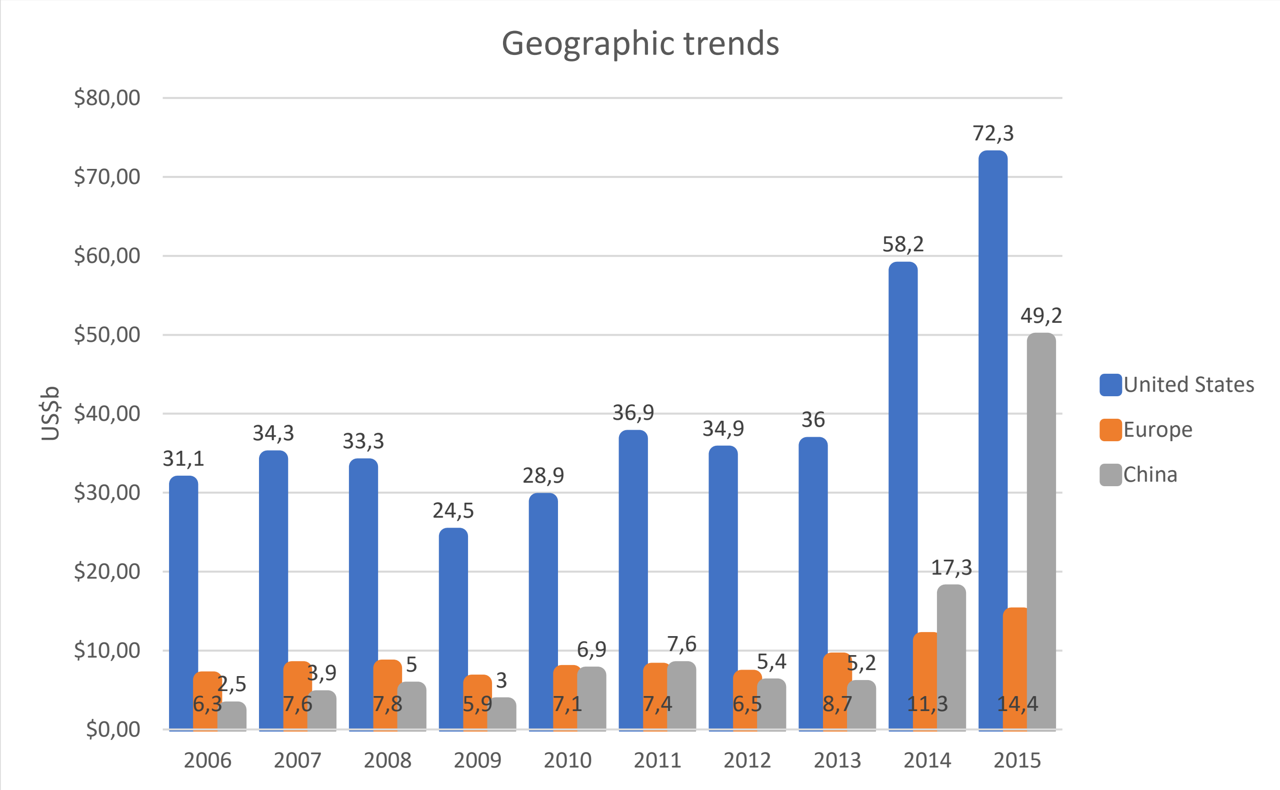


Figure 4. VC trend in the U.S., Europe and China between 2006 and 2015. Data are in US$b

While more mature VC markets like US and Europe favoured earlier-stage investments, China and India generally preferred later-stage and less risky firms. Moreover, globally, VC funding has been evenly spread across sectors and life-cycle stages.

2012 saw a new drop in the amount of VC investment by 13%. While they remained quite strong in US and Europe, the most affected countries this time were China and India, with a more than 30% drop. The investment pattern changed as well: almost all venture capitalists preferred to focus their projects on the revenue generating stages rather than the seed and the start-up stages, seen as a riskier option.

Reversing the decline of the previous year, 2013 was characterize by an increase in the global VC market of 15.5%. Europe saw a 34% rise in capital invested, while China had its poorest year since 2007 falling to US$ 5.2 billion. India, which was the fourth in the global VC ranking, saw a remarkable increase in the amount of dollars invested, confirming its uptrend. But the global investment pattern remained the same: while only developed markets like US and Europe invested in business at the early-stage, in general the preference to make bigger investments at the second or later stages was confirmed.

Investments globally tended to focus on two sectors: consumer services and information technology. The first one offers a more rapid feedback on whether the investment are likely to pay off because it has a direct connection with consumers. This sector is preferred by Europe, China and India, while information technology companies got more financing in US, Canada and Israel.

From 2014 onwards, the venture capital industry saw an outstanding growth both in the amount raised and in the number of deals. Global investments increased by 75%, in particular, the amount raised grew by 62% for the US, 30% for Europe and it more than doubled for China.

The consumer services sector continued to lead the global VC landscape in terms of amount invested. Even looking at the number of rounds, investors preferred to focus in the consumer services sector more than in the information technology, which has been the leading sector for the previous three years (figure 5 shows investments in these two sectors in year 2013).

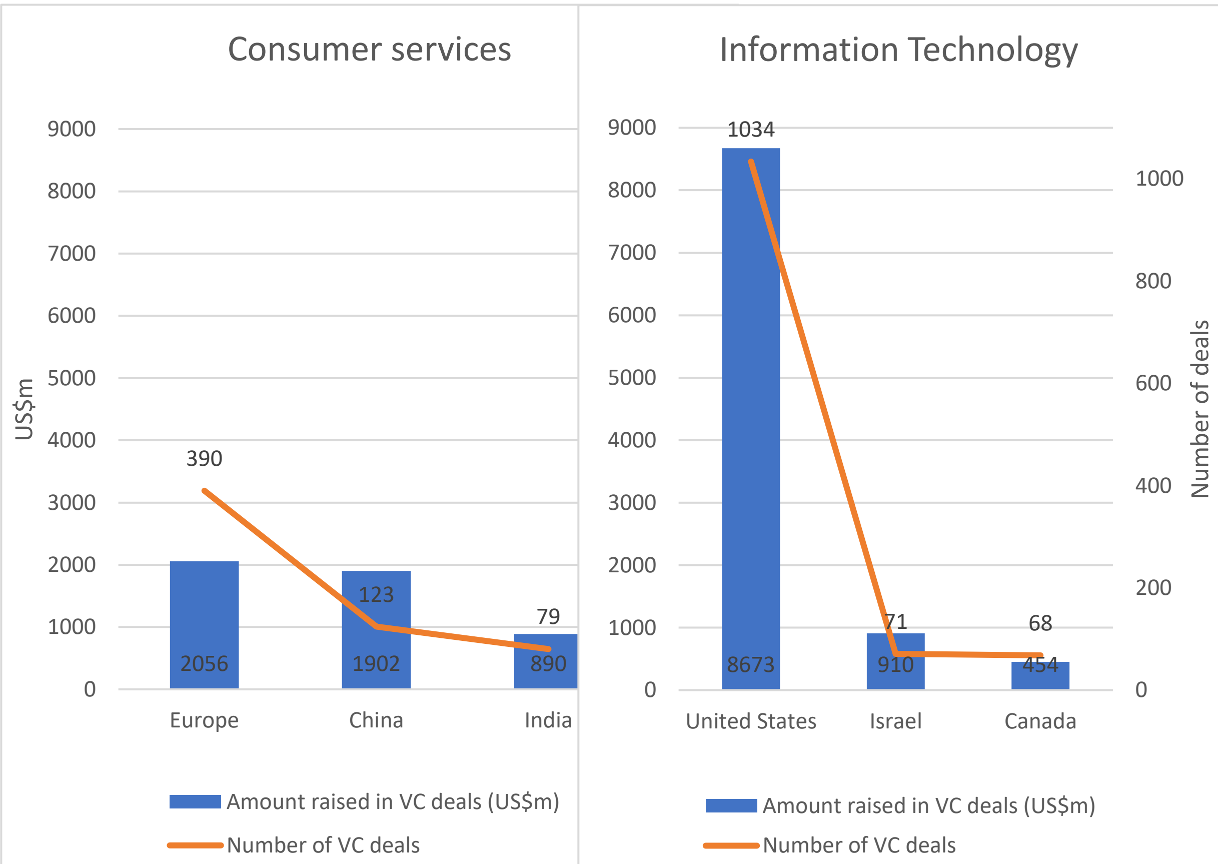


Figure 5. VC investments in consumer services and information technology industries in 2013

In 2015 the venture capital activity reached its highest value in almost two decades: the amount raised increased by US$ 52b (54.17%) and the number of deals by 9%. This difference in the percentages reflected the preference of venture capitalists to make fewer but bigger deals, financing more established business in the later rounds which can generate higher returns.

What surprises the most, is the considerable increase in the activity of China: it has grown seven-fold in five years, from 2010 to 2015. For the first time China outclassed Europe, reaching more than three times its amount of investments.

The global uptrend has been confirmed also in the following years, up until 2017 with an increase of about 11% in the amount raised compared to 2015. However, the number of deals is slowly declining; this, combined with the growth of the size of funding rounds, highlights the focus that investors have placed on investing in companies with the highest potential for success (KPMG; NVCA).

2.2. Europe

2016 was a really good year for Europe which saw an increase of about 13% in the amount raised, while venture capital funding in the U.S declined about 10%.

Looking at each country individually, it is evident that this growth has been strong in most parts of Europe and Israel, while there was a slowdown in UK and Germany during 2016. Figure 6 and 7 show a decline in the amount raised of about 18% and 38% in United Kingdom and Germany respectively. The overall growth has been mostly driven by France, Switzerland, Norway, Finland, Spain, Italy, Ireland and Belgium (figure 8, 9, 10 and 11).

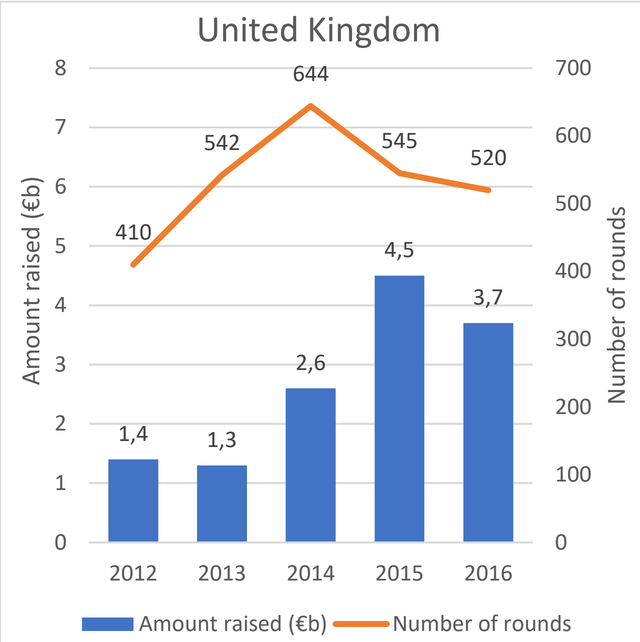


Figure 6. VC investment trend in United Kingdom between 2012 and 2016. Data are in €b

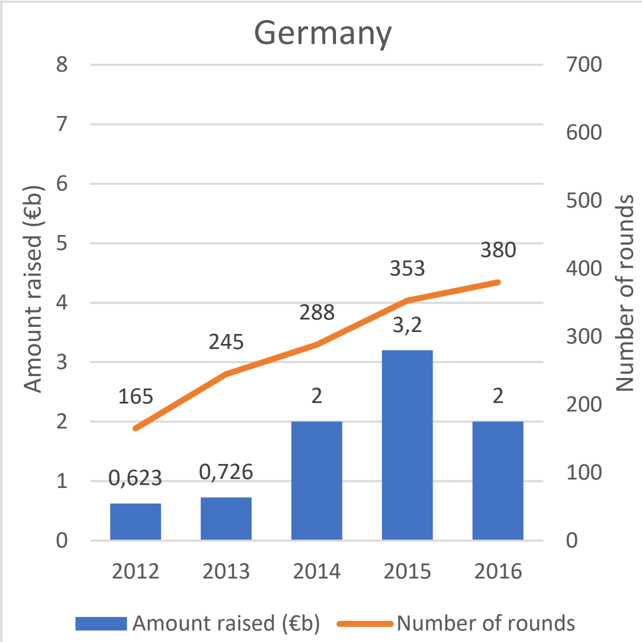


Figure 6. VC investment trend in Germany between 2012 and 2016. Data are in €b

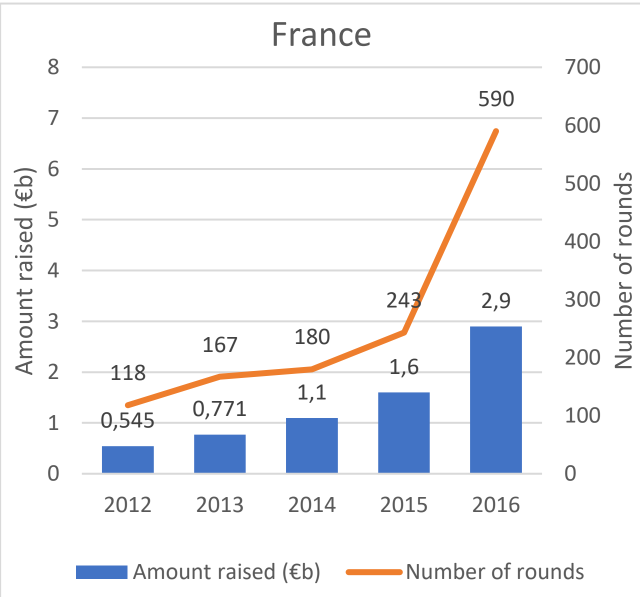


Figure 8. VC investment trend in France between 2012 and 2016. Data are in €b

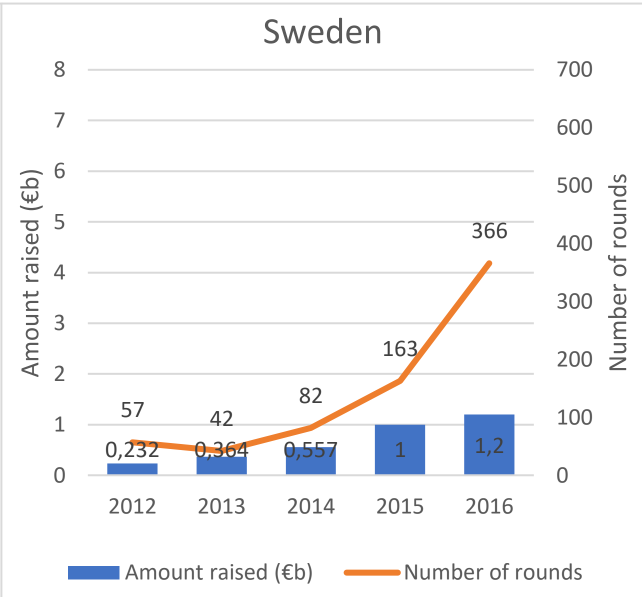


Figure 9. VC investment trend in Sweden between 2012 and 2016. Data are in €b

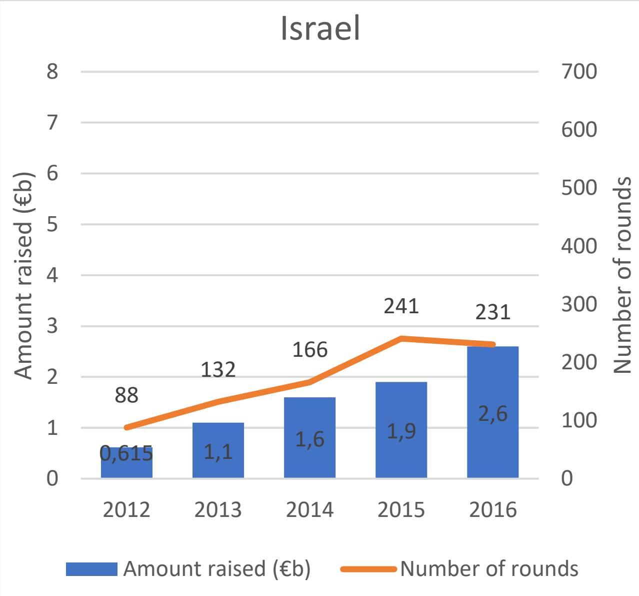


Figure 10. VC investment trend in Israel between 2012 and 2016. Data are in €b

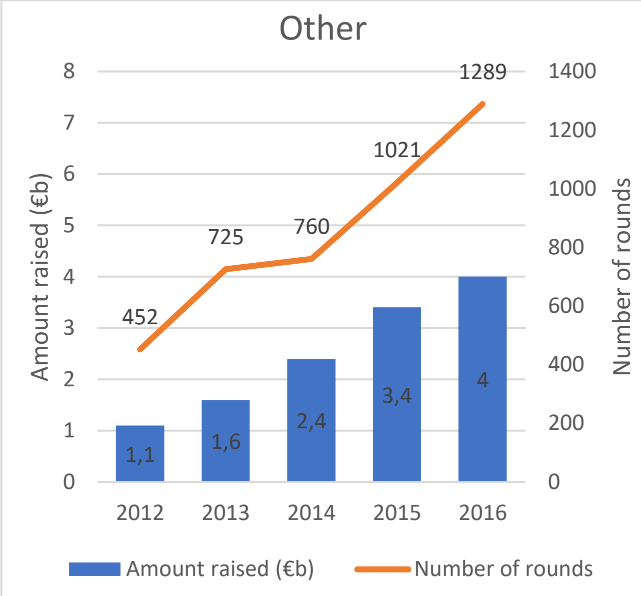


Figure 11. VC investment trend in the other European countries between 2012 and 2016. Data are in €b

As it has happened globally, also in Europe growth has been driven by increase in the amount raised in later stage. This was the trend up until 2015. In 2016, the main contribution to growth is due to early stage and mid stage rounds; later stage financings slowed down in that year, while the correspondent number of rounds kept growing (figure 12, 13, 14, 15 and 16). The number of European VC-financed start-ups increased in the last years, but a smaller proportion can reach the next funding round stage.

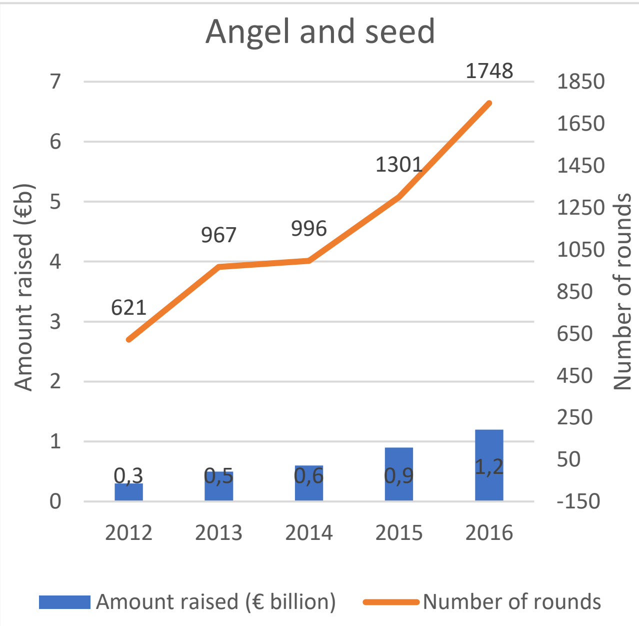


Figure 12. VC trend in angel and seed stages between 2012 and 2016. Data are in €b

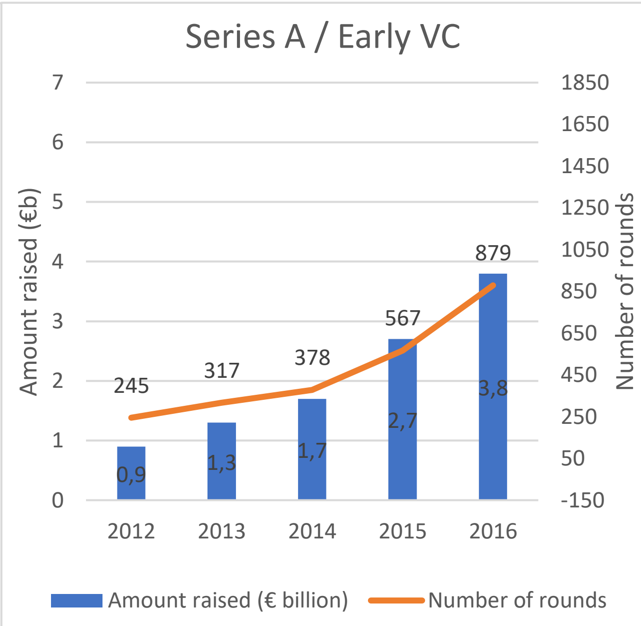
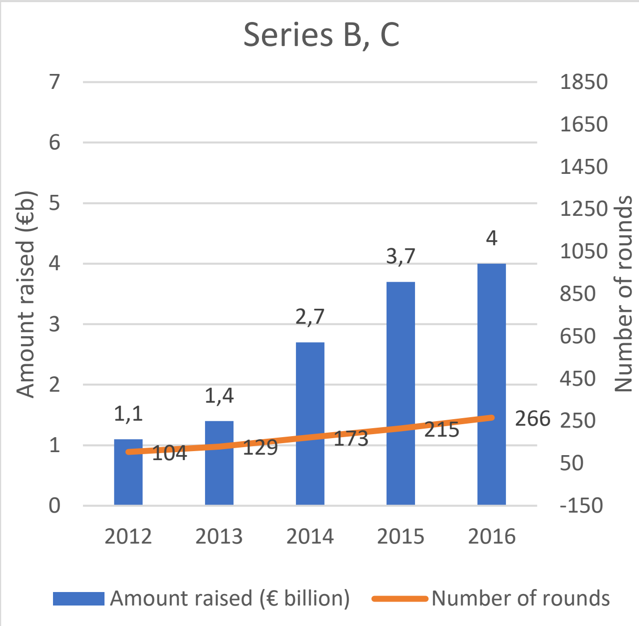


Figure 13. VC trend in the early stages between 2012 and 2016. Data are in €b



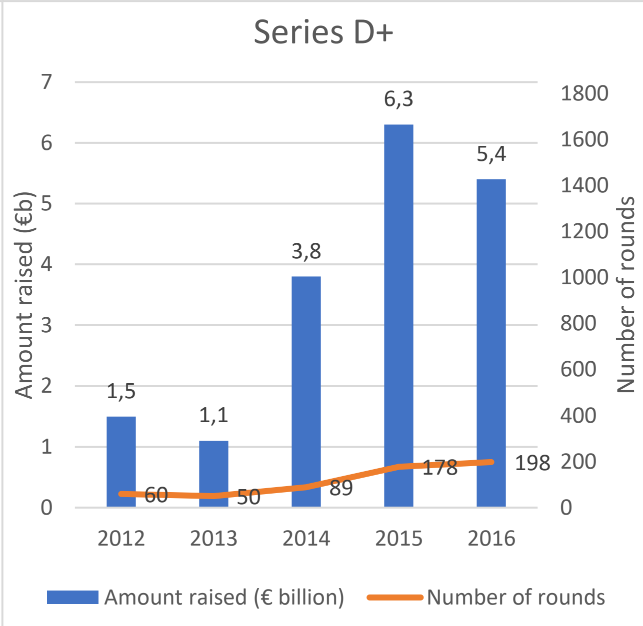


Figure 14. VC trend in B and C series between 2012 and 2016. Data are in €b

Figure 15. VC trend in D+ series between 2012 and 2016. Data are in €b

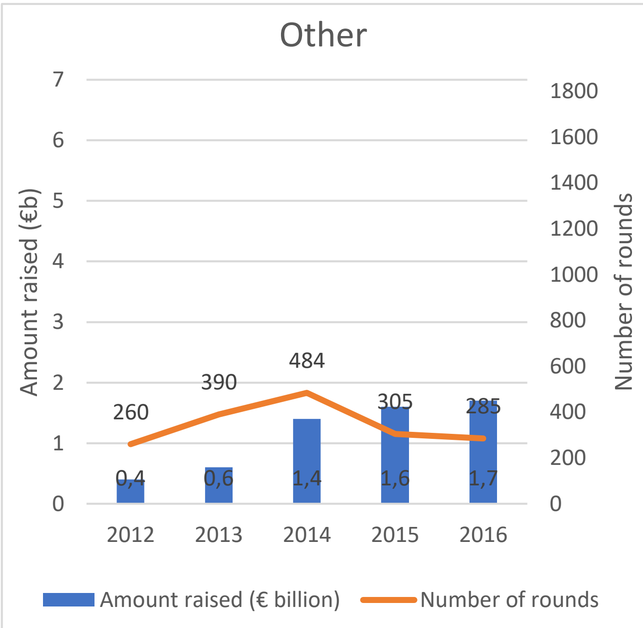


Figure 16. VC trend in all the other stages between 2012 and 2016. Data are in €b

Despite the global trend then, European venture capitalists seem to have higher risk appetite.

Following the global trend, in 2017 the amount raised continued to increase, while the number of rounds declined, and the size of each round started to grow. Figure 17 shows the situation in 2017.

U.K. remains the dominant hotbed in Europe, with investments up by 103% between 2016 and 2017. It is followed by Germany, France, Switzerland and Sweden. Outside Europe, Israel is growing at a very rapid rate, becoming the second country for investment intensity after U.K.

The United Kingdom accounts for about 40% of the European activity while U.K., Germany and France together account for over 66%.

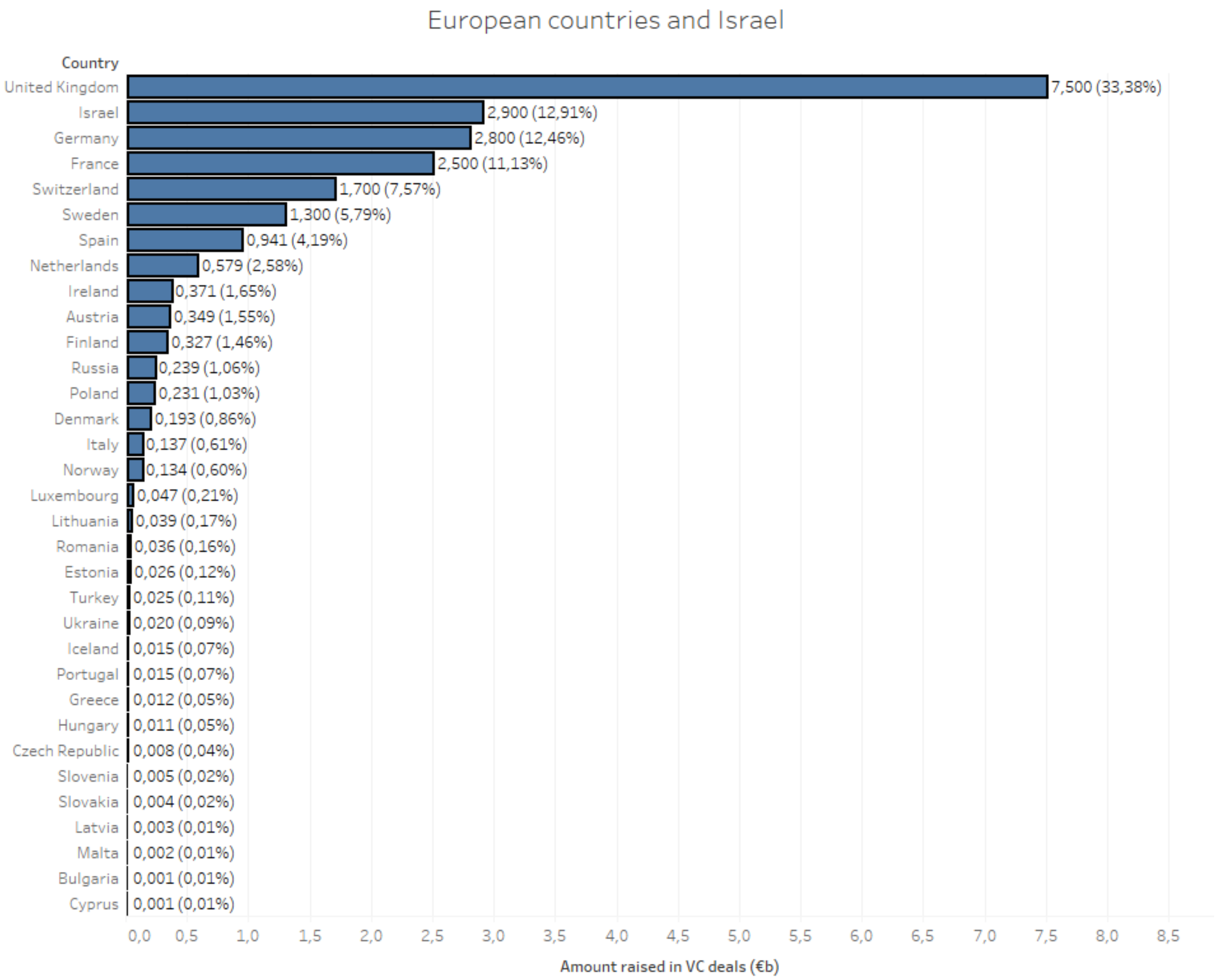


Figure 17. European VC investments in 2017. Data are in €b

Industries in which investors have focused changed over time (figure 18). Up until 2013 the most represented sectors were fintech and content. The last one includes companies owning and providing mass media and media metadata. Starting from 2014 two other industries started their outstanding growth: the transportation industry increased the amount of VC raised by almost four times between 2014 and 2017 and the travel sector rose about by 3 times.

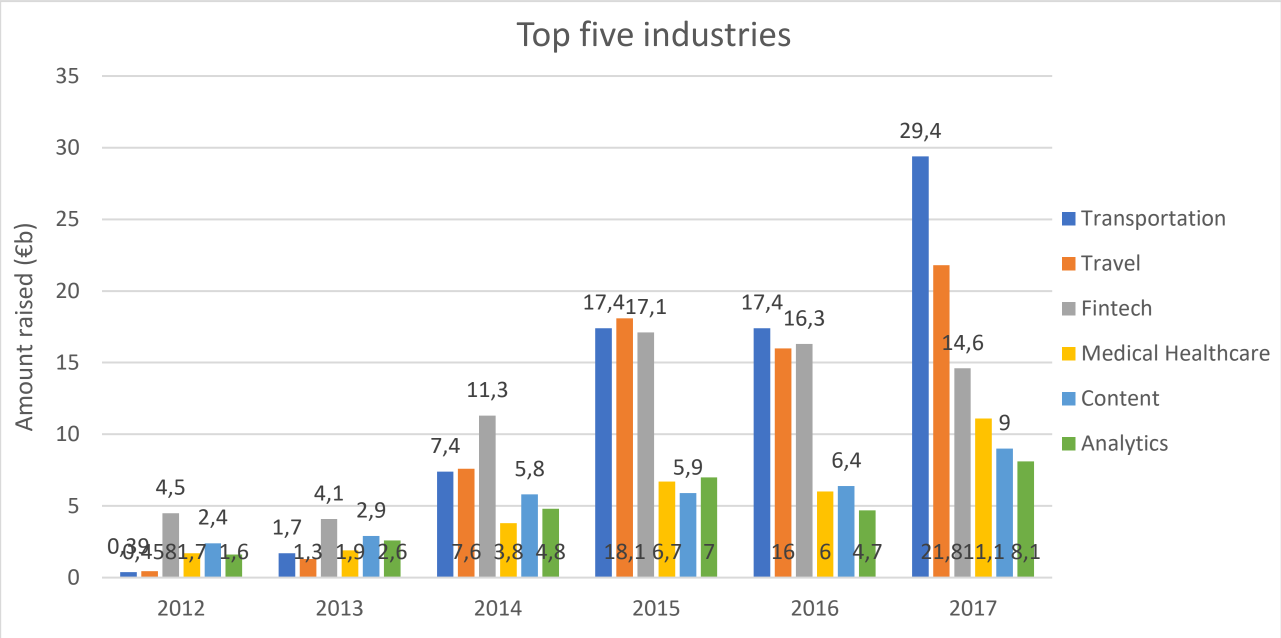


Figure 18. Top five industries in Europe and their trend between 2012 and 2017. Data are in €b

Chapter 3

3. Data

In this chapter are described the operations on data used in the analysis, which databases have been used, how data have been filtered and matched.
Data used in this study originate from two databases.

The first one is Amadeus, a database of comparable financial information for public and private companies across 45 European countries covering a period from 2005 to 2016. It is published by Bureau van Dijk and it covers a number of firm-specific variables, such as standardised annual accounts, financial ratios, sectorial activities and ownership data. The database does not include information on whether the firms are venture-funded or not, but this information have been found in the site Crunchbase. The last one is a database of innovative start-ups that collects data about the investors, funds and funding rounds.

The second database is Orbis. It includes information on 220 million companies worldwide about their financial situation, industries, patents, intellectual property, corporate actions, M&A operations, legal data and ownership.

Orbis, like Amadeus, is created by Bureau van Dijk Electronic Publishing which is a Moody's Analytics subsidiary publisher of business information.

3.1. Data collection process

At the beginning of the study, a list with 1169 VC-backed firms was available; each company was characterized by its name, country and city. The purpose of the data processing was to identify these firms in Amadeus in order to match each of them with a twin, characterized by the same country, date of birth and industry. The final database will have the same number of VC-backed and non-VC-backed companies, each one with information about its financial situation, ownership data, VC-financing data and patents.

The data collection process can be divided in seven steps.

In the first stage, each firm of the list had to be identified in Amadeus, using its name, country and city, to find its Bvdid code. The Bureau van Dijk ID number is an identification code by which each company is labelled and is used to classify firms in a univocal way.
It is possible to divide the initial list in three groups:

- ❖ Group 1: composed of 703 firms that were already been identified in Orbis with a correct match of their name, country and city. For these group, the available Bvdid code was presumably correct;
- ❖ Group 2: composed of 375 firms that were matched in Orbis using only their name:
    - ➢ Group 2a: 202 firms had the right correspondence also for the country;
    - ➢ Group 2b: 173 firms had a correct match on the name but the wrong country;

  Since the match was correct only for the name and only in some cases also for the country, the accuracy of the Bvdid number found for these companies was not ascertained;
- ❖ Group 3: composed of 91 firms which did not have any match in Orbis.

Firms in group 3 have been matched in Amadeus but only 28 of them (31%) have been found.

To test the reliability of the matches, different sample checks have been conducted; companies in the samples have been chosen randomly and for each of them the match has been checked manually in Amadeus to verify its accuracy.

- ❖ In the first group 5% of the firms have been controlled and for all of them the match was accurate.
- ❖ Conversely, matches in group 2 were not trustworthy:
    - ➢ 12% of the firms in group 2a were checked and 76% of them were exact, while for the other 24% data were not accessible on Amadeus;
    - ➢ 29% of the firms in group 2b were checked and 30% of them were exact, 24% were incorrect and 46% were not accessible.

Therefore, for group 2, a manual control has been conducted on each firm to verify each single match and correct the wrong ones. Firms with their main headquarter placed outside Europe, have been substituted with their relative European offices, when possible, after controlling that data for the two countries were similar.

At the end of the first stage, 925 firms (without distinguish between accessible or not accessible data) had a correct match on Amadeus (79% of the initial list).

In the second stage, the 925 companies have been searched in Amadeus to collect their data about country, city, date of incorporation, industry (NACE code) and number of employees. Of these 925 firms, only 675 were found in Amadeus (some of the not found were outside Europe).

For the remaining 424 companies of the initial sample, the same data were searched in Orbis and only 384 of them were found (in particular, 249 for group 1 and 135 for group 2).

Like before, another sample check has been conducted to test the accuracy of matches in Orbis. For group 1, 10% of the firms were checked and 92% of the matches were correct; for group 2, 37% of firms were checked and 80% of them were matched correctly.

At the end of this second step, 1059 VC-backed companies with their relative information were available (110 of them were outside Europe).

The purpose of the following steps was to find a twin firm for each of the 1059 companies. This research has been conducted in Amadeus, thus, countries outside Europe have been excluded.

In the third step, have been considered all the industries represented for each country (through the NACE code). Then, have been collected data of all the firms in Amadeus which operated in those industries for each country. In this way, a list of all the potential twins for each country was obtained.

In the fourth step, connections 1 to 1 between the VC-backed sample and the potential twins have been established. In order to do this, three parameters have been considered: country, NACE, and date of incorporation. Combining these variables each VC-backed firm has been connected to at least one potential twin. In establishing the connections, some constraints have been set. In particular:

- Potential twins with last-year sales > €100 million have been excluded;
- Potential twins with last-year total assets > €300 million have been excluded;

In so doing, 863 connections have been established. For firms with more than one potential twin, the connection with a unique twin has been made randomly. At this point, each selected twin has been checked manually on Crunchbase to control the absence of any VC involvement.

At the end of this step, 827 univocal matches have been found. Of the remaining firms:

- 18 had any match;
- 18 had unintelligible idioms and were therefore excluded.

To solve the first problem, the constraint on the incorporation date has been relaxed. In this way, a twin has been identified also for those 18 VC-backed firms.

At this point, the database was made of: 845 VC-backed firms and 845 twin firms which represent the control group.

All these 1690 companies have been searched in Amadeus to collect their data about the financial situation, patents and ownership.

Of the total number of firms, only 1443 have been found on Amadeus (600 among the VC-backed group and 843 among the control group).

In order to maintain a univocal relationship between the financed group and the control group, only firms with just one twin have been considered.

Therefore, the final database is made of 1196 companies, 598 for each group.

3.2. Database structure

In the final database are gathered information for the 1196 companies about their financial and income statements, ownership, industry and patents between 2001 and 2016.

Each firm is identified by its Bvdid code and its information are repeated for each available year; therefore, for each company there are sixteen rows, where the ownership data are always the same while the financial and patent data vary according to the years.

Information about the VC financing are structured in the following way. Two dummy variables, *hq_usdum* and *hq_eudum,* distinguish the headquarter of the VC fund which can be in the U.S. or in Europe. The variable *age_at_deal* shows the age of the VC-backed companies at each financing stage and *amountvc* exhibits the amount of each single round.

Then, there are six variables for the number of rounds: *roundum_s* in an integer and indicates the number of seed rounds that a company has received in a specific year; similarly, the other variables for the following stages: *roundum1, roundum2, roundum3, roundum4, roundum5.*

Chapter 4

4. Descriptive statistics

This chapter includes the descriptive analysis of the final database. The purpose is to display a detailed picture of the gathered data in order highlight possible differences between the VC-backed and the non-VC-backed groups and to evaluate the usability of the available information.

The first paragraph describes some general data of companies in the database; the second paragraph studies the financial information of the two sample groups. In particular, some measures are deepened because very meaningful: capital, total assets, long-term debt, turnover, number of employees and EBITDA; in the third paragraph are summarised data about the financing rounds of the VC-backed companies and some statistics about patents.

4.1. General statistics

Data analysed in this paragraph, regard information about firm's dimension, countries, industries and patent intensity.

4.1.1. Companies size

Companies in the dataset are classified by their dimension. Amadeus identifies four classes of firm size: small companies, medium sized companies, large companies and very large companies. In building these categories, Amadeus considers the dimensions of different variables: total assets, number of employees and operating revenues. In particular, it adopts the following rules:

Table 1. Classification parameters according to Amadeus database

Category	Total Assets	Employees	Operating Revenues	Notes
Very Large Companies	≥ 200 million EUR	≥ 1000	≥ 100 million EUR	Companies for which Operating Revenue, Total Assets and Employees are unknown but have a level of Capital over 5 million EUR are also included in the category
Large Companies	≥ 20 million EUR	≥ 150	≥ 10 million EUR	Companies for which Operating Revenue, Total Assets and Employees are unknown but have a level of Capital comprised between 500 thousand EUR and 5 million EUR are also included in the category
Medium sized Companies	≥ 2 million EUR	≥ 15	≥ 1 million EUR	Companies for which Operating Revenue, Total Assets and Employees are unknown but have a level of Capital comprised between 50 thousand EUR and 500 thousand EUR are also included in the category
Small Companies	< 2 million EUR	< 15	< 1 million EUR	

However, this classification does not correspond to the division adopted by the European Commission. In the European Union, the criteria for defining the size of a company differ from country to country but there are some guide lines defined by the European Commission which define the Small and Medium-sized Enterprise (SMEs) based on the parameters in table 2:

Table 2. Classification parameters according to the European Commission

Category	Total Assets	Employees
Medium sized Companies	≤ 43 million EUR	< 250
Small Companies	≤ 10 million EUR	< 50
Micro sized Companies	≤ 2 million EUR	< 10

Figures 19 and 20 show the proportions of companies included in each size group according to the Amadeus classification. The graphs distinguish between the VC-backed group and the non-VC-backed one, in order to see if there are significant differences.

The most represented category for both groups, is the medium size, which covers a substantial part of the whole data. This category corresponds mostly to the SMEs defined by the European Commission. For this type of companies, it is usually difficult to access traditional sources of financing like banks because of their size. According to a European Commission survey[4], out of the SMEs who applied for bank loans over the last six months of 2011, 11% were rejected, 4% were refused because of high costs and 17% received less that they applied for.

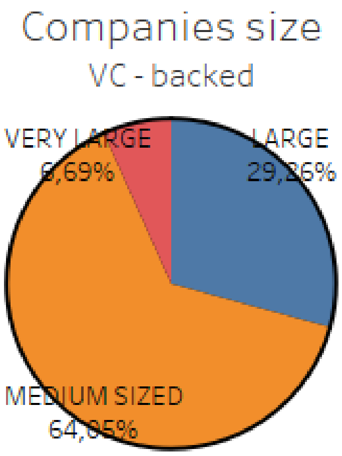


Figure 19. Size of VC-backed companies

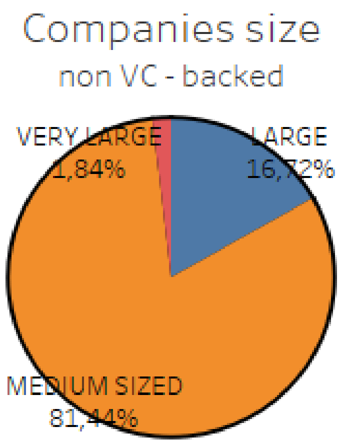


Figure 20. Size of non-VC-backed companies

[4] European Commission Press Release Database http://europa.eu/rapid/press-release_MEMO-11-879_en.htm?locale=en

This is to say that one out of three companies did not get the finance they had applied for. Therefore, venture capital is an important source of finance for SMEs to grow. These elements justify the great presence of medium sized companies in the dataset.
The VC-backed group have a greater percentage of large and very large companies compared to the non-VC-backed group, but the differences are not very remarkable.

4.1.2. Countries

Figure 21 shows the geographical distribution of the firms in the database. The three most represented countries in Europe are Great Britain, Germany and France, which all together cover 63.7% of the total data. As already described previously, these countries are the most developed venture capital markets in Europe, therefore, it is not surprising that they are the most frequent in the dataset.

Based on the methodology followed to build the dataset, described in chapter 3, the geographical distribution between the VC-backed and the non-VC-backed groups is symmetrical.

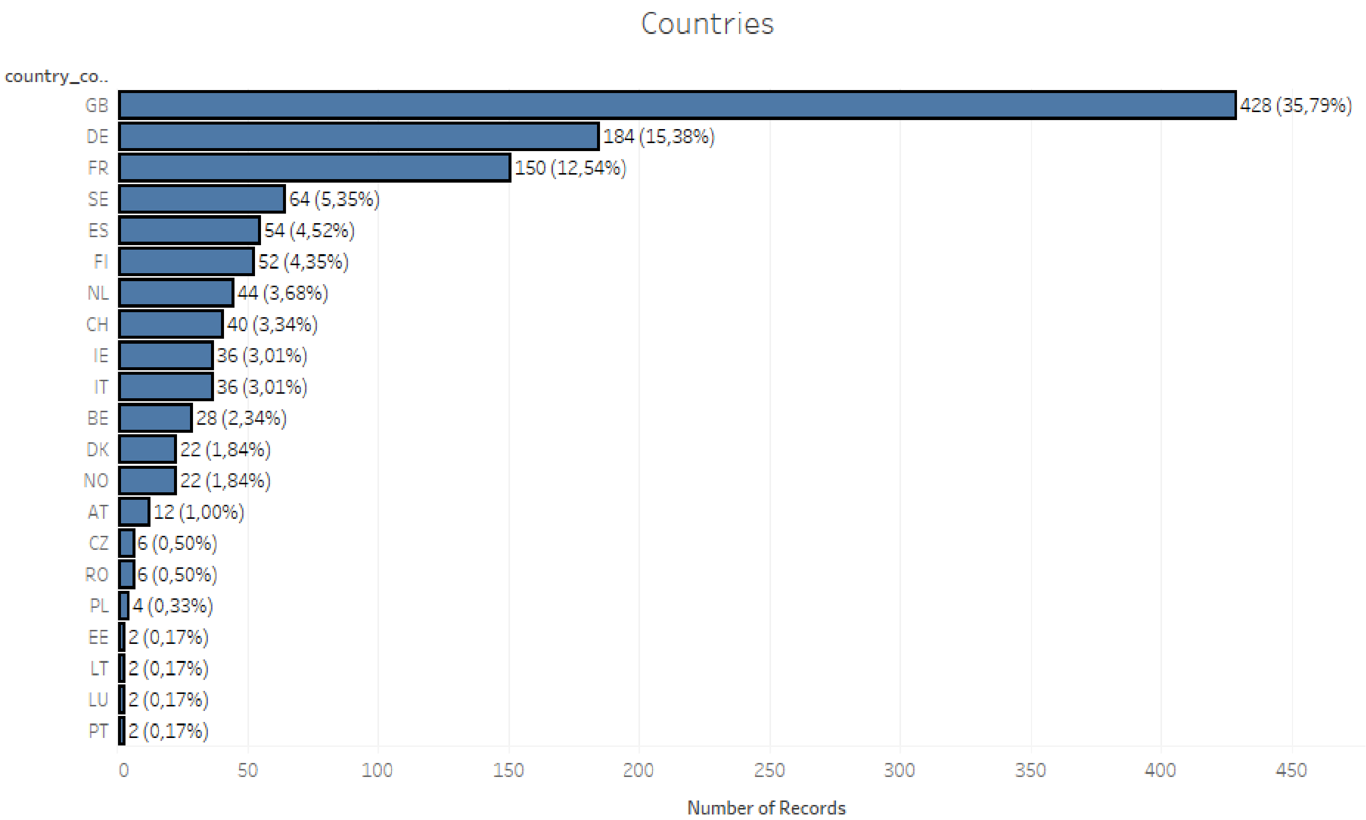


Figure 21. Geographic distribution. Data show the total number of firms for each country; in brackets are specified the percentage of firms in the specific country in relation to the total number of firms

4.1.3. *Industries*

Industries in Amadeus are identified by the NACE code which is the Statistical classification of economic activities in the European Community. Its name is the acronym of the French expression *Nomenclature statistique des Activités économiques dans la Communauté Européenne.* In particular, this is the NACE Rev. 2, which is a revised classification adopted at the end of 2006.

Industries are identified by a four-digit code and classified in 21 main sections.

Figure 22 shows that the most represented NACE category in the database is the information and communication section. It includes publishing activities, motion picture and sound recording activities, programming and broadcasting activities; telecommunications activities, computer programming, consultancy and related activities, and other information service activities.

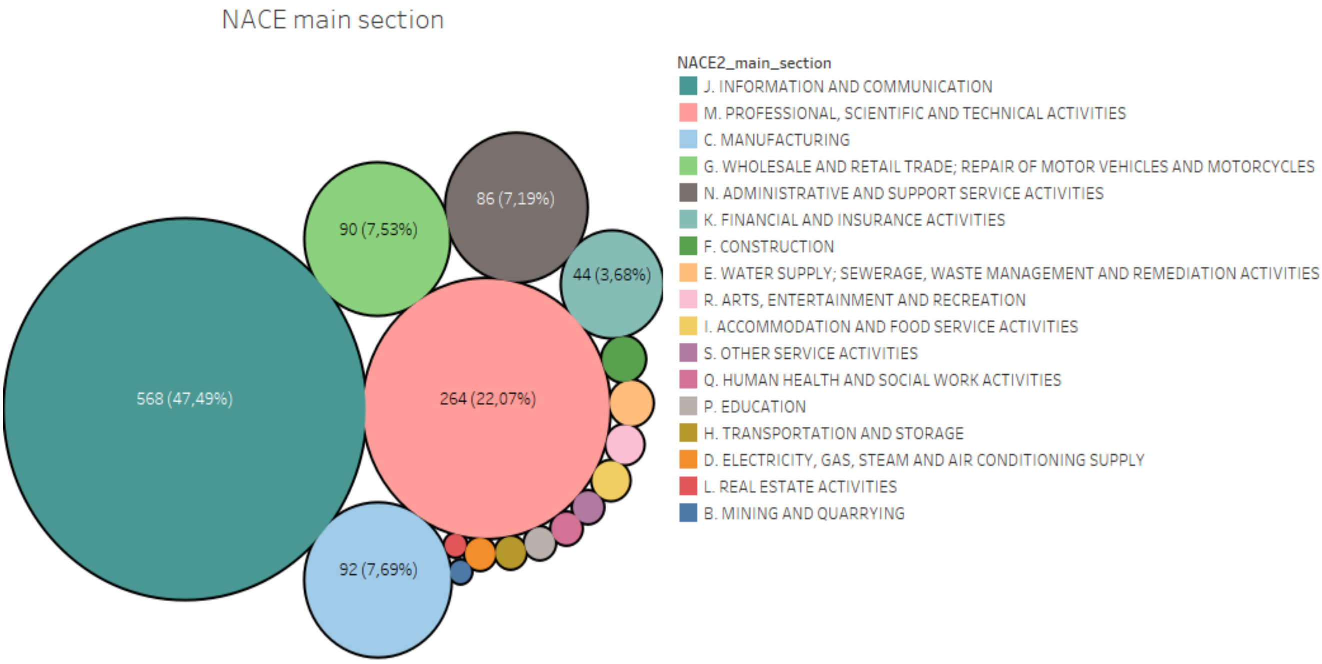


Figure 22. Industry distribution according to the NACE2 classification

The second main group includes professional, scientific and technical activities. It involves different practices such as legal and accounting activities, veterinary activities, architectural and engineering activities, advertising and market research, scientific research and development, activities of head offices and management consultancy activities. These works require a high degree of training, and even if they can be executed by every firms, usually companies tend to outsource them to specialists.

The following three groups have approximately the same representation in the database. The first one is the manufacturing sector, which includes numerous processes: from the manufacturing of food products to metals and machinery. Then, there is the wholesale and retail trade and repair of motor vehicles and motorcycles; it entails the wholesale and retail sale of any type of goods.

The last of these three categories is the administrative and support service section. These are activities that support general business operations, but which do not entail the transfer of specialised knowledge. For example, rental and leasing activities, employment activities, travel agency and reservation service activities, office administrative activities and services to buildings and landscape activities.

Like countries, also the industries have a symmetrical distribution between the VC-backed and the non-VC-backed groups.

4.1.4. Patent intensity

Patents are suitable to measure differences in inventive activity across different firms (Griliches, 1998).

In Figures 23 and 24 are presented the numbers of patents for each NACE category, divided between VC-backed companies and non-VC-backed companies. It seems to emerge substantial differences among the two groups and also among industries.

The first three most represented categories are the same for the VC-backed and the non-VC-backed groups.

In particular, the category with the greatest number of patents includes professional, scientific and technical activities, and it covers 54.21% of the total number of patents in the database. It is a very extended and heterogeneous group where the subcategory with most patents regards scientific research and development in two fields: natural science and engineering, and social sciences and the humanities. The first class includes, among the others, research and experimental development on biotechnology. These types of activities could be basic research, applied research or experimental development. The presence of the biotechnology field justifies the great patent intensity of this category because it is an industry where knowledge is highly codified, and patents offer a strong protection from imitation.

The second category in the rank is the manufacturing which covers 20.71% of the total number of patents. The most represented subcategory is the manufacture of computer, electronic and optical products. In particular, manufacture of electronic components and board, and of instruments and appliances for measuring, testing and navigation. Like the first category, the manufacturing is an industry where patents can be exploited successfully.

The third most important category includes 17.61% of the total number of patents and it is the information and communication division. The main subgroup includes computer programming, consultancy and related activities, which are writing, testing and supporting software; planning and designing computer systems to integrate the hardware part; and management and operation of data processing facilities. Even if the information and communication category is the most represented one in the whole database, it shows a lower patent intensity than other categories.

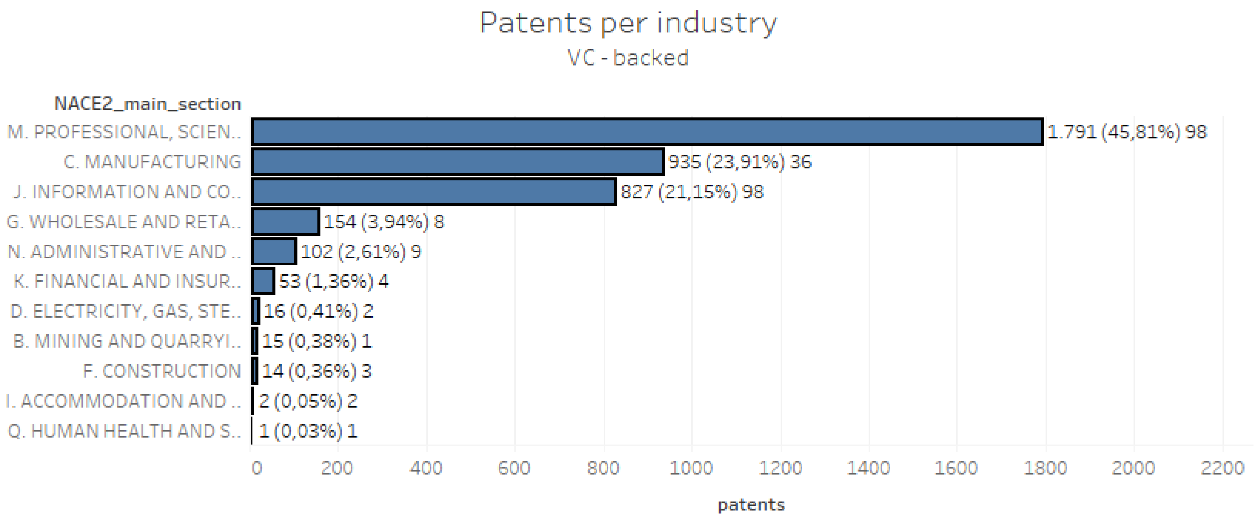


Figure 23. Patent intensity for each section. The first data shows the number of patents for the specific section. The value in brackets shows the percentage of patents for the specific section in relation to the total number of patents held by the VC-backed group. The last value shows the number of firms with at least one patent for the specific section

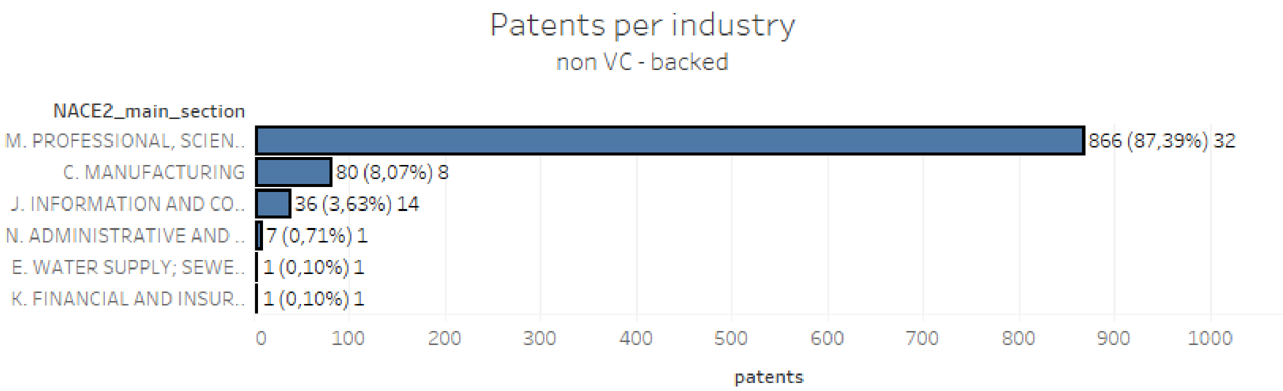


Figure 24. Patent intensity for each section. The first data shows the number of patents for the specific section. The value in brackets shows the percentage of patents for the specific section in relation to the total number of patents held by the non-VC-backed group. The last value shows the number of firms with at least one patent for the specific section

In the first two categories listed, patents are valuable and often necessary to sustain the firm’s business. Therefore, they show a high patent intensity. While, in the other categories firms tend to use alternative mechanism of protection, such as secrecy, because they have been proved to be more effective. This is why these groups have a low patent intensity.

The patent intensity has the same pattern between VC-backed and non-VC-backed firms, showing that the concentration of patents is, above all, a property of each industry. However, even if the ranking overall is the same, the total number of both patents and firms with at least one patent for the VC-backed group is significantly higher than their counterparts. The VC-backed group counts 3910 patents (which is the 80% of the total number), while the non-VC-backed group has just 991.

The number of firms with at least one patent is 262 for the VC-backed and 57 for the others. This means that among the VC-backed, 44% of them have at least one patent, and on average each firm owns 15 patents; for the non-VC-backed group only 9.5% of them have at least one patent and the average is 17 patents per firm.

A noteworthy element regards the information and communication division. This is the most represented category in the database, but it shows a low patent intensity; moreover, almost the total amount of the patents in this section are held by VC-backed companies (96% of the total number).

In Table 3 are displayed the details about the mean number of patents for each industry divided by VC-backed and non-VC-backed groups.

Table 3. Mean number of patents for each industry

	Mean number of patents	
	VC-backed	Non-VC-backed
M. Professional, scientific and technical activities	18.28	27
C. Manufacturing	26	10
J. Information and communication	8.44	2.57
N. Administrative and support activities	11.33	7
K. Financial and insurance activities	13.25	1
G. Wholesale and retail trade; repair of motor vehicles and motorcycles	19.25	-
E. Water supply; sewerage, waste management and remediation activities	-	1
D. Electricity, gas, steam and air conditioning supply	8	-
B. Mining and quarrying	15	-
F. Construction	4.67	-
I. **Accommodation and food service activities**	1	-
Q. Human health and social network activities	1	-
All industries	15	17

4.2. Financial analysis

In Table 4 are shown the mean values of the main financial measures for the VC-backed group and the non-VC-backed one. Values in brackets indicate the percentage of missing data for each measure.

In order to conduct a better analysis, the comparisons are based on one year for each variable; in particular the year selected is the one with the smaller number of missing data.

Table 4. Mean financial values for the VC-backed and non-VC-backed groups expressed in k€. Values in brackets show the percentage of missing data

	Mean value [% of missing data]		**Year**
	VC-backed	Non-VC-backed	
Capital	2000.57 [16.22%]	985.25 [11.04%]	2014
Total assets	26636.22 [18.73%]	9749.23 [13.88%]	2014
Long-Term Debt	3344.56 [36.45%]	3948.11 [39.63%]	2014
Number of employees	107.58 [37.46%]	41.74 [41.81%]	2015
Operating revenue (Turnover)	38305.12 [41.64%]	9637.52 [40.3%]	2014
EBITDA	-1552.41 [46.49%]	848.44 [52.84%]	2014
Sales	27763.98 [63.21%]	5330.69 [63.21%]	2014
R&D expenses	4016.5 [93.65%]	1557.35 [97.99%]	2013

The following graphs analyse in depth the distribution of these variables along the life of the two groups of firms. The analysis has been conducted only for those measure with a sufficient number of data; therefore, sales and research and development expenditures are not taken into consideration.

4.2.1. Total assets

The comparison is based on data in 2014 because this is the year with the least amount of missing data. Moreover, the choice of any year from 2014 onwards guarantees that all the firms in the VC-backed sample have received their financing rounds, therefore, the comparisons on performance are made after the VC involvement for all the companies.

Total assets are a useful measure because they can be used as a proxy for a company performance.

The following table shows the summary statistics for this variable; both the mean and the standard deviation differ considerably, they are higher for the VC-backed group. The mean value for the VC-backed companies is almost three time higher compared to the other group and the standard deviation is more than five times bigger. Moreover, minimum and maximum values suggest that the venture capitalist involvement seems to be decisive in the firm's performance.

Table 5. Summary statistics for total assets in year 2014. Data are in k€

-> dummy_VC = 0

Variable	Obs	Mean	Std. Dev.	Min	Max
total_assets	515	9749.227	27850.12	.0012856	313050.8

-> dummy_VC = 1

Variable	Obs	Mean	Std. Dev.	Min	Max
total_assets	486	26636.22	147535.9	90.00377	2740789

Figures 25 and 26 compare the average total assets for the two groups considering the age of the companies in order to underline the trend of this measure over time.

Substantial differences emerge between the two analysed groups. While in the early years the average total assets do not differ significantly, VC-backed companies from three years-old onward, have a considerably higher value than the other group; it is a steep increase that makes the average total assets for the financed group almost seven time higher than the correspondent value for the non-VC-backed firms.

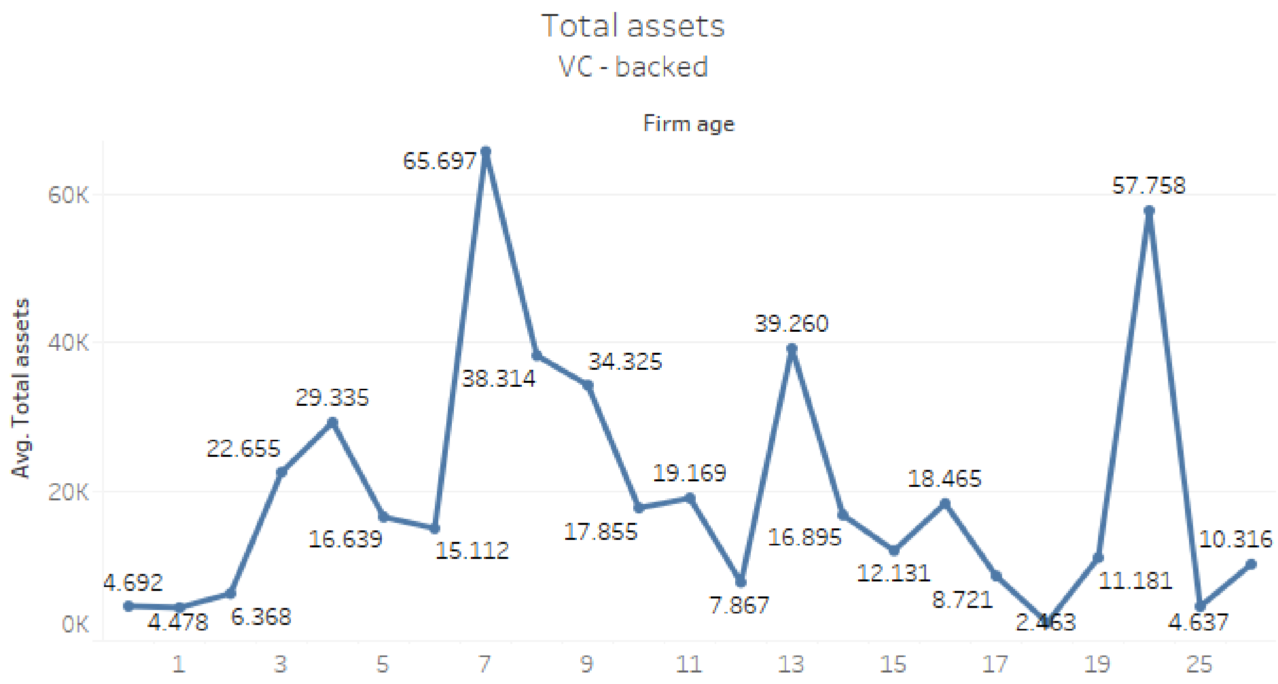


Figure 25. Average of total assets for the VC-backed sample in 2014. Data are in k€

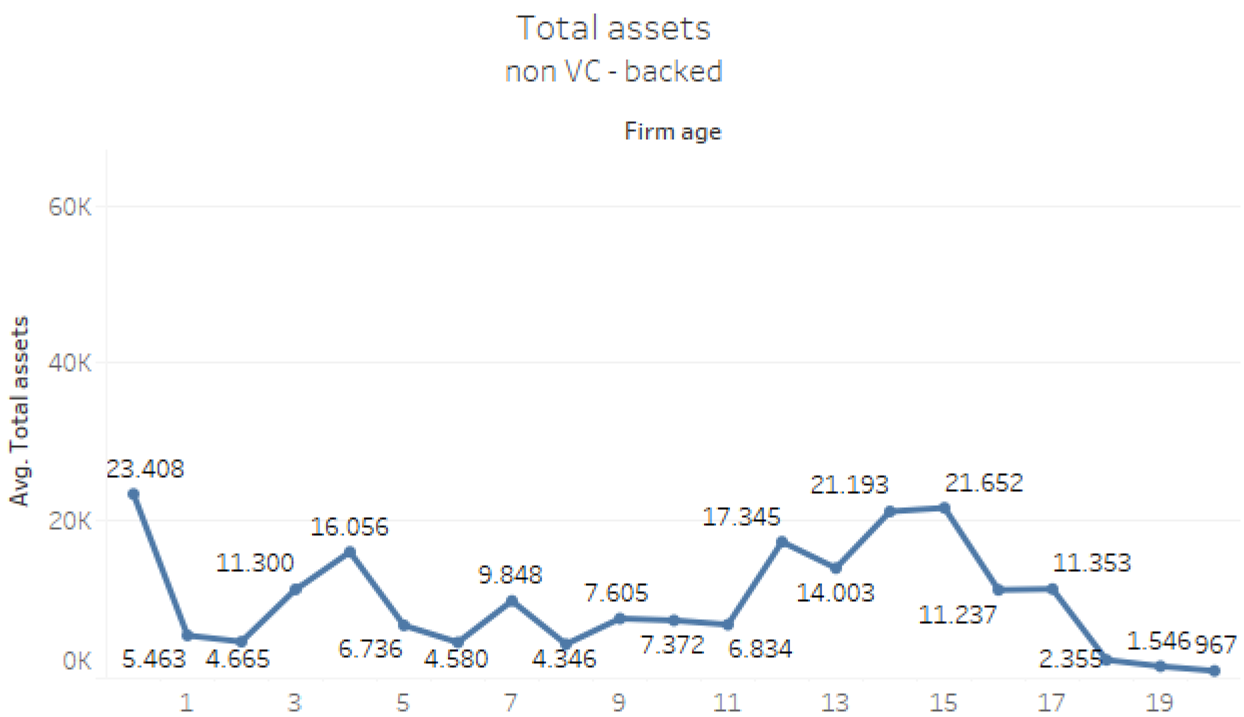


Figure 26. Average of total assets for the non-VC-backed sample in 2014. Data are in k€

The difference continues to be high also in the following years, even if the gap is less noticeable because the two values seem to converge in the long-run.

Total assets are also useful to represent the size of a company. From these graphs, it is evident that VC-backed companies are larger and develop much faster than non-VC-backed firms.

4.2.2. *Number of employees*

The selected year for this comparison is 2015 and like total assets, also the number of employees is a good measure of a firm's performance. It can track the corporate growth in terms of size.

Like before, values differ remarkably, and the VC-backed group shows on average a bigger size.

Table 6. Summary statistics for number of employees in year 2015. Data are in k€

-> dummy_VC = 0

Variable	Obs	Mean	Std. Dev.	Min	Max
number_o~ees	348	41.74138	70.64191	0	505

-> dummy_VC = 1

Variable	Obs	Mean	Std. Dev.	Min	Max
number_o~ees	374	107.5829	242.2392	0	2843

The trend of this measure in Figures 27 and 28 is similar to the previous one. Values are not very different until the fourth year of age but then they diverge considerably confirming the better performance for the VC-backed companies which develop more and faster.

Differently than before, the size difference of the two groups is still present even in the long-run.

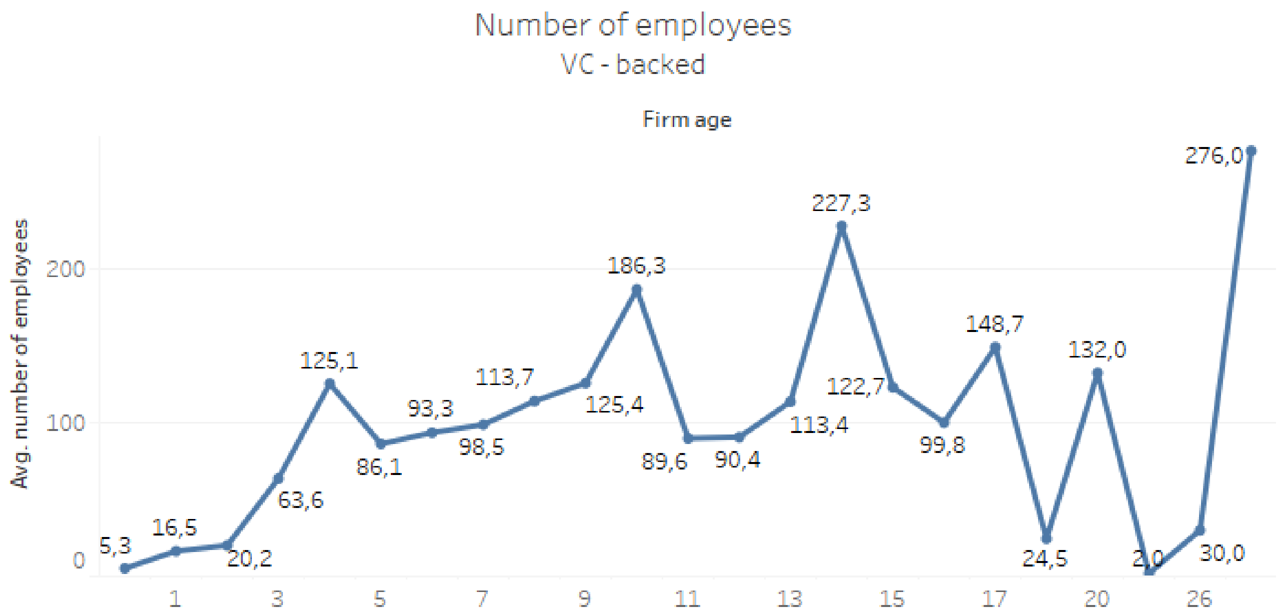


Figure 27. Average number of employees in the VC-backed sample in 2015. Data are in k€

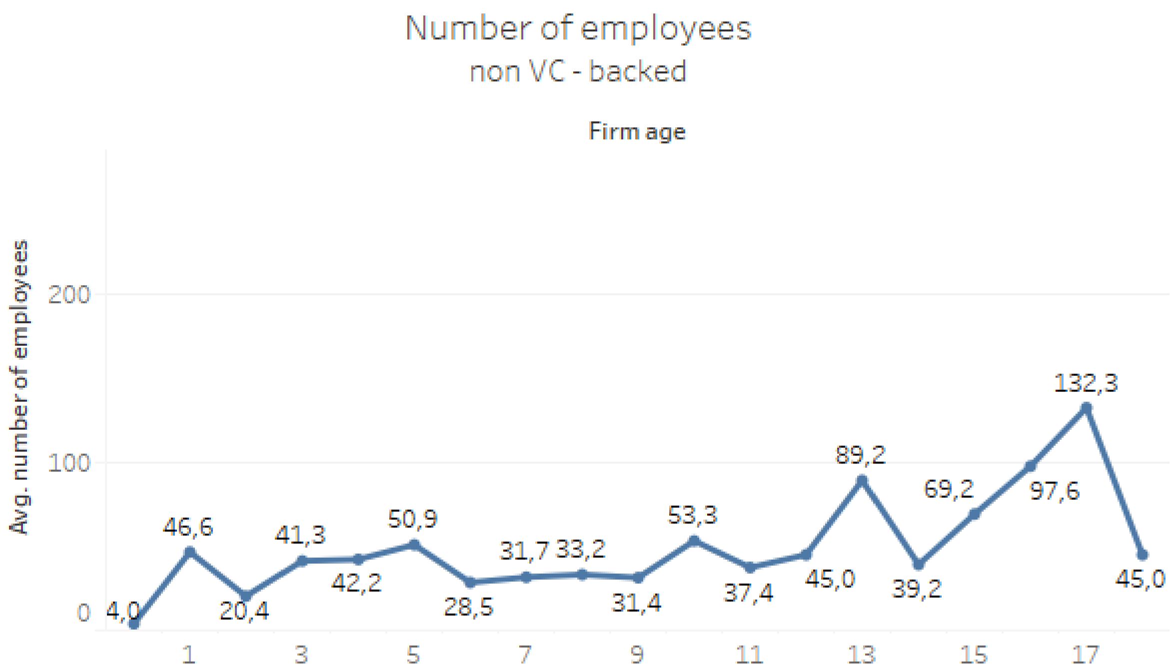


Figure 28. Average number of employees in the non-VC-backed sample in 2015. Data are in k€

4.2.3. Long-term debt

Unlike the two previous measures, the average long-term debt does not vary that much between the two samples.

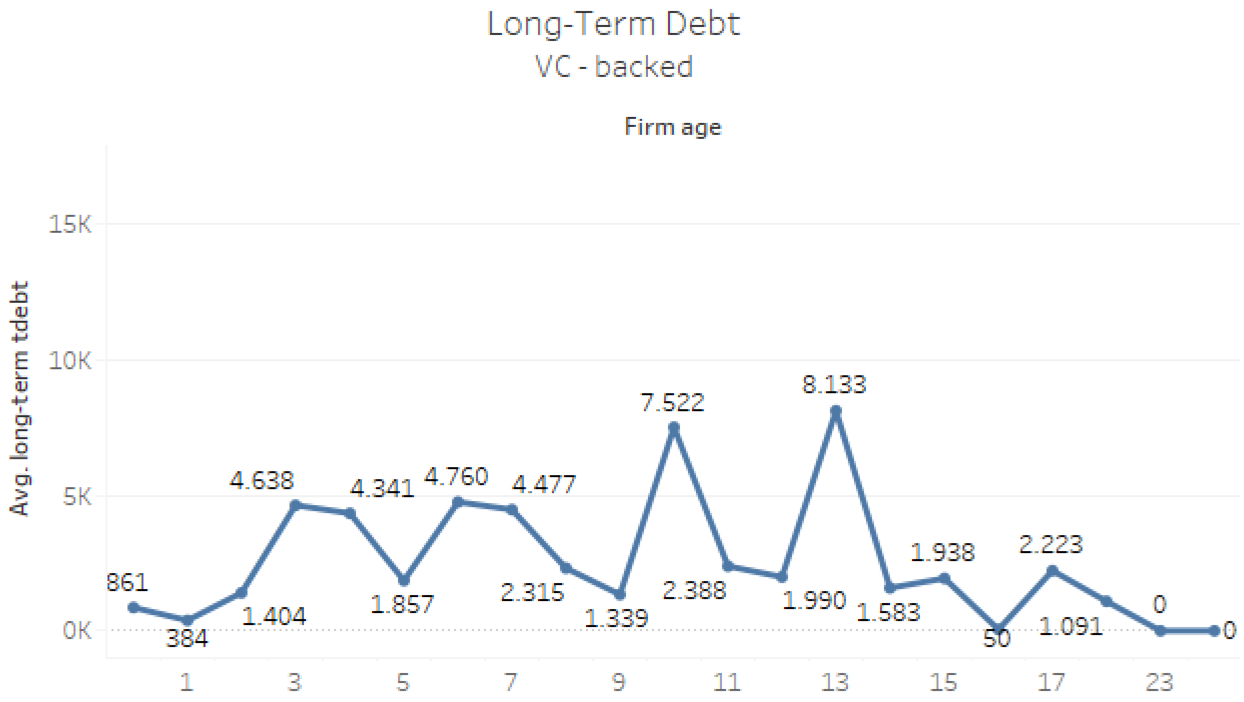


Figure 29. Average of Long-Term Debt for the VC-backed sample in 2014. Data are in k€

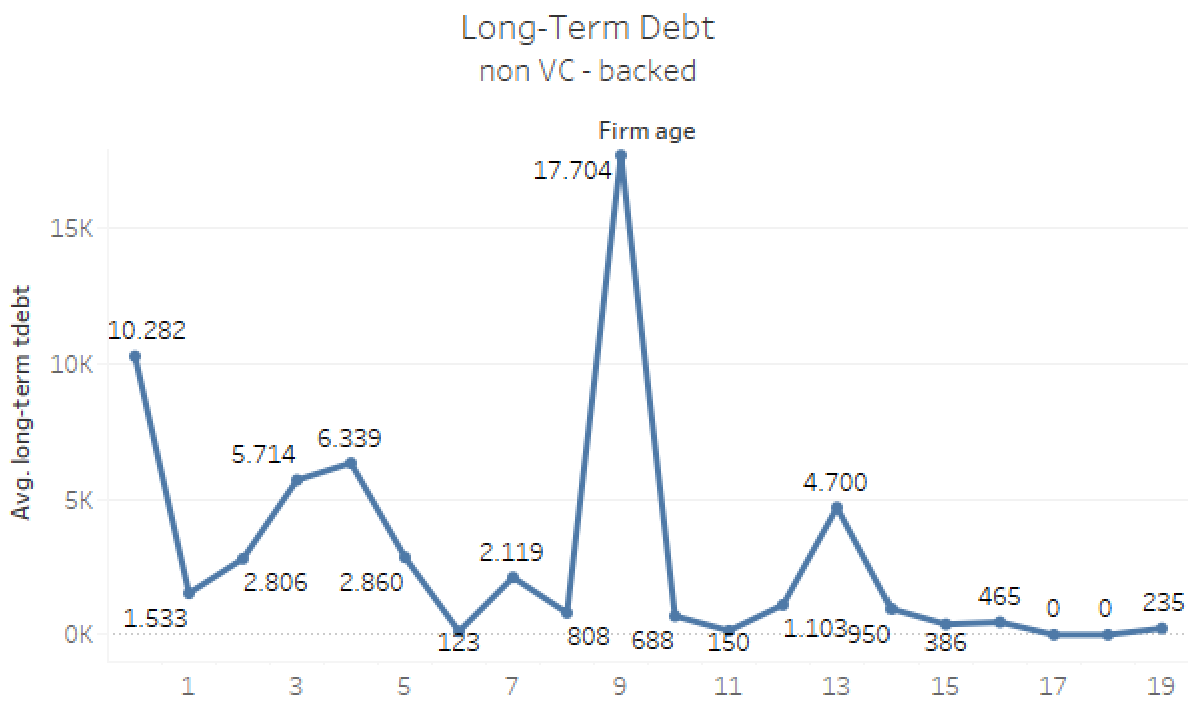


Figure 30. Average of Long-Term Debt for the non-VC-backed sample in 2014. Data are in k€

Overall, the value for the VC-backed companies is lower than the correspondent for the non-VC-backed companies, even if the difference is not considerable. The trend between the two groups is similar: the higher values are observed when the firms are between four and thirteen years old; after this age, the average long-term debt decreases for both groups.

4.2.4. Capital

This is the company's capital stock. Data in figures 31 and 32 are referred to year 2014 and are in k€.

The average amount of capital is remarkably higher in the early years of life for the VC-backed group. From the tenth year of age onward, the value for the financed companies starts to decrease while the correspondent measure for the non-VC-backed group begins to increase; the two values slowly converge over time.

Overall, young VC-backed have a greater amount of capital and their equity to total assets ratio is smaller than for the non-VC-backed firms. There are some inversions but in general it seems that VC-backed firms rely mainly on capital rather than on debt and the vice versa is true for the non-financed firms.

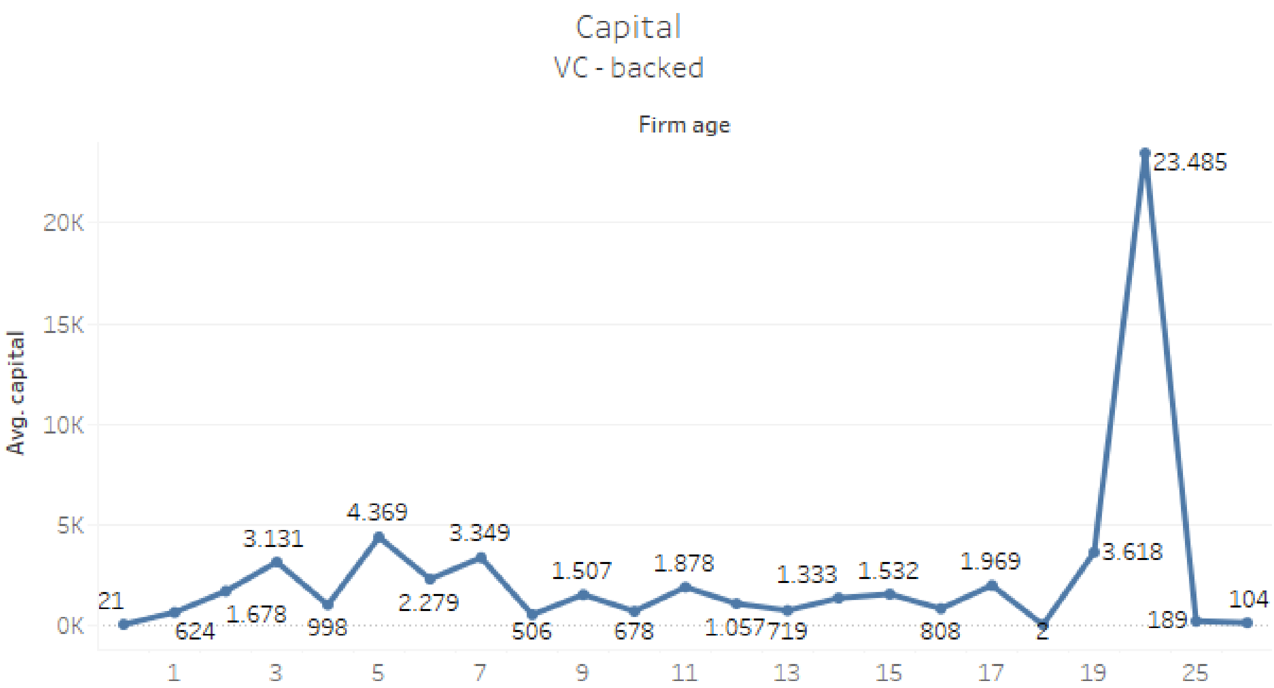


Figure 31. Average value of capital for the VC-backed sample in 2014. Data are in k€

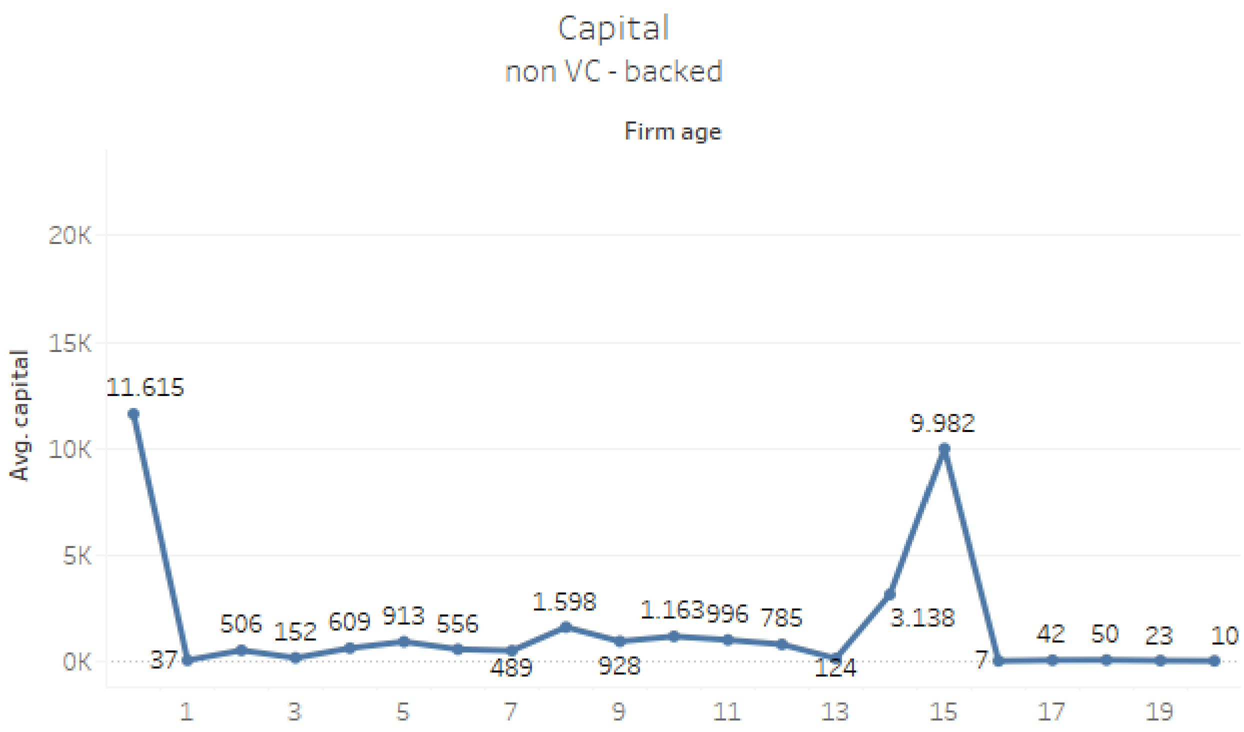


Figure 32. Average value of capital for the non-VC-backed sample in 2014. Data are in k€

4.2.5. Operating revenues - Turnover

Looking at the profit and loss account, figures 33 and 34 show the trend of the operating revenues for the two samples. This variable is a measure of the amount produced by the company in one year. Again, the summary statistics in table 7 show substantial differences between the two groups.

Table 7. Summary statistics for operating revenues in year 2014. Data are in k€

-> dummy_VC = 0

Variable	Obs	Mean	Std. Dev.	Min	Max
turnover	357	9637.524	20469.69	0	239333.4

-> dummy_VC = 1

Variable	Obs	Mean	Std. Dev.	Min	Max
turnover	349	38305.11	264035.7	0	4477017

The VC-backed companies have a turnover which is almost four times higher compared to the other group and its standard deviation is almost thirteen times bigger.

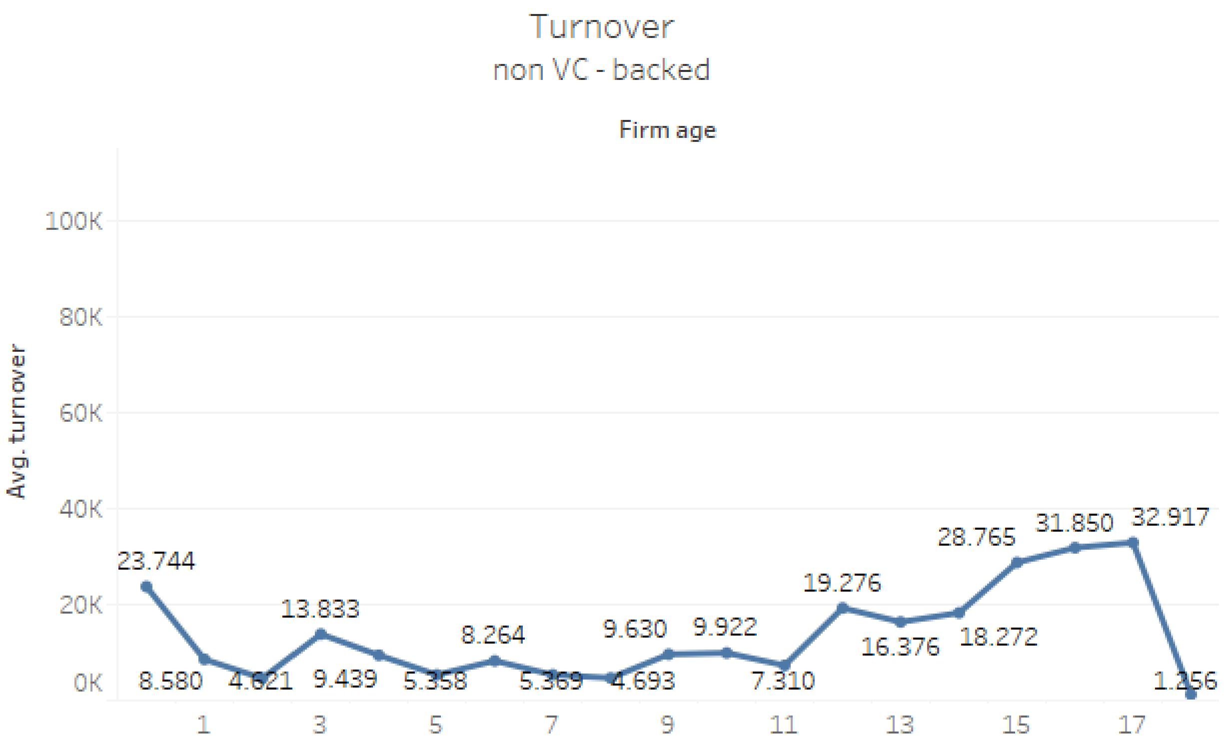


Figure 33. Average value of operating revenues for the VC-backed sample in 2104 divided by age. Data are in k€

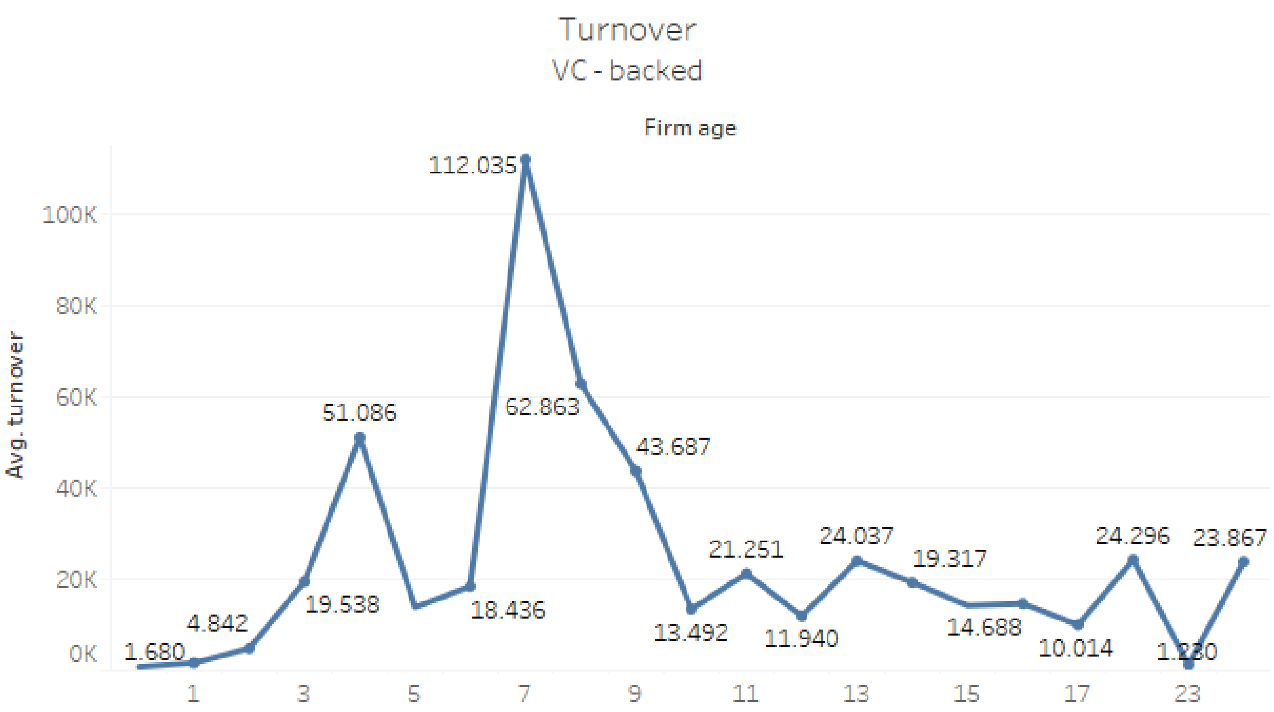


Figure 34. Average value of operating revenues for the non-VC-backed sample in 2104 divided by age. Data are in k€

The tendency is similar to that seen for total assets, but the gaps are much more marked. Until the third year of life, the VC-backed group exhibits lower performance compared to the non-VC-backed sample; however, from the following year onwards, its turnover increases dramatically, becoming even five times as much as its counterpart in the fourth year. The continuous and pronounced increase also in the next years, confirms the superior performance and the faster growth of the VC-backed sample compared to the non-VC-backed group.

4.2.6. EBITDA

The Earnings Before Interests, Taxes, Depreciation and Amortization is a good proxy for a company's current operating profitability. It is based on the operational management of the firm.

Table 8. Summary statistics for EBITDA in year 2014. Data are in k€

-> dummy_VC = 0

Variable	Obs	Mean	Std. Dev.	Min	Max
EBITDA	282	848.4355	4211.091	-21580.62	23621.75

-> dummy_VC = 1

Variable	Obs	Mean	Std. Dev.	Min	Max
EBITDA	320	-1552.412	32195.78	-144275.9	514945.4

Figures 35 and 36 show the trend for this measure without grouping the age segments. The two groups have almost opposite tendencies.

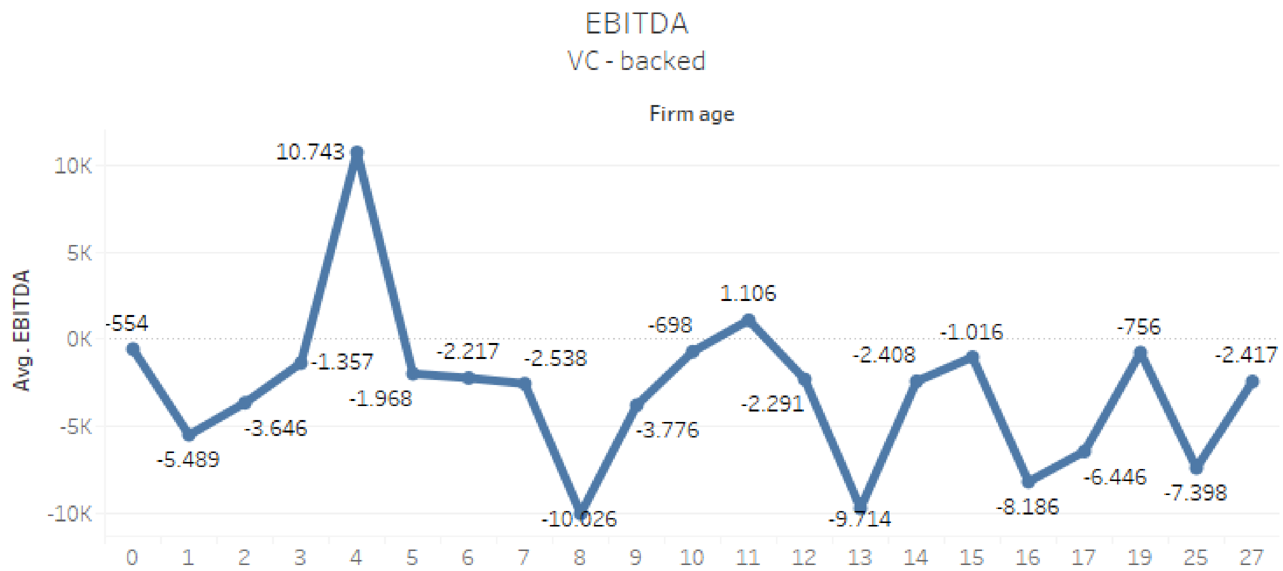


Figure 35. Trend of the average EBITDA for the VC-backed sample in 2014 divided by age. Data are in k€

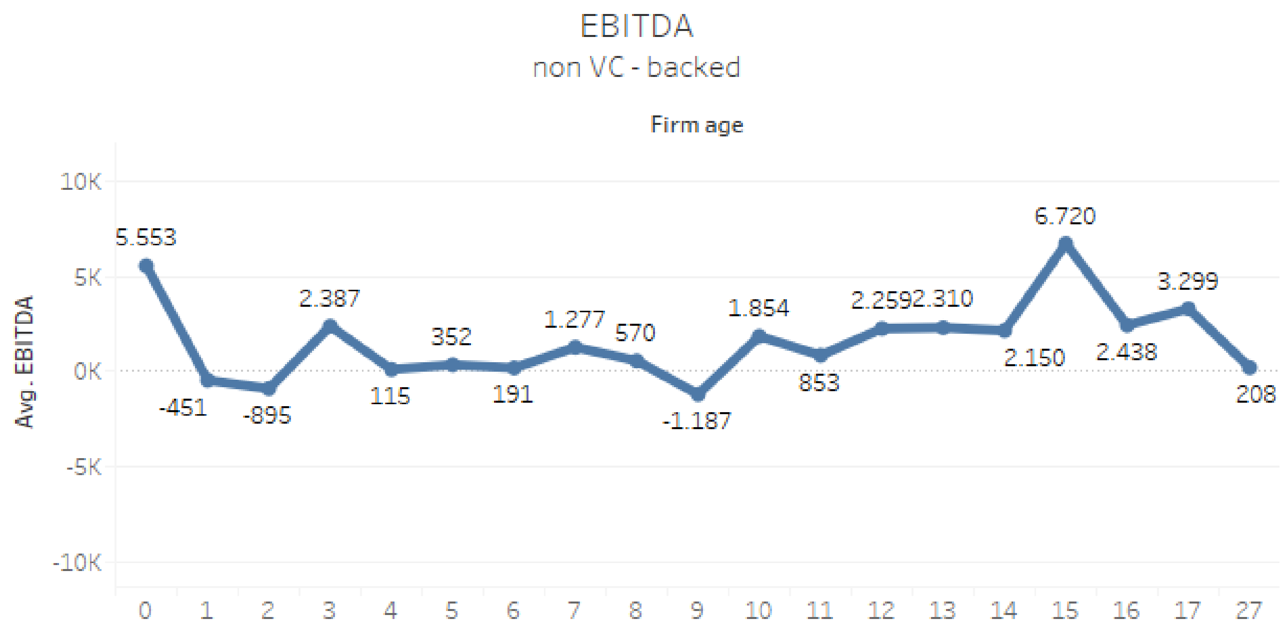


Figure 36. Trend of the average EBITDA for the non-VC-backed sample in 2014 divided by age. Data are in k€

In general, for very young companies some years are required before they can become profitable. The EBITDA then, is usually highly negative because the business generates more costs than revenues. This trend is confirmed in figures 35 and 36 where the average EBITDA is negative for both samples in the first early years. Up to three years after the initial investment, most companies have still a negative EBITDA.

For the non-VC-baked companies then, the trend is reversed starting from the tenth year onwards. Their performance improves considerably, and they start to become profitable.

4.2.7. Pre- and post-financing comparison

In order to verify if the VC involvement impacts the performance of a firm, a further analysis has been conducted. For the VC-backed group, all the previous financial measures have been considered before and after the financing date. Results are reported in tables 9 and 10.

Table 9. Performance of the VC-backed group before the financing date

Variable	Obs	Mean	Std. Dev.
Age	1890	2.68836	3.022541
total_assets	787	4868.819	38776.87
number_o~ees	321	28.91277	94.7073
long_term_~t	565	782.9973	2806.997
capital	829	1205.872	10450.32
EBITDA	355	-580.6177	1966.726
turnover	390	7908.875	44143.99

Table 10. Performance of the VC-backed group after the financing date

Variable	Obs	Mean	Std. Dev.
Age	3841	6.571205	4.059864
total_assets	2609	25122.08	171297.1
number_o~ees	1896	92.43407	243.8515
long_term_~t	2007	3862.39	25230.55
capital	2707	1701.654	9909.592
EBITDA	1764	-1455.929	35899.98
turnover	1914	29505.14	213117.4

Data show a considerable improvement in all the financial variables considered, apart from the EBITDA; this growth could be determined by the venture capital presence, but it could also be due to the development of the companies themselves. In fact, their average age is remarkably different before and after the financing, therefore, the improvement in the performance could be a consequence of the expansion and evolution of firms over time.
Trying to distinguish between these two effects, the same financial performances have been analysed for the non-VC-backed group considering the same age range. Tables 11 and 12

report these measures for non-financed companies with an average age of about 2.5 and 6.5 years and they evidence that an improvement in performance is still present. Nevertheless, the increase is much less pronounced than for the VC-backed group. Non-financed firms have an increase of average total assets of about 30% while the same growth for the VC-backed companies is more than 400%; similarly, the increase in turnover is about 22% and 273% for the non-VC and VC-backed respectively.

Table 11. Performance of the non-VC-backed group when they are about 2.5 years old

Variable	Obs	Mean	Std. Dev.
Age	1152	2.498264	.5002141
total_assets	776	7177.746	25561.67
number_o~ees	406	35.2734	79.40866
long_term_~t	574	2836.274	11344.25
capital	795	629.9867	3372.76
EBITDA	379	739.083	3528.393
turnover	494	7697.315	22579.46

Table 12. Performance of the non-VC-backed group when they are about 6.5 years old

Variable	Obs	Mean	Std. Dev.
Age	866	6.453811	.4981497
total_assets	632	9352.702	33510.85
number_o~ees	383	40.65274	85.41045
long_term_~t	454	2913.316	18905.45
capital	663	811.8849	4023.222
EBITDA	350	652.655	4653.178
turnover	435	9405.458	38884.94

This comparison suggests that the VC presence could actually improve the company performance, even if the extent of this involvement is not easily quantifiable.

4.3. Financing rounds

As already said in chapter 1, there are several stages in the financing cycle. They are different in terms of risk, return, amount of money, frequency and firm's age. Needs of the companies financed are different based on the stage they are, and the venture capitalist's involvement is more or less intense depending on the phase of the firm lifecycle.

The following tables analyse some of these characteristics of the founding rounds collected in our database.

4.3.1. Frequency, age and amount

In Table 13 are shown the frequency of each financing round and the correspondent number of firms financed.

Table 13. Frequency of financing for each round and number of firms financed in each stage

	Seed	A Round	B Round	C Round	D Round	E Round
Number of financing	183	452	255	144	51	58
%	16.01%	39.55%	22.31%	12.6%	4.46%	5.07%
Number of firms	154	408	239	132	50	44

The seed round is characterized by the highest level of uncertainty and thus is the riskiest one. For this reason, the correspondent number of financing rounds is lower than round A and B which, instead, take place when companies are already starting their operations. The increase in the number of firms financed between the seed stage and the A round is 165%, which is a very significant growth. The frequency is maximum for round A and then it decreases rapidly in the following stages.

As already explained, the frequency of the financing tends to decrease while the amount of each financing stage increases because companies become better established and less and less risky. Table 14 shows the average age of firms in each phase: in the seed stage companies are very young, their average age is about 2.5 year.

Moreover, there is a trade-off between the higher risk which characterizes the early stages and their higher return which attracts venture capitalist interest.

Table 14. Summary statistics for the age at deal of companies in each stage

	Mean age at deal [years]	Dev.st. age at deal [years]	Minimum value [years]	Maximum value [years]
Seed	2.5	2.7	0	14
A Round	3.9	2.9	0	15
B Round	4.8	2.9	0	14
C Round	6.1	2.7	1	14
D Round	7.2	3	1	14
E Round	8.4	2.8	1	14

The whole trend becomes clearer looking at Table 15 where the average amount of each stage is specified.

Table 15. Average amount and relative standard deviation for each stage. Data are in k€

	Average amount [k€]	Std. Dev. [k€]	Minimum value [k€]	Maximum value [k€]
Seed	1.732	1.847	0.01	14.5
A Round	7.477	9.612	0.02	93.86
B Round	13.444	16.211	0.18	165
C Round	21.106	23.004	0.74	155
D Round	30.271	28.353	1.33	112
E Round	34.548	62.800	0.14	374.2

Companies in their early stages require less money than those in later stages and the average amount of each round increases. As companies grow the uncertainty about their business decreases and the risk associated with the investment diminishes as well. Therefore, the amount financed can increase to sustain the growing business.

The total number of VC round is 1143 and on average, each company received approximately 1.9 rounds.

Companies in the dataset received at least one round and maximum six rounds. Almost half of them (49.4%) received just one round, while 92.4% of them received three or less rounds.

4.3.2. Financing and patents

Not all firms had patents before their first financing round. In the sample, 87% of the companies held at least one patent at the moment they received the financing, while the remaining 13% obtained the first patent after the VC involvement. In terms of total number of patents, 41.08% of them were already held by companies before the first financing round, the remaining 58.92% has been obtained later.

The size of the average portfolio of a VC-backed company with at least one patent is 13.03 families with a standard deviation of 22.52.

Chapter 5

5. Methodology and results

In this chapter two different econometric analysis has been developed.
The first model, described in paragraph 5.1, is built to investigate the existence of a relationship between the presence of patents in a firm's portfolio and its probability of being financed; paragraph 5.1.1 reports the results of the analysis.
The second study focuses on some specific characteristics of patents to verify which ones, among them, contribute the most to the signalling effect. This model, reported in paragraph 5.2, has been developed based on the methodology used by Caviggioli, Colombelli, De Marco, Paolucci (2017); results are shown in paragraph 5.2.1.
Finally, section 5.3 illustrates the conclusion of the study and paragraph 5.4 highlights the limitations of the analysis.

5.1. The signalling effect model

In order to analyse the relationship between patents and the presence of a VC funding, a probit regression framework has been used. The baseline equation is the following:

$$dummy\_VC_{i,t} = \beta X_{i,t} + \gamma C_{i,t} + \varepsilon_{i,t} \qquad (1)$$

The dependent variable ($dummy\_VC_{i,t}$) is boolean and it assumes value 1 if company i has received a financing at time t, and 0 otherwise.
Among the independent variables $X_{i,t}$ includes the explanatory variable and $C_{i,t}$ represents the vector with the control variables.

The model is composed of two steps: in the first one only control variables are evaluated, while in the second one a patent-related measure has been included.
The set of controls analysed is described in table 16. Time, industry and nation dummies have all been used as controls in the analysis, as well as the age of the companies; to evaluate which economic variables should be included a correlation analysis has been conducted. The most significant results are the following:

- Total assets and the number of employees are positively and significantly correlated; the coefficient is equal to 0.4861, therefore both can be used as proxies for the company's size;
- Total assets and the long-term debt are positively and significantly correlated, and the coefficient is equal to 0.5291;
- EBITDA, EBIT and turnover are obviously highly correlated, they all are measures of the company's profitability.

Given these correlations, some measures have been excluded. Between the number of employees and total assets, only the second measure has been included in the analysis because it counts more observations and also it turned out to be more significant; the turnover is not significant, therefore it has been excluded from the study; both EBIT and EBITDA are significant but only the second one has been considered because of the smaller p-value.
Therefore, the first model includes total assets and long-term debt as size measures and EBITDA to monitor the performance; all of them are significant.
The potential patent measures considered in the second step are $flow\_patents_{i,t}$, $patents_i$, and $stock\_patents_{\ i,t}$; they are alternative variables but only the last one has been included because of its higher significance.

Table 16. Variables description

Variable name	Description	Used
$\boldsymbol{year\_*}$	It consists of sixteen variables, one for each available year, from 2001 to 2016	Yes
$\boldsymbol{industry\_*}$	It consists of seventeen variables, one for each available industry	Yes
$\boldsymbol{nation\_*}$	It consists of twenty-four variables, one for each available country	Yes
$\boldsymbol{age_{i,t}}$	Age of company i at time t	Yes
$\boldsymbol{total\_assets_{i,t}}$	Total assets of company i at time t	Yes
$\boldsymbol{long\_term\_debt_{i,t}}$	Long term debt of company i at time t	Yes
$\boldsymbol{EBITDA_{i,t}}$	EBITDA of company i at time t	Yes
$\boldsymbol{stock\_patents_{i,t}}$	Cumulated number of patents for a single firm i up to a specific year t	Yes

Equation 1 then, assumes the following form:

$$dummy\_VC_{i,t} = b \cdot stock\_patents_{i,t} + c_1 \cdot total\_assets_{i,t} + c_2 \cdot long\_term\_debt_{i,t} + c_3 \cdot EBITDA_{i,t} + c_4 \cdot year_{i,t} + c_5 \cdot industry_{i,t} + c_6 \cdot nation_{i,t} + c_7 \cdot size_{i,t} + \varepsilon_{i,t}$$

After the probit regression, a panel framework has been used to take in consideration that different observations in the entire sample are referred to the same company in different years. This type of analysis in STATA is performed with the xtprobit regression. Variables and equations used remain the same as well as the model's structure.

5.1.1. Results

Results of the probit regression are reported in table A1 in the Appendix. Column 1 includes only control variables while column 2 presents the full model; coefficients specify the marginal effect for each variable.

The analysis confirms the existence of the signalling effect of patents; variable *stock_patents* is highly significant, and its coefficient is positive, showing that the higher the number of patents a firm has in its portfolio at time t, the higher its probability in being financed in that year. Controlling for size, age, country, industry and performance of a company, the number of patents positively influences the VC funding, in particular, looking at the marginal effect, one patent increases the probability of obtaining a round by 0.9%.

Table 17. Xtprobit regression results. The dependent variable is $dummy\_VC_{i,t}$. Coefficients express the marginal effects

VARIABLES	(1) Model	(2) Model
total_assets	2.31e-05***	1.22e-05*
	(5.89e-06)	(7.33e-06)
long_term_debt	-1.51e-05	-1.32e-05
	(1.75e-05)	(1.09e-05)
EBITDA	-3.44e-05***	-2.81e-05**
	(9.72e-06)	(1.19e-05)
stock_patents		0.334***
		(0.0383)
Time, Industry, Country dummies	Y	Y
Age	0.0610*	0.0340
	(0.0355)	(0.0335)
Observations	3,778	3,778
Number of ID	787	787
chi2	38.86	157.1
loglike	-549.5	-548.9

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

This result is confirmed also looking at the xtprobit regression in table 17. Not only the number of patents remains highly significant, but the coefficient is even bigger than before: if a company owns one addition patent in its portfolio, the probability of being financed will increase by 33%. In the panel model what changes is the significance of the control variables: the age is no longer significant in the full model, nor is the long-term debt; while total assets and EBITDA remain positively correlated and significant.

These results are a confirmation of the signalling effect of patents; the existence of the phenomena has already been demonstrated by other authors in the academic literature and this study seems to reinforce the concept: patents are considered as a quality measure about the innovative behaviour of a company by VC investors.

5.2. The characteristics of a patent portfolio

The second econometric analysis has the purpose to investigate the relationship between the characteristics of a company's patent portfolio and the amount of VC financing received by that firm. This work and the methodology used are based on the study by Caviggioli, Colombelli, De Marco, Paolucci (2017). To perform this analysis, only the VC-backed sub-sample of the initial dataset has been considered.

The role of patents and their application in measuring the innovative activity of a firm has already been anticipated in chapter 3 and confirmed in the previous paragraph; in particular, the number of patent applications has largely been used in the literature to estimate a firm's innovative behaviour because this is a relatively simple variable to obtain (Engel and Keilbach, 2007; Dushnitsky et al., 2005).

Nevertheless, this measure presents some limitations and to overcome them, authors tried to include other patent related measures like the number of citations or the geographical extension of patents, in order to improve the knowledge about which characteristics have a broader impact on patents value. For example, Dushnitsky et al. (2005), trying to capture the technological opportunities available per industry, included a new measure in their study: the average number of citation-weighted patents applied to by firms in a given year in a given industry.

In this study, several patent related variables are considered, which are described below and whose summary statistics are shown in table 18.

An OLS regression has been used and the baseline equation is the following:

$$amount\_VC_{i,t} = \alpha + \beta \cdot X_{i,t} + \gamma \cdot C_{i,t} + \varepsilon_{i,t} \qquad (2)$$

Like before, $X_{i,t}$ represent the explanatory variables while $C_{i,t}$ is the set of controls.

Table 18. Summary statistics of the analysed variables

	Observations	Mean	Std. Dev.	Min	Max
amount_VC$_{i,t}$	1457	10.13071	19.75288	.01	374.2
fam_dum$_{i,t}$	1457	.3877831	.487412	0	1
fam_cum$_{i,t}$	1457	.6680716	1.034571	0	4.905275
assignees_avg$_{i,t}$	565	1.145869	.3906459	1	4
inventors_avg$_{i,t}$	565	2.471913	1.249045	1	8.1
IPC_scope_avg$_{i,t}$	565	1.879672	.7530992	1	4.66666
countries_avg$_{i,t}$	565	3.356314	1.910675	1	14
bwd_cit_avg$_{i,t}$	565	12.34821	14.47622	1	246
science_avg$_{i,t}$	565	1.556744	1.759103	0	14.8
wei_fwd_avg$_{i,t}$	565	.0064421	.0076449	.0006662	.11
age_at_deal$_{i,t}$	1457	4.221002	3.132692	0	15

The dependent variable is the $amount\_VC_{i,t}$, which indicates the amount of each financing round for company i at time t, expressed in millions of $US.

As far as the independent variables are concerned, in table 19 is depicted their correlation matrix.

One of these measure is the number of forward patent citations. It is a proxy for the rate of innovation (Dushnitsky et al., 2005; Trajtenberg, 1990) and it is positively related to the economic and technological importance of the underlying technology (Haeussler et al., 2014; Harhoff et al., 2002). Hoenen et al. (2014) also used forward patent citations as a proxy of patent quality because the more a patent is cited the higher is its significance and applicability. In the following analysis the variable $wei\_fwd\_avg_{i,t}$ has been used, which identifies the average number of received citations associated to each patent family in the portfolio of a company; it is a proxy of the economic value characterizing the patent.

The number of forward citations is also used as a measure for patent generality: if a patent is cited by a large number of subsequent studies which belong to a wide range of fields, then it has a widespread impact and its generality increases (Hall, Jaffe and Trajtenberg, 2001).

Similarly, the number of backward citations represents the originality of a patent. If a patent cites previous patents belonging to a small set of fields, its originality is low, while if the range of fields is wider, the originality will be higher as well (Hall, Jaffe and Trajtenberg, 2001).

In the study, the variable $bwd\_cit\_avg_{i,t}$ identifies the average number of backward patent citations associated to each patent family in the portfolio of a company i at time t.

Both the number of forward and backward citations vary over time and also across industries.

Analogously, the number of non-patent citations is a proxy for the originality and the complexity of a patent. This measure is represented by the variable $science\_avg_{i,t}$, the average number of non-patent citations associated to each patent family in the portfolio of a company i at time t; the positive and significant correlation between $science\_avg_{i,t}$ and $bwd\_cit\_avg_{i,t}$ underlies their similar meaning of originality.

Variable $IPC\_scope\_avg_{i,t}$ indicates the average number of different IPC subclasses associated to each patent family in the portfolio of a company i at time t. The International Patent Classification (IPC) is a scheme that classifies patents hierarchically according to the different areas of technology to which they pertain. It is a four-digit code that represents the technological scope of a patent. The relationship between patent scope and the patents value seems to be positive: Lerner (1994) found that it significantly affects the firm’s value.

As already said in chapter 1, patents are costly to obtain. The filing cost of a patent application is the first and most expending part of obtaining patent protection and after this phase, many countries require firms to pay periodic renewal or maintenance fees to keep patents in force (Putnam, 1997; Harhoff et al., 1999). Therefore, the longer a patent is renewed, the higher is its value.

Moreover, the acceptance process of patents, differs across countries; then, the number of different jurisdictions in which a patent protection is accepted is an estimate of the global value of that patent (Putnam, 1997). This is why the variable $countries\_avg_{i,t}$ has been included in the analysis. It represents the average number of jurisdictions associated to each patent family in the portfolio of a company i at time t. Both $countries\_avg_{i,t}$ and $IPC\_scope\_avg_{i,t}$ have an impact on the firm's value, and they also are positively and significantly correlated; additionally, both are positively correlated with $wei\_fwd\_avg_{i,t}$.

Harhoff et al. (2002) found that also the family size helps to approximate the patent right's value; the variable $fam\_cum_{i,t}$ is the logarithm of the size of the patent portfolio of a company i at time t; this variable is positively correlated with the control variable $age\_at\_deal_{i,t}$.

Other two measures are used to proxy the patent value: the number of assignee and the number of inventors. Those are two distinct figures; the inventor is the one who conceived the invention and has the intellectual domination over it. It has to be a person who directly contributed to the conception of the invention and not someone who were just involved, for example, like a supervisor.

On the other hand, the assignee is the entity that has the property right to the patent. This figure can change over time, it could happen that there are different assignees in different time frames, while the inventor/s remain always the same.

The number of inventors of a patent, seems to be positively correlated with the patent value (van Zeebroeck and van Pottelsberghe, 2001). This variable, named $inventors\_avg_{i,t}$, indicates the research efforts made to design the invention and van Zeebroeck and van Pottelsberghe use it as a measure for the technical complexity of patents.

The average number of assignees associated to each patent family in the portfolio of a company i at time t is identified by the variable $assignees\_avg_{i,t}$.

Finally, another considered variable is $fam\_dum_{i,t}$ which is a dummy equal to 1 if company i has at least one patent at time t, and 0 otherwise.

Among the control variables the same time, industry and nation dummies used in the first regression have been considered; additionally, variable $age\_at\_deal_{i,t}$ has been added, which measures the age of a firm i when it receives a financing round in time t. Another control is represented by the round dummies which take into consideration how many rounds each firm has received at time t and consider also the type of each round (seed, first round, second round, third round, fourth round, fifth round).

Table 19. Correlation matrix of independent variables

	fam_cum	assignees_avg	inventors_avg	IPC_scope_avg	countries_avg	bwd_cit_avg	science_avg	wei_fwd_avg	age_at_deal
fam_cum	1								
assignees_avg	-0.0536	1							
inventors_avg	0.0343	0.1137**	1						
IPC_scope_avg	0.1181**	-0.1062	0.1979**	1					
countries_avg	0.1723**	-0.2327**	0.1565**	**0.3758****	1				
bwd_cit_avg	0.0039	-0.1013	0.1702	**0.3181****	**0.3242****	1			
science_avg	-0.0625	0.0123	0.2724**	0.1891**	0.2905**	0.2300**	1		
wei_fwd_avg	0.1437**	-0.0750	0.1105**	0.1633**	**0.3239****	**0.5238****	0.1534**	1	
age_at_deal	**0.3267****	-0.0028	0.0402	0.1318**	0.1081**	0.0074	0.0777	0.0088	1

As already discussed in chapter 4, firms considered in the sample operate in different industries, and have therefore, a different patent intensity depending on their sector. In order to account for these differences, another control variable has been included in the analysis. In particular, two IP regimes have been identified based on the patent intensity levels, and they are described in tables 20 and 21. Industries with a value equals to 1 are characterized by a weak IP regime, while those with a value equals to 2 have a strong IP regime.

Table 20. IP regimes classification

IP regime	Industry	Number of firms	% of total firms	Mean fam_cum
1	Consulting	2	0.14%	0
1	Advertising, Marketing, Marketplaces	74	5.08%	0.2412
1	Art, Fashion, Design, Architecture	10	0.69%	0
1	Consumer goods, Food	1	0.07%	0
1	Content, Media	14	0.96%	0.582
1	Education	8	0.55%	0.3466
1	Gaming	32	2.2%	0.3732
1	Energy	2	0.14%	0.8959
1	Financials	38	2.61%	0.335
1	Internet	482	33.08%	0.26
1	Logistics	1	0.07%	0
1	Services	1	0.07%	0
1	Software, Mobile	384	26.36%	0.5414
1	Sports	1	0.07%	0
1	Travel, Tourism	22	1.51%	0
2	Pharma – Biotech – Medical Tech	141	9.68%	1.3916
2	Audio, Video, Photo	2	0.14%	0
2	Health care	33	2.26%	1.1761
2	Cleantech	73	5.01%	1.597
2	Hardware, Electronics, Semiconductors	100	6.86%	1.8567
2	Manufacturing, Automotive	20	1.37%	1.4095
2	Telecommunications, IT	9	0.62%	1.4994
2	Security	6	0.41%	0.7607
2	Materials	1	0.07%	1.3863

Table 21. Summary statistics of IP regimes

Patent Intensity	Number of firms	% of total	Mean fam_cum	Average VC amount
Low	1072	73.6%	0.3624	10.073
High	385	26.4%	1.5193	10.291
Full sample	1457	100%	0.6681	10.131

Among the industries with a weak IP regime, the most represented in the sample are *Internet* (33.08%) and *Software, Mobile* (26.36%); while among industries with a high patent intensity, the most frequent in the sample are *Pharma – Biotech – Medical Tech* (9.68%), *Hardware, Electronics, Semiconductors* (6.86%), and *Cleantech* (5.01%).

The two groups show a significant difference in the mean value of the variable *fam_cum*, showing that companies operating in weak IP regime industries have, on average, smaller patent portfolios than the others. On the contrary, the difference in the average VC amount received by the two groups does not seem to be significant.

5.2.1. Results

Table A2 in the Appendix shows the regression results. In the first two columns two explanatory variables are used alternatively to test their significance: the logarithm of the size of a patent portfolio is more significant than the dummy $fam\_dum_{i,t}$, showing that the size of a portfolio is more important. Models 3 and 4 consider also the other patent characteristics but none of them seem to be significant; however, variable $fam\_cum_{i,t}$ increases its significance, confirming that companies with larger patent portfolios receives larger amounts of VC funding.

This result is confirmed in table A3, which presents the same regression with the addition of the IP regime as control variable. In this case, the coefficient of the variable $fam\_cum_{i,t}$ is even higher than before, reinforcing the previous result.

Table A4 reports the same regressions on two sub-samples: the first one with the low IP regime and the second one with the strong IP regime. The variable $fam\_cum_{i,t}$ remains positively and significantly correlated with the VC amount but the coefficient is bigger for companies operating in industries with a low patent intensity. This notable result shows that patents really represent a signal for venture capitalists, who are more willing to invest their financial resources in companies with larger patent portfolios.

The number of received citations is significant for both groups, but the sign is different: for companies with high IP regime, the positive coefficient seems to suggest that companies with higher technical merit receive higher amounts of financing; while the relationship is reversed for companies with a low IP regime. A possible explanation for the last finding could be the presence of alternative sources of financing that can allow start-ups with relevant inventions to grow, without turn to venture capitalists.

Moreover, the number of backward citations is positively and significantly correlated with the VC amount only for sectors with weak IP regimes; the coefficient is small (0.491) but it suggests the existence of a positive relationship between the number of backward citations and the patent's value, confirming the results of Harhoff et al. (2002).

Results slightly change when considering the different financing rounds. In table A5 the same regressions are repeated for the seed stage, round A, and later stages. The only significant variable remains the size of patent portfolios, whose coefficient more than triple from round A to the later stages; in the seed stage, any patent related measure seems to be significant.

Tables 22, 23 and 24 report the same discussed models but using a panel framework. Like before, this model takes in consideration that different observations are referred to the same company in different years, and it is performed in STATA using the xtreg command.

Table 22 shows the same results seen in table A2; outcomes in table 23 are the same than those in table A3 with two little differences for industries with low IP regimes: the coefficient of the variable $fam\_cum_{i,t}$ is bigger, showing that the size of a portfolio is increasingly relevant, and the number of backward citations is strongly significant.

Table 22. Panel framework results. The dependent variable is the VC amount

VARIABLES	(1) Model	(2) Model	(3) Model	(4) Model
fam_dum	2.310			
	(1.507)			
fam_cum		1.588**	3.980***	4.044***
		(0.749)	(1.166)	(1.184)
assignees_avg			3.340	3.370
			(2.440)	(2.445)
inventors_avg			0.333	0.329
			(0.760)	(0.761)
IPC_scope_avg			-1.251	-1.232
			(1.490)	(1.493)
countries_avg			-0.379	-0.347
			(0.564)	(0.573)
bwd_cit_avg			0.0472	0.0571
			(0.0644)	(0.0712)
science_avg			0.257	0.272
			(0.594)	(0.596)
wei_fwd_avg				-44.27
				(136.0)
Time, Industry, Country dummies	Y	Y	Y	Y
age_at_deal	-0.555**	-0.591**	-0.552	-0.558
	(0.231)	(0.232)	(0.347)	(0.347)
Round dummies	Y	Y	Y	Y
IP_reg	1.375	1.887	0.415	0.532
	(1.894)	(1.924)	(2.685)	(2.712)
Constant	122.4***	119.1***	52.45	52.84
	(36.67)	(36.70)	(44.56)	(44.62)
Observations	1,086	1,086	463	463
Number of ID	600	600	264	264
R2-overall	0.225	0.227	0.283	0.283
chi2	296.9	299.6	158.9	158.6

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

Table 23. Panel framework results. The dependent variable is the VC amount. Model 1, 2 and 3 refer to the low IP regime; column 4, 5 and 6 refer to the strong IP regime

	Low IP regime			Strong IP regime		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model	Model	Model	Model	Model	Model
fam_dum	1.956			2.373		
	(1.996)			(1.790)		
fam_cum		1.056	6.310**		2.992***	3.986***
		(1.209)	(2.571)		(0.680)	(1.140)
assignees_avg			1.350			4.162
			(4.007)			(2.998)
inventors_avg			-0.478			-0.117
			(1.333)			(0.888)
IPC_scope_avg			-2.210			-2.197
			(3.203)			(1.385)
countries_avg			-0.912			-0.0102
			(1.213)			(0.549)
bwd_cit_avg			0.525**			0.0147
			(0.255)			(0.0559)
science_avg			0.581			-0.255
			(1.296)			(0.547)
wei_fwd_avg			-487.3*			363.3*
			(260.2)			(204.1)
age_at_deal	-0.596*	-0.605*	-1.024*	-0.224	-0.254	-0.0786
	(0.307)	(0.312)	(0.622)	(0.284)	(0.275)	(0.377)
Time, Industry, Country dummies	Y	Y	Y	Y	Y	Y
Round dummies	Y	Y	Y	Y	Y	Y
Constant	115.5***	114.5***	75.40*	53.61	0	0
	(29.80)	(29.86)	(43.89)	(33.61)	(0)	(0)
Observations	777	777	230	309	309	233
Number of ID	418	418	131	182	182	133
R2-overall	0.252	0.251	0.361	0.328	0.370	0.441

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

Finally, in table 24 regressions are divided by rounds; for the seed stage the full model is not available because of lack of data, but models 1 and 2 exhibit that both variables $fam\_dum_{i,t}$ and $fam\_cum_{i,t}$ are weakly significant, in particular, the first variable has a bigger coefficient, showing that the presence of at least one patent increase the VC amount by 91.3%. For later stages the results are the same than before; while for round A in the full model, the size of patent portfolios is no longer significant, but other two patent characteristics become statistically relevant. First, variable $IPC\_scope\_avg_{i,t}$ is negatively and significantly related to the VC amount, suggesting that venture capitalists prefer more focused inventions, with a small number of IPC subclasses associated to patents. Second, the number of non-patent citations ($science\_avg_{i,t}$) is weakly but positively correlated to the VC amount, implying that a higher scientific base incentivizes venture capitalists.

*Table 24. Panel framework results. The dependent variable is the VC amount. Columns from 1 to 3 refer to the seed stage; from 4 to 6 refer to stage A; from 7 to 9 refer to later stages. Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1*

	Seed			Stage A			Later stages		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Model	Model	Model	Model	Model	Model	Model	Model	Model
			Insufficient						
fam_dum	0.913*		Data	1.964			3.558		
	(0.468)			(1.202)			(3.329)		
fam_cum		0.521*			1.918***	2.236		4.387***	9.114***
		(0.313)			(0.705)	(1.448)		(1.443)	(1.966)
assignees_avg						2.168			3.820
						(3.513)			(4.864)
inventors_avg						-0.744			-0.214
						(0.912)			(1.249)
IPC_scope_avg						-3.589**			-2.624
						(1.776)			(2.632)
countries_avg						-0.921			0.195
						(0.622)			(0.977)
bwd_cit_avg						0.0485			0.288
						(0.0563)			(0.228)
science_avg						1.200*			0.438
						(0.695)			(0.941)
wei_fwd_avg						19.37			-451.5
						(71.06)			(355.6)
age_at_deal	-0.00827	-0.0175		-0.136	-0.190	0.0827	-0.0685	-0.368	-0.486
	(0.0658)	(0.0668)		(0.186)	(0.186)	(0.378)	(0.492)	(0.496)	(0.589)
Time, Industry, Country dummies	Y	Y		Y	Y	Y	Y	Y	Y
IP_reg	0.200	0.0531		-0.392	0.0918	-2.940	2.289	5.437	6.193
	(0.584)	(0.578)		(1.433)	(1.439)	(2.781)	(4.409)	(4.506)	(5.542)
Constant	2.340	2.339		2.742	2.479	1.871	26.97	24.84	6.969
	(2.269)	(2.288)		(10.36)	(10.29)	(19.37)	(18.76)	(18.60)	(33.61)
Observations	176	176		447	447	172	492	492	266
Number of ID	154	154		409	409	160	309	309	168
R2-overall	0.194	0.188		0.0730	0.0869	0.0786	0.0901	0.106	0.244

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

5.3. Conclusions

This study has analysed the presence of the signalling effect of patents looking at a sample of 1196 European companies between 2001 and 2016. Two models have been developed: the first one considers the full sample and investigates whether the presence of patents in a start-ups' portfolio incentivizes the obtaining of a VC financing; the second one focuses only on the VC-backed companies and it looks at the characteristics of a patent portfolio to highlight which aspects, if any, are considered more important by investors.

Results of the first analysis show that venture capitalists are more willing to invest in companies with larger patent portfolios; this is a confirmation of the signalling effect since patents are considered as a proxy of a firm's value. Start-ups with a greater number of patents and which increase this number year by year, have a higher probability of being financed.

This is confirmed by the second analysis that shows that, in general, venture capitalists seem to not take in consideration the technical content of patents, but they look at the total number of patented inventions. This study underlines that firms with a greater amount of patents have both a higher probability of being financed and receive also higher amount for each round.

Looking at the industries, results are more relevant for sectors with low IP regimes. In these industries, where patents are less used to protect the intellectual property, the signalling effect of patents is more pronounced, showing that start-ups do not have the need to protect their inventions legally but use such instruments anyway as signals for the investors. In these cases, venture capitalists take in consideration not only the total number of patents, but also some patent's characteristics like the number of backward citations, preferring more general inventions.

On the other hand, in industries with a strong IP regime, quantity matters more than quality.

Finally, the results show that the size of a patent portfolio is more relevant for companies in later stages, which, by increasing the number of patents they can also receive higher amounts. By contrast, for companies in early stages, in particular stage A, investors prefer companies with more focused inventions.

The quality of patents is more important for earlier stages and in industries where the intellectual property is not usually protected, that is to say, in those situations in which both the uncertainty and the risk are higher. When, in the later stages, the uncertainty and the information asymmetries are reduced, the size of the patent portfolio becomes more relevant.

From a start-up perspective, the strategy to follow depends on the stage and the industry in which the company is operating.

5.4. Limitations

One of the main limitations of this study regards data availability. The initial number of firms in the database was 1690, while after the data collection process, the final sample counts 1196 companies because of scarcity of data regarding the remaining firms.

Moreover, even among these 1196 start-ups, some of them have different financial measures missing; this is why some variables (like the R&D expenses) have not been used in the analysis.

A greater data availability could help to obtain more accurate results, particularly for the seed stage, where the lack of data did not allow to reach reliable conclusions.

The second limitation is related to the inverse causality. As discussed in the academic literature, it is difficult to determine if the presence of patents attracts VC investors or, if venture capitalists foster innovation.

In this study, the existence of an empirical association has been detected, but the causal relation cannot be verified with confidence.

Appendix

A1. Regression results. The dependent variable is $dummy\_VC_{i,t}$. Coefficients express the marginal effects

VARIABLES	(1) Model	(2) Model
total_assets	1.94e-06***	1.35e-06***
	(2.66e-07)	(2.56e-07)
long_term_debt	-2.50e-06***	-2.02e-06***
	(6.38e-07)	(5.82e-07)
EBITDA	-4.16e-06***	-3.06e-06***
	(5.85e-07)	(5.71e-07)
stock_patents		0.00896***
		(0.00101)
Time, Industry, Country dummies	Y	Y
Age	0.0101***	0.00578**
	(0.00228)	(0.00235)
Observations	3,778	3,778
chi2	256.9	341.7
loglike	-2480	-2438
pseudoR2	0.0492	0.0655

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

A2. Probit regression results. The dependent variable is the VC amount

VARIABLES	(1) Model	(2) Model	(3) Model	(4) Model
fam_dum	2.113			
	(1.482)			
fam_cum		1.401*	3.939***	3.988***
		(0.725)	(1.135)	(1.148)
assignees_avg			3.319	3.340
			(2.434)	(2.437)
inventors_avg			0.325	0.320
			(0.757)	(0.758)
IPC_scope_avg			-1.304	-1.300
			(1.448)	(1.450)
countries_avg			-0.381	-0.352
			(0.563)	(0.572)
bwd_cit_avg			0.0466	0.0555
			(0.0642)	(0.0707)
science_avg			0.250	0.261
			(0.591)	(0.593)
wei_fwd_avg				-40.73
				(134.6)
age_at_deal	-0.558**	-0.591**	-0.543	-0.546
	(0.231)	(0.232)	(0.341)	(0.342)
Time, Industry, Country dummies	Y	Y	Y	Y
Round dummies	Y	Y	Y	Y
Constant	6.272	13.01	5.084	5.289
	(33.55)	(33.43)	(45.25)	(45.31)
Observations	1,086	1,086	463	463
R-squared	0.225	0.226	0.283	0.283
R2adj	0.178	0.179	0.178	0.176
Loglike	-4735	-4734	-1957	-1957

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

A3. Probit regression results considering the IP regime as additional control. The dependent variable is the VC amount

VARIABLES	(1) Model	(2) Model	(3) Model	(4) Model
fam_dum	2.310			
	(1.507)			
fam_cum		1.588**	3.980***	4.044***
		(0.749)	(1.166)	(1.184)
assignees_avg			3.340	3.370
			(2.440)	(2.445)
inventors_avg			0.333	0.329
			(0.760)	(0.761)
IPC_scope_avg			-1.251	-1.232
			(1.490)	(1.493)
countries_avg			-0.379	-0.347
			(0.564)	(0.573)
bwd_cit_avg			0.0472	0.0571
			(0.0644)	(0.0712)
science_avg			0.257	0.272
			(0.594)	(0.596)
wei_fwd_avg				-44.27
				(136.0)
age_at_deal	-0.555**	-0.591**	-0.552	-0.558
	(0.231)	(0.232)	(0.347)	(0.347)
Time, Industry, Country dummies	Y	Y	Y	Y
Round dummies	Y	Y	Y	Y
IP_reg	1.375	1.887	0.415	0.532
	(1.894)	(1.924)	(2.685)	(2.712)
Constant	4.425	10.70	21.07	21.25
	(33.65)	(33.51)	(47.45)	(47.50)
Observations	1,086	1,086	463	463
R-squared	0.225	0.227	0.283	0.283
R2adj	0.177	0.179	0.176	0.174
Loglike	-4735	-4734	-1957	-1957

Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

A4. Probit regression results. The dependent variable is the VC amount. Model 1, 2 and 3 refer to the low IP regime; column 4, 5 and 6 refer to the strong IP regime

	Low IP regime			Strong IP regime		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model	Model	Model	Model	Model	Model
fam_dum	1.956			2.373		
	(1.996)			(1.790)		
fam_cum		1.056	5.482**		2.992***	3.986***
		(1.209)	(2.545)		(0.680)	(1.140)
assignees_avg			1.170			4.162
			(3.963)			(2.998)
inventors_avg			-0.256			-0.117
			(1.297)			(0.888)
IPC_scope_avg			-1.994			-2.197
			(3.127)			(1.385)
countries_avg			-1.036			-0.0102
			(1.184)			(0.549)
bwd_cit_avg			0.491*			0.0147
			(0.250)			(0.0559)
science_avg			0.814			-0.255
			(1.262)			(0.547)
wei_fwd_avg			-492.4*			363.3*
			(257.8)			(204.1)
age_at_deal	-0.596*	-0.605*	-1.098*	-0.224	-0.254	-0.0786
	(0.307)	(0.312)	(0.612)	(0.284)	(0.275)	(0.377)
Time, Industry, Country dummies	Y	Y	Y	Y	Y	Y
Round dummies	Y	Y	Y	Y	Y	Y
Constant	103.2**	110.2***	56.45	34.89	9.005	45.66
	(41.32)	(42.36)	(52.30)	(26.05)	(26.44)	(33.19)
Observations	777	777	230	309	309	233
R-squared	0.252	0.251	0.364	0.328	0.370	0.441
R2adj	0.193	0.193	0.173	0.207	0.257	0.279
Loglike	-3461	-3461	-1005	-1170	-1160	-877.2

Standard errors in parentheses - *** $p<0.01$, ** $p<0.05$, * $p<0.1$

*A5. Probit regression results. The dependent variable is the VC amount. Columns from 1 to 3 refer to the seed stage; from 4 to 6 refer to stage A; from 7 to 9 refer to later stages. Standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1*

	Seed			Stage A			Later stages		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Model	Model	Model	Model	Model	Model	Model	Model	Model
fam_dum	0.728			1.925*			3.558		
	(0.472)			(1.168)			(3.329)		
fam_cum		0.381	0.934		2.054***	2.823**		4.387***	9.177***
		(0.309)	(1.563)		(0.689)	(1.167)		(1.443)	(1.953)
assignees_avg			-0.488			2.508			3.278
			(0.932)			(2.633)			(4.854)
inventors_avg			0.318			0.217			0.0158
			(1.040)			(0.721)			(1.244)
IPC_scope_avg			-2.574			-0.455			-2.700
			(1.513)			(1.427)			(2.613)
countries_avg			0.907			-0.264			0.195
			(0.459)			(0.510)			(0.967)
bwd_cit_avg			0.271			0.0213			0.268
			(0.165)			(0.0424)			(0.227)
science_avg			0.866			-0.116			0.483
			(0.623)			(0.561)			(0.944)
wei_fwd_avg			-237.4			61.21			-484.0
			(157.9)			(87.66)			(353.6)
Time, Industry, Country dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
age_at_deal	-0.0147	-0.0217	0.625	-0.132	-0.192	0.0558	-0.0685	-0.368	-0.509
	(0.0624)	(0.0631)	(0.229)	(0.181)	(0.181)	(0.303)	(0.492)	(0.496)	(0.585)
IP_reg	0.0910	-0.0405	2.543	-0.627	-0.0710	-1.466	2.289	5.437	6.057
	(0.557)	(0.546)	(1.282)	(1.389)	(1.393)	(2.053)	(4.409)	(4.506)	(5.448)
Constant	5.735	5.456	-4.203	8.200	8.686	3.132	-15.32	-22.72	-37.56
	(3.671)	(3.699)	(5.023)	(17.23)	(17.07)	(16.86)	(51.04)	(50.63)	(47.02)
Observations	176	176	35	447	447	172	492	492	266
R-squared	0.198	0.193	0.977	0.075	0.089	0.194	0.090	0.106	0.246
R2adj	-0.0241	-0.0304	0.613	-0.0292	-0.0137	-0.0851	0.000549	0.0183	0.0871
Loglike	-336.8	-337.4	-0.160	-1627	-1623	-602	-2329	-2324	-1180

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