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# Venture Capital Fueling Innovation in Sweden: A Panel Data Analysis of Patent Activity and Productivity Growth from 2000 to 2020

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**Abstract:**
This thesis investigates the relationship between Venture Capital (VC) investments and innovation in the context of Sweden. Utilizing a panel data analysis with fixed effects, the study examines the impact of VC funding on two key measures of innovation: patent applications and total factor productivity (TFP) growth. The data is within the time frame of year 2000 to 2020, encompassing detailed financial and innovation-related metrics for Swedish VC funded companies. The finding indicates that VC investment significantly enhances both patent activity and TFP growth, supporting the "Venture Capital First Hypothesis". This hypothesis says that VC investment acts as a catalyst for innovation. The analysis highlights differential impacts of VC investment stages, underscoring the importance of VC funding in earlier stages of innovation activity for both patents and TFP growth as measures of innovation. The results consistently show that the study cannot say anything about later stage investments for both patent and TFP growth. The discussion ends up in a conclusion that our study aligns with previous research, showing that venture capital investments are more crucial in the earlier stages.

**Keywords:** Venture Capital, Private Equity, Innovation, Patents, Total Factor Productivity (TFP), Fixed Effects Model, Sweden, Startups, R&D Expenditure, Panel Data Analysis, Investment Stages, Financial Markets.

**JEL Classification:** G24, O31, C23

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# 1. Introduction

## 1.1 Background

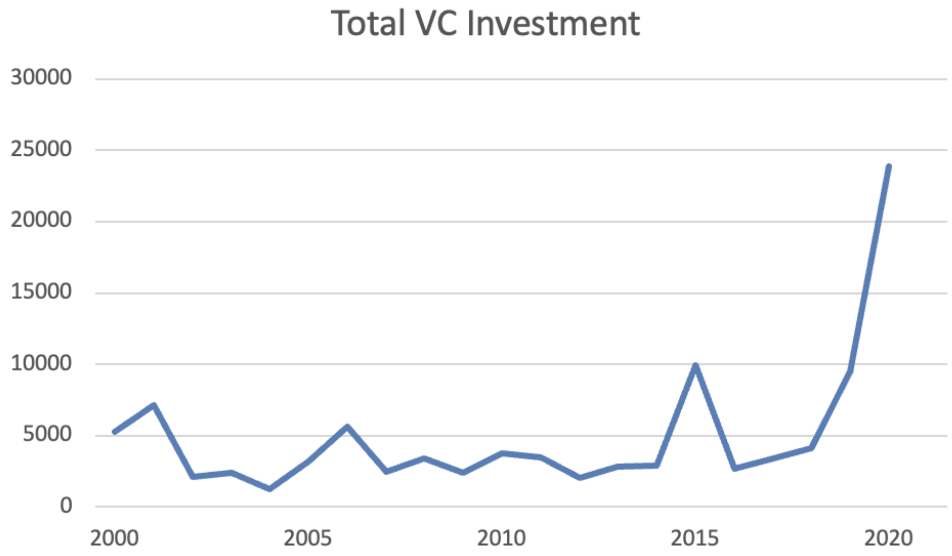
For modern economies innovation is considered crucial for the development of economic growth. Innovation can act as a developer of existing industries as well as create new ones. Romer (1989) underscores that both in developed and developing countries, innovation is central to economic expansion. Additionally, Bessant and Tidd (2015) emphasize that funding is crucial for successful innovation. Although the funding of innovation can be rather difficult, this is especially true in economies where the banking system is usually less effective in supporting innovation compared to more market-oriented economies like Sweden and the UK. Policymakers regard Venture Capital (VC) to be a better way to finance innovation than banks (Popov & Roosenbom, 2012). Governments aiming to boost economic growth frequently focus on scaling up the venture capital industry. Examples of this can be found in the United States and the Small Business Investment Company initiative as well as initiatives establishing the stock market with relaxed criteria for VC investments. There are two objectives to this, firstly to address challenges in insufficient investment in innovation and smaller as well as newer companies (Hall, 2002). Secondly to help these companies accelerate in growth and profitability in the future (Sahlman, 1990).

Venture Capital (VC) is an investment method to channel funds while also handling the risk associated with investing in new entrepreneurial companies. The venture capitalist, that is the investors, take on a high-risk investment in hopes of a high growth rate by the companies' innovation ideas (Carpenter & Petersen, 2002). The venture capitalist usually invests in young privately held companies like startups (Kortum & Lerner, 2000). The venture capitalist is regarded as the financial intermediary that is more active in the investment (Kortum & Lerner, 2000). The information asymmetry is usually regarded to be smaller since venture capitalists screen potential investment opportunities and therefore are more likely to be accurate in evaluating the potential of the company (Ueda, 2004). Venture capital has even been described as the money of invention from the book "Money Of Invention: How Venture Capital Creates New Wealth" by Gompers and Lerner (2001). Increased venture capital investments have been shown to lead to a substantial increase in the amount of patented innovations in both the United States (Kortum & Lerner, 2000) and Germany (Tykvova, 2000). Increased venture capital activity has also been shown to create a substantial impact on the rise of new business creation (Popov & Roosenboom 2013). The growth rate of venture capital-backed companies has been shown to be greater (Sahlman 1990, Hellmann & Puri 2000, Engel 2002, Hall 2002), as well as them being more efficient in bringing new products to the market (Hellmann & Puri 2000).

The relationship between innovation and venture capital has been questioned, whether there could exist some reverse causality; that venture capital spurs innovation in companies rather than innovative companies attract venture capital. Hirukawa & Ueda (2011) question the causality of previous work and find evidence for the phenomenon in the US manufacturing industry, where they use total factor productivity growth and amount of patents as measures of innovation. Prof Josh Lerner of Harvard University is one of the most well known researchers of the topic on venture capital. He states that a boost of venture capital improves innovative activities. Lerner also states that assistance of VC funding has two dimensions: they ensure a long-run success and accelerate growth (Lerner, 2009).

In terms of the Swedish context, Sweden has been one of the better economies that stimulates innovative corporate environments (Global innovation index, 2018). The importance of stimulating an innovative climate for Swedish companies is supported by the Swedish government. For example by forming the Swedish National Innovation Council, with the aim to promote innovative competitiveness towards other countries (Government Offices of Sweden, 2018). Until the early 1990s the VC market primarily took place in the US, but later by internationalization found its way to Sweden. In 2011 the total investment of VC amounted to €234 million which could be considered a modest investment size for an entire industry. But as shown in diagram 1 below, the industry has risen and statista has stated an anticipation of further growth through the year 2025 (Statista, 2024).

Diagram 1: Total Venture Capital in Sweden by year and Million SEK in total 2000 to 2020.




(Eikon, 2024).

To conclude, the exploration of venture capital's impact on innovation presents an interesting topic for research, particularly within emerging markets where traditional financing mechanisms fall short. In this study, we hope to uncover insights that enhance our understanding of venture capital dynamics in the context of the Swedish market. As well as get an extended understanding of innovative capabilities that drive economic growth.

## 1.2 Purpose and Research Questions

The purpose of this thesis is to investigate the relationship between innovation and VC investments in a Swedish context. Additionally, this thesis aims to examine the extent to which VC investments influence innovation activities. The thesis aims to both broaden the already existing empirical work in this field by testing significance between VC activity and the two chosen measures of innovation defined as granted patent applications and yearly TFP growth on a company level. With the hope to contribute new information to the area of research and find an alternative way of interpreting the relationship between innovation and venture capital in the Swedish market for future investing in Venture Capital. This area has been studied with regards to the following research questions.

- To what extent does venture capital investment influence innovation in Sweden?
- How do different stages of venture capital investment affect innovation?

## 1.3 Disposition

Previous section presented the setting for the importance of financing innovation and venture capital investment. In chapter 2 the report shows previous research that is found important to motivate the aim of the study and chosen limitations to this study. The chapter also contains the results from previous studies which have found different answers to the question whether venture capital investments spur innovation or not. This being a predecessor to chapter 3 consisting of the theoretical framework. In Chapter 4 the method used is presented. For this study, a quantitative method referred to as Fixed Regression analysis to measure the effect on innovation from receiving an investment from a venture capitalist. Chapter 5 presents the statistical results showing whether we have statistical significance on the relationship between venture capital investment and innovation. These results are then analyzed in chapter 6 with the main conclusions being presented in chapter 7 as well as suggestions for future research.

# 2. Previous research

A study done by Kortum & Lerner (2000) “Assessing the Contribution of Venture Capital to Innovation” explores the relationship between venture capital funding and innovation, measured as the number of patented innovations. Using a quantitative approach with a focus on the manufacturing sector in the US over a three-decade period, they found that venture capital has a strong positive impact on patents. This holds also after controlling for R&D expenditure and technological opportunities. They also investigate potential problems of patents to measure innovation in a VC investment setting. One potential issue could be that VC investment triggers the number of patents, but not innovation. This stems from VC-backed companies patenting more compared to non-venture-backed companies, which can be a way to attract investors and/or due to a fear that investors will exploit their ideas. They find that companies gaining venture capital investment do patent more, but that it does not lower the quality of patents. The conclusion is that VC investment has a positive and significant effect on innovation. Caselli et al (2006) in their study “Are Venture Capitalists a Catalyst for Innovation, or Do They Simply Exploit it?” explores venture-backed and non-venture-backed companies in Italy and focuses on innovation at the company level, using the number of patents as a proxy for innovation. They explore if innovation is important when companies decide to invest and thereafter if investors sustain or exploit innovation. They find a positive connection between innovation and venture capital, which supports existing studies. They also conclude that in the period after investment, venture capital does not spur innovation because venture-backed companies register fewer patents compared to their “twin” company, which is a similar company, but non-venture-backed. Finally, venture capitalists concentrate more on trading past innovations rather than developing innovations.

Another study done by Ni et al (2014) “Can venture capital trigger innovation? New evidence from China, explores whether venture capital impacts innovation and continues into the causality between the two variables in a Chinese context. Innovation is defined as patent counts and associated productivity growth. They discuss the challenges of defining innovation and four different theories regarding the link between VC investment and innovation. VC investment should spur innovation in theory, but in underdeveloped markets like China, its effect might be reduced. They conclude that VC investment has a positive, but limited effect on innovation, with a stronger impact on total factor productivity growth than patent counts. As well as both the venture capital first and innovation first hypothesis being supported. Although they highlight the importance to address the fact that the Chinese regulatory framework differs significantly from Western markets. Despite the positive correlation between venture capital investment and innovation, the overall effect is less pronounced in China compared to developed countries. A second study using the same two measures of innovation is Hirukawa & Ueda (2011) "Venture Capital and Innovation: Which is First?". This study presents an in-depth analysis of the relationship between venture capital investment and innovation in the US manufacturing industry using total factor productivity (TFP) growth and patent count as measures of innovation. Traditionally venture capitalists address the underinvestment in innovative activities and help new companies grow quickly. This research acknowledges evidence that VC-backed companies grow faster and often are more innovative but questions the direction of the relationship. They use a panel autoregressive model to test for Granger-type causality between innovation and VC investments. The studied period covers the years of 1968 to 2001. They constructed two hypotheses to test for reverse causality. The venture capital first hypothesis and the innovation first hypothesis. The study finds weak evidence on the venture capital first hypothesis when TFP growth is tested for. The relationship between lagged first-round VC investments and TFP growth is significant, but the following round does not show significance. The results are different when patent count is used to measure innovation, with little evidence supporting the VC-first hypothesis. For the innovation first hypothesis, there is evidence supporting it when TFP growth is used as an innovation measure, lagged TFP growth is positively related to the first round of investment. There is no significance for the hypothesis when patent count is used as a measure of innovation.

# 3. Theoretical framework

Venture Capital is a part of the Private Equity industry. Venture Capitalists wish to find financial gains by investing in innovative business ideas that are not traded by the public. Then they can develop the investment by assisting in the development of the business and monitoring the investment (Isaksson, 2006). For a start-up or venture, in general, this funding is crucial for survival and development (Howell et al, 2020). The relationship between venture capitalists and entrepreneurs can be viewed through the Agent-Principal theory, where the invested company acts as the agent and the Venture Capitalists as the principal. This dynamic allows Venture Capitalists to structure financial contracts to align the company's actions with their interests, effectively mitigating potential agency conflicts when interests align (Kaplan & Strömberg, 2001). Therefore venture capital investment typically contributes more than capital, because the investors typically engage with business operations and performance (Kim et al, 2010). Post the investment, the investor continues to use influence through mechanisms like contract stipulations that grant them substantial managing control. Moreover, investors mitigate investment risks by structuring finances in stages, allowing them to cease funding for underperforming projects, and by syndicating investments, this spreads the risk (Hall & Lerner, 2010). While not the perfect financing solution for every small company, VCs fulfill a critical role for those ambler companies that benefit from active, engaged ownership.

## 3.1 Different stages of Venture Capital investment

VC investments can be divided into different stages. These stages are important to recognize since they are affected differently by different drivers of VC funding. As well as other researchers frequently explain the importance of including the stages when researching the topic of venture capital (Streng & Örneblad, 2021). In Jeng & Philippe (2000) one of the more relevant results in their research is that different types of VC financing, in other words the stages, are affected differently by innovation measures. This highlights the importance of considering different VC investment stages when studying VC, especially differentiating between the earlier and later stages.

Investment stages shall not be mixed with the definition of investment rounds. Because within each of the investment stages, there could be several funding rounds (Streng &

Örneblad, 2021). The first stage is called the seed stage funding, this stage is pre-marketing and consists of the very first capital introduced. The funding is mostly used to develop a product or service, team, market research, and business plan. After this stage, the venture goes into the early startup stage, which usually is when the first large funding round happens. The venture is still working on the development of a product or service, marketing as well as pinpointing key features for future growth. At this point a larger number of investors are now involved. Then we have the expansion phase which is in the middle/late of the development. Now the inflow of capital is used to increase sales and profit. The company has a finalized business plan and is in full operation. Worth noting is that seldom the companies are at profit in this stage. The later stage within venture capital typically occurs after it has developed its product. This stage typically has less risk than early stages of venture capital.The culmination of venture capital funding ushers in a pivotal phase: the prospect of a liquidity event, wherein a company may transition to public ownership through an IPO or merge with another entity. This period signifies the enterprise's evolution into a mature entity poised for significant financing to underpin critical corporate milestones. After this stage the venture enters the mezzanine stage, precursor to going public. The enterprise stands as a robust, market-validated entity. This exit of founding investors paves the way for financiers who are drawn by the potential windfalls of an impending IPO or company sale. The IPO, or Initial Public Offering, represents a strategic leap from venture capital financing to public market capitalization. This transition not only mobilizes significant capital for a startup but also furnishes rewards for the original stakeholders, including founders and the core team (Silicon Valley Bank, n.d).

## 3.2 Measures of innovation

Before discussing the topic of venture capital and innovation, it is important to consider the definition of innovation and its different measures. Joseph Schumpeter, an Austrian-American economist in 1934, extensively defined innovation as a significant economic driver with multiple aspects. He identified innovation types relevant to this research: the introduction of a new good or a new quality of a good, and the introduction of an improved production method. Baregheh et al. (2009) synthesized Schumpeter's definitions, describing innovation as a multi-stage process where organizations transform ideas into enhanced products, services, or processes to compete effectively in their markets. Tidd and Bessant (2018) describe innovation as the process through which new ideas are turned into practical applications that lead to enhanced products, services, or processes. This process is crucial for maintaining competitive advantage and addressing market demands. They emphasize that innovation is not limited to technological advancements but includes changes in business models and management practices.

**Table 1**: Overview of previous studied measures of innovation and VC investments

| Source | Measure of innovation | Geographic area | Findings |
|---|---|---|---|
| Kortum, S., & Lerner, J. (2000) | Patents | US | Venture Capital positively impacts the number of patents filed |
| Caselli et al (2006) | Patents | Italy | They find a positive connection between innovation in terms of venture capital investment and patents filed. |
| Dahlberg & Sörling (2019) | Patents | Sweden | The result indicates that VC financed companies, on average, become 23% more innovative after receiving financing from a VC. |
| Hellmann and Puri (2000) | R&D expenditure | US | VC-backed companies tend to have higher R&D expenditures compared to non-VC-backed companies |
| Peneder (2010) | R&D expenditure | Europe | study highlights that VC funding significantly boosts R&D expenditure in companies, driving innovation efforts. |
| Hirukawa and Ueda (2011) | Patents and TFP growth | US manufacturing industry | VC investments are associated with significant TFP growth in VC-backed companies, |
| Ni et al (2014) | Patents and TFP growth | China | This study found that VC investment has a positive but limited effect on innovation, with a stronger impact on TFP growth than on patent counts. |
| Puri & Zarutskie, (2012) | Market performance metrics | US | VC-backed companies show superior market performance, highlighting the role of VC in translating innovative efforts into commercial success. |
| Hochberg et al (2014) | Market performance metrics | US | VC-backed companies outperform non-VC-backed companies in terms of market growth and profitability. |

As the table above describes, we can see that there exists many definitions on how innovation can be measured. As discussed in previous sections, patents are a widely used measure of innovation. R&D expenditures is also a commonly used metric. Other measures used in previous studies are market performance metrics such as revenue growth, market share and profitability. Most of the studies done on venture capital investment and innovation are US based, although some studies exist in other geographical areas. With this context it can be concluded that not any previous studies has been done in Sweden using patent and TFP growth as measures of innovation. As Hirukawa & Ueda (2008) write in their study, it is interesting to study patent and TFP growth together. An important difference between these two is that TFP growth results from adopting new technology, patents on the other hand are based on ideas about new technology that might have not been adopted yet.

### 3.2.1 Patents

A widely used and accepted measure of innovation is the number of patent applications. Companies might apply for patents if they want to protect their innovations because having a patent protects the output of an innovation process from being copied by others. Nevertheless, using patents as a measure of innovation has been criticized. Not all innovations get patented because some innovations are not patentable, the patent application process can be too long compared to the innovation cycle duration, and information concerning the innovation has to be revealed to apply. Innovations can also be protected using other methods, like speed of innovation or secrecy. (Engel & Keilbach, 2007).

Thus, patent applications are widely regarded as the primary method for quantifying innovative output, also due to the data being very detailed and well-documented. This thesis, like many other studies, follows Kortum & Lerner (2000) and uses the number of patent applications as a key metric to assess companies' innovation output.

### 3.2.2 Total Factor Productivity

Compared to patent count, Total Factor Productivity (TFP) is measured as a dependent variable in percentage. TFP growth measures the efficiency and effectiveness with which all inputs are used in the production process. It is a crucial component of economic growth as it captures the effects of technological advancements and efficiency improvements that are not attributed to increased input usage. Essentially, TFP growth represents the productivity growth that occurs beyond what can be explained by changes in labor and capital alone. TFP is particularly significant in economic studies because it includes factors such as technological innovation, skill levels, organizational improvements, and other efficiencies that contribute to output growth without additional inputs. It reflects the ability of an economy to produce more output with the same amount of inputs or the same output with fewer inputs (Hirukawa & Ueda, 2008).

### 3.2.3 Hypothesis

In reviewing the relevant literature, it appears that obtaining financing is notably challenging for smaller companies, particularly startups. Venture capitalists represent an alternative source of financing for these companies. Moreover, VCs often play an active role in the companies they invest in, exerting significant influence to align the companies' development with their interests. Most studies, including those by Kortum and Lerner (2000) and Popov and Roosenboom (2012), have identified a positive link between venture capital and innovation. There is evidence suggesting that companies receiving venture capital can grow faster as well as engage in innovative activities (Hirukawa & Ueda 2011). Kortum and Lerner (2001) observed that patents from VC back companies are cited more frequently, thus indicating that VC investments might have a high impact on innovation. Additionally, VC investment tends to have a substantial influence on patent counts than R&D expenditures, suggesting a direct role of VC on innovation. Hirukawa and Ueda (2011) conclude this as the "Venture Capital first hypothesis", which suggests VC to be the driving force behind innovation in new companies. Given this background, it is plausible to anticipate a positive association between venture capital and innovation within the Swedish context. To explore this effect in Sweden and address the research question, the following hypothesis will be studied: "Venture capital investment positively influences innovation in Swedish startups, leading to higher patent counts and increased total factor productivity growth."

Forming the following null hypothesis:
**H0:** Venture capital financing has no effect on innovation.
**H1:** Venture capital financing has an effect on innovation.

# 4. Method

## 4.1 Data

The first step of the method was to gather data and create a useful data set to complete the necessary analysis. The data used was gathered from the databases Refinetiv Eikon, Serrano, and PAtLink. This study is based on secondary data, which is a less time consuming and cost effective way of gathering data (Bryman & Bell, 2005). The use of secondary data is considered the most optimal way in this kind of research since previous research within the area also uses secondary data (Gompers & Lerner, 1998; Gompers & Lerner 2003).

### 4.1.2 Databases

Refinitiv Eikon is a database used both in academia and industry. It includes data on both developed and emerging markets, covering a range of financial instruments. Crucially, this database also contains private equity and venture capital data (Eikon, n.d). When we filtered in the database we filtered for "pure venture capital deals", when filtering for this the existing 4 stages of seed, early, expansion and late stage are left in the data. Therefore the thesis does not include the stages of mezzanine and IPO. We also filtered for only Swedish companies since the thesis aims to investigate Sweden, as well as only including the years of 2000 to 2020, since we aim to investigate a period of 20 years. Finally, we got detailed VC data that specified the company name, industry, investment stage and invested amount per year.

The Serrano Database provides a detailed financial history at the company level, dating back to 1997. This database includes financial data sourced from financial statements provided by the Swedish Companies Registration Office (Bolagsverket, n.d). A key feature of the Serrano Database is its structure by organization numbers, where each company (identified by its corporate ID) has a separate data entry for every calendar year. This structure ensures that each data field reflects the information as of December 31st of that year. This database was necessary to calculate total factor productivity on a yearly level from 1999 to 2020 for each individual company (Swedish House of Finance, 2019). The calculation for total factor productivity growth can be found in section 4.1.2.

PAtLink is a database encompassing all patents owned by Swedish companies from 1991 to 2021, with patent details sourced from a patent database called PATSTAT and organization numbers derived from the Serrano database. Relevant data from PAtLink included the company, organization number, and number of patent applications per year (Swedish House of Finance, 2019). The patent data included applications from private persons, which were all excluded. The time frame of this thesis is 20 years, ranging from 2000 to 2020. PAtLink has not provided complete patent data for 2021, resulting in only a handful of patent application observations, which is why 2021 is excluded in the analysis. 20 years was the longest time period deemed reasonable and manageable with regards to the time frame of this thesis.

### 4.1.2 Merging the databases

In order to create a useful dataset, the data from above databases needed to be merged. This was the biggest challenge for the study and proved to be more challenging and time-consuming than expected in the beginning of the research period. The merging process began with assigning organization numbers to the companies from Eikon. This was done using excel matching formulas using company names from Serrano database and matching these with company names from Eikon. By using the Serrano database we could assign the Eikon company names with organization numbers. Although this process was not foolproof, later on it would be needed to do some manual work on some companies to assign organization numbers. To be sure that no faults were made, samples were picked out to ensure correctness. These samples were checked manually. The dataset consisting of patents as well as the dataset consisting of financial data already had organization numbers and therefore had no need of being modified. The merging of the final patents and VC dataset as well as the TFP growth and VC dataset was done in STATA. This was done using the merge formula with organization numbers as the common variable. Finally, the complete dataset includes VC data, financial data, and the number of granted patents at both the company and industry level.

## 4.2 Panel Regression with fixed effects

The third step of the method was to test the significance of chosen dependent and independent variables to conclude the relationship between innovation and VC investment. Regression Analysis is a statistical technique to see the relationship between variables, in other words the causal effect of one variable upon another (Gallo, 2015). Fixed-effects, FE regression, is particularly valuable in causal analysis as highlighted by Gangl (2010). It is typically applied to panel data. This method addresses the limitations of standard regression models that may yield biased causal estimates in the presence of unobserved confounders. FE regression, under specific assumptions, offers a way to derive unbiased estimates where traditional methods fall short. Other approaches such as instrumental variables regression and regression discontinuity are also noted for addressing these issues. Unlike multilevel regression, which assumes no unit-specific or group-specific unobserved heterogeneity. FE regression operates under the assumption of no unit-specific unobserved heterogeneity alone. It incorporates group-specific constants, known as 'fixed effects,' effectively eliminating group-specific unobserved heterogeneity. This adjustment allows the identification of causal effects under less stringent assumptions compared to standard regression models, making FE regression a preferred choice for researchers conducting causal analyses. For example national analyses, country fixed effects control for country-level heterogeneity, and for longitudinal studies, individual fixed effects adjust for person-level heterogeneity (Best & Wolf, 2014).

A typical panel data regression model can be represented as

$$Y_{it} = \beta_0 + \beta_1 X_{it} + A_i + \varepsilon_{it}$$

where Y is the dependent variable, X is the independent variable, β are coefficients, and A represents the fixed effect which identifies all unit specific characteristics that do not change over time. $\varepsilon_{it}$ represents the error term (Brandom, 2008). The following models were used for regression analysis and are labeled as Model 1, Model 2, Model 3, Model 4 and Model 5.

**Model 1**:

$$TFP\ growth\ or\ Patent = \beta_0 + \beta_1 Seed_t + \beta_2 Early_t + \beta_3 Expansion_t + \beta_4 Later_t + \varepsilon$$

**Model 2**:

$$TFP\ growth\ or\ Patent = \beta_0 + \beta_1 Seed_t + \beta_2 Early_t + \beta_3 Expansion_t + \beta_4 Later_t + \beta_5 R\&D_t + \beta_6 GDP\ growth_t + \varepsilon$$

**Model 3**:

$$TFP\ growth\ or\ Patent = \beta_0 + \beta_1 Seed_t + \beta_2 Early_t + \beta_3 Expansion_t + \beta_4 Later_t + \beta_5 R\&D_t + \beta_6 GDP\ growth_t + \beta_7 Industry_t + \varepsilon$$

**Model 4**:

$$TFP\ growth\ or\ Patent = \beta_0 + \beta_1 Seed_{t-2} + \beta_2 Early_{t-2} + \beta_3 Expansion_{t-2} + \beta_4 Later_{t-2} + \beta_5 R\&D_t + \beta_6 GDP\ growth_t + \varepsilon$$

**Model 5**:

$$TFP\ growth\ or\ Patent = \beta_0 + \beta_1 Seed_{t-4} + \beta_2 Early_{t-4} + \beta_3 Expansion_{t-4} + \beta_4 Later_{t-4} + \beta_5 R\&D_t + \beta_6 GDP\ growth_t + \varepsilon$$

The decision on using fixed effects or random effects methods depends on whether the unobserved effects are correlated with the explanatory variables. If it is uncorrelated with the explanatory variables, the random-effects estimator is appropriate. However, if it is correlated with the explanatory variables, the random effects estimator becomes biased and inconsistent, making the fixed effects estimator preferable for its consistency and unbiasedness. In fixed effects the data are transformed to eliminate company specific effects, allowing for an unbiased and consistent estimation regardless of the correlation between the dependent variable and the independent variables (Best & Wolf, 2014). The decision for using fixed effects will be tested down below using a Hausman test, results in table 6 and 7. As well as checking for correlation between independent variables which can be found down below in table 8.

In the study Hirukawa and Ueda (2008) they use two different lagged scenarios, a 2 year lag and a 4 year lag. These were chosen because of the fact that start-ups have a realistic chance to grow typically 2-4 years after a VC investment. The use of lagged values shows that the dependent variable is influenced by the past values of the independent variables. Using lagged values helps identify that the dependent variable is influenced by past values of the independent variables. Including lagged variables can help mitigate the problem of endogeneity by ensuring that the independent variables are not correlated with the error term, thereby providing more robust estimates. Innovation outcomes such as patents application or TFP growth may not respond immediately to VC investment. There could be a delay before the full impact of VC funding is observed. Lagged values help capture this effect (Feinstein et al, 2002). Therefore this thesis has also chosen to use the two lagged scenarios of 2 and 4 years. The lagged variables were the interaction terms as shown above in previous sections.

Since the other variables, R&D and GDP growth, were control variables and we were not interested in their effect, only control for it, we did not lag these variables.

### 4.2.1 Variables

We conduct a regression with company and year fixed effects which allows for controlling of differences between companies and across the time period of the study. Company fixed effects controls for the unobservable heterogeneity when it is constant over time period and removes any time invariant specific and unobservable characteristics that could affect both dependent and independent variables of the regression (Wooldridge, 2002). The dependent variable is TFP growth and a dummy for patents on the independent VC investment. Included control variables are industry, chosen due to the fact that some industries may be more innovative than others. Which could create a biased result. The industry variable came from Eikon. GDP growth is included because it may reflect broader economic trends that affect company productivity. Numbers of GDP growth were gathered from Statistik Databasen (SCB) and were calculated on an annual level. The last control variable is Research and Development (R&D) expenditure which is commonly associated with innovation that leads to productivity growth or patent applications. By including R&D as a variable, we can control for its specific contribution to TFP growth and number patent application. VC investment was divided into 4 stages in the dataset, namely seed, early, expansion and later stages. Dummy variables were then created for these different investment stages. Interaction terms were thereafter created between a dummy for having any venture capital input at all and each stage. These interaction terms are named Seed, Early, Expansion and Later.

### 4.2.2 Panel regression for patents

In order to use patent applications in the panel regression, a dummy variable was created to reflect the patent application data. This approach was chosen so that the analysis can focus on the presence or absence of patent applications, allowing for easier interpretation of the results. Using a dummy variable also has other advantages, such as simplifying interpretations and mitigating issues related to skewness of the patent data due to many firms having no patents and a few having many patents. This can ultimately lead to more robust and reliable estimates.

### 4.2.3 Panel regression for TFP growth

To estimate a production function, typically assuming a Cobb-Douglas form, which relates the inputs to the output. This function takes the form of:

$$Y=A\times L\alpha\times K\beta$$

where Y is output, A is a measure of TFP, L is labor input, K is capital input, and α and β are the output elasticities of labor and capital, respectively (Hirukawa & Ueda, 2008). The data set for TFP growth came from the Serrano financial database using company specifics on net sales, employees and total assets. These are turned into natural logs to linearize the percentage and allow for easier interpretation. The variable of TFP was then created to subtract the weighted sum of the growth rates of labor and capital from the growth rate of output. Which is in line with the Solow residual calculation (Solow, 1957), where TFP growth is the proportion of output growth not explained by the growth in inputs. The TFP growth was calculated from one year to the other by computing the change of the logarithmic values of TFP between the consecutive years for each individual company. By doing this it captures the percentage change in TFP and it gives an annual growth percentage per each company. In conclusion TFP growth is calculated as the one year productivity growth for company *i* in year *t*.

When using TFP growth as measurement of capital it can be difficult due to quality heterogeneity and therefore the growth will be dependent on how capital is measured. Quality of heterogeneity is for example that two factories might have the same number of equipment, but one might have more efficient equipment, therefore this can impact the productivity calculations in the Cobb Douglas production function (Hirukawa & Ueda, 2008). Although the use of TFP growth as an indicator of performance of innovation is well established in literature. Literature argues that TFP incorporates factors that lead to more output than what can be explained by input alone. For example technological progress, organizational innovation and economies of scale (Croce et al, 2013) (Grilli & Murtinu, 2012). Despite some challenges posed, the Cobb Douglas production function remains a relevant tool to calculate TFP growth and assess innovation performance.

# 5. Results

The models presented in this section were set up in the software Stata and gave the following results.

## 5.1 Descriptive Statistics

The following section provides the descriptive statistics for the data used. The summary of the final sample that was extracted from Eikon can be seen below. Giving the values for each year from 2000 to 2020 of some key numbers. In Table 2 below the overall trend of TFP growth suggests periods of economic expansion and contraction. Number of applied and granted patents does not show remarkable differences from year to year. A peak can be noted in 2008 and the lowest point in 2020. A slow increase of amounts invested in the different stages of VC investment for each year can be seen. In the year of 2020, it is shown a remarkable increase of VC investments for all stages. This number seems rather remarkable and can be explained by the 61% increase of foreign investment fund investments done in 2020 (SVCA, 2021). Investment in seed stage varies but generally remains low, reflecting the more risky nature of earlier stages of venture capital investments. Early stage investments show variability, with significant spikes in certain years such as 2001 with a volume of 920 million SEK. The expansion stage shows higher and more consistent investments, peaking in 2020 with an invested amount of 12148 million SEK, indicating that venture capital investors prefer funding companies that have moved past initial stages and are scaling up operations. Later stage investments are relatively high in certain years, notably in 2015 with 7942 million SEK and in 2020 with 8714 million SEK invested, suggesting venture capital investors in some years, to a higher degree, support companies nearing maturity.

**Table 2**: Summary statistics by year

| Year | TFP growth (%) | # applied patents each filing year | # companies receiving VC | VC investment Million SEK Seed | Early | Expansion | Later | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0,46% | 599 | 156 | 193 | 814 | 2932 | 1299 | 5237 |
| 2001 | 0,23% | 815 | 153 | 448 | 920 | 5292 | 444 | 7104 |
| 2002 | -0,03% | 785 | 76 | 85 | 220 | 1802 | 15 | 2122 |
| 2003 | 0,05% | 884 | 132 | 219 | 212 | 997 | 955 | 2383 |
| 2004 | 0,10% | 758 | 163 | 82 | 138 | 771 | 227 | 1218 |
| 2005 | 0,20% | 751 | 278 | 457 | 390 | 2026 | 322 | 3195 |
| 2006 | 0,31% | 690 | 327 | 531 | 384 | 4387 | 295 | 5598 |
| 2007 | 0,18% | 823 | 84 | 31 | 390 | 1356 | 655 | 2432 |
| 2008 | 0,20% | 693 | 92 | 289 | 1082 | 756 | 1260 | 3389 |
| 2009 | 0,04% | 635 | 84 | 6 | 1305 | 452 | 602 | 2364 |
| 2010 | 0,16% | 585 | 114 | 50 | 2159 | 781 | 747 | 3738 |
| 2011 | 0,13% | 632 | 127 | 98 | 629 | 2181 | 548 | 3457 |
| 2012 | 0,09% | 689 | 89 | 25 | 500 | 1027 | 457 | 2008 |
| 2013 | 0,09% | 726 | 61 | 40 | 120 | 2159 | 493 | 2812 |
| 2014 | 0,07% | 704 | 65 | 74 | 565 | 1603 | 676 | 2917 |
| 2015 | 0,12% | 723 | 51 | 23 | 649 | 1304 | 7942 | 9918 |
| 2016 | 0,16% | 802 | 54 | 0 | 535 | 754 | 1408 | 2697 |
| 2017 | 0,11% | 764 | 52 | 0 | 675 | 2423 | 314 | 3412 |
| 2018 | 0,16% | 864 | 43 | 0 | 1681 | 811 | 1614 | 4107 |
| 2019 | 0,10% | 515 | 47 | 0 | 1928 | 1660 | 5887 | 9476 |
| 2020 | 0,09% | 206 | 60 | 2 | 3031 | 12148 | 8714 | 23895 |

*Notes: All figures are annual and computed over the 20 year sampling period*

In Table 3 below, the wide range in TFP growth (-6.83 to 6.71) suggests significant differences in productivity changes across different companies and the years. This variability could be reflective of the diverse impact that VC funding has on companys' productivity. Companies that receive VC funding might experience substantial growth in productivity due to enhanced resources and strategic guidance, while others might struggle due to various market and operational challenges. The distribution of VC funding across different stages, with the expansion stage having the highest mean (0.0824), followed by the early stage (0.0505), seed stage (0.0313), and late stage (0.0307), suggests that venture capital investors are more prone to invest in companies that have moved beyond the initial ideation and early development phases.

**Table 3:** Summary statistics for dependent variables and VC dummy variables

| | Patent dummy | TFP growth | VC_dummy x Seed | VC_dummy x Early | VC_dummy x Expansion | VC_dummy x Late |
|---|---|---|---|---|---|---|
| Min | 0 | -6,83 | 0 | 0 | 0 | 0 |
| Max | 1 | 6,71 | 1 | 1 | 1 | 1 |
| Mean | 0,1934 | 0,14 | 0,0313 | 0,0505 | 0,0824 | 0,0307 |
| SD | 0,3950 | 0,71 | 0,1742 | 0,2189 | 0,2749 | 0,1726 |
| #Obs. | 10 644 | 9449 | 10 644 | 10 644 | 10 644 | 10 644 |

*Notes: All figures are annual and computed over the 20 year sampling period*

## 5.2 Patent Results

**Table 4:** The results of the regression models

| **Model** | **1** Patent | **2** Patent | **3** Patent | **4** Patent | **5** Patent |
|---|---|---|---|---|---|
| Seed | -0,0752*** | 0,0498 | 0,0498 | 0,1263*** | 0,0772*** |
| Early | -0,0083 | 0,0608*** | 0,0609*** | 0,0378** | 0,0297* |
| Expansion | -0,0207* | 0,0385*** | 0,0385*** | 0,0434*** | 0,0333*** |
| Later | -0,0196 | 0,0245 | 0,0245 | -0,0022 | -0,0186 |
| R&D | - | 0,0000*** | 0,0000*** | 0,0000** | 0,0000** |
| GDP growth | - | 0,3097*** | 0,3095*** | 0,2961*** | 0,3193*** |
| Constant | 0,1981*** | -0,1963* | -0,0046 | -0,1813 | -0,2058* |
| Observations | 10644 | 8895 | 8895 | 7277 | 5920 |
| F | 5,28*** | 8,13*** | 6,97*** | 8,81*** | 5,62*** |
| Industry | - | NO | YES | NO | NO |
| Within $R^2$ | 0,0022 | 0,0061 | 0,0061 | 0,0082 | 0,0065 |

**Note:** The dependent variable for all models is a dummy variable for patent application. Model 1 is regressed using no control variables. Model 2 through 5 is conducted with the control variables R&D and GDP growth. Model 2 is also conducted without any controls for industry. Model 3 is conducted with control for industry. Model 4 and Model 5 are conducted using a 2 year lag and 4 year lag, respectively, for dummy variables representing VC investment in seed, early, expansion and later stages.

* Means statistically significant at the 10% level.

** Means statistically significant at the 5% level.

*** Means statistically significant at the 1% level.

The value of coefficients in the models is interpreted as follows: a positive (negative) sign before a coefficient is related to have a positive (negative) effect on the dependent variable. It can be noted that the observations range from 10 644 in Model 1, with the inclusion of control variables the observations lowers to 8895. The observations might be lower due to the inclusion of control variables that may be missing on some of the companies in the patent data. Some companies may or may not report R&D data, or other economic data may be missing. The drop of almost 2000 might seem large, but the models are still significant indicating that it is not a major issue for the study. A sample size of thousands of observations are generally considered to be robust. As mentioned, the prob > F remains highly significant on the 1% level through all models, indicating that overall the models are robust. The $R^2$

values is considered quite low, but compared to the highly significant prob > F values, it still suggests the models provide important relationships. The low $R^2$ values indicate the complexity of capturing the patenting activity. When using interaction terms, the variable will capture the combined effect of receiving venture capital funding and getting it in the seed stage of the investment phase (or other investment stages) and how it affects the likelihood of patenting, beyond the individual effects of being in the seed stage and receiving VC funding. The interpretations of the coefficients model 1 through 3 is as follows: The combined effect for companies getting VC funding and being in a certain stage, are X units more/less likely to file for a patent compared to companies not receiving VC funding, keeping all other constants. The interpretation regarding the 2-year lagged scenario is as follows: Two years after receiving seed stage VC funding, the increase in likelihood of petenting is 0,1263 units.

Regarding the seed stage initially seed stage VC investments show a negative impact on the likelihood of patenting. This is also the case for the expansion stage. The inclusion of control variables as well as industry fixed effect, the negative effect becomes positive. Although in the seed stage this change is not significant, it is significant in the early and expansion stage. Shifting the focus to the two lagged scenarios, both lags at the seed stage are highly significant on the 1% level. For 2-year respective 4-year lag the positive effect is larger for the 2-year lag with a coefficient of 0,1263 that reduces for the 4-year lag to 0,0772. For early stage investment the 2-year lag is significant on the 5% level while the 4-year lag is significant on the 10% level. Regarding the expansion stage we see statistical significance through all models. The two lagged scenarios are significant at the 1% level. Regarding later stage VC investments, there is no significance through any of the models used. Controlling for industry has either no or marginal effect on the coefficients compared to model 2.

To summarize, model 2 and 3 support our hypothesis in the stages early and expansion. The null hypothesis can be rejected and looking at the 1% significance we can say with confidence that venture capital financing has an effect on innovation in these two stages. Introducing the lagged values in model 4 and 5. We can reject the null hypothesis with confidence on the 1% significance level in model 4 (seed and expansion stage), and model 5 (seed and expansion stage). Consistently the later stage has no significance and we cannot reject the null hypothesis in any of the 5 models.

## 5.3 TFP Results

**Table 5:** The results of the regression models

| **Model** | **1** TFP growth | **2** TFP growth | **3** TFP growth | **4** TFP growth | **5** TFP growth |
|---|---|---|---|---|---|
| Seed | 0,5820*** | 0,5596*** | 0,5723*** | 0,1957*** | 0,0651 |
| Early | 0,5042*** | 0,5159*** | 0,5400*** | 0,0943* | 0,1224*** |
| Expansion | 0,1921*** | 0,1988*** | 0,2076*** | 0,0463 | -0,0113 |
| Later | 0,0580 | 0,0473 | 0,0471 | -0,0741 | -0,0592 |
| R&D | - | 0,0000 | 0,0000 | 0,0000 | 0,0000 |
| GDP growth | - | 1,7089*** | 1,7077*** | 0,9949*** | 1,0019*** |
| Constant | 0,111*** | -1,6869*** | -2,2886 | -1,0067*** | -1,0369 |
| Observations | 8896 | 8895 | 8895 | 7102 | 5713 |
| F | 35,66*** | 132,58*** | 115,95*** | 112,73*** | 110.09** |
| Industry | NO | NO | YES | NO | NO |
| Within $R^2$ | 0,0176 | 0,1031 | 0,1048 | 0,1118 | 0,1340 |

**Note:** The dependent variable for all models is TFP growth, calculated as a logarithm. Model 1 is regressed using no control variables. Model 2 through 5 is conducted with the control variables R&D and GDP growth. Model 2 is also conducted without any controls for industry. Model 3 is conducted with control for industry. Model 4 and Model 5 are conducted using a 2 year lag and 4 year lag, respectively, for dummy variables representing VC investment in seed, early, expansion and later stages.

* Means statistically significant at the 10% level.

** Means statistically significant at the 5% level.

*** Means statistically significant at the 1% level.

The value of coefficients in the models is interpreted as follows: a positive (negative) sign before a coefficient is related to have a positive (negative) effect on the dependent variable. It can be noted that the observations of the models range from 8896 in model 1 to 5713 in model 2. The decrease in observations is due to the lagged variables, which naturally reduce the sample size because the earlier years of data will be excluded. The F value in all models has a prob > F lower than a 1% level. This means all models are highly statistically significant. The within $R^2$ values rise significantly when introducing the first control variables in model 2. To then be raised again with the introduction of lagged variables, with the highest $R^2$ value being in model 5 with the 4-year lag. Which suggests that the inclusion of lagged variables might provide a more comprehensive understanding of their effects on productivity, although it is noted that the change is quite small going from 0,1118 in model 4 to 0,134 in model 5. When using interaction terms, the variable will capture the combined effect of receiving venture capital funding and getting it in the seed stage of the investment phase and how it affects TFP growth, beyond the individual effects of being in the seed stage and receiving VC funding. The interpretations of the coefficients in model 1 through 3 is: the combined effect of getting VC funding and being in a certain stage, will increase or decrease TFP growth with X units, keeping all others constant. When using lagged variables it means that, for example, if using 2-year lag. Two years after receiving seed stage VC funding, the increase in TFP growth is 0,1957 units.

The results indicate that seed stage investment has a positive impact on TFP growth across model 1 through 4. In Model 1, that lacks control variables, the coefficient is 0,582 and highly significant on the 1% level. When control variables are introduced the coefficient is not changing on a noticeable level. In the introduction of a 2-year lag it shows a substantial reduction in the coefficient to 0,1957 and remains significant at a high statistical level of 1%. Introducing the 4-year lag the results are no longer significant. Early stage investments also exhibit positive impacts, and through all models used. The coefficient increases slightly when additional control variables are introduced, ending up in a more positive coefficient of 0,54 also highly significant at the 1% level. The 2-year lag being significant at the 10% level and the 4-year lag significant at the 1% level both show decreasing coefficients, with the 2-year lag having the biggest reduction to 0,0943. For the expansion stage the coefficients range from model 1 with 0,1921 to 0,2076 in model 3 having industry fixed effects with all of them being highly significant at the 1% level. Model 4 through 5 does with lag show no statistical significance. The later stage investment, on the other hand, shows no significance on any of the models 1 through 5.

To summarize, looking through model 1 to 3 our hypothesis can be supported in the stages of seed, early and expansion. The null hypothesis can be rejected and looking at the 1% significance we can say with confidence that venture capital financing has an effect on innovation in the first three stages. Introducing the lagged values in model 4 and 5. We can reject the null hypothesis with confidence on the 1% significance level in model 4 (seed stage), and model 5 (early stage). Consistently the later stage has no significance and we cannot reject the null hypothesis in any of the 5 models.

## 5.4 Robustness test

In order to validate the chosen method for this research. To conclude that models and results are reliable enough to say anything about the underlying population a robustness test has been conducted. To begin we use a Hausman Test to check whether fixed effects or random effects are more appropriate. Results can be seen below. In econometric analysis, choosing between fixed effects and random effects is crucial for ensuring the validity of the estimates. The Hausman test helps determine the appropriate model by testing if the unique errors (unobserved effects) correlate with the regressors (Hausman, 1978).

### 5.4.1 Hausman test

**Table 6**: Hausman fixed random for patent regression

| | Chi-Sq Statistic | p-values | Type of regression model |
|---|---|---|---|
| Model 1 | 22,98 | 0,0001*** | Fixed effects |
| Model 2 | 46,07 | 0,0000*** | Fixed effects |
| Model 3 | 45,52 | 0,0000*** | Fixed effects |
| Model 4 | 17,11 | 0,0018*** | Fixed effects |
| Model 5 | 6,96 | 0,0138** | Fixed effects |

**Table 7**: Hausman fixed random for tfp_growth regression

| | Chi-Sq Statistic | p-values | Type of regression model |
|---|---|---|---|
| Model 1 | 10,22 | 0,0368** | Fixed effects |
| Model 2 | 36,34 | 0,0000*** | Fixed effects |
| Model 3 | 37,01 | 0,0000*** | Fixed effects |
| Model 4 | 27,33 | 0,0000*** | Fixed effects |
| Model 5 | 16,83 | 0,0048** | Fixed effects |

Based on the Hausman tests above, the fixed effects model is more appropriate than the random effects model for the analysis. The significance on the p-value indicates that there are systematic differences between the coefficients estimated by the fixed effects model and those estimated by the random effects model. Implying that the random effects model is violated under the assumption that unobserved effects are uncorrelated with the regressors. The Hausman tests above yield p values lower than 5% significance in all 5 models for both tfp_growth and patent. Therefore in both tests the null hypothesis can be rejected and the fixed effects model is concluded to be suitable (Hausman, 1978).

### 5.4.2 Correlation matrix

**Table 8**: Correlation matrix on the independent variables

| | Seed | Early | Expansion | Later | R&D | GDP growth | Industry |
|---|---|---|---|---|---|---|---|
| Seed | 1 | | | | | | |
| Early | -0,0135 | 1 | | | | | |
| Expansion | -0,0201 | -0,0352 | 1 | | | | |
| Later | -0,0131 | -0,0229 | -0,0341 | 1 | | | |
| R&D | -0,0120 | -0,0121 | 0,0087 | 0,0157 | 1 | | |
| GDP growth | 0,0551 | -0,0082 | 0,0580 | -0,0011 | -0,0519 | 1 | |
| Industry | 0,0053 | 0,0329 | 0,0257 | 0,0024 | 0,0118 | -0,0103 | 1 |

To examine the relationships between the variables used, we formed the above correlation matrix. This provides the correlation coefficients between each pair of variables. These coefficients indicate the strength and direction of the linear relationships between the variables ranging from -1 (perfect negative correlation) and 1 (perfect positive correlation), with 0 indicating no relationship. The weak correlations imply that each variable provides unique information about each of the dependent variables, TFP growth and patent applications. This enhances the robustness of the chosen models and independent variables. Given the weak correlations we can be more confident that inclusion of these variables in our regression model will help in understanding their individual contributions to the dependent variable without running the risk of multicollinearity (Feinstein et al, 2002).

# 6. Discussion

## 6.1 The result

This study investigates the impact of Venture Capital (VC) investments on Total Factor Productivity (TFP) growth and patent applications. The analysis is grounded in the previously presented theories and research. The results shown above indicate that generally VC investment does have an impact on innovation in terms of presence of patent applications and TFP growth. The analysis is framed within the “Venture Capital First Hypothesis”.

Analyzing patents the relationship between VC investment and patent output demonstrates for the most part positive. The relationship between VC investments and patent application demonstrates a positive impact for all models except model 1, particularly for early stage investments. Although it should be noted the positive impact is rather weak. These findings align with the "Venture Capital First Hypothesis”. Seed stage investments initially show a negative impact on patent applications, but turn positive in the lagged models. This delayed effect suggests that the benefits of seed investments on innovation take time to materialize. The initial negative impact might be due to the early stages of product development, where firms are focused on foundational R&D and may not yet have reached the patenting phase. Over time, as these early investments mature, they translate into patentable innovations, reflecting the transformative role of VC in enabling long-term R&D activities (Kortum & Lerner, 2000). Early stage investments show a significant positive impact on patent presence from model 2 through 5. Model 2 and 3 indicate that early-stage VC funding is crucial for enabling firms to patent their innovations. This aligns with the theory that highlights the importance of VC investments in supporting the development of innovation (Gompers & Lerner, 2001). The relationship between VC investments and the presence of patent application in the expansion stage investments follows a similar pattern to seed stage investments, with positive coefficients except for in model 1. The positive but little smaller coefficients for expansion stage investments reflect the role of VC investment in helping firms upscale their operations, which can lead to patentable innovations, but may be less immediate than the initial stages of R&D (Popov & Roosenboom, 2012). Later stage investments, however, do not show significant impacts on the likelihood of patenting. This lack of significance indicates that mature companies, which have already established their market presence and operational foundations, may not benefit as much from additional VC investment funding in terms of producing new patents. This aligns with the diminishing returns theory, suggesting that the incremental benefits of additional investments decrease as firms mature and have already optimized their innovation processes (Mollica & Zingales, 2007).

Analyzing TFP growth we see that seed stage investment does have significant positive impact Generally it can be seen that the effect of VC investment on TFP growth decreases in all stages and all models. This suggests that  immediate productivity gains are effective shortly after the investment, aligning with the phase of product development and market strategy formulation, where initial financial support is crucial. The impact of seed investments on TFP growth becomes less significant with a two-year lag and is not significant with a four-year lag, indicating that the immediate benefits of these investments lessen over time. This pattern can be connected to the theory that early-stage VC investments are crucial for future productivity gains. The initial high significance of seed stage investments aligns with the "Venture Capital First Hypothesis," which posits that early-stage funding provides essential resources for R&D and initial market entry activities, crucial for establishing a strong foundation for future growth. These early investments often fund high-risk, high-reward projects that traditional financing could avoid (Kortum & Lerner, 2000). However, as the time goes the immediate impacts of these investments lessen. The decline in significance with a two-year lag and the insignificance with a four-year lag suggest that the initial burst of productivity spurred by seed funding is not sustained without ongoing innovation and reinvestment. This phenomenon is consistent with the dynamic nature of technological progress, where initial innovations need continuous development and refinement to maintain their competitive edge and productivity contributions (Gompers & Lerner, 2001). Early stage investments also show a significant positive effect on TFP growth, with coefficients remaining significant across models. The positive impact decreases with a two-year lag (0.0943 in Model 4) but remains significant, highlighting that the initial impact is strong but diminishes over time. This trend mirrors the impact observed with seed stage investments, reinforcing the importance of early VC funding in providing the necessary capital and strategic support for firms to scale their operations and improve productivity. The sustained significance even with a 4-year lag suggests that early stage investments might have a slightly longer-lasting impact compared to seed stage investments, possibly due to the more mature nature of firms at this stage, which can better leverage the VC resources for productivity improvements (Popov & Roosenboom, 2012). Expansion exhibits weaker and often insignificant impacts on TFP growth. The coefficients for expansion stage investments are positive but less significant (0.1921 in Model 1, decreasing to 0.0463 in Model 4), reflecting short-term effects that fade over time. Later stage investments consistently show no significant impact as in patents, indicating that mature companies may not experience substantial productivity gains from additional VC investment funding. This decreasing impact of later stage investments aligns with the theory that the marginal returns on investment decrease as firms mature. Once companies reach a certain level of development, the additional capital might not translate into proportional productivity gains because these firms have already optimized many of their processes and scaled their operations. This concept is supported by the diminishing returns to scale in economic theory, which suggests that as a firm grows, the incremental benefits of additional investments decrease (Mollica & Zingales, 2007).

In summary the results indicate that VC investment impacts innovation (defined as patents and TFP growth), particularly in the seed and early stages. These findings align with the "Venture Capital First Hypothesis," emphasizing the importance of early-stage funding in fostering innovation. Although the impact can be regarded as quite low referring to the rather low coefficients.

## 6.2 Limitations

Potential limitations to the study are important to notice. Firstly, this study only includes two inputs of innovation, TFP growth and patents, among various other measures of innovation. The choosing of only two inputs was due to the limited timespan of the study. Other studies within the area have included several other measures. Naser & Weiderborn (2023) for example is a study where IPO, GDP growth and interest rate were included. Other studies have looked at R&D expenditure and level of entrepreneurship. Regarding the variable of patent, this thesis used patent as a dummy variable, meaning 1 for having any patent at all and 0 for not having patents. Other interpretations of patents could be citation-weighted patents, which could further analyze how useful the granted patents really are. This would give stronger indication if VC investments lead to innovation or not. The amount of patent renewal (of the granted patents) could also be a stronger indicator of the usefulness. Using both citation weighted and/or amount of renewal would be a better indicator of how innovative and useful these patents really are. For example ten patents could be just as innovative as five patents depending on their usefulness.

Another potential limitation is the dataset used. There could exist potential biases because the dataset used only includes observations with companies who have gotten venture capital investment. The included companies may only reflect a certain type of innovative company. Some other studies have included a control group which has been used to compare the non venture backed and the venture backed companies. A control group could give more robust results, because it would isolate the effect of venture capital on the innovation outcomes. Although establishing and creating a control group requires time consuming work, which were discussed during the writing of this thesis. For example, how can one be sure that the control group is representative with regards to size and existing innovativeness. It was in the end considered to be too much workload ensuring a representative control group, with regards to time frame as well as having enough data available.

# 7. Conclusion and Future Research

The results of this study can be interpreted as an indicator that VC investment has a positive effect on both TFP growth and presence of granted patent applications, although the positive impact differs between the stages. This study underscores the critical role of VC investments in driving innovation and productivity growth for Swedish companies receiving VC funding. Seed and early stage investments are particularly effective, providing essential financial support that fosters initial innovation efforts and enhances productivity. By strategically investing in early-stage ventures, VC investors can help improve both productivity and innovation outputs, contributing to expansion of economic growth and technological progress. These findings offer insights for policymakers and investors aiming to stimulate economic growth through targeted VC funding, highlighting that earlier stages of funding can maximize innovative outputs and productivity improvements.

Future research should introduce other metrics as discussed under section 6.2 limitations. For example citation-weighted patents, as well as the amount of patent renewal of the granted patents and other metrics of innovation as discussed above. Furthermore, this study focused on the "Venture Capital First Hypothesis", but there also exists an "Innovation First Hypothesis". Further analysis from this study could explore the second hypothesis. Exploring this can be problematic due to causality and reverse causality, which is why serious care needs to be taken when interpreting results, to minimize measurement error. Additionally, the fact that highly innovative firms are more likely to receive VC funding, an eventual positive relationship may be driven by pre existing innovativeness rather than the number of granted patent applications/TFP growth in itself. Using a control group, as mentioned above in section 6.2, could mitigate this problem by isolating the effects and better see the direction of the causality.

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# Appendix

Explanation variables defined in datasets and used in the regressions

| **VARIABLE** | **EXPLANATION** |
|---|---|
| TFP growth | The calculated annual TFP growth per company. |
| Patent | A dummy variable for patent application. Takes value 1 if there is a patent application which has been granted, otherwise value 0. |
| Seed | Interaction term for getting venture capital investment and in the seed stage. |
| Early | Interaction term for getting venture capital investment and in the early stage. |
| Expansion | Interaction term for getting venture capital investment and in the expansion stage. |
| Later | Interaction term for getting venture capital investment and in the later stage. |
| R&D | Amount R&D investment in each company. |
| GDP growth | GDP growth calculated annually over each year. |
| Industry | Industry is a variable controlling for 12 different industries. |