

Exploring Venture Capital Investment Impact on Innovation

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ABSTRACT: It is widely held that venture capital investments play an important role in stimulating innovation; however, most of the existing research centers around venture capital funding of innovation. Different quantitative empirical studies on the topic are utilized in this paper to achieve a qualitative, in-depth understanding of the effect venture capital investment has on innovation and vice versa. In this research, the intersection of innovation and venture capital will be explored under three thematic frameworks: patent count, productivity & patent count, and persistence of innovation. This paper supports the innovation-first hypothesis as it suggests that venture capital investment may not spur innovation, but instead, likely benefits from innovation by selecting firms with high innovative capabilities, as they have high potential for growth. In fact, venture capital investment can often prevent further innovation to monetizing existing innovation.

KEYWORDS: Economics, Venture Capital, Innovation, Patents, Productivity.

■ Introduction

As an industry, venture capital was created to close the gap between institutional funding and early-stage companies, often referred to as startups. Venture capitalists make investments in startups in the form of equity.¹ Thus, they partake in the profits and losses from the company's innovation.¹ Venture capital plays an important role in driving growth and is likely to continue to fuel growth and prosperity.² As a result, it has played a crucial role in changing the trajectory of the innovation economy around the world. It has funded the launch of major markets and leading companies like Google, Oracle, and Apple.^{3,4} Other leading venture-backed companies include Alphabet, Facebook, Microsoft, and Alibaba.⁵ However, picking a winning company continues to remain one of the greatest challenges for a venture capitalist.⁴ Innovation and technological progress can be difficult, taking years to make a major impact on the market before finding an unexpected result.² However, multiple studies have found that venture-backed firms grow faster, have better financial results, and report more innovation than firms that are not venture-backed.⁶ To effectively encourage innovation, venture capitalists subsidize new firms and provide them with capital, along with managerial resources.⁷ Documented investment cycles on venture capital have often shown a relationship between radical innovations and financial market activity.⁸

In addition to venture capitalists, the other element to consider is governmental impact on innovation. If this paper finds that venture capital investment does, in fact, help spur innovation, there are multiple policy implications. Economists and policymakers have agreed that greater innovation is needed, especially due to lagging productivity growth in multiple Western nations.⁹ Policymakers should consider the impact venture capital has on an economy due to its ability to encourage innovation.⁶ The government is critical to fueling the venture capital industry, which can, in turn, promote economic growth, job creation, and better standards of living.¹⁰ To promote in-

novation, governments can make policies that help facilitate venture capital investment.⁶ In addition, the government can take steps to ensure that the legal ecosystem is favorable for venture capital to drive more investments, and thus increase innovation.⁶

While it is clear that innovation is a crucial element in venture capital, the measures of innovation can vary. A study by Kortum and Lerner,¹¹ a study conducted by Engel and Keilbach,¹² and a study by Caselli, Gatti, and Perrini¹³ attempt to use patent count to measure innovation because innovation as an ideology is difficult to quantify. Patent count measures the growth of new technology even if it has not been adopted yet.⁷ Therefore, it is believed to be an effective measure of innovation, as newly developed technology does not necessarily have to be put into use and be adopted to be considered innovation. In addition, patents granted to companies backed by venture capitalists are usually cited more often, implying that venture capitalists do play a role in innovation. Venture capitalists helping stimulate patent count is associated with the "VC-first hypothesis"⁷ created by Hirukawa and Ueda⁷ to explain the idea that venture capitalists spur innovation.

However, Hirukawa and Ueda⁷ bring to the surface the point that this approach is one-sided, as it fails to consider the opposite: that innovation opportunities lead to more firms and start-ups tapping into that new opportunity. This will then lead to a greater desire among venture capitalists to invest in these new startups, accelerating the growth in the venture capital market. Hirukawa and Ueda described this concept as the "innovation first hypothesis."⁷ This concept essentially states that venture capitalists choose to invest in more innovative firms. Both ideologies must be considered when understanding the relationship between venture capital investment and innovation.

Some researchers mention how innovation can exist without the creation of any patents.^{2,7,14,15} Instead, existing technologies can exist uniquely, creating a new product or service without

having to create a new technology.² Arvanitis and Stucki¹⁴ found that the two main reasons why patents count as a measure of innovation can be limited. Firstly, not all innovations can be patented, and secondly, the process of applying for and receiving a patent can take time and is associated with high costs.¹⁴ The main disadvantage of only measuring patents is that many other forms of innovation are not captured.¹⁵ To address this issue, Hirukawa and Ueda⁷ measure innovation in two different ways: total factor productivity and patent count. Unlike patent counts, total factor productivity tests innovation and growth resulting from adopting new technology.⁷ Therefore, innovation driven by utilizing existing technology in a new way will still be accounted for through this approach. It is crucial to account for both measures of innovation to achieve a well-rounded understanding of venture capital and innovation.

Others argue that labor productivity growth could be a better measure of innovation than total factor productivity growth, as it does not require non-labor inputs to be measured. These non-labor inputs include capital, material, and energy. The measurements of non-labor inputs are difficult, so the estimated total factor productivity is greatly dependent on the method used to measure it.¹⁶ On the other hand, labor productivity growth is not the most accurate measure of innovation either. Labor productivity only measures one aspect of productivity, unlike total factor productivity. Labor productivity could increase simply due to other productive inputs being used instead of labor inputs, even when there is no actual improvement in efficiency. Therefore, the proportion of the productive inputs must remain the same in order for labor productivity to be an accurate measure of innovation.¹⁶ Thus, even though each measure of innovation has its drawbacks, it is important to consider each of them when evaluating the impact on innovation, as they each fit into a slightly different, but crucial, definition of innovation.

However, venture capital does not always have positive impacts. Many potential problems exist between companies and venture capitalists, including conflicts with the allocation of effort, information asymmetries, and the valuation of the commitment the financier has to the company's development.¹³ Therefore, it is critical to consider that venture capital could have a neutral or even negative impact on innovation. To solve this, the difference in innovation in venture-backed and non-venture-backed firms has to be reviewed further by understanding the effect on innovation before and after funding. Innovation should undoubtedly be found before venture capitalist involvement if the venture capitalists are searching for innovation in potential firms. Since venture capital is designed to aid firms in using innovation to give them an advantage in the market, innovation should also be evaluated after investments from venture capitalists. Thus, it is necessary to test if innovation is sustained after venture capital involvement.¹³

It is also crucial to consider that venture capital investment may have a different effect on innovation in the short-term activities of firms versus the long-term activities of firms. This is especially important because venture capital investment may stimulate innovation in the long-term, even if it does not have an effect in early stages.¹⁴ Thus, the time horizon of the invest-

ment needs to be taken into account. The innovative results one year after venture capital investment may vary from four years post-investment. Therefore, persistence of innovation activities must be taken into consideration.

Other researchers have focused specifically on how venture capital investment promotes open innovation or corporate innovation.^{17,18} Additionally, some researchers go as far as stating that innovation is no longer consistently driven by research and development within corporations, but, instead, venture capitalists are needed to spur breakthrough innovation.¹⁹ In 2021, Yi, Wang, Lyu, and Xia conducted a study to determine whether venture capital investment promotes open innovation in China. Open innovation is a process in which sharing and combining innovation are used to reduce development costs, prevent long-term development cycles, and improve efficiency in innovation.¹⁷ They found that venture capital investment does have a positive effect on open innovation, but the extent varies in different regions.¹⁷ In 2025, Wang, Ma, Yu, and Guo explored how venture capital investment influences corporate innovation. They concluded that venture capital investment does positively affect corporate innovation, but the effect is more significant when the firms have intense industry competition or lack financial resources. Their findings also suggest that earlier venture capital investment has a more significant effect on the innovation of the firm.¹⁸ Lee, Oh, Shin, and Yoon²⁰ also determined that venture capital investment has a positive influence on corporate innovation even in areas with government intervention like Korea.²⁰

While there are multiple studies researching the way in which venture capital affects certain aspects or sections of innovation, there is a lack of resources discussing how venture capital affects innovation using multiple definitions of innovation. Considering all of the above, the present paper is a synthesized review of the empirical literature in order to explore the intersection of venture capital and innovation through patent count as innovation, productivity as innovation, and short-term and long-term effects on innovation qualitatively, and discuss whether venture capital or innovation comes first. This paper utilizes existing quantitative empirical studies to extrapolate a qualitative perspective of venture capitalists' effect on innovation through three thematic analytical components:

1. Patent count

Venture-backed firms patent more than non-venture-backed firms, but this exists before the venture capital investment.

2. Productivity and patent count

The "innovation-first hypothesis"⁷ is supported in regard to both total factor productivity and patent count.

3. Persistence of innovation

Venture capitalists do not spur innovation in initial innovative activities or the persistence of innovative activities.

The findings from the three themes explored inform a synthesized review of the effect venture capital has on innovation.

■ Methods

This paper will perform a thematic analysis based on secondary data from existing literature. For the data accessed, a

keyword search has been performed to identify the necessary quantitative literature regarding 'venture capital influence on innovation'. This search finds three relevant articles, but a greater selection of literature is needed. Therefore, 'innovation and venture capital' is used as a more general key search term, resulting in five more articles to be found. Each of the articles is read in depth to choose a more selective list of six articles that have the appropriate quantitative research needed for the study.

The chosen six papers are then categorized into three themes after a deeper analysis of their research inquiry. Each of the papers within each theme used different empirical models to test innovation. The organization of the papers into the three themes (patent count, productivity & patent count, and persistence of innovation) is illustrated in Table 1, Table 2, and Table 3. Each paper is categorized into one of the three themes to be analyzed individually, to eventually gather a holistic understanding of the theme, and to inform a review of the venture capital effect on innovation.

Table 1: Organization of articles into patent count thematic framework.

Themes	Title	Authors & Year of Publication	Research Inquiry	Methods	Limitations
Patent Count	1. Does venture capital spur innovation?	1. Samuel Kortum & Josh Lerner (1998)	1. Direct impact of patent count on innovation in 20 industries from 1965 to 1992	1. Linearized patent production function with VC investment and R&D as inputs	1. Limited analysis with a simple stylized model because they were the first in the field, and they only used patent count as an innovation measure. ¹¹
Patent Count	2. Firm-level implications of early-stage venture capital investment—an empirical investigation	2. Dirk Engel, Max Keilbach (2006)	2. Difference in innovation and firm growth in 21,541 young German firms with 0.66% venture-backed firms before and after venture capital involvement	2. Statistical matching procedures, probit estimation	2. They used only patent count as a measure of innovation, which is a narrow measure. ¹²
Patent Count	3. Are venture capitalists a catalyst for innovation	3. Stefano Caselli, Stefano Gatti, & Francesco Perrini (2008)	3. Difference in innovation and firm growth in 37 venture-backed and 37 non-venture-backed firms that got an IPO in Italy in 1995-2004 by measuring innovation before and after venture capital involvement to test if innovation existed before venture capital intervention or if venture capital was spurring the innovation, as well as measuring firm growth	3. Statistical matching procedure, Selection process with consideration to the time horizon model on the development of patents	3. They used only patent count as a measure of innovation, and findings can only be generalized to venture-backed firms that use IPO as an exit strategy. ¹³

The patent count thematic framework contains three articles: Kortum and Lerner's¹¹ study in 1998; Engel and Keilbach's¹² study in 2006; and Caselli, Gatti, and Perrini's¹³ study in 2008. Each article has its own research focus and limitations, but all of them use patent count as the measure of innovation.

Table 2: Organization of articles into productivity and patent counts thematic framework.

Themes	Title	Author & Year of Publication	Research Inquiry	Methods	Limitations
Productivity & Patent Count	1. Venture capital and industrial "innovation"	1. Masako Ueda & Masayuki Hirukawa (2008)	1. Re-test Kortum and Lerner's study on patent count in 19 US manufacturing industries with an extended time period of 1968-2001, and additionally test for total factor productivity growth and labor productivity growth	1. Linearized patent production function with VC investment and R&D as inputs *Use instrumental variables to lessen bias	1. They patent count, total factor productivity, and labor productivity as measures of innovation, each of which each have their own drawbacks. Additionally, when extending Kortum and Lerner (1998) to 2001, they had to hand-collect observations for data with undeterminable SIC codes and had to extend the database themselves, as the NBER discontinued in 1997. (They used the same method the NBER used to construct their database). ¹⁴
Productivity & Patent Count	2. Venture capital and innovation: which is first	2. Masako Ueda & Masayuki Hirukawa (2011)	2. Venture capital investment impact on total factor productivity growth and patent count from 1968 to 2001 in the manufacturing industry	2. Panel AR (autoregressive) models, including testing for Granger-type causality	2. Used total factor productivity and patent count as measures of innovation, which each have their own limitations by definition. ¹⁵

The productivity and patent count thematic framework contains two articles: Ueda and Hirukawa's¹⁶ study in 2008 and Ueda and Hirukawa's⁷ study in 2011. Each article has its own research focus and limitations, but both use productivity (total factor productivity or labor productivity) and patent count as measures of innovation.

Table 3: Organization of articles into the persistence of innovation thematic framework.

Themes	Title	Authors & Year of Publication	Research Inquiry	Methods	Limitations
Persistence of Innovation	1. The impact of venture capitalism on the persistence of innovation activities of startups	1. Spyros Arvanitis & Tobias Stucki (2013)	1. Early stage venture capital effect on short-term and long-term innovation of start-ups by analyzing startups founded in Switzerland in 1996/7 over a span of 10 years *Initial innovation activities are defined as 3 years after startup creation	1. Selection model and propensity score matching model	1. There are natural limitations to the selection model and propensity score matching model used in the study. ¹⁴

The persistence of innovation thematic framework contains one article: Arvanitis and Stucki's¹⁴ study in 2013 study. The article used the selection model and propensity score matching model as methods to measure the persistence of innovation.

In this paper, there is an important distinction between the selection effects and the treatment effects. In the six papers, venture-backed firms tended to have higher levels of innovation and non-venture-backed firms tended to be less innovative, in general. So, there is consistent evidence across the six review papers that venture capitalists tend to select more innovative firms. Thus, the selection effects are strong. However, the treatment effects were mixed, as some of the papers found that venture capital did spur certain measures of innovation, while others found no such evidence. The majority of the papers that did not find evidence were using a matched pair system or time-lag system that allowed them to measure innovation before and after venture capital investment.

The methodology used in this paper has various limitations. Firstly, this paper only uses existing data, each with its own limitations, to inform the understanding of venture capital's impact on innovation (Table 1, Table 2, and Table 3). Secondly, each theme uses only a limited number of articles in order to create a central concept on a subset of innovation. Thus, the restricted search categories may be a limitation that had an effect on the findings of the study. Additionally, the six papers used to understand each thematic framework are relatively old and may not reflect the most recent developments in the field. Therefore, it does not aim at empirical generalization, but a synthesized review of the existing literature in the field. However, venture capital's impact on innovation may differ across industries, but this paper doesn't explore industry differences, which may be a limitation of the findings. To mitigate the existing limitations, this paper uses a wider variety of data across themes to ensure a more informed conclusion on the overall effect of venture capital on innovation.

■ Results and Discussion

3.1. Patent Count:

To understand the direct impact that venture capital has on patent count as a measure of innovation, existing studies provide important context. In 1998, Kortum and Lerner

conducted a study on the intersection of venture capital and innovation, utilizing patent count as their measure of innovation. Their study was the first conducted on the topic of venture capital and innovation. It laid the framework for all future studies. They explored twenty industries in the United States manufacturing sector from 1965 to 1992. The industry of a firm was determined by the technological classification of the patent. Their study utilized reduced-form regressions to analyze the impact venture capital funding had on the number of innovations granted patents. Additionally, they controlled for research and development (R&D) funding. Their research found that venture capital funding is correlated with an increase in patenting. However, the simple reduced-form regression model Kortum and Lerner¹¹ utilized in their study might have overstated the effect of venture capital funding on innovation. Instead, venture capital and patents could be affected by the arrival of entrepreneurial opportunities, an additional unobservable variable. To address this, they considered the discontinuity in the venture capital industry in 1979 when the Employee Retirement Income Security Act was clarified, consequently allowing pensions to invest in venture capital and leading to an increase in venture capital funds.¹¹

The exogenous change allows for a separation of the arrival of entrepreneurial opportunities and the role of venture capital. Kortum and Lerner¹¹ explored this through instrumental variable regressions. In addition, they estimate venture capital funding's impact on the patent-R&D ratio, instead of solely patenting, to address the majority of the causality problems. Even after considering the causality concerns, venture capital funding was still found to have a significant positive impact on innovation. Their results imply that compared to a dollar of traditional R&D, a dollar of venture capital would be ten times more successful in stimulating patents. Yet, it is necessary to consider whether patents, the dependent variable utilized in the analysis, are an effective measure of innovation. It is possible that venture capital funding spurs patents without indicating any relationship between venture capital and innovation. Firms backed by venture capital may have a higher number of patents granted than non-venture-backed firms solely because they are concerned that their investor may expropriate their idea or hope to impress possible investors by obtaining a patent even if it is of marginal worth.¹¹

The increase in patenting could simply be caused by the venture financing process's natural inclination to patent innovations. Kortum and Lerner¹¹ studied 530 venture-backed and non-venture-backed firms in Middlesex County, Massachusetts, to understand if the increase in patent filing associated with venture capital was solely caused by a greater propensity to patent. They found that companies backed by venture capital do patent more, but not to the extent that the economic importance of the patent is diluted. Venture-backed patents just tend to be fought more aggressively and to be cited more in other patents. This suggests that the increase in patent count is not simply due to the greater inclination of venture-backed firms to patent.¹¹

When considering the validity of Kortum and Lerner's¹¹ research, it is important to consider if their study accurately

measured a strong positive correlation between venture capital and patents. There was an issue in the way they only estimated the impact venture capital has on patenting without considering research and development, as that would lead to a drastically positively skewed result. However, after further analyzing their own research and results, they realized this issue and instead estimated the impact venture capital had on the ratio of patents to R&D, still finding a positive correlation. There was also a concern that other unmeasured variables that had not been taken into account were affecting the positive relationship between venture capital and patents. Kortum and Lerner¹¹ did eventually address this, though, and considered that the unmeasured variable of entrepreneurial opportunities could have been impacting the correlation between venture capital and patents. But this theory was disproved by utilizing the discontinuity in 1979. Therefore, the positive impact of venture capital on patent count that Kortum and Lerner¹¹ found seems to have significant validity.

Additionally, it must be understood that Kortum and Lerner¹¹ assumed a proportional relationship between patents and innovation. However, in reality, this is not always the case, as multiple different innovative characteristics or variants can be part of the same patent. At the same time, though, if the two innovations are fundamentally different, separate patent applications will be needed, but this is not always the case. It is also crucial to consider that patenting, at a minimum, is a somewhat effective measure of innovation because it accounts for technological innovation that has not been created and may not have been adopted yet.⁷ Therefore, while patenting an innovation may not have a linear relationship, a direct link between patenting and innovation does exist. Thus, even though a strongly positive relationship was found between patenting and venture capital, the implied relationship between venture capital and innovation may be exaggerated in their results. Instead, their study suggests that a milder positive correlation between venture capital and innovation actually exists.

Another study conducted by Engel and Keilbach¹² in 2006 also analyzed the relationship between venture capital investment and innovation using patent count as a measure of innovation. The study also examines the impact venture capital investment has on firm growth. Engel and Keilbach¹² found the number of employees of a firm and sales to be almost linearly correlated, possibly signifying a strong correlation between the variables, so they chose to use employment level as the measure of firm growth. They used a dataset of 21,541 young German firms that were founded between 1995 and 1998. 0.66% of these young German firms were venture-backed. This dataset allowed them to identify the exact movement of the venture capital investment and allowed them to identify "twin" firms, with one venture-backed firm and one non-venture-backed firm. The use of matched pairs helped correct the industry and timing biases that may have existed in Kortum and Lerner's data.¹²

Their study finds that venture-backed firms have more patent applications than non-venture-backed firms, but these applications are obtained before the involvement of venture capitalists. However, after the venture capital investment, the

patent count has an incredibly weak significant difference between venture-backed firms and non-venture-backed firms. The likelihood of a venture-backed firm applying for a patent is greater, but the difference is insignificant, so no correlation between venture capital investment and driving innovation can be found. On the other hand, venture capital investment does correlate with greater employment growth rates. The average growth rate for venture-backed firms is twice the rate for non-venture-backed firms. These findings suggest that venture capitalists look to select firms with the greatest growth potential, and innovative potential is an important factor in finding these firms. So, the higher levels of innovation found in venture-backed firms are likely due to the venture capital selection process rather than being a result of the funding. Thus, it is likely that venture capitalists mainly aid their firms in commercialization, instead of aiding with further innovation, as that would maximize return.¹² While it is very possible that patent applications do not account for all innovation, there is a correlation between patents and innovation. Thus, Engel and Keilbach's¹² findings of a greater number of patent applications in venture-backed firms before the venture capital investment came can be concluded.

Engel and Keilbach's¹² findings, however, are contradictory to Kortum and Lerner's¹¹ study, which found that venture capital investment does have a correlation with innovation measured as patent count. The difference may be because Kortum and Lerner¹¹ did not examine innovation before and after venture capital investment. Instead, they solely looked at whether venture-backed firms had a higher patent count and found this to be true. If this is the case, then their findings are in line with the study conducted by Engel and Keilbach.¹² Both Engel and Keilbach¹² and Kortum and Lerner¹¹ found that venture-backed firms do patent more. However, when Engel and Keilbach¹² looked at the difference in innovation between venture-backed and non-venture-backed firms before and after investment, they found the difference to be significant only before venture capital investment. Thus, it is likely that Kortum and Lerner's¹¹ findings are correct in that venture-backed firms patent more, but due to the method of their study, they did not come to the conclusion that the greater number of patents disappears after venture capital investment. Therefore, this paper finds that venture-backed firms do patent more, but these are obtained before venture capital investment, implying that venture capital selects innovative firms rather than spurring innovation.

In 2008, Caselli, Gatti, and Perrini¹³ conducted a similar study to analyze the intersection between venture capital and innovation as well as firm growth. In regard to innovation, they examine whether innovation exists before and after venture funding, focusing on whether innovation is important for intervention by venture capital and whether venture capitalists can sustain and improve the firm's innovation. Innovation is measured as the number of registered patents, and firm growth is defined as the net sales growth rates. They utilized a sample of 37 Italian venture-backed firms and 37 of 112 non-venture-backed twin firms that all went public from 1995 to 2005 on the Italian Stock Exchange. The dataset allows for a list of all

innovations registered to be built, including innovations that were not registered in Italy. Caselli, Gatti, and Perrini¹³ compared the patent count in the five years before the firm received venture capital investment and the period between the initial venture capital investment and 2004. The non-venture-backed twin firms are examined during the same periods, even though the discontinuity of the venture capital investment does not exist.¹³

Caselli, Gatti, and Perrini¹³ found that venture capital investment does not promote innovation. Before the initial venture capital investment, venture-backed firms register 0.3327 patents more per year than non-venture-backed firms, but after the investment, venture-backed firms register 0.53825 fewer patents than their non-venture-backed counterparts. However, venture capital investment was found to be correlated with sales growth, as venture-backed firms had a sales increase of 5.5% over non-venture-backed firms. This implies that innovation is an important factor that is considered during the venture capitalists' selection process, but once funding begins, venture capitalists do not advance or increase innovation. In fact, it may actually block the firm's continued innovation. Instead, after funding begins, venture capitalists help aid the improvement of economic aspects of the firm, such as firm growth. These results could be interpreted as such that venture capitalists value innovation as a factor in growth potential, but after the investment, they focus their efforts on maximizing firm growth in the hope of a future deal.¹³ It could also suggest that venture capitalists see high innovation activities as a sign of potential monetary success and see that as an opportunity to exploit instead of looking to further advance the innovation of the firm.

When considering the findings of Caselli, Gatti, and Perrini,¹³ it is necessary to acknowledge that their dataset only included firms that had gone public on the Italian Stock Exchange. Thus, their results cannot be generalized to all venture-backed firms, just the venture-backed firms whose exit strategy was an IPO. Therefore, the great shift towards sales and away from innovation may be solely correlated with venture-backed firms that went to an IPO.¹³ However, Engel and Keilbach,¹² who did not solely look at firms that went public, found similar results that found that venture-backed firms patent more, but only before venture capital investment, while firm growth increases after venture capital involvement. Thus, this can be concluded for all venture-backed firms.

It is possible that the slight variation in results from Engel and Keilbach's¹² study and Kortum and Lerner's¹¹ study is due to the different structure and goals of venture capitalists in different countries.¹³ It could also be because Caselli, Gatti, and Perrini¹³ only studied firms that had gone public on the Italian Stock Exchange. However, overall, the results are consistent with those found by Engel and Keilbach¹² and Kortum and Lerner,¹¹ suggesting that venture-backed firms patent more than their non-venture-backed counterparts but only before venture capital involvement.

However, these findings only consider one measure of innovation, patent count, that has its own inherent limitations. Patents legally protect the innovation of a firm from being

copied, so it is incredibly likely that these firms would patent if they believed it was a worthwhile way of protecting their innovation.¹² However, it is possible that firms do not patent even if an innovation exists. This could be due to the fact that not all innovations can be patented. It is also possible that a patentable innovation is not patented, as the patent process is too long in the firm's eyes, and they would, instead, prefer to use secrecy or speed to protect their innovation. Lastly, a firm may not want to disclose knowledge in the innovation that would inevitably be disclosed in the patent application.¹² It is also necessary to consider that firms may apply for multiple patents if aspects of the innovation are fundamentally different, increasing the number of patent applications without increasing the amount of innovation. Yet, it is possible that if the different applications had gotten approved, that would signify that the innovations are fundamentally different and can be considered two separate innovations. It is also important to consider if the increase in patenting was simply due to a natural tendency of the venture capitalists to file for patents without a change in the innovation, but Kortum and Lerner¹¹ found no validity to this concern. Patenting must be at least a somewhat effective measure of innovation because it accounts for technological innovation that has not been created and may not have been adopted yet.⁷ Therefore, we must extend the measure of innovation to productivity in addition to patent count.

3.2. Productivity and Patent Count:

To understand the impact venture capital has on innovation, as measured by both patent count and productivity, existing studies provide important information. In 2008, Ueda and Hirukawa¹⁶ conducted a study by modifying the length and variables of Kortum and Lerner's study.¹¹ They extended the length of the sample to 2001 to include the NASDAQ bubble period, leading to a dataset between 1968 and 2001. They looked at nineteen U.S. manufacturing industries and utilized a linear patent production function with R&D and venture capital investment as inputs and instrumental variables to lessen bias, the same model Kortum and Lerner¹¹ used. Ueda and Hirukawa¹⁶ measure innovation as patent count, their total factor productivity growth, NBER total factor productivity growth, labor productivity growth, and production labor productivity growth. Their study finds that venture capital investment does have a significant positive effect on patent count even in the extended time period, reconfirming Kortum and Lerner's¹¹ results. A positive relationship between venture capital investment and labor productivity growth was also found, but no significant positive relationship was found between venture capital investment and total factor productivity growth.¹⁶

Extending the sample until 2001 had unexpected results. Hirukawa and Ueda¹⁶ found that venture capital investments, in comparison to R&D, are more effective in bringing about patents. This effect only increased during 1993 to 2001, the extended period of the sample, including the NASDAQ bubble period. When they disregard the period from 1993 to 2001 in the sample, their coefficients on the ratio of venture capital to R&D are significantly smaller. Therefore, the positive correlation between venture capital investment and patent count

simply increased during the 90s.¹⁶ It is also possible that this data implies that the NASDAQ bubble period increased innovation when measured as patent count. So, there may be a correlation between bubble periods and an increase in innovation, though this must be studied further for a more concrete answer to be found.

However, even when the sample period was restricted to 1968 to 1992, the estimated coefficients found by Hirukawa and Ueda¹⁶ were still considerably higher than the estimated coefficients found by Kortum and Lerner.¹¹ This is most likely due to survivorship bias within their data set, which would occur as a greater percentage of the older data points would be surrounding venture capital funds that have survived. The more successful venture capital funds will probably also make higher-quality investments.¹⁶ It is also necessary to consider whether firms backed by venture capital patent low-quality innovations as a strategy. Hirukawa and Ueda¹⁶ did not find that the quality of patents declines with an increase in venture capital. However, the breadth of knowledge that the patents contain was found to have a positive correlation with venture capital investment. These results may be a benefit of more access to technology and knowledge bases given to venture-backed firms, which are surfacing in the way in which those firms patent.¹⁶

In regard to productivity, Hirukawa and Ueda¹⁶ found a positive correlation between venture capital investment and labor productivity growth but did not find a significant correlation between venture capital and total factor productivity growth. This could be due to the measurability of total factor productivity and labor productivity, as well as their relationship with innovation. The main issue with total factor productivity growth as a measure of innovation is that it is difficult to measure quality improvements. To identify quality improvements, a great amount of knowledge is needed in assessing product quality and identifying the change in product quality. Therefore, this aspect of total factor productivity growth is often not incorporated, unlike cost-reducing innovation. This means that total factor productivity growth may be underrepresented.¹⁶ Thus, even though Hirukawa and Ueda¹⁶ did not find a positive correlation between venture capital investment and total factor productivity growth, it is possible that a correlation does exist and that it was just underrepresented due to the difficulty in measuring quality improvement.

On the other hand, some researchers believe that labor productivity growth is a better measure of innovation in comparison to total factor productivity growth, as nonlabor inputs, i.e., capital, material, and energy, do not need to be measured.^{7,16} Most of these nonlabor inputs are difficult to measure, so the estimate of the total factor productivity growth relies on whether the nonlabor inputs are measured accurately. However, there are also criticisms of labor productivity growth as a measure of innovation, as it only partially measures productivity. An unproportional change in any labor-productive input would change the labor productivity growth. So, the proportion of each would need to stay constant in order to successfully measure innovation. Thus, the positive impact venture capital investment has on labor productivity is most likely just driven

by substitutions of labor.¹⁶ Therefore, while a positive relationship between venture capital investment and labor productivity growth, this paper does not conclude that this relationship would be indicative of a relationship between venture capital and innovation. Labor productivity growth only partially measures innovation and can also positively affect the substitution of input factors, which are unrelated to innovation.

Another study was conducted by Ueda and Hirukawa⁷ in 2011 to understand the causality of venture capital investment and innovation. They considered both the “VC-first hypothesis” in which venture capital investment spurs innovation and the “innovation-first hypothesis” in which innovative opportunities are exploited by firms and venture capitalists invest in these innovative firms. They analyze five different U.S. manufacturing industries that account for 88% of all venture capital investment from 1963 to 2001. Ueda and Hirukawa⁷ measure innovation as both total factor productivity growth and patent count. Innovation is examined with a 1-year lag, 2-year lag, and 4-year lag in both first-round and follow-on-round investments.⁷

In the premise of total factor productivity growth, their study found weak evidence of the “VC-first hypothesis.”⁷ The 1-year lag of the first-round investment found a negative relationship between venture capital spurring innovation, but the 2-year lag found a positive relationship between venture capital spurring innovation. No evidence of venture capital spurring innovation was found in the follow-on round investment. However, Hirukawa and Ueda⁷ found that innovation does lead to venture capital investment, in the context of total factor productivity growth. While the 1-year lag of the first round and the 1-year lag of the follow-on investment had a negative correlation with total factor productivity growth, the 2-year lag of the first-round investment and the follow-on investment both had a significant positive relationship with total factor productivity growth. Thus, this finding provides evidence of the “innovation-first hypothesis”⁷ when considering total factor productivity.

Conversely, Hirukawa and Ueda⁷ found no relationship between venture capital investment and innovation regarding both the “VC-first hypothesis”⁷ and the “innovation-first hypothesis.”⁷ The patent count was found to be lower in both the 1-year lag of the first round and the follow-on round of venture capital investment in each industry. After the 1-year lag, no evidence was found to support the “VC-first hypothesis”⁷ in regard to patent count. Evidence was found that supported the “innovation-first hypothesis,”⁷ however, it was not significant. Therefore, no support was found for innovation spurring venture capital investment.⁷

Interestingly, a negative relationship is found with both total factor productivity growth and patent counts in the 1-year lagged venture capital investments, which suggests that venture capital slows down innovation in the first year after investment. This negative relationship may be due to venture capitalists supplying firms with immense resources, leading to inefficiencies in strategic decision-making immediately after the investment. This result appears to be consistent with the studies conducted by Engel and Keilbach¹² and Caselli, Gatti, and Perrini,¹³ who found that patenting decreases after venture

capital investment due to a desire to monetize existing innovation rather than create innovation.⁷

When considering the validity of Hirukawa and Ueda’s¹⁶ and Hirukawa and Ueda’s⁷ conclusions, we must first understand the drawbacks of patent count and total factor productivity as a measure of innovation, as they found a positive relationship between total factor productivity growth and venture capital investment. At the bare minimum, patent count has to be a somewhat effective measure of innovation, as it accounts for technological innovation that has not been created in the past, even if that technology has not yet been adopted.⁷ So, even though patent count does not always necessarily account for existing technology adapted in innovative ways, it is still a measure of innovation. Therefore, a positive relationship between venture capital and innovation, as patent count can be concluded from Hirukawa and Ueda’s¹⁶ study. Total factor productivity measures innovation resulting from adopting new or existing technology, which is not always measured by patent count.⁷ However, an accurate measure of total factor productivity is heavily reliant on the measurement of nonlabor inputs that affect total factor productivity, which are difficult to measure.¹⁶ While total factor productivity is not a perfect measure of innovation, it is still a sufficient measure of innovation, and therefore, this paper concludes that evidence of innovation spurring venture capital investment regarding total factor productivity in Hirukawa and Ueda’s⁷ study can be found.

However, these findings are initially not consistent with the findings of Hirukawa and Ueda,¹⁶ which found a positive correlation with venture capital and patent counts, but no correlation between venture capital and total factor productivity. It is possible that this could be due to the challenges in measuring total factor productivity. It is quite difficult to identify and assess quality improvements, so it is often not incorporated in the measure of total factor productivity growth. Thus, the results found by Hirukawa and Ueda¹⁶ in regard to total factor productivity could be underrepresented.¹⁶ Therefore, the results with total factor productivity growth are consistent in both Hirukawa and Ueda¹⁶ and Hirukawa and Ueda,⁷ supporting the “innovation-first hypothesis.”⁷

Yet, there is still a discrepancy with the findings of Hirukawa and Ueda⁷ with the other studies on the relationship between venture capital and patent count. Hirukawa and Ueda,¹⁶ Engel and Keilbach,¹² and Caselli, Gatti, and Perrini¹³ all found a positive relationship between venture capital investment and patent counts. Engel and Keilbach¹² and Caselli, Gatti, and Perrini¹³ additionally found that innovations spur venture capital investment in regard to patents. This discrepancy is likely due to the method by which Hirukawa and Ueda⁷ conducted their study. The patent filing process is extensive and takes a great period of time before being finalized. Therefore, the method of measuring innovation at the 1-year lag, 2-year lag, and 4-year lag of venture capital investment may not accurately capture the relationship between venture capital investment and patent count. The 4-year lag timeline is probably too short, proportionally to the length of the patent filing process. This is likely consistent with Hirukawa and Ueda,⁷ as they found positive, but insignificant evidence of the “innovation-first hy-

pothesis⁷⁷ in regard to patent count. This insignificance could be due to the underrepresentation of patents due to the short time period considered in the study. Therefore, this paper finds that innovation does lead to venture capital investment in regard to patent count.

This discrepancy could also be due to the varying locations of the samples of the studies. Hirukawa and Ueda⁷ conducted their study with data from the United States. However, Engel and Keilbach¹² utilized a German dataset, while Caselli, Gatti, and Perrini¹³ examined firms in Italy. The different goals of venture capitalists in different countries could be causing this discrepancy.¹³ How venture capitalists in the country choose venture capital firms to invest in could be heavily affected by the individual goals of that country.

3.3. Persistence of Innovation:

To understand the impact venture capital has on initial innovation and persistence of innovation, existing studies provide important context. In 2013, Arvanitis and Stucki¹⁴ conducted a study on whether venture capital stimulates early-stage innovation or persistence of innovative activities in start-ups. They utilized a representative cohort of all startups founded in 1996 or 1997 in Switzerland. To analyze the initial and continuous innovation activities, they measured innovation performance after three, six, and nine years after the firm's foundation for those that survived. In their study, initial innovative activities were defined as occurring three years after firm creation. Arvanitis and Stucki¹⁴ used five binary innovation measures: propensity of new products, propensity of modified products, propensity of either new or modified products, propensity of R&D activities, and propensity of patent applications.¹⁴ They found that venture-backed firms, on average, have a higher inclination to initial innovative activities in comparison to other firms in four of the five innovation measures. However, when Arvanitis and Stucki¹⁴ controlled for the innovation capabilities that the firms initially had, the statistical significance disappeared. Besides a weak effect on patenting, venture-backed firms do not have significantly higher innovation activities than non-venture-backed firms, even after matching. Thus, their study finds no positive correlation with venture capital investment and initial innovation activities.¹⁴

Arvanitis and Stucki¹⁴ also found no positive relationship between venture capital investment and the persistence of innovation activities. Before matching, venture-backed firms have a higher propensity for introducing new or modified products than non-venture-backed firms. However, after the initial stage and a longer period, there is no statistical significance for the persistence of innovation in any of the five measures of innovation. Thus, Arvanitis and Stucki¹⁴ found that venture capital investment does not affect the firm's innovativeness.¹⁴ It is possible that the insignificance found between persistence of innovation and venture capital investment could be due to the restrictive definition of persistence they used in the study. To test this, they utilize a less limited definition of persistence, defining persistence as innovative activities in two out of the three periods measured. Even though there were slight changes, the results were still statistically insignificant in regard to

all measures of innovation. Arvanitis and Stucki¹⁴ also considered whether the time period between the investment and the measurement of innovation was too short for real results to be found. However, no significant difference was found.¹⁴

In addition, Arvanitis and Stucki¹⁴ did not include the volume of funding in the definition of venture capital investment, even though innovation could have a positive relationship with the amount of funding. This change did have a statistically significant increase in patenting propensity after matching. The increase in patenting is logical, as patenting is a costly type of innovation, and a greater volume of funding is likely to increase patenting.¹⁴ Even though venture capital was not found to have a significant correlation with initial innovation or persistence of innovation, excluding a slight increase in patenting, the finding can signify validity in the "innovation first hypothesis."⁷⁷ The greater innovation propensity in venture-backed firms before matching could suggest that venture capitalists choose to fund startups with above-average innovation or at least the potential for above-average innovation. However, venture capital investment itself does not seem to be a stimulator of innovation.¹⁴ Thus, venture capitalists likely seek out innovative firms and benefit from that innovativeness to increase profit and scale instead of being the ones to spur the innovation.

These findings go hand in hand with the other studies included in this paper. Engel and Keilbach¹² and Caselli, Gatti, and Perrini¹³ found that innovation is greater in venture-backed firms in comparison to their non-venture-backed counterparts before they received venture capital investment. However, this disappeared after they were matched and received venture capital investment. At first glance, this seemed inconsistent with Hirukawa and Ueda¹⁶ and Kortum and Lerner,¹¹ who both found a positive correlation between venture capital investment and innovation as patent count. However, after deeper examination, these two studies that found that venture capital investment positively affects patent count did not consider the difference in innovation before and after venture capital investment. Instead, they simply found that venture-backed firms have a greater number of patents, which is consistent with the other results. Venture-backed firms are more innovative, but not due to the venture capital investment itself. On the contrary, it seems to be due to the selection process of the venture capitalists. They likely choose to fund more innovative ventures as they are likely to have more potential for profit and scaling. This is consistent with the findings of Engel and Keilbach¹² (2006) and Caselli, Gatti, and Perrini,¹³ who found that venture capital investment does spur firm growth even though it does not spur innovation. Hirukawa and Ueda⁷ found that innovation spurs venture capital investment in regard to total factor productivity, but not patent count, which is inconsistent with the other studies that found a positive relationship with patent count. This discrepancy is likely due to the method by which Hirukawa and Ueda⁷ conducted their study. The patent filing process is extensive and takes a long period of time before being finalized. Therefore, the method of measuring innovation at the 1-year lag, 2-year lag, and 4-year lag of venture capital investment may not accurately capture the relationship between venture capital investment and patent count, as the

timeline is too short. This is further supported by the fact that Hirukawa and Ueda⁷ found a positive, but insignificant relationship with patent count spurring venture capital investment, highlighting how this relationship could have been underrepresented. Thus, this paper finds support for the “innovation first hypothesis,”⁷ that venture capitalists chose more innovative firms to fund in regard to innovation, as both patent count and total factor productivity.

■ Conclusion

Since the selection effects are strong, but the treatment effects are mixed in the existing literature, this paper supports the “innovation-first hypothesis.”⁷ It suggests that capital may exploit innovation by selecting firms with high innovative capabilities that are likely to have more potential for profit and scaling instead of spurring innovation. Thus, this paper finds support for the “innovation-first hypothesis”⁷ in regard to both patent count and total factor productivity.

However, further research is needed as there are various limitations to this study. First, this paper has various data limitations. This study only utilizes data from existing studies that each have their own limitations to reach an understanding of venture capital's impact on innovation. In addition, each thematic framework only has a limited number of articles that are relatively old to inform the central concept of that theme. Secondly, this paper contains various scope limitations. A few of the articles used in this paper utilize a dataset that cannot be generalized to all venture capital investments, but rather a specific subset of venture capital. Some examples include venture capital investment in firms that went public through an IPO as an exit strategy, venture capital in specific countries, and venture capital during a bubble period. Thus, there may be specific nuances in each article that are not fully taken into account when developing a synthesized review of venture capital investment and innovation. To mitigate these methodological limitations, this paper uses a wide variety of data across themes to reach a more informed conclusion on the overall relationship between venture capital and innovation. This variety is also a strength as it allows for multiple lenses to be considered before reaching an informed conclusion.

The findings of this paper suggest multiple avenues for future research. There may be a difference in the relationship between venture capital and innovation across different industries or sectors, which was not a focus of this study. Future research could examine how various industries create nuance in regard to venture capital and innovation. Additionally, the papers utilized in each thematic framework are relatively old, as there is a lack of current research on the topic. While this study is a review of the empirical work up to this point, more primary empirical studies should be conducted to understand if the relationship between innovation and venture capital has changed. In this paper, there was a causality issue, which may be partly attributed to the lack of qualitative data in the field. Thus, more qualitative studies without any oversights of the existing papers' limitations would be an avenue for future research. There is also a minuscule possibility that venture capital

investment does have a mild effect on patent count in relation to funding intensity, but further research would need to be conducted to verify this. In addition, geographic variations in the dataset led to slight variations in the findings of the studies. Further research could be conducted on the ways in which geographic variation in venture capital affects the relationship between venture capital and innovation. In addition, Ueda and Hirukawa¹⁶ found that the NASDAQ bubble period had an interesting effect on innovation. Thus, a future study could be conducted focusing on how bubble periods affect the relationship between venture capital investment and innovation. Finally, the study conducted by Casselli, Gatti, and Perrini¹³ looked at a dataset of purely venture-backed and non-venture-backed companies that had gone public on the Italian Stock Exchange. Even though no extreme differences were found that affected the findings of this paper, future research could examine how venture capital's effect on innovation varies when the venture capitalist has an end goal of a specific exit strategy.

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