Persistence of Innovation around Initial Public Offerings:

Evidence from VC- and NonVC-Backed IPOs

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Abstract

We study the innovation activity of firms going public and find that post-IPO innovation activity is highly associated with pre-IPO innovation activity at both venture-capital- and non-venture-capital-backed firms. This persistence in innovation suggests that firms' pre-IPO innovation experience might influence the effect of venture-capital-backing on post-IPO innovation. Indeed, we find that venture-capital-backing helps companies with low pre-IPO innovation activity to produce more innovation output post-IPO, while it is negatively associated with post-IPO innovation at companies with some pre-IPO innovation experience, which we try to explain with an IPO timing argument. We attempt to address potential endogeneity issues in a matching framework.

Keywords: Venture Capital, Initial Public Offerings, Innovation, Patents, Persistence

JEL Classification: G24 G30

I. Introduction

Innovation is crucial for a firm's future profitability and growth (Porter, 1992; Kogan et al., 2015) as well as overall economic growth (Solow, 1957). Going public is an important milestone in the life cycle of a firm, and various firm dynamics may change after going public that might impact the corporate innovation process. As such, numerous papers have studied how firm innovation changes around initial public offerings (IPOs). Nonetheless, the majority of studies in this literature so far have ignored a large part of the IPO sample, namely the non-venture-capital-backed (nonVC-backed) IPOs, and focused on venture-capital-backed (VC-backed) IPOs only.[1] While VC-backed IPOs are important to understand the effect of venture capital (VC) on IPO performance, nonVC-backed IPOs constitute a substantial chunk of the IPO sample, and constraining innovation studies to VC-backed companies only may lead to misleading conclusions. In this paper, we study nonVC-backed IPOs together with VC-backed IPOs, which allows us to draw new conclusions about the interplay between *VC, innovation, and IPOs*.[2] Comparing the innovation activity of VC-backed versus nonVC-backed companies around their IPOs, we find evidence suggesting that innovation is highly persistent regardless of VC-backing.

VC financing is regarded as an important factor for the innovative performance of firms (Kortum and Lerner, 2000). However, whether VC indeed fosters innovation or identifies the most promising innovative companies is still an open question that needs to be answered (Hellman and Puri, 2000). Building upon our finding on the persistence of innovation, we

[1] For example, Aggarwal and Hsu (2014) in their study of VC-backed IPOs find that innovation quantity and quality both decline post-IPO. Chemmanur et al. (2014) finds that corporate venture capital-backed firms are more innovative than independent VC-backed firms post-IPO.

[2] Bernstein (2015) and Acharya and Xu (2017) also study all firms going public; however, they do not differentiate between VC-backed and nonVC-backed IPOs. Bernstein (2015) finds that internal innovation quantity and quality deteriorate after going public while Acharya and Xu (2017) find that the impact of going public on innovation depends on the need for external capital.

investigate the impact of VC-backing on post-IPO innovation by comparing innovative versus non-innovative firms, i.e. firms with versus without innovation experience pre-IPO. Our results indicate that nonVC-backed companies with prior innovation activity continue to innovate after going public at least as much as VC-backed companies do, while VC-backing indeed might be hurting post-IPO innovation output at companies with some prior innovation experience. On the other hand, we find evidence that VC-backing fosters innovation at companies with no prior innovation activity. In short, the actual impact of VC-backing on post-IPO innovation depends on how innovative the firm was pre-IPO.

There is evidence that VC-backed IPOs outperform nonVC-backed IPOs (Brav and Gompers, 1997; Chan et al., 2008). Taking post-IPO innovation as a measure of firm performance, we find that VC-backing does not make a difference in terms of post-IPO performance. Our findings show that both VC-backed and nonVC-backed firms perform similarly in terms of innovation quantity and quality post-IPO. However, VC-backing helps foster innovation activity post-IPO if the firm going public had no pre-IPO innovation experience. This suggests that the advice, guidance, and monitoring from venture capitalists regarding innovation might be only useful for firms that do not have prior innovation experience.

We first examine the persistence of innovation around IPOs as measured by the number of patents and citations, and document that post-IPO innovation activity is positively associated with pre-IPO innovation activity. We analyze the innovation activity of IPO firms prior to the IPO and classify firms as *innovative* versus *non-innovative* based on having produced at least one patent prior to the IPO year.[3,4] This kind of a broad classification in fact biases us against finding

[3] Cao, Jiang, and Ritter (2015) use a similar classification in their study on the long-run performance of VC-backed IPOs.

any persistence in innovation activity around IPOs. However, even with this conservative classification we find a significant positive association between pre- and post-IPO innovation activity. Furthermore, we find that this persistence holds for both VC-backed and nonVC-backed IPO firms. Regardless of VC-backing, firms that have produced at least one patent pre-IPO have higher post-IPO innovation activity measured both by patent and citation counts revealing a strong pattern of persistence in innovation.

Our measure of firm innovativeness might be subject to endogeneity concerns making it difficult to identify the actual relationship between pre-IPO innovativesness and post-IPO innovation. To address this concern, we estimate the treatment effect of pre-IPO innovation in a matching framework. More specifically, in order to control for the selection into treatment, we employ the nearest-neighbor matching model, which compares post-IPO innovation activities of firms that are treated, i.e. that are innovative, to structurally similar firms that are not treated, i.e. that are non-innovative. We find that pre-IPO innovation has a positive and significant effect on post-IPO innovation even after taking the potentially endogenous nature of firm innovativeness into account.[5]

Having established that post-IPO innovation is associated with pre-IPO innovation activity, we move on to another important question: Does VC-backing make a difference to how firms going public perform in terms of innovation considering the persistence we document? Our univariate analysis suggests that VC-backed and nonVC-backed IPO firms behave similarly in

[4] We are trying to capture a firm's familiarity with producing patents with this broad classification. A firm might have patents pending that they are working on or high R&D investment that they eventually hope to turn into patents, but we would still classify such a firm as "non-innovative" (i.e. not yet familiar with patent production) if the patent is not filed for pre-IPO and eventually materialized.

[5] We are not arguing that pre-IPO innovation by itself causes post-IPO innovation. The persistence in innovation that we document might simply imply that there is an inherent firm characteristic that is associated with innovation and going through an IPO, regardless of VC-backing, does not change this association. Thus, we further investigate the impact of VC-backing on post-IPO innovation in light of this persistence.

terms of innovation activity post-IPO if firms within these two groups are compared conditional on being innovative versus non-innovative pre-IPO. We then confirm this finding in our multivariate analyses. Controlling for firm characteristics at the time of IPO as well as industry and year fixed effects, we find that the number of post-IPO patents and the number of citations are both positively associated with pre-IPO innovation while VC-backing does not seem to have a significant impact on post-IPO innovation. This finding seems to be at odds with the conclusions of earlier studies on the positive impact of VC on firm innovation. However, it is important to note that we are looking at innovation activity around IPOs only, and, more importantly, control for pre-IPO innovation activity. As such, the evidence we provide suggests that, on average, VC-backing is not a determinant of post-IPO innovation once we control for pre-IPO innovation.

Next, we divide our sample into two subsamples based on the pre-IPO level of innovation activity and study whether VC-backing has different impacts on post-IPO innovation output for innovative versus non-innovative companies. We indeed find that the effect of VC-backing highly depends on whether the firm has pre-IPO innovation experience (is innovative) or not (is non-innovative). VC-backing is associated with higher post-IPO innovation when the firm is a non-innovative firm, i.e. has no prior innovation experience pre-IPO, while it is found to be negatively associated with post-IPO innovation when the firm is an innovative firm, i.e. has some prior innovation experience pre-IPO. We repeat the same analysis with cumulative number of post-IPO patents as well as citations. We calculate the total number of patents and citations within 2–5 years post-IPO, and using these cumulative numbers as the measure of post-IPO innovation performance we find very similar results: Pre-IPO innovation experience is a significant determinant of future innovation performance of firms after going public.

Furthermore, VC-backing fosters post-IPO innovation at non-innovative firms, whereas it is negatively associated with post-IPO innovation at innovative firms.

Self-selection into treatment is a concern in existing literature on the effect of venture capital on various firm policies. A typical concern is that VC firms self-select themselves into certain companies pre-IPO and if those selected companies perform differently post-IPO, the empiricist might conclude that the different behavior is caused by the VC-backing while in fact those different firms were purposefully selected by the VC firm to start with. In particular, VC firms are typically known to select innovative companies which would lead to a spurious positive correlation between VC-backing and post-IPO innovation performance. Our results do not seem to directly suffer from this type of selection as our findings suggest the exact opposite: VC-backing does not lead to superior post-IPO innovation performance if the company was already innovative pre-IPO. Nonetheless, a concern regarding our findings could be that VC firms select non-innovative companies rather than innovative companies which then might lead to a spurious correlation between non-innovative companies' VC-backing and their post-IPO innovation performance.[6] This, however, seems implausible since VC-backing, as expected, is more common for innovative firms in our sample. Specifically, we find that while 64% of innovative firms are VC-backed, only 36% of non-innovative firms are VC-backed. Still, to alleviate concerns about the endogenous nature of VC-backing, we test the impact of VC-backing on post-IPO innovation in a matching framework. We apply the nearest-neighbor matching model for two subsamples of firms: innovative firms and non-innovative firms. We find that VC-backing has a positive and significant effect on post-IPO innovation in the non-innovative subsample of firms that are structurally similar otherwise, whereas it has a weakly negative effect in the

[6] This might be the case if VC firms see more room for improvement at non-innovative companies and think that their expertise could be more effectively implied at those companies.

innovative subsample of structurally similar firms. This verifies our main result that VC is most helpful for non-innovative firms regarding post-IPO innovation performance.

Lastly, in an attempt to explore the mechanisms underlying the effect of VC-backing and more clearly understand why they might be different for innovative and non-innovative firms, we focus on VC-backed IPOs only and study two important VC characteristics and their impact on post-IPO innovation. We hypothesize and find that VC tenure (the time between the first VC investment and the IPO) is negatively associated with post-IPO innovation at innovative firms suggesting that venture capitalists are timing the IPO of innovative firms in such a way that the firm produces the maximum amount of innovation output pre-IPO to maximize IPO proceeds which then naturally leads to a drop in innovation output post-IPO. This explains the negative association we identify between VC-backing and post-IPO innovation output at innovative firms: VC-backing does not hurt innovation per se, it rather maximizes it pre-IPO. As for the non-innovative companies, we find that the number of investing VC firms is positively associated with post-IPO innovation output suggesting that the additional expertise and knowledge brought by multiple VC firms are helpful for non-innovative companies and lead to higher post-IPO innovation.

Our finding about pre-IPO patent production affecting post-IPO innovation performance is related to the findings of a recent IPO study by Cao, Jiang, and Ritter (2015). Like many other studies in the literature this one also mainly focus on VC-backed IPOs. However, the novelty of their study is that it makes a distinction between companies with successful pre-IPO patent grants versus others when examining post-IPO stock performance. The main finding is that VC-backed IPOs with successful pre-IPO patent grants outperform those without in terms of 3-year post-IPO buy-and-hold returns. They explain this by the potential undervaluation of innovation-

intensive companies at the time of IPO which might lead to higher long-run abnormal returns post-IPO. Our findings on the persistence of innovation activity around IPOs might also explain the outperformance of IPO firms with prior innovation experience and hence complement their findings: Companies with pre-IPO innovation activity continue to innovate post-IPO which might be reflected in better stock performance.

Our paper contributes to two main lines of literature. First, we find evidence for a strong pattern of persistence in innovation around IPOs contributing to the growing literature on the determinants of firm innovation. Various firm characteristics such as corporate governance (Meulbroek et al., 1990), stock liquidity (Fang, Tian, and Tice, 2013), firm boundaries (Seru, 2012), analyst coverage (He and Tian, 2013), and institutional ownership (Aghion, Van Reenen, and Zingales, 2013) have been found to be associated with innovation. Our findings suggest that a time-invariant firm characteristic is an important determinant of innovation performance, and innovative companies stay innovative post-IPO.

Secondly, comparing post-IPO innovation performance of VC-backed versus nonVC-backed companies conditional on pre-IPO innovation experience, we contribute to the existing literature on the relation between VC and innovation by adding the dimension of prior innovation to the discussion. On one hand, we find that VC-backing does not matter for innovation when the company has already had some innovation experience pre-IPO. On the other hand, we still find evidence that VC fosters innovation at non-innovative companies suggesting that VC provides guidance and expertise to companies with limited innovation experience. To the best of our knowledge, ours is the first systematic study of the relation between VC-backing and newly public firms' innovation conditional on pre-IPO innovativeness.

The rest of the paper is organized as follows. Section 2 discusses the data and presents summary statistics. Section 3 compares the aggregate innovation output of nonVC-backed and VC-backed IPO firms. Section 4 presents our findings about the persistence of innovation. Results comparing the effect of VC on post-IPO innovation at innovative versus non-innovative companies are discussed in Section 5. Section 6 attempts to explain the different impact of VC-backing at innovative versus non-innovative firms with findings on VC tenure and the number of investing VC firms, and Section 7 concludes.

II. Data and Descriptive Statistics

Our IPO data come from Thomson Reuters Securities Data Company (SDC) and cover all US IPOs over the 26-year period from 1981 to 2006, with total proceeds equal to or greater than $1.5 million and an offer price equal to or greater than $5 per share. These cutoffs are imposed to ensure that our sample will include IPOs of a certain minimum size with reliable data available. We also restrict our sample to those firms for which Compustat data are available and exclude financial firms from our sample. After these restrictions, there are 5,540 IPOs that meet the sample selection criteria. For firms that have gone public more than once during the sample period, we only include the earlier IPO in our sample. Our final sample consists of 5,490 IPO firms.

Panel A of Table 1 presents the year distribution of our sample of IPO firms. The number of IPOs in our sample varies over time, with a minimum of 48 IPOs in 2003 and a maximum of 525 IPOs in 1996. A total of 2,249 IPOs, i.e. 41% of our sample IPOs, are VC-backed.[7] This number is consistent with Cao, Jiang, and Ritter (2015) who study VC-backed IPOs in the same

[7] The data on VC backing at the time of the IPO come from SDC's new issues database.

time period. The percentage of VC-backed IPOs reaches a maximum of 60% and 70% in years 1999 and 2000, respectively, coincident with the Internet boom.

In order to study the changes in the innovation activity of IPO firms in our sample, we use the patent database created by Hall, Jaffe, and Trajtenberg (2001) and provided by the National Bureau of Economic Research (NBER). This database gives detailed information on all US patents granted by the United States Patent and Trademark Office (USPTO) between 1963 and 1999 and all citations made to these patents between 1975 and 1999.[8] Updates of the patents and citations data through 2006 and the match of all the patent assignees to Compustat firms are obtained from the NBER Patent Data Project (PDP). Using the updated patent database we are able to analyze the innovation output of our sample firms in terms of the patents they produce and the citations they receive for the whole sample period from 1981 to 2006.[9]

We use the number of patents produced by our sample firms as a measure of their innovation output. Following the innovation literature, we take the patent application year rather than the patent grant year as the year of patent production since a patent's application year better captures the actual time of innovation.[10] Trajtenberg (1990) and Hall, Jaffe, and Trajtenberg (2005) document that patent citations received in subsequent years are a better measure of the value of innovations, because they show a patent's impact on future research activities and its

[8] The initial study by Hall, Jaffe, and Trajtenberg (2001) covers patent data until the end of year 1999. This work is then extended by Bronwyn H. Hall until the end of year 2006.

[9] NBER records a patent only after it is granted by the United States Patent and Trademark Office (USPTO), which causes a truncation problem in the patent data. In particular, most of the patents filed in 2005 or 2006 are not granted until after 2006 because the review process by the USPTO takes two years on average, and therefore these patents will be recorded by NBER only after 2006. The NBER Patent Data Project (PDP) addresses this truncation problem and provides the patent and citation numbers that are corrected for truncation using the methodology described by Hall, Jaffe, and Trajtenberg (2001). Lerner and Seru (2015) further discuss the truncation problem and provide insights into other challenges that researchers might face when using the patent data.

[10] If a firm files a patent application in a given year that is eventually granted by the USPTO, we count this as a patent production in that year.

economic importance. Thus, we also analyze the total number of citations received on the patents of our sample firms as a measure of the technological and economic significance of the patents.

We classify our sample firms according to their innovativeness based on their innovation activity prior to the IPO year. More specifically, an IPO firm is defined as *innovative* if it has produced at least one patent before its IPO, and *non-innovative* if it has not produced any patent before its IPO. Panel A of Table 1 presents the year distribution of the number and the percentage of IPO firms with prior innovation activity, i.e. the number and the percentage of *innovative* firms in our IPO sample, during 1981-2006. A total of 1,037 IPOs, i.e. 19% of our sample IPOs, are innovative.[11] Column 5 shows that the percentage of innovative firms ranges from a low of 2.1% in year 1985 to a high of 46% each in years 2000 and 2001.

Panel B of Table 1 presents the year distribution of our sample of IPO firms split into two subsamples according to their VC-backing. On average, 12.5% of nonVC-backed firms in an IPO cohort year produced at least one patent before their IPO, whereas this percentage is 27.4% for VC-backed firms. Moreover, a comparison of the two subsamples over the years shows that the percentage of innovative firms is lower for the nonVC-backed IPO subsample every single year.

Firm financials for our sample firms come from Compustat. Table 2 presents the mean values of financial variables within the IPO year and 1–3 years after the IPO for nonVC- and VC-backed firms. Using our innovativeness measure, we split each group of firms further into two subsamples of innovative and non-innovative firms. We calculate three measures of firm size, namely the market capitalization, the market value of assets and the book value of assets. A

[11] We find that 1,025 out of these 1,037 IPO firms produced their patents within the last 5 years in the pre-IPO period whereas only 12 of them produced their patents in an earlier time period.

comparison of these size measures within the group of nonVC-backed firms in panels A and B of Table 2 shows that innovative nonVC-backed firms are much larger than non-innovative nonVC-backed firms. More specifically, innovative nonVC-backed firms have total assets of $863 million in the IPO year whereas non-innovative nonVC-backed firms have total assets of only $266 million in the IPO year. Similarly, a comparison of the size measures within the group of VC-backed firms in panels C and D of Table 2 shows that innovative VC-backed firms are larger than non-innovative VC-backed firms. Moreover, a comparison of innovative firms of nonVC- and VC-backed firms reveals that nonVC-backed innovative firms are much larger than VC-backed innovative firms. In terms of firm size, the relationships that we observe in the IPO year also hold for the three years following IPO.

Taking Tobin's Q as a proxy for firms' growth opportunities, we find that, as expected, nonVC-backed non-innovative firms have the lowest Tobin's Q and VC-backed innovative firms have the highest Tobin's Q throughout all years after IPO. Finally, Table 2 shows no significant differences in the remaining firm characteristics between the two groups of firms regardless of their innovativeness.

III. Innovation Activity of IPO Firms: NONVC- versus VC-backed Firms

We study the innovation activity of firms around their IPOs as measured by the number of patents they produce and the number of citations they receive. Figure 1 shows the distribution of the total number of patents around the IPO year for those firms in our sample that have produced at least one patent during the sample period. In our analysis, we distinguish between VC-backed and nonVC-backed IPO firms. Comparing the aggregate patent counts for these two groups of firms around the IPO year reveals an interesting pattern. Both VC- and nonVC-backed sample firms have approximately a constant level of patent output up until three years before

their IPO, after which we observe a steady increase in their patent counts until two years after their IPO. More interestingly, we observe that nonVC-backed firms produce a higher number of patents than VC-backed firms, which is in contrast with the finding of a positive impact of VC on firm innovation in existing literature. Figure 2 shows the distribution of the number of patents per firm around the IPO year for the two groups of firms. Similar to the aggregate results, we observe that nonVC-backed firms produce a higher number of patents per firm than VC-backed firms. Overall, Figures 1 and 2 suggest that nonVC-backed IPO firms produce more patents than VC-backed IPO firms both in the period before and in the period after their IPO both in aggregate terms and on a per firm basis.

When we compare the aggregate patent and citation counts of nonVC-backed and VC-backed IPO firms during the whole sample period, we find that nonVC-backed firms produce a total number of 55,450 patents during the sample period whereas VC-backed firms produce 88,122 patents. Even if VC-backed firms seem to be more innovative, this difference disappears once we calculate the average number of patents produced per firm per year in these two groups. More specifically, Panel A of Table 3 shows that nonVC-backed firms produce 12.2 patents per year, on average, during the sample period while VC-backed firms produce 13.3 patents, the difference not being statistically significant. Comparing the mean and the median number of patents within each group of firms in Panel A of Table 3 shows that patent counts have a skewed distribution. Therefore, in addition to comparing the means, we also compare the median patent counts for the nonVC-backed and VC-backed subsamples. We find that the median values of the number of patents produced per firm per year differ significantly from each other for the two groups of firms. Specifically, nonVC-backed firms produce a median number of 2 patents per year whereas VC-backed firms produce a median number of 3 patents per year during the whole

sample period, indicating that VC-backed firms are more innovative when considering all available years in the sample period rather than only years around the IPO. We obtain similar findings for the number of citations received per IPO firm during the whole sample period.

Panel B of Table 3 compares the innovation output of nonVC-backed and VC-backed firms within 1–5 years after they go public. We find that nonVC-backed firms produce 13.8 patents per year, on average, after going public whereas VC-backed firms produce only 6.0 patents, the difference being statistically significant at the 1% level, indicating that, on average, nonVC-backed firms are more innovative than VC-backed firms post-IPO. Panel B of Table 3 also shows that the economic importance of the patents, as measured by the total number of citations received on these patents produced within 1–5 years post-IPO, is significantly higher for those patents produced by nonVC-backed firms, on average. Comparing the median numbers, on the other hand, shows that the median number of patents (citations) of VC-backed firms is significantly higher than that of nonVC-backed firms.

In order to analyze the post-IPO innovation activity of nonVC- and VC-backed IPO firms further, in Panels C and D of Table 3, we provide the summary statistics for the innovation output within 1–5 years after going public for the subsamples of non-innovative and innovative firms, respectively. We define an IPO firm as *non-innovative* if it has not produced any patent before its IPO and *innovative* if it has produced at least one patent before its IPO. Among the nonVC-backed IPO firms, the mean (median) number of patents produced per year is 3.7 (1) for non-innovative firms whereas this number is 23.4 (4) for innovative firms, the difference being statistically significant at the 1% level. Similarly, among the VC-backed IPO firms, the mean (median) number of patents produced per year is 3.8 (2) for non-innovative firms whereas this number is 7.5 (3) for innovative firms, the difference being statistically significant at the 1%

level. We observe similar differences for the number of citations as well where innovative firms receive significantly higher number of citations for the patents produced within 1–5 years post-IPO compared to non-innovative firms, both within the group of nonVC-backed firms and the group of VC-backed firms. These univariate comparisons show that nonVC-backed and VC-backed IPO firms behave similarly in terms of post-IPO innovation activity when firms within these two groups are compared conditional on being innovative versus non-innovative pre-IPO. That is, firms that are innovative pre-IPO continue to innovate post-IPO regardless of their VC-backing.

Panel C of Table 3 shows that within the group of non-innovative firms, nonVC- and VC-backed firms have a similar level of innovation output within 1–5 years post-IPO. We find that, on average, nonVC-backed firms produce 3.7 patents per year and VC-backed firms produce 3.8 patents, the difference not being statistically significant. The median number of patents produced per year, on the other hand, is significantly lower for nonVC-backed firms compared to VC-backed firms, indicating that VC-backing might help firms with no prior innovation experience to innovate post-IPO. When we compare the innovation output within the group of innovative firms, it turns out that, on average, nonVC-backed firms produce a significantly higher number of patents within 1–5 years post-IPO. More specifically, Panel D of Table 3 shows that within the group of innovative firms, nonVC-backed firms produce 23.4 patents per year, on average, after going public whereas VC-backed firms produce only 7.5 patents, the difference being statistically significant at the 1% level. Similarly, comparing the median innovation output levels shows that within the group of innovative firms, nonVC-backed firms produce a median number of 4 patents post-IPO whereas VC-backed firms produce a median number of 3 patents post-IPO, the difference being statistically significant at the 1% level. The significantly higher number of

post-IPO patent counts for the nonVC-backed subsample suggests that VC-backing does not lead to a higher level of innovation output post-IPO at innovative firms; in fact, it seems to hurt post-IPO innovation output. Finally, in Panel D of Table 3, we also find that there is a significant difference in the citation counts of these two groups of innovative firms, with the nonVC-backed innovative firms receiving more citations on patents produced post-IPO compared to VC-backed innovative firms. This finding suggests that VC-backing does not improve the level of economic significance of the patents produced post-IPO at innovative firms.

Overall, the results of our univariate analysis suggest that the well documented positive impact of VC-backing on the innovative activities of IPO firms might be driven by firms with no prior innovation experience, whereas firms with prior innovation experience continue to innovate post-IPO regardless of their VC-backing. Indeed, VC-backing seems to adversely impact the innovation output of those IPO firms that are already innovative.

IV. Persistence of Innovation around IPOs

Our univariate results show that firms classified as innovative according to their pre-IPO innovation output continue to innovate post-IPO regardless of their VC-backing. In this section, we investigate whether the persistence of innovation around IPOs also holds in a multivariate setting. In Table 4, we employ OLS regression models where the dependent variable is the innovation output of our sample firms within the first year after IPO, as measured by the number of patents they produce in models (1) and (2), the number of citations they receive on these patents in models (3) and (4), and the ratio of citation counts to patent counts, called normalized citations, as a proxy for the economic importance of the patents, in models (5) and (6). All dependent variables we use are adjusted by year and technology group which accounts for year and industry fixed effects. Specifically, the number of patents is adjusted by dividing the number

of patents obtained by a firm by the mean number of patents in the same cohort, to which the patent belongs, where the cohorts are constructed for each year and technology group defined by USPTO.[12] Similar adjustments are made for the number of citations and normalized citations as well.

Our main variables of interest in Table 4 are *Pre-IPO Innovation* and *VC-backed*. *Pre-IPO Innovation* is a dummy variable that takes the value of one if the firm has produced at least one pre-IPO patent and zero otherwise. *VC-backed* is a dummy variable that takes the value of one when the firm is backed by venture capital and zero otherwise. We also include firm characteristics that are found to have a significant effect on firm innovation in existing literature such as firm size, Tobin's Q, return on assets, leverage, research and development expenses (R&D), and intangibles as control variables in our models. All control variables are measured at the time of IPO, and the standard errors are clustered by year.

In Model (1), the coefficient on *Pre-IPO Innovation* is positive and statistically significant at the 1% level, indicating that pre-IPO innovation activity is associated with higher post-IPO innovation activity measured by the number of patents. On the other hand, the coefficient on *VC-backed* turns out to be negative and statistically significant at the 10% level, indicating that, if anything, the effect of VC-backing on post-IPO innovation activity measured by patents is negative rather than positive. We get similar results in model (2), where we include additional firm-level control variables. Moreover, we find that larger firms and firms with lower leverage are associated with higher levels of innovation output measured by patents.

[12] The technology groups defined by USPTO are: computers and communications, drugs and medical, electrical and electronics, chemical, mechanical, and others.

In Model (3), where we measure the post-IPO innovation activity by the number of citations received, the coefficient on *Pre-IPO Innovation* is again positive and statistically significant at the 1% level, indicating that pre-IPO innovation activity is associated with higher post-IPO innovation activity. The coefficient on *VC-backed* is negative but statistically insignificant, showing that there is no significant effect of VC-backing on post-IPO innovation activity measured by citations. Similar results are obtained in model (4), where we include additional firm-level controls. Moreover, larger firms and firms with lower leverage are associated with higher levels of innovation output measured by citations. Finally, in models (5) and (6), which have the normalized citation counts as the dependent variable, we obtain results similar to those for citation counts.

In the multivariate models of Table 4, we use a broad classification of firm innovativeness, where firms are defined as innovative if they have produced at least one patent pre-IPO. Using this conservative classification, we find a significantly positive association between pre- and post-IPO innovation activity; that is, firms that have produced at least one patent pre-IPO innovate more post-IPO. As a robustness test, we also investigate whether the quantity and quality of pre-IPO innovation activity would make a difference to the post-IPO innovation activity of firms conditional on having produced at least one patent pre-IPO. We repeat the OLS regressions in Table 4 with an alternative measure of pre-IPO innovation activity for the subsample of firms with pre-IPO innovation output. More specifically, we define *Pre-IPO Innovation* as a dummy variable that takes the value of one if the firm produced a higher number of pre-IPO patents than the median firm in the sample of firms with at least one pre-IPO patent and zero otherwise. In untabulated results using this alternative measure of pre-IPO innovation we confirm our previous results, i.e. we find a positive and significant relation

between pre- and post-IPO innovation activity. Additionally, we find that the magnitude of the coefficients on *Pre-IPO Innovation* is higher in all models that use the alternative measure of pre-IPO innovation compared to the corresponding models in Table 4, indicating that the effect of pre-IPO innovativeness on post-IPO innovativeness is especially strong for the most active innovators. Overall, we find that among the firms with at least one pre-IPO patent, those firms with an above-median number of pre-IPO patents continue to produce more patents and also receive more citations on those patents in the period after the IPO than those firms with a below-median number of pre-IPO patents.[13]

In addition to studying the innovation activity within the first year after IPO, we also create cumulative patent and citation counts up to 5 years post-IPO as an alternative, longer-run, measure of post-IPO innovation. Table 5 shows OLS regression results where the dependent variable is the cumulative number of patents produced by our sample firms within 1–5 years post-IPO. In all the models we consider, the coefficient on *Pre-IPO Innovation* is positive and statistically significant at the 1% level, indicating that pre-IPO innovation activity is associated with higher post-IPO innovation activity measured by the number of patents. In terms of economic magnitudes, the coefficient estimates in model (1) indicate that the adjusted number of patents produced post-IPO is 0.36 higher for innovative firms compared to non-innovative firms. Given that the mean adjusted number of patents is 0.10 for this subsample of firms, this effect is economically large. On the other hand, the coefficient on *VC-backed* turns out to be negative and statistically significant at the 10% level in all the models, indicating that VC-backing is

[13] As a further robustness test, we also use a citation-based measure, indicating the quality of the patents produced, as another alternative measure of pre-IPO innovation activity in our baseline regressions of Table 4. Specifically, we define *Pre-IPO Innovation* as a dummy variable that takes the value of one if the firm received a higher number of citations for its patents produced pre-IPO than the median firm in the sample of firms with at least one pre-IPO patent and zero otherwise. Our results are robust to this alternative definition as well. These results with alternative measures of pre-IPO innovation activity are available upon request.

negatively related to the number of patents produced post-IPO. We also find that larger firms and firms with lower leverage are associated with higher cumulative number of patents within 1–5 years post-IPO. These results suggest that pre-IPO innovation experience is a significant determinant of future innovation performance of firms within 1–5 years after going public.

Table 6 repeats our analysis in Table 5 for the cumulative number of citations. All our results for patents also hold for citations. More specifically, pre-IPO innovation experience is a significant determinant of the economic importance of post-IPO patents as measured by the number of future citations received for these patents produced within 1–5 years after going public. Moreover, VC-backing has a negative relation to the number of citations as well. In Table 7, where we model the normalized number of citations, the coefficient estimates verify our previous finding of the positive effect of pre-IPO innovation on post-IPO innovation within 1–5 years after going public. In these models, VC-backing turns out to be positive but is statistically insignificant throughout.

One concern about our results on the persistence of innovation around IPOs could be that our innovativeness measure is endogenous; that is, firms might not be randomly selected into the treatment group, namely the group of innovative firms. Self-selection into the innovative group could be related to firms' post-IPO innovation activities, therefore making it difficult to identify the causal effect of pre-IPO innovation on post-IPO innovation. To address this concern and estimate the treatment effect of pre-IPO innovation, we use the nearest-neighbor matching model where each firm with pre-IPO innovation activity is matched to three similar firms with no pre-IPO innovation activity based on size, Tobin's Q, VC-backing, IPO year and industry.[14] Table 8

[14] Since the matching method is based on a limited number of observable firm characteristics, we cannot rule out the possibility of some unobservable factors driving the relationships that we document. However, firm fixed effects cannot be used in our models to control for these potential unobservable time-invariant factors, since the sample includes a single data point for each IPO firm.

shows the average treatment effect of pre-IPO innovation on post-IPO innovation in different specifications. Columns 1–5 report the results for the number of patents, citations, and normalized citations being measured within 1–5 years post-IPO, respectively. Consistent with our OLS results, we find that pre-IPO innovation has a positive and significant effect on post-IPO innovation at the 1% level in all specifications we consider, after taking the potentially endogenous nature of firm innovativeness into account.[15,16]

Overall, our results reveal a strong pattern of persistence in innovation activity by IPO firms even after controlling for VC-backing and other important firm characteristics, implying that firms that have produced at least one patent pre-IPO have higher post-IPO innovation activity measured both by patents and citations.

V. VC-Backing and Post-IPO Innovation: Innovative versus Non-Innovative Firms

Our paper is motivated by the fact that nonVC-backed IPOs were mostly overlooked and left out of sample in existing research although they constitute a substantial portion of the IPO sample. Our results so far show that pre-IPO innovation is the most significant determinant of post-IPO innovation whereas VC-backing only has a weakly negative effect on post-IPO innovation. To have a clearer understanding of the effect of VC-backing conditional on the level of pre-IPO innovation activity, we split the sample firms into two subsamples according to their innovativeness. Tables 9–12 show the OLS regression results where we investigate the effect of

[15] Our results remain the same when we include the R&D intensity of the sample firms as a matching variable in the nearest-neighbor matching models in addition to size, Tobin's Q, VC-backing, IPO year and industry.

[16] When we repeat the matching analysis using propensity scores, we get identical results. Indeed, when each firm with pre-IPO innovation activity is matched to three similar firms with no pre-IPO innovation activity based on propensity scores calculated using size, Tobin's Q, VC-backing, IPO year and industry, pre-IPO innovation still has a positive and significant effect on post-IPO innovation. This implies that the action of innovating pre-IPO has an effect on innovation post-IPO after controlling for a firm's potential to innovate using observables. It is important to note that the persistence in innovation we document might simply imply that there is an inherent firm characteristic that is associated with innovation and going through an IPO, regardless of VC-backing, does not change this association. We use this as a motivation to study the impact of VC-backing on innovation at innovative versus non-innovative firms in the following section.

VC-backing on post-IPO innovation for the subsamples of innovative and non-innovative firms. In effect, we are trying to find the answer to the following question in a multivariate setting: Does VC-backing have a different impact on post-IPO innovation conditional on the firm's level of pre-IPO innovativeness?

The models in Table 9 are similar to the OLS models in Table 4 where we now run the regressions for the subsamples of innovative and non-innovative firms in models (1)-(3) and (4)-(6), respectively. The dependent variable is the innovation output of our sample firms within the first year after IPO, as measured by the number of patents in models (1) and (4), the number of citations in models (2) and (5), and the number of normalized citations in models (3) and (6), with all dependent variables adjusted by year and technology group. Our main variable of interest is *VC-backed* which is a dummy variable that takes the value of one if the firm is backed by venture capital and zero otherwise. We include the usual control variables as before in our models.

In model (1) of Table 9, the coefficient on *VC-backed* is negative and statistically significant at the 5% level for the innovative subsample, indicating that VC-backing is associated with lower innovation activity measured by the number of patents produced within the first year after IPO for firms that are found to be innovative based on their pre-IPO innovation activity. In model (4), on the other hand, the coefficient on *VC-backed* is positive and statistically significant at the 5% level for the non-innovative subsample, indicating that VC-backing leads to higher post-IPO innovation activity for firms that are found to be non-innovative based on their pre-IPO innovation activity. This result implies that the expertise, guidance, and monitoring from VC might be helping non-innovative firms in terms of learning how to innovate and producing patents. We also perform formal chi-square tests for difference in coefficients after

simultaneously estimating the regressions on the two subsamples of innovative versus non-innovative firms and find that the coefficients on VC-backed are indeed statistically significantly different from each other across these two subsamples. These findings suggest that VC-backing fosters innovation only when the IPO firm is a non-innovative firm, i.e. has no prior innovation experience, and does not seem to contribute to the post-IPO innovation output of already innovative firms. Indeed, VC-backing is negatively associated with post-IPO innovation activity at firms with pre-IPO innovation activity.

In models (2) and (5) of Table 9, we repeat our multivariate analysis of innovative and non-innovative subsamples for the number of citations that are received on the post-IPO patents produced. In these models, we verify our previous finding of a negative (positive) association of VC-backing with post-IPO innovation at innovative (non-innovative) firms as shown by the negative coefficient of VC-*backed* in model (2) for innovative firms and the positive coefficient of *VC-backed* in model (5) for non-innovative firms. In models (3) and (6), where we regress normalized citations, we get consistent results; however, *VC-backed* variable loses its significance. Overall, our results in Table 9 suggest that while VC-backing might be helping firms with no pre-IPO innovation experience to produce more innovation output post-IPO, it is not contributing to, possibly even hurting, the innovation output of firms that are already innovative.

Table 10 shows OLS regression results for the innovative and non-innovative subsamples where the dependent variable is the cumulative number of patents produced by our sample firms within 2–5 years post-IPO. In all the models we consider for the innovative subsample, the coefficient on *VC-backed* is negative and statistically significant, showing that VC-backing is associated with lower post-IPO innovation activity measured by the cumulative number of

patents for firms that are innovative. We also find that larger firms and firms with lower leverage are associated with higher cumulative number of patents within 2–5 years post-IPO for the innovative subsample.

For the non-innovative subsample in Table 10, the coefficient on *VC-backed* is positive and statistically significant, showing that VC-backing is associated with higher post-IPO innovation activity measured by the cumulative number of patents for firms that are non-innovative. We also find that firms with higher operating performance measured by ROA and firms with higher R&D outlays produce more patents within 2–5 years post-IPO if they are non-innovative in the pre-IPO period. Overall, these results suggest that VC-backing has opposite effects on future innovation performance of firms depending on their pre-IPO innovativeness, with the non-innovative firms benefiting the most from the existence of VC firms backing them.

Table 11 repeats our analysis in Table 10 for the cumulative number of citations. All our results for patents also hold for citations. That is, VC-backing is related to the economic importance of patents produced within 2–5 years after going public, as measured by the number of future citations received on these patents. Specifically, the coefficient on *VC-backed* is negative and statistically significant for the innovative firms in all the time windows that we consider, and it is positive in all the time windows and statistically significant within the first three years after the IPO for the non-innovative firms. Finally, in Table 12, where we model the normalized number of citations, the coefficient estimates verify our previous finding of the positive relation of VC-backing to innovation output of non-innovative firms for all the time windows that we consider in the post-IPO period. For the innovative subsample, the coefficient on *VC-backed* is still negative but becomes insignificant.

The main challenge in studies on venture capital concerns the difficulty in identifying causal effects of VC-backing on firm policies since VC firms might self-select themselves into certain companies. To address this concern and estimate the treatment effect of VC-backing, we use the nearest-neighbor matching model, where each VC-backed firm is matched to three similar nonVC-backed firms based on size, Tobin's Q, IPO year and industry. We split our sample firms into two subsamples based on our innovativeness measure and find the average treatment effect of VC-backing on post-IPO innovation for these two subsamples. Table 13 shows the estimation results for different specifications. Columns 1–5 report the results for the number of patents, citations, and normalized citations being measured within 1–5 years post-IPO, respectively. Panel A shows the results for the subsample of innovative firms and Panel B shows the results for the subsample of non-innovative firms. Consistent with our OLS results, we find that, for the subsample of already innovative firms, there is no significant effect of VC-backing on post-IPO innovation activity. If anything, the effect of VC-backing on post-IPO innovation is negative. For the subsample of non-innovative firms, on the other hand, VC-backing has a positive and statistically significant effect on post-IPO innovation in all the specifications we consider.[17,18]

One caveat about our matching results is that the matching model is based on a limited number of observable firm characteristics. It is possible that there could be some unobservable factors that might affect firms' choice of VC-backing as well as their innovation output. However, it seems hard to reconcile the existence of such a common factor with our finding of an opposite effect of VC-backing on post-IPO innovation output in innovative and non-innovative firms.

[17] Our results remain the same when we include the R&D intensity of the sample firms as a matching variable in the nearest-neighbor matching models in addition to size, Tobin's Q, IPO year and industry.

[18] Our results remain the same when we use propensity score matching instead of nearest-neighbor matching.

Acharya and Xu (2017) document a higher innovation output by public firms compared to private firms in external finance dependent industries, and show that this result is driven by relaxation of the financial constraints after firms become public. If the need for external capital drives our results, we would expect non-innovative firms to become more innovative post-IPO regardless of VC-backing as going public would provide them with needed capital. In fact, we would expect this to be more pronounced at nonVC-backed non-innovative companies as those presumably would be more in need of external capital than their VC-backed peers. However, we find that innovation output is higher only for VC-backed non-innovative firms. Our findings, therefore, cannot be explained by the relaxation of the financial constraints in the post-IPO period.

Overall, our findings show the importance of distinguishing between firms according to their pre-IPO innovation experience when analyzing the effect of VC-backing on post-IPO innovation. We find that the difference that VC-backing makes to firms' innovativeness around their IPO depends on whether these firms experienced innovation activity in the pre-IPO period. It turns out that nonVC-backed IPO firms, which were mostly overlooked in existing research, innovate more than the VC-backed IPO firms after going public if these firms are already innovative in the pre-IPO period. Firms that are not innovative in the pre-IPO period, on the other hand, innovate more after going public if backed by a VC firm implying that the expertise and the guidance of VC is most helpful for non-innovative firms.

VI. Why does VC have different impacts on post-IPO innovation at innovative versus non-innovative firms?

Our results so far show a negative effect of VC-backing on post-IPO innovation output for innovative companies and a positive effect for non-innovative companies. We investigate this

seemingly opposite effect of VC-backing in innovative and non-innovative portfolio companies further by incorporating some VC firm related characteristics into our analysis. In particular, the duration of the stay of the VC firms in the portfolio company, i.e. the VC tenure, and the number of VC firms investing in the portfolio company might have different effects on post-IPO innovation depending on the portfolio companies' innovativeness, and these potential channels are what we study next.

VI.I. VC Firm Tenure

Our findings indicate that VC-backing has a negative association with post-IPO innovation output at companies with pre-IPO innovation activity. One possible explanation for this finding could be that VC firms rush these companies into an IPO before they are ready for it, which then might adversely impact their innovation production post-IPO.[19] The negative association of VC-backing with post-IPO innovation output hence might be the result of this "rushing". If that is the case, we might expect the duration of the stay of the VC firms at the portfolio company, i.e. the VC tenure, to be related with the innovation output of portfolio companies. More specifically, we would expect VC tenure to be positively associated with post-IPO innovation output, i.e. rushed IPO firms would experience a drop in innovation activity post-IPO.

To test whether the documented effect of VC firms on the innovative activities of their portfolio companies is due to VC firms' "rushing", we run multivariate models for the subsample of VC-backed companies only. Table 14 shows the results of OLS regressions where the dependent variable is the cumulative number of patents produced by our sample of VC-backed companies within 1–5 years post-IPO adjusted by year and technology group. We include the

[19] A "rushed" exit might happen due to various factors such as pressure from limited partners or reputational concerns for future fundraising activity.

usual control variables as before.[20] Our main variable of interest is *VC-tenure* which is defined as the standardized value of the number of years between the first VC investment in a company and its IPO.[21] In Panels A, B and C, we run our models for the full sample of VC-backed companies, for the subsample of innovative VC-backed companies and for the subsample of non-innovative VC-backed companies, respectively.

In all the models we consider in Panel A of Table 14, the coefficient on *Pre-IPO Innovation* is positive and statistically significant at the 1% level, verifying our main result that pre-IPO innovation activity is positively associated with innovation activity within 1–5 years post-IPO. The coefficient on *VC-tenure* is, to the contrary of a "rushing" story, negative and statistically significant at the 5%-10% levels indicating that VC-backed companies innovate less in the post-IPO period when the VC firms stay for a longer duration before they take their portfolio company public. When we split the sample of VC-backed companies into innovative and non-innovative subsamples, in Panels B and C, respectively, we find that the negative effect of VC tenure on post-IPO patent production that we document in Panel A is driven by the subsample of innovative companies. Specifically, in Panel B, we find that the coefficient on *VC-tenure* is negative and statistically significant at the 5% level for all time windows that we consider, indicating that the VC tenure negatively affects the number of post-IPO patents in companies that are found to be innovative, i.e. that have produced patents in the pre-IPO period. In Panel C, the coefficient on *VC-tenure* turns out to be insignificant, indicating that the VC tenure does not have an effect on post-IPO innovation activity for companies that are non-

[20] The sample sizes in Table 14 drop considerably compared to our baseline models in Table 5 since the models in Table 14 are estimated for the subsample of VC-backed firms.

[21] We define the VC tenure as the tenure of the lead venture capitalist which is, following the definition by Gompers (1996), the VC firm that has invested in the company for the longest amount of time. Gompers (1996) argues that this investor has significant control over the decisions of the company and monitors the company more actively.

innovative. Formal chi-square tests confirm that the coefficients on *VC-tenure* are indeed statistically significantly different from each other across the two subsamples of innovative versus non-innovative firms.

Our findings on the effect of VC tenure on post-IPO innovation activity suggest that VC firms time the IPOs of their portfolio companies differently depending on whether these companies are innovative or non-innovative. In particular, we find that lower VC tenure is associated with higher post-IPO innovation whereas higher VC tenure is associated with lower post-IPO innovation for innovative companies. The VC tenure, on the other hand, is not associated with post-IPO innovation for non-innovative companies.

Our multivariate results do not support the predictions of the VC firms' "rushing" since in such a case we would expect that shorter VC tenure will lead to higher post-IPO innovation output in non-innovative companies and to lower post-IPO innovation output in innovative companies, pointing to a negative coefficient on *VC-tenure* for non-innovative companies and to a positive coefficient on *VC-tenure* for innovative companies, which are in contradiction with our findings.

Rather than a "rushing" story, these results might possibly be explained with the innovation cycle of a company and the timing of the IPO. In a typical company's innovation cycle, we expect internal innovation output to first increase over time, eventually reach a maturity, and then start to decline creating an inverted U-shape. If a company follows this type of a pattern, the change in the innovation output around IPOs will differ depending on whether VC firms take their portfolio companies public before or after the point of maturity in innovation. In case the VC firms take their portfolio companies public before maturity, the innovation output will continue to increase in the post-IPO period. If, on the other hand, the IPO occurs after the

maturity, the innovation output will decline in the post-IPO period. Figure 3 illustrates the timeline for an innovative company's life cycle, and presents the two cases, namely the short VC tenure case and the long VC tenure case, for both of which we observe a negative correlation between VC tenure and post-IPO innovation output. It is also possible that companies are taken public by their VC firms even before they start their innovation cycle, in case of which innovation would increase after IPO and we would not expect VC tenure to be related to the post-IPO innovation output of these non-innovative companies.

Our findings therefore are consistent with the VC firms' "IPO timing" with respect to the innovation cycle of the portfolio company. Specifically, since the innovation cycle has started for companies that have produced patents, i.e. innovative companies, the post-IPO innovation output of these companies will be negatively affected by the duration of the VC firms' stay, i.e. the VC tenure, as depicted in Figure 3 and verified by our multivariate results. This finding supports the notion that VC firms stay longer and wait for the maturity of their portfolio companies in terms of internal innovation output if these companies are already innovative; in other words, the VC firms exploit their portfolio companies in terms of the maximum possible innovation production. On the other hand, companies that have not produced patents yet, i.e. the non-innovative companies, are taken public before the start of their innovation cycle and therefore the VC tenure does not have an effect the post-IPO innovation output of non-innovative portfolio companies.[22]

Overall, we verify the persistence of innovation around IPOs for the subsample of VC-backed companies, and show that our results on the effect of VC-backing on post-IPO innovative

[22] We find that the VC tenure is longer for innovative companies compared to non-innovative companies. Specifically, the VC tenure is 5.1 years for innovative VC-backed companies, on average, whereas it is 4.2 for non-innovative VC-backed companies, with the difference being statistically significant at the 1% level. The median level of VC tenure is 4 and 3 years for the innovative and non-innovative VC-backed companies, respectively, with the difference being statistically significant at the 1% level. So, VC firms take their portfolio companies public later if these firms are innovative compared to companies that are non-innovative.

activities are consistent with the innovation cycle and the IPO timing argument. Our findings on the VC tenure provide an explanation for the negative impact of VC-backing on post-IPO innovation for the subsample of innovative companies. We show that this seemingly negative effect is driven by the duration of the stay of the VC firms in the portfolio company. Therefore, VC firms' timing of their portfolio company's IPO seems to be the channel for the negative association between VC-backing and patenting output of innovative companies after their IPO.

For the case of non-innovative companies, VC tenure does not seem to have an impact on post-IPO innovation and hence it is still unclear how VC-backing is contributing to post-IPO innovation of these non-innovative companies which is what we explore further in next section.

VI.II. Number of VC Firms

VC firms not only provide capital to their portfolio companies but are also actively involved in the management of these companies by providing advice and support to them (Gompers, 1995; Lerner, 1995; Bernstein et al., 2016). As such, VC firms accumulate a lot of experience regarding innovative activities through their involvement with the management of their portfolio companies over the years. As different VC firms might bring in different types of expertise to the table, we expect our sample companies to become more active innovators, the higher the number of VC firms backing them.[23] We expect this effect to be especially strong for companies with no prior innovation experience.

We explore this in Table 15. We run OLS regressions for the subsample of VC-backed companies only, where our main variable of interest is the *number of VC firms* which is defined as the standardized value of the number of VC firms investing in the company pre-IPO. The dependent variable is the cumulative number of patents produced by our sample VC-backed

[23] Tian (2012) finds that, compared to individual VC firms, VC syndicates are better able to understand and evaluate the technology of their entrepreneurial firms and nurture innovation due to the heterogeneous skills, information, industry expertise, and networks of VC syndicate members.

companies within 1–5 years post-IPO adjusted by year and technology group. We include the usual control variables as before.[24] As in Table 14, in Panels A, B and C, we run our models for the full sample of VC-backed companies, for the subsample of innovative VC-backed companies and for the subsample of non-innovative VC-backed companies, respectively.

As before, in all the models we consider in Panel A of Table 15, the coefficient on *Pre-IPO Innovation* is positive and statistically significant at the 1% level, verifying our main result on the persistence of innovation around IPOs. We also verify our previous result on VC tenure that the coefficient on *VC-tenure* is negative and statistically significant at the 5% level in all these models for the full sample. Moreover, as predicted, the coefficient on the *number of VC firms* is positive and becomes statistically significant over the years. When we split the sample of VC-backed companies into innovative and non-innovative subsamples, in Panels B and C, respectively, we verify our previous finding on VC tenure which shows that shorter VC tenure is associated with higher post-IPO innovation output for innovative companies. In Panel B, the coefficient on the *number of VC firms* is positive but statistically insignificant in explaining the post-IPO innovation for innovative companies. We find that the positive effect of the *number of VC firms* on post-IPO patent production that we document in Panel A is driven by the subsample of non-innovative companies. Specifically, in Panel C, we find that the coefficient on the *number of VC firms* is positive and statistically significant for all time windows that we consider, indicating that the higher the number of VC firms backing a company that has been non-innovative, the higher the patent production becomes after its IPO.

Our results on the number of VC firms suggest that while the post-IPO innovation output of already innovative companies is not affected by the number of VC firms, the non-innovative

[24] The sample sizes in Table 15 drop considerably compared to our baseline models in Table 5 since the models in Table 15 are estimated for the subsample of VC-backed firms.

companies benefit the most from VC firms' existence. More specifically, the higher the number of VC firms backing a non-innovative company, the higher its post-IPO patenting output. This could be due to VC firms bringing in different perspectives and therefore contributing collectively to the innovation process of their portfolio companies that have been non-innovative before. It is not surprising that the positive effect of the number of VC firms on post-IPO innovation output is not strong for innovative companies since these companies have already produced patents and therefore are not likely to need as much help from the VC firms as the non-innovative companies in order to produce innovation.

Overall, our empirical investigation of the channels for the effect of VC-backing on post-IPO innovation for innovative and non-innovative companies reveals that while the negative effect is explained by VC firms' timing the IPO with respect to the innovation cycle of innovative companies, the positive effect is driven by VC firms providing their expertise and guidance to the non-innovative companies which need their help the most.

VII. Conclusion

We study post-IPO innovation at VC-backed versus nonVC-backed companies conditional on their pre-IPO innovation experience, and find that VC-backing is not an important determinant of post-IPO innovation performance for companies with prior innovation experience, while it is for companies with no prior innovation experience. Companies with prior innovation activity continue to innovate post-IPO whether backed by VC or not, with nonVC-backed companies innovating more than VC-backed companies. We also document a strong pattern of persistence in innovation around IPOs: Post-IPO innovation is significantly and positively associated with pre-IPO innovation activity. The evidence we provide on the impact of pre-IPO innovation on post-IPO innovation performance highlights the importance of pre-IPO

innovation in IPO studies and nicely complements the recent study by Cao, Jiang, and Ritter (2015) who find that pre-IPO innovation production has a significant and positive impact on post-IPO firm performance.

To mitigate any potential endogeneity concerns on firm innovativeness and VC-backing and to clearly identify causal effects, we further test the persistence of innovation around IPOs and the effect of VC-backing on post-IPO innovation by employing nearest-neighbor matching models, where each treated firm is matched to structurally similar firms that are not treated. Our results remain the same after addressing the endogeneity concerns associated with firm innovativeness and VC-backing.

Overall, our results suggest that focusing solely on VC-backed IPOs can lead to misleading conclusions about the impact of VC on IPO performance and innovation. Our findings suggest that VC does not contribute much to the innovation performance of companies that already are innovators themselves, and post-IPO innovation output seems to decline at those firms as VCs most likely time their IPOs to exploit maximum innovation output pre-IPO. On the other hand, VC benefits non-innovative companies, i.e. companies that were not innovators at the time of their VC funding, in terms of future innovation production through their guidance and expertise.

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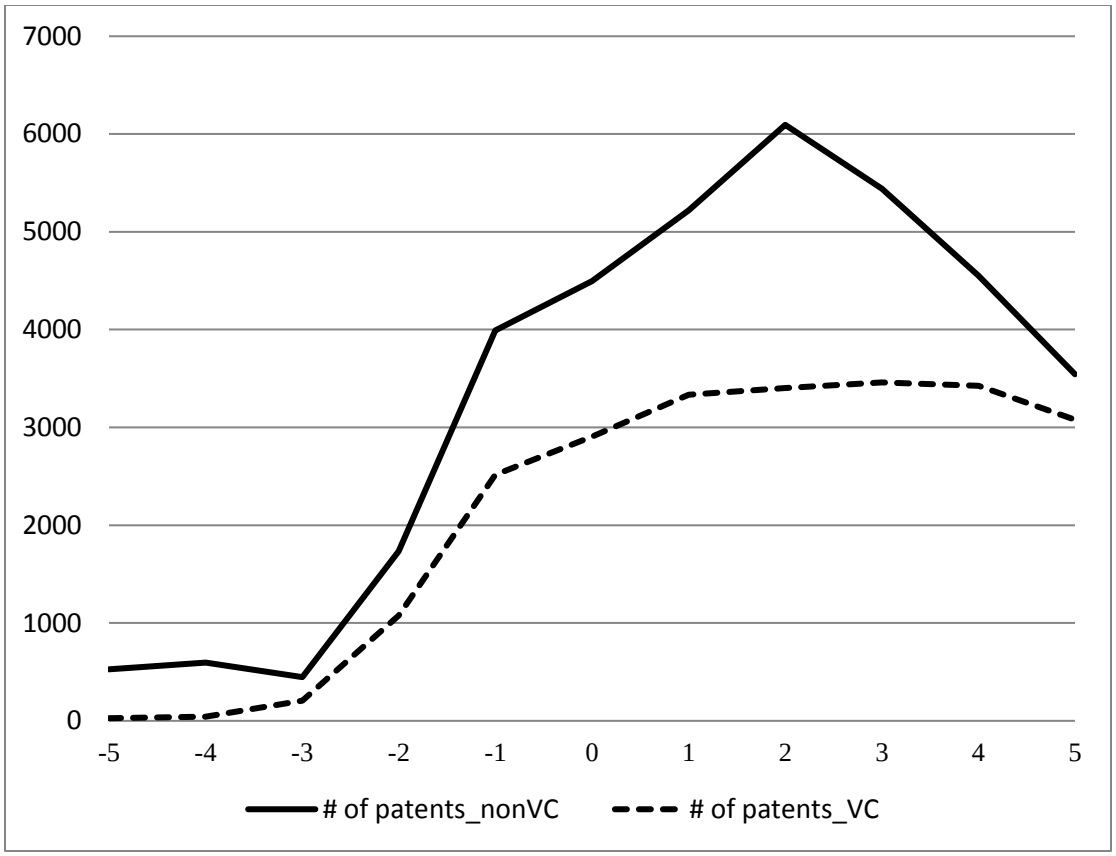

Figure 1: Distribution of patents around IPO year

This figure plots the aggregate number of patents produced by IPO firms around the time of IPO. Year 0 denotes the IPO year. The solid line represents NONVC-backed firms and the dashed line represents VC-backed firms.

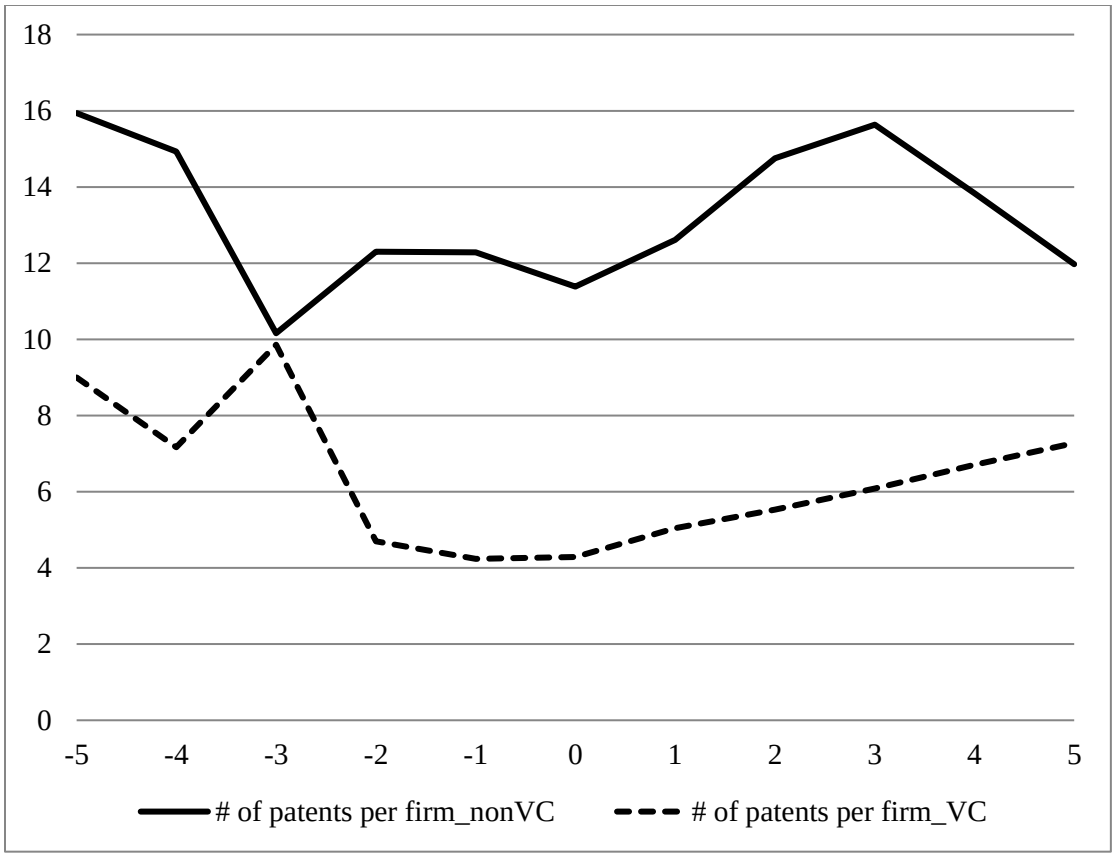

Figure 2: Distribution of patents per firm around IPO year

This figure plots the average number of patents produced per IPO firm around the time of IPO. Year 0 denotes the IPO year. The solid line represents NONVC-backed firms and the dashed line represents VC-backed firms.

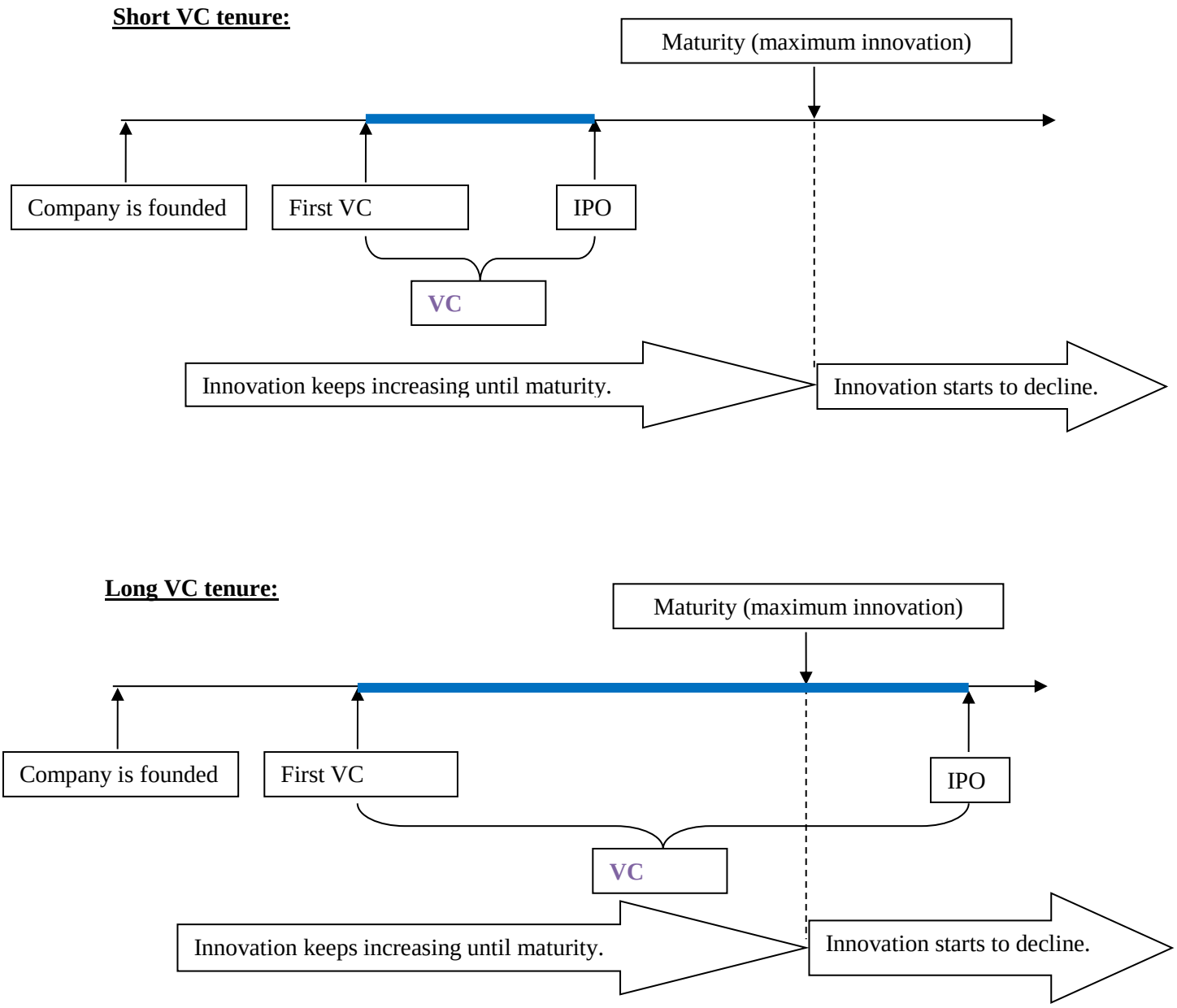

Figure 3: IPO timing and innovation

This chart depicts the innovation cycle firms might go through and presents how the duration of the stay of VC firms interplays with how innovation changes post-IPO depending on IPO timing.

TABLE 1: Year Distribution of IPOs, 1981 - 2006

This table presents the year distribution of all initial public offerings between 1981 and 2006. The sample includes all US IPO firms (excluding financial firms) with IPO proceeds equal to or greater than $1.5 million and an offer price equal to or greater than $5 per share, for which Compustat data are available. In Panel A, Column 1 reports the total number of IPOs, Column 2 (3) reports the number (percentage) of venture-capital-backed IPOs, and Column 4 (5) reports the number (percentage) of IPO firms with prior innovation activity where prior innovation activity is defined as at least one patent production prior to the IPO year. Panel B reports the corresponding numbers for NONVC- and VC-backed IPO firms.

Panel A

	1	2	3	4	5
IPO year	Number of IPO firms	Number of VC-backed IPO firms	Percentage of VC-backed IPO firms	Number of IPO firms with prior innovation activity	Percentage of IPO firms with prior innovation activity
1981	160	61	38.13	11	6.88
1982	64	22	34.38	4	6.25
1983	354	113	31.92	32	9.04
1984	135	46	34.07	6	4.44
1985	143	40	27.97	3	2.10
1986	291	88	30.24	32	11.00
1987	212	67	31.60	29	13.68
1988	84	30	35.71	10	11.90
1989	90	34	37.78	16	17.78
1990	88	33	37.50	12	13.64
1991	206	99	48.06	37	17.96
1992	300	136	45.33	62	20.67
1993	407	158	38.82	85	20.88
1994	337	124	36.80	45	13.35
1995	343	148	43.15	69	20.12
1996	525	210	40.00	108	20.57
1997	350	109	31.14	69	19.71
1998	212	67	31.60	46	21.70
1999	374	224	59.89	84	22.46
2000	289	200	69.20	132	45.67
2001	59	31	52.54	27	45.76
2002	54	22	40.74	15	27.78
2003	48	22	45.83	9	18.75
2004	130	78	60.00	53	40.77
2005	116	36	31.03	25	21.55
2006	119	51	42.86	16	13.45
1981-2006	5,490	2,249	40.63	1,037	18.76

Panel B						
	1	2	3	4	5	6
	NONVC-backed IPO Firms			*VC-backed IPO Firms*		
IPO year	Number of firms	Number of firms with prior innovation activity	Percentage of firms with prior innovation activity	Number of firms	Number of firms with prior innovation activity	Percentage of firms with prior innovation activity
1981	99	4	4.04	61	7	11.48
1982	42	2	4.76	22	2	9.09
1983	241	11	4.56	113	21	18.58
1984	89	1	1.12	46	5	10.87
1985	103	2	1.94	40	1	2.50
1986	203	11	5.42	88	21	23.86
1987	145	16	11.03	67	13	19.40
1988	54	4	7.41	30	6	20.00
1989	56	7	12.50	34	9	26.47
1990	55	7	12.73	33	5	15.15
1991	107	13	12.15	99	24	24.24
1992	164	18	10.98	136	44	32.35
1993	249	35	14.06	158	50	31.65
1994	213	17	7.98	124	28	22.58
1995	195	26	13.33	148	43	29.05
1996	315	43	13.65	210	65	30.95
1997	241	29	12.03	109	40	36.70
1998	145	24	16.55	67	22	32.84
1999	150	25	16.67	224	59	26.34
2000	89	31	34.83	200	101	50.50
2001	28	11	39.29	31	16	51.61
2002	32	7	21.88	22	8	36.36
2003	26	1	3.85	22	8	36.36
2004	52	10	19.23	78	43	55.13
2005	80	12	15.00	36	13	36.11
2006	68	5	7.35	51	11	21.57
1981-2006	3,241	372	12.47	2,249	665	27.38

TABLE 2: Financial Variables for NONVC- and VC-backed IPO Firms with versus without pre-IPO Innovation Activity

This table presents the mean values for selected financial variables at the IPO-year as well as 1, 2, and 3 years following the IPO between 1981 and 2006. Panel A reports the values for NONVC-backed IPO firms with no pre-IPO innovation activity, Panel B reports the values for NONVC-backed IPO firms with pre-IPO innovation activity, Panel C reports the values for VC-backed IPO firms with no pre-IPO innovation activity, and Panel D reports the values for VC-backed IPO firms with pre-IPO innovation activity. *Market Cap* is the market capitalization of the company's equity. *MV of Assets* is the market value of assets. *BV of assets* is the book value of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *OCF* is operating cash flow over total assets. *Leverage* is book value of total debt over total assets. *CAPEX* is capital expenditures over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets.

NONVC-backed Firms								
	IPO-year		Year 1		Year 2		Year 3	
	N	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
Panel A: Non-Innovative								
Market Cap	2,514	318.97	2,616	358.93	2,330	364.32	2,069	379.51
MV of Assets	2,513	498.70	2,615	570.58	2,329	612.27	2,067	671.64
BV of Assets	2,775	266.24	2,634	329.82	2,346	382.27	2,094	431.72
Tobin's Q	2,513	2.76	2,615	2.28	2,329	2.08	2,067	2.01
ROA	2,745	0.10	2,620	0.04	2,338	0.03	2,085	0.00
OCF	2,498	0.10	2,376	0.06	2,126	0.04	1,897	0.02
Leverage	2,765	0.22	2,623	0.25	2,337	0.29	2,085	0.31
CAPEX	2,732	0.10	2,601	0.11	2,322	0.09	2,066	0.08
R&D	2,744	0.03	2,614	0.03	2,335	0.03	2,077	0.05
Intangibles	2,769	0.73	2,629	0.70	2,341	0.69	2,090	0.69
Panel B: Innovative								
Market Cap	351	1,220.39	353	1,422.52	331	1,634.36	302	2,135.18
MV of Assets	351	1,780.05	353	2,058.51	331	2,352.39	302	2,973.70
BV of Assets	367	862.77	354	970.67	331	1,111.60	304	1,448.52
Tobin's Q	351	3.66	353	2.93	331	2.67	302	2.60
ROA	365	0.07	354	-0.02	330	-0.08	303	-0.04
OCF	329	0.09	315	0.01	297	-0.04	279	-0.02
Leverage	366	0.18	353	0.19	330	0.21	302	0.24
CAPEX	362	0.07	352	0.08	327	0.06	298	0.05
R&D	366	0.10	354	0.10	329	0.13	303	0.12
Intangibles	367	0.80	354	0.77	331	0.77	304	0.77

VC-backed Firms								
	IPO-year		Year 1		Year 2		Year 3	
	N	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
Panel C: Non-Innovative								
Market Cap	1,373	416.18	1,412	348.77	1,244	370.40	1,097	463.90
MV of Assets	1,373	466.38	1,412	428.21	1,244	474.50	1,097	593.63
BV of Assets	1,536	106.07	1,417	159.59	1,256	206.05	1,106	240.72
Tobin's Q	1,373	4.19	1,412	2.81	1,244	2.61	1,097	2.52
ROA	1,526	0.00	1,408	-0.04	1,248	-0.07	1,096	-0.04
OCF	1,379	0.02	1,260	-0.02	1,119	-0.04	984	-0.02
Leverage	1,533	0.14	1,414	0.16	1,250	0.20	1,100	0.20
CAPEX	1,514	0.09	1,393	0.09	1,233	0.08	1,089	0.07
R&D	1,523	0.09	1,403	0.10	1,240	0.12	1,096	0.12
Intangibles	1,536	0.81	1,417	0.79	1,255	0.78	1,105	0.78
Panel D: Innovative								
Market Cap	642	609.47	634	734.46	583	688.61	532	946.97
MV of Assets	642	658.10	634	800.25	583	774.11	532	1,049.54
BV of Assets	658	127.71	638	194.00	586	209.59	533	252.32
Tobin's Q	642	4.84	634	3.41	583	2.99	532	3.35
ROA	657	-0.10	629	-0.17	582	-0.19	528	-0.19
OCF	516	-0.07	495	-0.12	453	-0.12	408	-0.12
Leverage	657	0.07	635	0.09	586	0.13	532	0.18
CAPEX	654	0.06	627	0.07	580	0.06	526	0.05
R&D	658	0.16	634	0.21	585	0.23	531	0.24
Intangibles	658	0.89	637	0.87	586	0.85	533	0.84

TABLE 3: Summary Statistics for NONVC- vs. VC-backed IPO Firms' Innovation Activity

This table presents the summary statistics for the innovation activity of all IPO firms between 1981 and 2006. *Patents* is the total number of patents produced, and *Citations* is the total number of citations received on those patents, on a per firm basis. Panel A reports the means and medians across all years. Panel B reports the means and medians within 1–5 years post-IPO. Panel C reports the means and medians within 1–5 years post-IPO for firms with no pre-IPO innovation activity, i.e. for non-innovative firms. Panel D reports the means and medians within 1–5 years post-IPO for firms with pre-IPO innovation activity, i.e. for innovative firms. In Panels A–D, the means and the medians are reported for NONVC- versus VC-backed IPO firms, and the corresponding t- and z-statistics are provided. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	NONVC-backed Firms			*VC-backed Firms*			*Comparison between NONVC- and VC-backed Firms*	
Variable	**N**	**Mean**	**Median**	**N**	**Mean**	**Median**	**t-stat**	**z-stat**
Panel A: All Years								
Patents	4,535	12.23	2	6,604	13.34	3	-0.93	-6.88***
Citations	4,535	192.04	28.00	6,604	278.91	43.60	-3.41***	-9.46***
Panel B: 1-5 Years Post-IPO								
Patents	1,800	13.81	2	2,779	6.01	3	4.31***	-2.66***
Citations	1,800	226.08	28.29	2,779	127.80	38.44	2.88***	-3.73***
Panel C: 1-5 Years Post-IPO, Non-Innovative								
Patents	878	3.72	1	1,124	3.82	2	-0.26	-4.81***
Citations	878	105.69	20.36	1,124	102.30	34.89	0.19	-6.49***
Panel D: 1-5 Years Post-IPO, Innovative								
Patents	922	23.41	4	1,655	7.49	3	4.58***	2.99***
Citations	922	340.72	41.93	1,655	145.12	42.42	3.05***	1.25

TABLE 4: Persistence of Innovation Activity around IPOs

This table presents the results of OLS regressions where the dependent variable is a measure of innovation activity within the first year after IPO. The dependent variable is number of patents for Columns 1 and 2, number of citations for Columns 3 and 4, and number of normalized citations (citations per patent) for Column 5 and 6. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *Pre-IPO Innovation* is a dummy variable which equals to 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	1	2	3	4	5	6
Dependent Variable	Patents	Patents	Cites	Cites	Norm. Cites	Norm. Cites
Pre-IPO Innovation	0.42***	0.36***	0.53***	0.47***	0.54***	0.53***
	(5.32)	(6.83)	(4.76)	(6.16)	(3.73)	(4.20)
VC-backed	-0.06*	-0.08*	-0.06	-0.08	0.04	0.01
	(1.74)	(1.92)	(1.14)	(1.50)	(0.27)	(0.05)
Size		0.09**		0.10*		0.09*
		(2.17)		(1.83)		(1.74)
Tobin's Q		-0.00		-0.00		-0.01
		(1.26)		(0.57)		(0.87)
ROA		-0.06		-0.07		0.09
		(1.06)		(0.93)		(0.51)
Leverage		-0.24**		-0.32**		-1.00**
		(2.34)		(2.22)		(2.49)
R&D		0.13		0.13		-0.11
		(1.64)		(1.27)		(0.84)
Intangibles		-0.01		-0.01		0.27
		(0.27)		(0.09)		(0.46)
N	5,441	4,765	5,441	4,765	1,026	922
Adj. R^2	0.03	0.04	0.02	0.03	0.02	0.03

TABLE 5: Persistence of Innovation Activity around IPOs – 5-year Post-IPO Patents

This table presents the results of OLS regressions where the dependent variable is the number of patents produced post-IPO. Columns 1, 2, 3, 4, and 5 report results of the same specification with the number of patents being measured within 1, 2, 3, 4, and 5 years post-IPO, respectively. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *Pre-IPO Innovation* is a dummy variable which equals to 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	1	2	3	4	5
Dependent Variable	Patents1	Patents2	Patents3	Patents4	Patents5
Pre-IPO Innovation	0.36***	0.74***	1.08***	1.33***	1.54***
	(6.83)	(6.45)	(6.63)	(6.90)	(7.11)
VC-backed	-0.08*	-0.18*	-0.25*	-0.28*	-0.28*
	(1.92)	(1.99)	(1.88)	(1.77)	(1.71)
Size	0.09**	0.19**	0.27*	0.32*	0.34**
	(2.17)	(2.07)	(2.01)	(2.05)	(2.11)
Tobin's Q	-0.00	-0.01	-0.01	-0.01	-0.01
	(1.26)	(1.24)	(1.18)	(1.03)	(0.96)
ROA	-0.06	-0.10	-0.10	-0.08	-0.00
	(1.06)	(0.81)	(0.60)	(0.36)	(0.01)
Leverage	-0.24**	-0.52**	-0.72**	-0.87**	-0.96**
	(2.34)	(2.33)	(2.28)	(2.39)	(2.56)
R&D	0.13	0.26	0.37	0.47	0.53
	(1.64)	(1.45)	(1.37)	(1.30)	(1.22)
Intangibles	-0.01	-0.01	-0.01	-0.02	-0.05
	(0.27)	(0.14)	(0.11)	(0.15)	(0.24)
N	4,765	4,748	4,739	4,733	4,730
Adj. R^2	0.04	0.03	0.03	0.03	0.04

TABLE 6: Persistence of Innovation Activity around IPOs – 5-year Post-IPO Citations

This table presents the results of OLS regressions where the dependent variable is the number of citations that the patent receives post-IPO. Columns 1, 2, 3, 4, and 5 report results of the same specification with the number of citations being measured within 1, 2, 3, 4, and 5 years post-IPO, respectively. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *Pre-IPO Innovation* is a dummy variable which equals to 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	1	2	3	4	5
Dependent Variable	Cites1	Cites2	Cites3	Cites4	Cites5
Pre-IPO Innovation	0.47***	0.96***	1.37***	1.65***	1.89***
	(6.16)	(6.12)	(6.26)	(4.57)	(6.94)
VC-backed	-0.08	-0.19*	-0.27*	-0.31*	-0.33*
	(1.50)	(1.74)	(1.76)	(1.79)	(1.77)
Size	0.10*	0.22*	0.31*	0.36*	0.39**
	(1.83)	(1.91)	(1.89)	(1.96)	(2.06)
Tobin's Q	-0.00	-0.01	-0.01	-0.01	-0.01
	(0.57)	(0.64)	(0.60)	(0.43)	(0.34)
ROA	-0.07	-0.09	-0.06	0.03	0.17
	(0.93)	(0.58)	(0.26)	(0.11)	(0.56)
Leverage	-0.32**	-0.69**	-0.97**	-1.17**	-1.32***
	(2.22)	(2.31)	(2.33)	(2.55)	(2.85)
R&D	0.13	0.25	0.36	0.41	0.45
	(1.27)	(1.16)	(1.09)	(0.96)	(0.88)
Intangibles	-0.01	-0.01	0.01	0.01	0.01
	(0.09)	(0.05)	(0.07)	(0.07)	(0.05)
N	4,765	4,748	4,739	4,733	4,730
Adj. R^2	0.03	0.03	0.03	0.03	0.04

TABLE 7: Persistence of Innovation Activity around IPOs – 5-year Post-IPO Normalized Citations

This table presents the results of OLS regressions where the dependent variable is the number of normalized citations (citations per patent) received post-IPO. Columns 1, 2, 3, 4, and 5 report results of the same specification with the number of citations being measured within 1, 2, 3, 4, and 5 years post-IPO, respectively. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *Pre-IPO Innovation* is a dummy variable which equals to 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	1	2	3	4	5
Dependent Variable	Norm. Cites1	Norm. Cites2	Norm. Cites3	Norm. Cites4	Norm. Cites5
Pre-IPO Innovation	0.53***	1.32***	1.81***	2.19***	2.52***
	(4.20)	(7.69)	(7.18)	(6.72)	(6.17)
VC-backed	0.01	0.11	0.18	0.34	0.44
	(0.05)	(0.49)	(0.60)	(0.94)	(0.97)
Size	0.09*	0.23***	0.27**	0.32*	0.31
	(1.74)	(2.98)	(2.35)	(1.93)	(1.44)
Tobin's Q	-0.01	-0.00	-0.00	-0.01	-0.02
	(0.87)	(0.64)	(0.28)	(0.61)	(0.98)
ROA	0.09	0.51	0.95*	1.42**	2.09**
	(0.51)	(1.65)	(1.96)	(2.20)	(2.66)
Leverage	-1.01**	-1.69***	-2.19***	-2.39**	-2.79**
	(2.49)	(3.25)	(3.15)	(2.54)	(2.22)
R&D	-0.11	-0.11	0.26	0.18	0.13
	(0.84)	(0.85)	(1.47)	(0.71)	(0.39)
Intangibles	0.27	0.32	-0.13	-0.15	-0.16
	(0.46)	(0.57)	(0.19)	(0.15)	(0.13)
N	922	1,146	1,257	1,318	1,356
Adj. R^2	0.03	0.06	0.06	0.06	0.06

TABLE 8: Persistence of Innovation Activity around IPOs – Nearest-Neighbor Matching

This table presents the average treatment effects of pre-IPO innovation on post-IPO innovation where the differences in post-IPO innovation are computed via nearest-neighbor matching estimators. Each firm with pre-IPO innovation activity is matched to three similar firms with no pre-IPO innovation activity based on size, Tobin's Q, VC-backing, IPO year and industry. Post-IPO innovation is measured with patents, citations, and normalized citations (citations per patent) in different specifications. Columns 1, 2, 3, 4, and 5 report results for the number of patents, citations, and normalized citations being measured 1, 2, 3, 4, and 5 years post-IPO, respectively. *Pre-IPO Innovation* is a dummy variable which equals 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. All matching variables are measured at the time of IPO. Robust Abadie-Imbens standard errors are used and associated z-statistics are reported in parentheses, and sample sizes are reported for each model. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Average Treatment Effect of Pre-IPO Innovation on:					
	1	2	3	4	5
	One Year	Two Years	Three Years	Four Years	Five Years
Patents	0.25***	0.53***	0.78***	0.96***	1.15***
	(8.56)	(7.69)	(7.55)	(7.65)	(7.91)
	4,825	4,808	4,799	4,793	4,790
Cites	0.34***	0.70***	1.02***	1.24***	1.45***
	(7.47)	(7.19)	(6.81)	(7.10)	(7.31)
	4,825	4,808	4,799	4,793	4,790
Normalized Cites	0.68***	1.51***	2.12***	2.63***	3.03***
	(4.16)	(7.21)	(7.51)	(7.63)	(7.53)
	927	1,152	1,263	1,324	1,362

TABLE 9: VC-backing and Post-IPO Innovation – Innovative vs. Non-Innovative Firms

This table presents the results of OLS regressions where the dependent variable is a measure of innovation activity within the first year after IPO. Columns 1-3 report results for the subsample of *innovative* firms and Columns 4-6 for the subsample of *non-innovative* firms, where a firm is classified as *innovative* if it has produced at least one pre-IPO patent and *non-innovative* otherwise. The dependent variable is number of patents for Columns 1 and 4, number of citations for Columns 2 and 5, and number of normalized citations (citations per patent) for Columns 3 and 6. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	Innovative Firms			*Non-Innovative Firms*		
	1	2	3	4	5	6
Dependent Variable	Patents	Cites	Norm. Cites	Patents	Cites	Norm. Cites
VC-backed	-0.25**	-0.27*	-0.03	0.01**	0.02**	0.21
	(2.12)	(1.77)	(0.16)	(2.68)	(2.70)	(1.09)
Size	0.44**	0.53*	0.08	0.00	0.00	0.06
	(2.10)	(1.78)	(0.95)	(0.66)	(0.37)	(0.95)
Tobin's Q	-0.02*	-0.02	-0.01**	0.00	0.00	-0.01
	(1.92)	(1.21)	(2.22)	(0.95)	(1.47)	(1.03)
ROA	-0.39	-0.43	0.73***	0.00	-0.01	-1.27**
	(1.34)	(1.08)	(3.24)	(0.64)	(0.56)	(2.73)
Leverage	-1.09**	-1.50**	-1.21*	0.00	-0.01	-0.74
	(2.35)	(2.19)	(2.00)	(0.11)	(0.57)	(1.57)
R&D	0.43*	0.48	-0.11	0.11**	0.10**	-1.80**
	(1.83)	(1.46)	(0.91)	(2.55)	(2.59)	(2.62)
Intangibles	0.02	0.08	0.02	0.01	0.02**	0.93*
	(0.04)	(0.13)	(0.02)	(1.34)	(2.18)	(1.94)
N	953	953	598	3,812	3,812	324
Adj. R^2	0.07	0.05	0.02	0.02	0.02	0.06

TABLE 10: VC-backing and 5-year Post-IPO Patents – Innovative vs. Non-Innovative Firms

This table presents the results of OLS regressions where the dependent variable is the number of patents produced post-IPO. Columns 1, 2, 3, 4 report results of the same specification with the number of patents being measured within 2, 3, 4, and 5 years post-IPO, respectively, for the subsample of *innovative* firms. Columns 5, 6, 7, 8 report results for the subsample of *non-innovative* firms in a similar fashion. A firm is classified as *innovative* if it has produced at least one pre-IPO patent and *non-innovative* otherwise. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	Innovative Firms				*Non-Innovative Firms*			
	1	2	3	4	5	6	7	8
Dependent Variable	Patents2	Patents3	Patents4	Patents5	Patents2	Patents3	Patents4	Patents5
VC-backed	-0.59**	-0.82**	-0.91*	-0.95*	0.02**	0.03**	0.04**	0.05
	(2.25)	(2.12)	(2.03)	(1.94)	(2.36)	(2.53)	(2.05)	(1.56)
Size	1.01*	1.41*	1.62*	1.68*	0.00	0.01	0.01	0.02
	(1.98)	(1.90)	(1.91)	(1.90)	(1.17)	(1.08)	(1.14)	(1.25)
Tobin's Q	-0.04*	-0.05*	-0.06	-0.06	0.00	0.00	0.00	0.00
	(1.86)	(1.81)	(1.86)	(1.64)	(0.52)	(0.70)	(0.65)	(0.44)
ROA	-0.82	-1.05	-1.09	-0.93	0.03*	0.05**	0.11***	0.17***
	(1.17)	(1.02)	(0.91)	(0.72)	(1.84)	(2.65)	(3.33)	(3.42)
Leverage	-2.33**	-3.22**	-3.87**	-4.24**	-0.01	-0.01	-0.03	-0.06
	(2.27)	(2.24)	(2.28)	(2.38)	(0.83)	(0.43)	(0.65)	(0.83)
R&D	0.96	1.34	1.53	1.57	0.24**	0.38**	0.62**	0.81**
	(1.96)	(1.60)	(1.52)	(1.42)	(2.52)	(2.56)	(2.62)	(2.70)
Intangibles	0.23	0.38	0.12	-0.39	0.02	0.02	0.03	0.05
	(0.22)	(0.25)	(0.07)	(0.20)	(1.19)	(0.93)	(1.05)	(1.02)
N	947	945	946	946	3,801	3,794	3,787	3,784
Adj. R^2	0.07	0.06	0.08	0.06	0.02	0.02	0.02	0.01

TABLE 11: VC-backing and 5-year Post-IPO Citations – Innovative vs. Non-Innovative Firms

This table presents the results of OLS regressions where the dependent variable is the number of citations received post-IPO. Columns 1, 2, 3, 4 report results of the same specification with the number of citations being measured within 2, 3, 4, and 5 years post-IPO, respectively, for the subsample of *innovative* firms. Columns 5, 6, 7, 8 report results for the subsample of *non-innovative* firms in a similar fashion. A firm is classified as *innovative* if it has produced at least one pre-IPO patent and *non-innovative* otherwise. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	Innovative Firms				*Non-Innovative Firms*			
	1	2	3	4	5	6	7	8
Dependent Variable	Cites2	Cites3	Cites4	Cites5	Cites2	Cites3	Cites4	Cites5
VC-backed	-0.64**	-0.95**	-1.08**	-1.14*	0.03**	0.04*	0.04	0.04
	(2.05)	(2.08)	(2.08)	(1.99)	(2.30)	(1.85)	(1.17)	(0.61)
Size	1.15*	1.69*	1.82*	1.88*	0.00	0.01	0.01	0.03
	(1.84)	(1.79)	(1.82)	(1.81)	(0.80)	(0.89)	(0.85)	(1.05)
Tobin's Q	-0.04	-0.05	-0.06	-0.06	0.00	0.00	0.01	0.01
	(1.34)	(1.33)	(1.24)	(1.16)	(1.18)	(1.34)	(1.21)	(1.00)
ROA	-0.81	-0.99	-0.96	-0.69	0.04	0.11***	0.23***	0.37***
	(0.95)	(0.79)	(0.66)	(0.44)	(1.39)	(2.93)	(3.40)	(3.09)
Leverage	-3.16**	-4.38**	-5.15**	-5.66**	-0.03	-0.05	-0.09	-0.16
	(2.23)	(2.25)	(2.34)	(2.48)	(1.49)	(1.28)	(1.55)	(1.48)
R&D	1.01	1.39	1.52	1.51	0.29*	0.52**	0.81**	1.11**
	(1.45)	(1.39)	(1.29)	(1.18)	(2.01)	(2.25)	(2.49)	(2.54)
Intangibles	0.35	0.62	0.36	-0.15	0.03	0.05*	0.07*	0.10
	(0.27)	(0.34)	(0.17)	(0.06)	(1.63)	(1.84)	(1.71)	(1.50)
N	947	945	946	946	3,801	3,794	3,787	3,784
Adj. R^2	0.06	0.06	0.06	0.06	0.01	0.01	0.01	0.01

TABLE 12: VC-backing and 5-year Post-IPO Normalized Citations – Innovative vs. Non-Innovative Firms

This table presents the results of OLS regressions where the dependent variable is the number of normalized citations (citations per patent) received post-IPO. Columns 1, 2, 3, 4 report results of the same specification with the number of normalized citations being measured within 2, 3, 4, and 5 years post-IPO, respectively, for the subsample of *innovative* firms. Columns 5, 6, 7, 8 report results for the subsample of *non-innovative* firms in a similar fashion. A firm is classified as *innovative* if it has produced at least one pre-IPO patent and *non-innovative* otherwise. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. *VC-backed* is a dummy variable which equals to 1 when the firm is backed by Venture Capital and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. *ROA* is EBITDA over total assets. *Leverage* is book value of total debt over total assets. *R&D* is research and development expenses over total assets. *Intangibles* is one minus property, plant and equipment over total assets. All control variables are measured at the time of IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

	Innovative Firms				*Non-Innovative Firms*			
	1	2	3	4	5	6	7	8
Dependent Variable	Norm. Cites2	Norm. Cites3	Norm. Cites4	Norm. Cites5	Norm. Cites2	Norm. Cites3	Norm. Cites4	Norm. Cites5
VC-backed	-0.12	-0.17	-0.13	-0.12	0.58***	0.72**	1.02***	1.11**
	(0.39)	(0.41)	(0.23)	(0.18)	(3.12)	(2.58)	(3.01)	(2.53)
Size	0.35**	0.37	0.43	0.33**	0.01	0.05	0.06	0.14
	(2.40)	(1.71)	(1.37)	(0.84)	(0.07)	(0.44)	(0.40)	(0.68)
Tobin's Q	-0.02**	-0.02	-0.04	-0.05*	0.00	0.01	0.01	0.00
	(2.71)	(1.62)	(1.64)	(2.00)	(0.44)	(1.33)	(0.74)	(0.15)
ROA	1.10**	1.67**	2.11*	3.03**	-0.27	0.20	0.73	1.36
	(2.26)	(2.14)	(1.99)	(2.44)	(0.42)	(0.29)	(0.92)	(1.32)
Leverage	-2.35**	-3.16**	-3.53*	-3.98*	-0.97**	-1.22**	-1.22*	-1.57
	(2.27)	(2.23)	(1.90)	(1.76)	(2.43)	(2.58)	(1.90)	(1.41)
R&D	-0.03	0.33	0.23	0.08	0.26	0.57	0.29	1.41
	(0.24)	(1.31)	(0.63)	(0.18)	(0.21)	(0.36)	(0.18)	(0.70)
Intangibles	0.37	-0.66	-1.81	-2.41	0.38	0.34	1.04	1.33
	(0.34)	(0.46)	(0.90)	(0.95)	(0.89)	(0.59)	(1.20)	(1.25)
N	673	696	706	712	473	561	612	644
Adj. R^2	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02

TABLE 13: VC-Backing and Post-IPO Innovation – Nearest-Neighbor Matching

This table presents the average treatment effects of VC-backing on post-IPO innovation in two subsamples where the differences in post-IPO innovation are computed via nearest-neighbor matching estimators. Each VC-backed firm is matched to three similar NONVC-backed firms based on Size, Tobin's Q, IPO year and industry. Post-IPO innovation is measured with patents, citations, and normalized citations (citations per patent) in different specifications. Panel A (B) presents the average treatment effects for the subsample of *innovative* (*non-innovativ*e) firms, i.e. firms with (without) pre-IPO innovation activity. Columns 1, 2, 3, 4, and 5 report results for the number of patents, citations, and normalized citations being measured 1, 2, 3, 4, and 5 years post-IPO, respectively. *Pre-IPO Innovation* is a dummy variable which equals 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *Size* is the natural log of total assets. *Tobin's Q* is market value of assets over book value of assets. All matching variables are measured at the time of IPO. Robust Abadie-Imbens standard errors are used and associated z-statistics are reported in parentheses, and sample sizes are reported for each model. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Average Treatment Effect of VC-backing on:					
	1	2	3	4	5
	One Year	Two Years	Three Years	Four Years	Five Years
Panel A: Innovative Firms					
Patents	-0.13	-0.35*	-0.51*	-0.57*	-0.64*
	(1.58)	(1.92)	(1.84)	(1.70)	(1.69)
	956	950	948	949	949
Citations	-0.17	-0.47*	-0.76*	-0.86*	-1.01*
	(1.36)	(1.73)	(1.85)	(1.80)	(1.84)
	956	950	948	949	949
Normalized Citations	-0.13	-0.35	-0.42	-0.36	-0.50
	(0.57)	(0.92)	(0.78)	(0.54)	(0.66)
	599	674	697	707	713
Panel B: Non-Innovative Firms					
Patents	0.01***	0.02***	0.04***	0.05***	0.07***
	(3.46)	(3.48)	(3.83)	(3.63)	(3.30)
	3,869	3,858	3,851	3,844	3,841
Citations	0.02***	0.03***	0.05***	0.06**	0.07*
	(3.22)	(3.05)	(3.02)	(2.44)	(1.91)
	3,869	3,858	3,851	3,844	3,841
Normalized Citations	0.27	0.73***	0.97***	0.99**	0.97**
	(1.37)	(2.89)	(3.02)	(2.44)	(1.99)
	328	478	566	617	649

TABLE 14: Post-IPO Innovation – Impact of VC Tenure

This table presents the results of OLS regressions attempting to identify the impact of VC tenure on post-IPO innovation. The dependent variable is the number of patents produced post-IPO. The sample consists of VC-backed IPOs as VC tenure is only defined for those observations. Columns 1, 2, 3, 4, and 5 report results of the same specification with the number of patents being measured within 1, 2, 3, 4, and 5 years post-IPO, respectively. Panel A reports results for the full sample, while Panel B (C) report results for the subsample of *innovative* (*non-innovative*) firms. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. All specifications include *Size, Tobin's Q, ROA, Leverage, R&D*, and *Intangibles* as control variables, but their coefficients are not reported for brevity. All control variables are measured at the time of IPO. *Pre-IPO Innovation* is a dummy variable which equals to 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *VC-Tenure* is the standardized value of the number of years between the first VC investment and the IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Dependent Variable	Patents1	Patents2	Patents3	Patents4	Patents5
	1	2	3	4	5
Panel A: Full Sample					
Pre-IPO Innovation	0.23***	0.44***	0.64***	0.82***	0.99***
	(9.67)	(10.99)	(9.29)	(7.43)	(6.43)
VC-Tenure	-0.01**	-0.02*	-0.03*	-0.06*	-0.08*
	(2.52)	(1.94)	(1.99)	(1.99)	(1.77)
Controls	Yes	Yes	Yes	Yes	Yes
N	1,609	1,602	1,596	1,593	1,592
Adj. R^2	0.14	0.013	0.12	0.09	0.07
Panel B: Innovative Firms					
VC-Tenure	-0.04**	-0.07**	-0.11**	-0.18 **	-0.23**
	(2.62)	(2.23)	(2.30)	(2.28)	(2.12)
Controls	Yes	Yes	Yes	Yes	Yes
N	551	546	545	545	545
Adj. R^2	0.02	0.02	0.02	0.02	0.02
Panel C: Non-Innovative Firms					
VC-Tenure	-0.00	0.00	0.00	0.00	0.00
	(0.32)	(0.17)	(0.49)	(0.40)	(0.18)
Controls	Yes	Yes	Yes	Yes	Yes
N	1,058	1,056	1,051	1,048	1,047
Adj. R2	0.03	0.02	0.03	0.03	0.02

TABLE 15: Post-IPO Innovation – Impact of the Number of Investing VC Firms

This table presents the results of OLS regressions attempting to identify the impact of the number of investing VC firms on post-IPO innovation. The dependent variable is the number of patents produced post-IPO. The sample consists of VC-backed IPOs as the number of VC firms is only defined for those observations. Columns 1, 2, 3, 4, and 5 report results of the same specification with the number of patents being measured within 1, 2, 3, 4, and 5 years post-IPO, respectively. Panel A reports results for the full sample, while Panel B (C) reports results for the subsample of *innovative* (*non-innovative*) firms. All dependent variables are adjusted by year and technology group which accounts for year and industry fixed effects. All specifications include *Size, Tobin's Q, ROA, Leverage, R&D*, and *Intangibles* as control variables, but their coefficients are not reported for brevity. All control variables are measured at the time of IPO. *Pre-IPO Innovation* is a dummy variable which equals to 1 if the firm has produced at least one pre-IPO patent and 0 otherwise. *VC-Tenure* is the standardized value of the number of years between the first VC investment and the IPO. *# of VC-firms* is the standardized value of the number of VC firms investing in the company pre-IPO. Standard errors are clustered by year and associated t-statistics are reported in parentheses. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Dependent Variable	Patents1	Patents2	Patents3	Patents4	Patents5
	1	2	3	4	5
Panel A: Full Sample					
Pre-IPO Innovation	0.23***	0.43***	0.63***	0.80***	0.97***
	(10.06)	(11.41)	(9.62)	(7.54)	(6.42)
VC-Tenure	-0.01**	-0.02**	-0.04**	-0.07**	-0.09**
	(1.92)	(2.29)	(2.39)	(2.37)	(2.17)
# of VC-firms	0.00	0.02	0.04	0.06*	0.09**
	(0.52)	(1.16)	(1.48)	(1.74)	(2.10)
Controls	Yes	Yes	Yes	Yes	Yes
N	1,609	1,602	1,596	1,593	1,592
Adj. R^2	0.14	0.14	0.12	0.09	0.07
Panel B: Innovative Firms					
VC-Tenure	-0.04**	-0.07**	-0.12**	-0.19**	-0.25**
	(2.62)	(2.44)	(2.53)	(2.54)	(2.40)
# of VC-firms	0.01	0.03	0.06	0.08	0.12
	(0.25)	(0.64)	(0.87)	(0.96)	(1.15)
Controls	Yes	Yes	Yes	Yes	Yes
N	551	546	545	545	545
Adj. R^2	0.02	0.03	0.02	0.02	0.02
Panel C: Non-Innovative Firms					
VC-Tenure	-0.00	-0.00	-0.00	-0.00	-0.01
	(0.73)	(0.62)	(0.22)	(0.31)	(0.48)
# of VC-firms	0.01*	0.02***	0.03***	0.05**	0.07***
	(1.75)	(2.83)	(2.87)	(2.59)	(2.80)
Controls	Yes	Yes	Yes	Yes	Yes
N	1,058	1,056	1,051	1,048	1,047
Adj. R^2	0.03	0.03	0.03	0.04	0.04