UNLEASHING INNOVATION*

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UNLEASHING INNOVATION

Abstract

Using a sample of venture capital (VC)-backed initial public offering (IPO) firms, we study the effect of financial intermediaries' tight leash on entrepreneurs' innovation productivity. We find that financial intermediaries' tight leash impedes innovation: IPO firms are significantly less innovative when VCs interfere with their development more frequently through staging—as measured by a larger number of VC financing rounds. To establish causality, we exploit plausibly exogenous variation in the frequency of direct flights between VC domiciles and IPO firm headquarters that are due to airline restructuring. Our identification tests suggest a negative, causal effect of VC staging on firm innovation. Furthermore, staging is more detrimental to innovation when innovation is more difficult to achieve and when VCs are less experienced with the industry in which their entrepreneurial firms operate. By documenting a previously under-recognized adverse consequence of VC stage financing, our evidence suggests that contract mechanisms are at play so that short-termist incentives can be cultivated even in a private equity market populated with long-term, sophisticated investors.

Keywords: Innovation, Stage financing, Venture capital, Short-termism

JEL classification: G24, O31, G34

UNLEASHING INNOVATION

1. INTRODUCTION

Technological innovation is vital for a country's economic growth (Solow, 1957) and a firm's competitive advantage (Porter, 1992). Nevertheless, how to effectively motivate and nurture innovation remains challenging for most countries and organizations. Existing literature proposes that a highly developed financial market helps promote innovation through improving capital allocation, reducing the cost of capital, and/or effectively monitoring managers and evaluating innovative projects (e.g., Schumpeter, 1911; Brown, Fazzari, and Petersen, 2009; Hsu, Tian, and Xu, 2013). However, a developed financial market could also give rise to various adverse externalities such as short-termism, rent-seeking, and opportunistic behaviors. In this paper, we focus on venture capital (VC)—a key ingredient of the financial market and a main driver of entrepreneurship and technological innovation in the United States—and explore the effect of a unique feature of VC financing, stage financing, on the innovation output of the initial public offering (IPO) firms they fund.

Stage financing, or staging, refers to the stepwise disbursement of capital from VC investors to entrepreneurial firms. Instead of an upfront, lump sum capital infusion, VC investors split financing into multiple rounds, where the next round investment is contingent upon whether the entrepreneurial firm meets the current round's performance target pre-specified by the VC. By allowing VC investors to retain the option to abandon the entrepreneur's project if it fails to meet stage targets, staging mitigates agency and information problems and could lead to more efficient investment decisions and better investment outcomes (e.g., Sahlman, 1990; Admati and Pfleiderer, 1994; Gompers, 1995).

However, whether and how VC staging affects innovation can be ambiguous *ex ante*. On the one hand, VC staging can mitigate the hold-up problem by the entrepreneur who undertakes innovation activities. As in the Hart and Moore's (1994) world of incomplete contracting, once the VC has made the investment and the innovation process begins, an entrepreneur who recognizes that the cost is sunk cannot contractually commit to staying with the firm, in which his unique human capital is critical to achieving the venture's full innovation potential. Neher (1999) suggests that VC staging can mitigate this hold-up problem because the gradual embodiment of the entrepreneur's human capital in the venture's physical capital is equivalent to the build-up of collateral, which reduces the entrepreneur's bargaining power and incentives to leave the firm. Hence, by keeping a tight leash on the entrepreneurs they fund, VC investors can mitigate agency and hold-up problems through stage financing.[1] This "agency hypothesis" implies that VC stage financing promotes innovation.

On the other hand, frequent and excessive interference through VC staging, thus a tight leash on the entrepreneur, may impede firm innovation. Unlike routine operations such as mass production and marketing, innovation involves a long, idiosyncratic process that is full of uncertainty and has a high probability of failure (Holmstrom, 1989). Tolerance for failure in the short run coupled with reward to succeed in the long run is thus necessary for effectively motivating innovation (Manso, 2011; Ferreira, Manso, and Silva, 2014).[2] Any external pressure to meet short-term targets imposed by investors discourages managers from undertaking long-term investment in innovation. While staged capital infusions allow VCs to avoid the hold-up problem, a short-termism problem can arise: due to the pressure to secure the next round of capital infusion from VC investors, the entrepreneur may forgo long-term value creation activities such as investing in innovative projects, and instead, aim for short-term success (i.e., "window dressing"). This "leashing hypothesis" thus argues that VC stage financing impedes innovation by imposing significant pressure on entrepreneurs to meet short-term stage targets and encouraging short-termist investments.[3]

We test the above two competing hypotheses by examining whether VC stage financing promotes or impedes the innovation of their IPO firms. Traditionally, the success of an entrepreneurial firm's investment in intangible assets and research and development (R&D) has been difficult to observe and assess. To capture firms' innovativeness, we make use of an observable innovation output, i.e., the number of patents granted to a firm after its IPO and the number of future citations received by each patent, which now has become standard in the innovation literature (e.g., Acharya and Subramanian, 2009; Aghion et al., 2013; Seru, 2014).

A standard and naïve ordinary least squares (OLS) regression suggests that VC staging (measured by the number of financing rounds that VCs invest in an entrepreneurial firm before it

[1] As Sahlman (1990, p. 506) argued, "The most important mechanism for controlling the venture (by the venture capitalists) is staging the infusion of capital."

[2] Recent empirical research providing supporting evidence for the implications of the failure tolerance theory includes Ederer and Manso (2013), who conduct a controlled laboratory experiment, and Azoulay, Graff Zivin, and Manso (2011), who exploit key differences among funding streams within the academic life science.

[3] Sahlman (1988) describes how the entrepreneur could try to improve short-term performance to ensure that his project will be refinanced in the next round.

goes public) does not appear to have an effect on an IPO firm's innovation output. However, this finding is likely driven by that the extent of VC stage financing is endogenously determined. Unobservable VC investor or entrepreneurial firm heterogeneity correlated with both VC staging and IPO firm innovation remains in the residual term of the regressions, which makes it difficult to draw correct statistical inferences.

To establish causality, we construct an instrumental variable (IV) for VC staging and undertake a two-stage least squares (2SLS) analysis. Our IV relies on plausibly exogenous variation in VC investors' opportunity costs of staging, captured by the frequency of direct flights between the cities where the entrepreneurial firm and the VC investor are located. The rationale behind this instrument is that the easier it is for VCs to access their entrepreneurial firms, approximated by more frequent direct flights between VC domiciles and entrepreneurial firm headquarters, the less vital it is for VCs to rely on the costly disciplining mechanism—stage financing.[4] However, it is reasonably to believe that the frequency of direct flights is not correlated with a firm's innovation output after it goes public through channels other than VC staging.

To further ensure the satisfaction of the exclusion restriction, we make use of the variation in the frequency of direct flights between the locations of VCs and entrepreneurs that is caused by airline restructuring activities such as bankruptcies, mergers and acquisitions, and strategic alliances. These restructuring activities are motivated by the strategic considerations of the airlines themselves rather than by the characteristics of VC investors and entrepreneurial firms located in the cities in which flight services are provided. Therefore, it is reasonable to believe that the number of direct flights between VCs and entrepreneurs affected by airline restructuring is not correlated with the entrepreneurial firms' innovativeness, and therefore the instrument is likely to satisfy the exclusion restriction.

The 2SLS analysis suggests a negative effect of VC staging on the innovation output of the entrepreneurial firms after they go public. One additional round of VC financing leads to a 28.3% reduction in the number of patents per year and a 31% reduction in the number of citations per patent. Overall, our findings support the leashing hypothesis but are inconsistent with the agency hypothesis.

[4] Tian (2011) argues that potential costs arising from VC stage financing include negotiation and contracting costs associated with each round of financing, forgone economies of scale due to divided capital infusions, underinvestment in early-stage viable ventures, and induced short-termist behavior on the part of entrepreneurs.

Comparing between the results based on the OLS and IV analyses, it appears that OLS biases the effect of VC staging on firm innovation upward due to endogeneity. This observation suggests that certain omitted variables simultaneously make firms more innovative and more likely to receive a larger number of VC financing rounds. The entrepreneurial firm's technology complexity could be an example of such an omitted variable. For instance, a new venture at the early stage of developing a new and complex technology is, by nature, difficult for its VC investors to evaluate. Therefore, the venture is likely to receive multiple financing rounds from the VC. Meanwhile, such technology is likely to result in many innovative products and patents. This positive correlation between staging and firm innovation arising from omitted variables thus biases the coefficient estimate upward. Once we use the IV to clean up the correlation between VC staging and the omitted variables, the endogeneity of VC staging is largely mitigated and the coefficient estimate decreases, i.e., becomes negative.

To help further identify the possible causal effect of VC staging on IPO firms' innovation output, we examine how VC staging affects IPO firm innovation differently in the cross section in the 2SLS framework. First, if VC staging indeed induces short-termism on the part of entrepreneurs and impedes their innovation, then a natural implication is that VC staging should be particularly detrimental in industries in which innovation is difficult to achieve. Consistent with our conjecture, we find that the negative effect of VC staging on firm innovation is more pronounced in pharmaceutical and electronics industries—in which innovation process is long, failure risk is high, and demands for resources are stronger—than in industries in which innovation is easier to attain.

We next examine how the extent of VC investors' experience in the industry in which their portfolio firms operate affects innovation. If VCs have expertise in their portfolio firm's industry, they should have a better understanding about the business nature of the entrepreneurial firm. As a result, their staged capital infusions should be less detrimental to firm innovation because the benefit of staging (preventing hold-up and keeping the abandonment option) dominates. Consistent with this conjecture, we find that more intensive staging leads to a lower level of innovation output only among firms backed by VCs who are less experienced with the industry to which these firms belong.

The above cross-sectional tests further lend credence to our causal inferences of a negative effect of VC staging on firm innovation. While it is possible that some omitted variables drive the documented results, it is difficult to conceive of an omitted variable that biases our results equally along all dimensions in firms that are in industries in which innovation is difficult or easy to achieve, and that are financed by VCs with more or less matched industry expertise. The differential effects of VC staging on firm innovation output along these dimensions alleviate the identification concern to some extent, as our results are unlikely to be entirely driven by VCs' endogenously selecting to invest fewer rounds in more innovative firms. Instead, it appears to suggest that a treatment effect is at least partially in play.

Our main findings are robust to various regression and sample specifications and ways the data are structured, and to alternative mechanisms and explanations. In particular, we present evidence suggesting that our instrument affects innovation through its effects on VCs' excessive interference (staging) rather than their monitoring and information acquisition costs. Furthermore, consistent with that the negative effect of VC staging on innovation is an unintended side effect of this investment arrangement, we show that an IPO firm's innovation productivity does not affect its investing VCs' own future performance. Therefore, VCs are unlikely to take their portfolio firms' post-IPO innovation productivity into consideration when they stage finance them in the first place.

Our research setting and empirical findings help shed light on our understanding about the tradeoff between public versus private equity market investors in terms of motivating long-term investment such as innovation. Existing literature on financial intermediation has identified VCs as long-term and sophisticated investors, and recognized VCs' value creation for their portfolio firms (see Da Rin, Hellmann, and Puri 2013 for a survey). Existing literature also highlights investor short-termism as one of the drawbacks of public markets (e.g., Stein 1989; Bushee 1998, 2001; Graham, Harvey, and Rajgopal 2005; Asker, Farre-Mensa, and Ljungqvist 2014). By focusing on the VC market in which investors generally have long-term investment horizons and deep pockets, we show that it is the contract mechanism between investors and investees rather than the type of investors that cultivates a firm's short-termist incentives. This insight highlights the importance of contract design in motivating innovation.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 describes the research design and variable construction. Section 4 discusses sample selection and reports summary statistics. Sections 5 and 6 present the empirical results. Section 7 describes the results from various robustness tests. Section 8 concludes the paper. Variable definitions are in Appendix.

2. RELATION TO THE EXISTING LITERATURE

Our paper contributes to three strands of literature. First, our paper is related to the emerging literature on finance and innovation. Theoretical work from Holmstrom (1989) argues that innovation activities may mix poorly with routine activities in an organization. Manso's (2011) model shows that managerial contracts that tolerate failure in the short-run and reward success in the long-run are best suited for motivating innovation. Ferreira, Manso, and Silva (2014) argue that a firm's ownership structure also affects innovation.

Empirical evidence suggests that various economic environment and firm characteristics affect managerial incentives to innovate. Specifically, a larger institutional ownership (Aghion, Van Reenen, and Zingales, 2013), corporate venture capital (Chemmanur et al., 2014), private instead of public equity ownership (Lerner, Sorensen, and Stromberg, 2011), and lower analyst coverage (He and Tian, 2013) alter managerial incentives and hence motivate managers to focus more on long-term innovation activities. Other studies examine the effects of venture capital investment, product market competition, bankruptcy laws, general market conditions, financial market development, firm boundaries, and investors' attitudes toward tolerance on firm innovation (e.g., Kortum and Lerner, 2000; Aghion et al., 2005; Acharya and Subramanian, 2009; Nanda and Rhodes-Kropf, 2012, 2013; Hsu et al., 2013; Seru, 2014; Tian and Wang, 2014). However, existing studies have largely ignored the role played by certain investment mechanisms that allow investors to keep a tight leash on investees in motivating investees' innovation activities. We contribute to this line of research by filling in this gap.

Our paper also builds on the empirical literature studying managers' short-termism. This literature shows evidence consistent with managerial myopia in publicly traded firms.[5] For example, Asker, Farre-Mensa, and Ljungqvist (2014) find that publicly listed firms exhibit substantial myopia behavior: compared with private firms, they invest less and their investment levels are less sensitive to changes in investment opportunities. Bushee (1998) shows that managers are more likely to cut R&D expenses in response to an earnings decline when a very

[5] Stein's (1989) model shows that managerial myopia is present even in a rational capital market, and the degree of myopic behavior will be influenced by capital market incentives that determine the extent to which managers care about short-term stock prices relative to long-term firm values.

large proportion of institutional ownership comes from short-term investors. Our paper instead focuses on the effect of VC staging on entrepreneurs' short-termism in a private, intermediated market populated by long-term and skilled investors.

Finally, our paper adds to the large literature on the role of VC investors for value creation in entrepreneurial firms. This literature has shown that VC firms' experience, intensive monitoring, reputation, syndication, network positions, and industry expertise all enhance the value of VC-backed entrepreneurial firms. Recent studies in this line of research include Hochberg, Ljungqvist, and Lu (2007), Sorensen (2007), Nahata (2008), Gompers, Kovner, and Lerner (2009), Chemmanur, Krishnan, and Nandy (2011), Tian (2011), and Puri and Zarutskie (2012). For a survey of the literature, see Da Rin, Hellmann, and Puri (2013). Our paper adds to this line of research by exploring a unique VC investment structure, staged capital infusions, on innovation productivity of their portfolio firms.

A contemporaneous paper by Bernstein, Giroud, and Townsend (2014) show that by reducing travel time between VCs and their portfolio firms, the introduction of new airline routes leads to more pre-IPO innovations and a higher likelihood of an IPO. The authors argue that this is because the reduction in travel time boosts VC activities, leading to better firm performance. While their findings are broadly consistent with our paper to the extent that intensive monitoring and staging (a contract mechanism that disciplines entrepreneurs) are substitutes (Tian, 2011), they do not narrow down the specific channels through which VCs' activities shape firm performance. This could be a limitation of their study, because VCs' value creation for entrepreneurial firms goes beyond intensive monitoring that reduces agency problems.[6] Instead of examining the aggregate effect of VC activities on pre-IPO firm performance, we focus on the stage financing arrangement, a contract mechanism explicitly designed to mitigate the agency problems that are inherent in this private, intermediated market. By exploiting the nature of innovation—projects that generally involve a long and risky process with a high probability of failure—as an economic experiment, we highlight that entrepreneurial firms' short-termism can still be cultivated even in a market in which investors with short-term horizons are absent.

[6] For example, existing literature has identified VCs' value-creating activities such as professionalization of managers, improving operation efficiency, advising, providing industry expertise, and enhancing corporate governance (e.g., Hellmann and Puri 2002; Chemmanur, Krishnan, and Nandy 2011; Gompers, Kovner, and Lerner 2009; Krishnan et al. 2011). A reduction in travel time allows VCs to spend more time on these value-adding activities and hence enhance firm performance.

3. RESEARCH DESIGN

3.1 Measuring Innovation and VC Staging

We use VC staging to capture the extent to which a VC investor keeps a tight leash on its IPO firm during the firm's incubation period. To measure the extent of VC staging, we use the number of financing rounds a VC invests in the IPO firm before it goes public.

The leashing hypothesis suggests that more excessive interference from VCs when interacting with their entrepreneurial firms induces more short-termist behaviors, discouraging these firms from investing in innovative projects, which otherwise tend to be risky and time-consuming. To clearly identify the effect of VCs' tight leash on entrepreneurial firms' innovation, we look for a firm's innovation output *after* it goes public. Specifically, innovation output for an IPO firm is measured for the period from year t to year $t + 5$, where t is the year when a VC-backed firm goes public. We design the test this way because before a firm goes public, VC staging and firm's innovation are mingled together; thus it is difficult to establish a causal link between them. After a firm goes public, the number of rounds is a done deal and all new patent filings should be affected by the number of VC financing rounds (if there is a causal effect from VC staging to firm innovation).[7]

To gauge an IPO firm's innovation output, we construct two measures based on the information retrieved from the National Bureau of Economic Research (NBER) patent database. Griliches, Pakes, and Hall (1988) argue that a patent's application year, instead of its grant year, better captures the actual time of innovation. Our first measure is thus an IPO firm's number of patent applications filed in a given year that are eventually granted. While patent counts are straightforward to compute, this measure cannot distinguish groundbreaking innovations from incremental technological discoveries. To further assess a patent's impact, we construct the second measure of innovation productivity by counting the number of citations that each granted patent receives in subsequent years. Controlling for firm size, the number of patents captures the quantity of a firm's innovation output while the number of citations per patent captures the quality of the firm's innovation output.

[7] By focusing on the post-IPO innovation activities, our analysis examines exclusively the effect of VC staging on firms that eventually go public, not on ventures that are sold or abandoned at various stages of their incubation period. Therefore, we explore the difference in innovation quantity and quality within IPO firms that are affected by different intensity of pre-IPO VC staging. One advantage of focusing on IPO firms is that the incubation period is complete, and thus the extent of staging is comparable, across our sample firms.

Following the existing innovation literature, we adjust the two innovation measures to address the truncation problems associated with the NBER patent database. The first truncation problem arises as the patents appear in the database only after they are granted. In fact, we observe a gradual decrease in the number of patent applications that are eventually granted as we approach the last few years in the sample period. This is because the lag between a patent's application year and grant year is significant (about two years on average) and many patent applications filed during these years were still under review and had not been granted by 2006. Following Hall, Jaffe, and Trajtenberg (2001, 2005), we correct for this truncation bias in patent counts using the "weight factors" computed from the application-grant empirical distribution using the patents filed and granted between 1995 and 2000.

The second type of truncation problem is regarding the citation counts, as a patent can keep receiving citations over a long period of time (e.g., 50 years), but we observe at best the citations received up to 2006. Following Hall, Jaffe, and Trajtenberg (2001, 2005), we correct for this truncation bias by dividing the observed citation counts by the fraction of predicted lifetime citations that is actually observed during the lag interval. More specifically, we scale up the citation counts using the variable "hjtwt" provided by the NBER patent database that relies on the shape of the citation-lag distribution.

One advantage of the NBER patent database is that it is unlikely to be affected by the survivorship bias. As long as a patent application is eventually granted by the United States Patent and Trademark Office (USPTO), it is attributed to the applying firm at the time of application even if the firm later gets acquired or goes bankrupt. Moreover, because patent citations are attributed to a patent but not the applying firm, the patent granted to a firm that later gets acquired or goes bankrupt can still keep receiving citations long after the firm disappears.

Our main measures for innovation are thus $ln(Patents)$ and $ln(Citations)$, computed as the natural logarithm of patent counts and the natural logarithm of the number of citations per patent, respectively. To avoid losing firm-year observations with zero patents or citations per patent, we add one to the actual values when calculating the natural logarithm.

It is important to note that using patenting activity to measure firm innovation is not without limitations. For example, patenting is only one of several ways in which firms use to protect returns from innovation, and different industries have various innovation duration and patenting propensity. However, we believe that an adequate control for heterogeneity in firm industries, firm development stages at the first round of VC financing, and VC investors should alleviate this concern and lead to reasonable inferences that can be applicable across industries and firms.

3.2 Identification Strategy

Identifying the casual effect of VC staging on an entrepreneurial firm's innovations is challenging, because VCs optimally stage finance their portfolio firms based on entrepreneurial firms' characteristics (including their innovation potentials) that may not be observable to econometricians. To establish causality, we construct an instrumental variable for VC staging by exploring plausibly exogenous variation in the frequency of direct flights between VC domiciles and IPO firm headquarters.

The rationale follows Tian (2011), who highlights potential costs associated with VC stage financing, including negotiation and contracting costs associated with each round of financing, forgone economies of scale due to divided capital infusions, underinvestment in early-stage viable ventures, and induced short-termist behavior on the part of entrepreneurs. Tian (2011) shows that the extent of VC staging and VC intensive monitoring are substitutes: an easier access to entrepreneurial firms (a lower VC monitoring cost) leads to a higher opportunity cost of stage financing and thus less stage financing. Intuitively, with more frequent direct flights, VCs rely less on staged capital infusions for their entrepreneurial firms, saving on the costs associated with staging.

Specifically, our instrument variable, *Direct Flight*, is calculated as the total number of direct flights (inbound and outbound) in the United States between the airports closest to the cities in which the VC and entrepreneurial firm are located during the firm's incubation period (from the first VC investment year to the firm's IPO year), scaled by the length of the incubation period. In case multiple VCs invest in one entrepreneurial firm, we weigh the frequency of each VC-entrepreneurial firm pair by the investment amount of each VC investor. If the locations of the VC and the entrepreneurial firm are within a driving distance (i.e., shorter than 250 miles), we assign to this pair the sample maximum of the frequency of direct flights.[8] Alternative cutoff points for this distance do not alter our results.

[8] Specifically, our sample maximum is 128 daily (inbound and outbound) flights. This is the route between Los Angeles (LAX) and San Francisco (SFO) during a period when carriers including Delta Airlines, United Airlines, US Airways, Alaska Airlines, and TWA compete against each other.

More frequent domestic direct flights allow for an easier access by a VC to the entrepreneurial firms that it funds. This easy access helps reduce the VC's monitoring cost and consequently, reduces its stage financing incentives. Therefore, the proposed instrument satisfies the relevance condition.

Existing literature has established that an airline company's decision to schedule and/or maintain direct flight routes between any city pair is primarily driven by airline companies' own strategic considerations, such as industry peer competition and dominance (Borenstein and Netz, 1999), choice between "point-to-point" network and "hub-and-spoke" network (Brueckner, 2004), and alliances with other airlines (Bamberger, Carlton, and Neumann, 2004). Pricing, a key determinant for flight scheduling, is affected by physical distance, operation costs, route concentration and competition, and passenger composition and market segmentation (e.g., Borenstein, 1989; Borenstein and Rose, 1994; Gerardi and Shapiro, 2009; Reiss and Spiller 1989). City-pair direct service market structure is also restricted by local population and labor force composition (Pai, 2010), government regulation, airport and aircraft fleet characteristics (Evens and Kessides, 1993; Pai, 2010),[9] and even the features of airlines' frequent flyer programs (Lederman, 2007).

Since city-pair direct flight service market structure is not directed at the locations of small start-up firms that may or may not go public in a foreseeable future, the availability and frequency of direct flights should affect a firm's post-IPO innovation output only through its effect on a VC investor's monitoring cost and therefore staging decisions. This rationale ensures that our instrument reasonably satisfies the exclusion restriction.[10]

One reasonable concern of the proposed instrument is that the frequency of direct flights may be related to the local economic conditions of the cities in which the entrepreneurial firms are located, where the local economic conditions happen to be spurred by the innovation of these entrepreneurial firms. Another reasonable concern is that when founding their firms, entrepreneurs with innovative projects endogenously choose to locate in cities that have more frequent direct flights to their investing VCs.

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[9] For example, with the arrival of the superjumbo jet Airbus 380, five airlines set to add seven new U.S. routes just between August and December of 2014. ("World's largest passenger plane gets more U.S. routes", Ben Mutzabaugh, October 6, 2014, USA Today.)

[10] See also Giroud (2013), who use the introduction of new airline routes as an exogenous variation in affecting the ease of monitoring and information acquisition about subsidiary plants by headquarters.

To address these concerns, we proceed as follows. First and most important, to account for (omitted) local shocks that may drive variation in the frequency of direct flights and local firms' post-IPO innovation productivity, we focus on the variation in direct flights that are unlikely to be driven by such shocks. Specially, we refine our instrument, restricting it to VC-entrepreneurial firm pairs in which the frequency of direct flights during the firm's incubation period is affected by airline restructuring events, such as bankruptcies, strategic alliances, and mergers and acquisitions. In these cases, the variation in the frequency of direct flights offered by an airline company arises from restructuring plans and strategic re-alignment, rather than local economic conditions (e.g., Kim and Singal, 1993; Park and Zhang, 1998; Borenstein and Rose, 2003; Cilibrto and Schenone, 2012).[11] More importantly, it is difficult to conceive of the scenario in which an entrepreneur with innovative projects is able to predict the occurrence of an airline restructuring event, let alone the final outcome of such an event.[12] Therefore, it is unlikely that an entrepreneur with innovative projects chooses venture location accordingly when he founds his entrepreneurial firm.

In the analyses with the refined instrument, we identify whether an airline operating direct flights between cities where VCs and their entrepreneurial firm reside experiences bankruptcy, strategic alliances, or mergers and acquisitions during the firm's incubation period. We then focus on VC-entrepreneurial firm pairs that are subject to this plausibly exogenous variation in the number of direct flights.[13]

Second, as described in Section 3.3 below, we include VC state fixed effects and IPO

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[11] For example, prior to the 2008 merger with Delta Airlines, Northwest Airlines flew profitable and popular direct flights between its Minneapolis/St. Paul hub and Honolulu, Hawaii, using its then new and advanced Airbus 330. This route was subsequently cancelled after the merger as Delta, which previously had no such aircraft, moved the A330s for other longer-range flights (http://www.flyertalk.com), forcing passengers in this area to connect via west coast cities such as Los Angeles.

[12] Airline mergers and alliances are often subject to complex, lengthy, and uncertain regulatory approvals and antitrust investigations (e.g., the U.S. Justice Department's probe of a planned merger of American Airlines and US Airways in 2013 just a couple of days before the deal came to close). Airlines' (successful and unsuccessful) merger activities can be related to bankruptcies (e.g., US Airways' $8 billion bid in 2006 for the bankrupted Delta that eventually failed). Airline mergers can also affect their strategic alliances: Delta's acquisition of Northwest Airlines resulted in Continental Airlines' departure from the SkyTeam Alliance, which later joined United Airlines for the Star Alliance.

[13] It is possible that a VC investor chooses to fly corporate jets to visit its entrepreneurial firms instead of taking commercial flights. However, the availability of corporate jets and the frequency of direct flights tend to be correlated. Most commercial airlines offer corporate jet services in addition to commercial flights. Econometrically, to identify causality by our IV and to ensure unbiased 2SLS estimates require not all, but only some, VC investors to take commercial flights. The extent of the exogenous variation generated by the IV affects only the power of the test, which we now provide several verifying statistics.

firm state fixed effects throughout our analyses. These location-based fixed effects control for time-invariant unobserved local factors that affect VC financing and an entrepreneurial firm's innovation potentials.

Lastly, it is also possible that unobserved time-varying local factors drive our results. For instance, more frequent direct flights could be related to a larger number of IPO firms that are innovative because of a local economic boom. Alternatively, more frequent direct flights could be related to more investments in innovative IPO firms because VCs are doing well. Our main approach—restricting our attention to VC-entrepreneurial firm pairs in which the frequency of direct flights during the firm's incubation period is affected by airline restructuring events—helps to address this potential concern. Nevertheless, to mitigate any lingering doubts, we control, additionally, local economic shocks that may affect IPO firms and VC investors. Specifically, to capture time-varying local shocks to VCs and IPO firms, we construct *Local IPO Market* and *Local VC market*. Following Benveniste et al. (2003), for each IPO firm i, we construct *Local IPO Market* by counting the number of firms located in the same state that go public during firm i's pre-IPO incubation period. For each VC j that invests in IPO firm i, we construct *Local VC Market* by counting the number of IPO firms that VC j has invested during firm i's incubation period. Using IPO proceeds instead of the numbers of IPOs generates similar results; these results are not reported but are available upon request.

3.3 Control Variables

We construct a vector of VC firm and investment characteristics that could affect an IPO firm's innovation output documented by the existing literature. First, we control for VC characteristics such as the size of VC syndicates (the number of VC investors investing in a given IPO firm) and VC reputation using a measure developed by Nahata (2008). Second, we control for *ex ante* IPO firm characteristics that may affect their post-IPO innovation productivity. Specifically, we include a firm's *ex ante* innovation output, captured by the number of patent counts and citations per patent at the time when it receives the first round of VC financing. We also include in the regressions a firm's age and its development stage when it receives the VCs' first round of investment, as well as the length of the firm's incubation period.

Following the innovation literature, we control for a vector of firm and industry characteristics that could affect a firm's innovation output post IPO. We compute each variable for IPO firm i over its fiscal year t after IPO. The controls include firm size (the natural logarithm of book value assets), investments in intangible assets (R&D expenditures over total assets), profitability (return on assets, or ROA), asset tangibility (net properties, plants, and equipment, or PPE, scaled by total assets), leverage, product market competition (the Herfindahl index based on sales), and institutional ownership.

To minimize the impact of outliers on our results, we winsorize all the continuous variables at the 1st and 99th percentiles. The exceptions are the Herfindahl index and institutional ownership, whose value ranges between 0 and 1.

Lastly, we include various fixed effects to control for unobserved industry-specific, IPO year-specific, and VC and IPO firm location-specific variations that can affect VC staging and firm innovation. In particular, VC state fixed effects and IPO firm's state fixed effects take into account time-invariant unobserved local factors that affect their financing and innovation potentials. As described in Section 3.2, to capture time-varying local shocks to VCs and IPO firms, we also control *Local IPO Market* and *Local VC Market* in the regressions.

4. DATA AND SAMPLE CHARACTERISTICS

4.1 Data Sources and Sample Selection

We extract a sample of equity IPOs between 1980 and 2004 from the SDC Global New Issues database. To allow for the availability of the post-IPO innovation output information from the NBER patent database, we end the sample period of IPOs in 2004. Following the IPO literature, we exclude from the initial IPO sample spin-offs, closed-end funds, Real Estate Investment Trusts (REITs), unit offerings, reverse leveraged buyouts (LBOs), foreign issues, offerings in which the offer price is less than $5, finance (SIC codes between 6000 and 6999), and utilities (SIC codes between 4900-4999). We also exclude firms with missing identities of their VC investors and those with missing or inconsistent data.

We obtain VC investment data from the Thomson VentureXpert database for entrepreneurial firms that went public in the sample period and merge it with our sample of IPO firms. We update and cross-reference the information provided by the VentueXpert database with other sources. Specifically, we update and fill in the missing observations for the date on which the firm was founded using Jay Ritter's database (http://bear.cba.uf.edu/ritter/ipodata.htm). We also manually correct obviously inconsistent information obtained from VentureXpert by visiting the firms' websites and reading firms' registration statements with Securities and Exchange Commission (SEC).

Our measure for VC staging is the number of financing rounds a VC invests in the IPO firm during the firm's incubation period. Gompers and Lerner (2006) show that VentureXpert reports 28% more financing rounds than actually occurred because Thomson frequently splits financing rounds. This practice leads to a single financing round to be presented as several separate rounds by different VC firms on different (but proximate) dates. We correct VentureXpert's over-reporting problem following the procedures described in Tian (2011).

We collect innovation output data and construct our main innovation variables from the latest version of the NBER patent database that is constructed based on information provided by the USPTO.[14] This database contains patent and citation information from 1976 to 2006. It provides annual information on patent assignee names, the number of patents, the number of citations received by each patent, a patent's application year as well as its grant year, a patent's technology class, etc.

To construct our instrument variable, we obtain information on direct flights from the U.S. Department of Transportation's Bureau of Transportation Statistics.[15] Specifically, its "Airline On-Time Performance Data" contains on-time arrival information for non-stop domestic flights by major commercial air carriers. The dataset covers direct flight information since October, 1987. Information on airline restructuring—bankruptcies, strategic alliances, and mergers and acquisitions—is from Wikipedia and airlines' websites.[16] We obtain from VentureXpert information on cities in which VC and entrepreneurial firms reside. We then manually identify the corresponding nearest commercial airports through internet searches, including using Google maps and MapQuest.

To construct control variables, we collect financial statement information from Compustat and institutional holdings data from Thomson's CDA/Spectrum database (form 13F).

Our final sample contains 1,840 VC-backed entrepreneurial firms that went public during the 1980-2004 period (10,755 firm-year observations). For the IV analyses, we restrict to the 1987-2004 period, during which 25 unique air carriers providing direct flight services between VC domiciles and IPO firm headquarters. A total of 54 airline restructuring events occurred, 35

[14] Available at http://www.uspto.gov/. See Hall, Jaffe, and Trajtenberg (2001) for details.
[15] Available at http://www.rita.dot.gov/bts/node/11792
[16] We also obtained airline merger and acquisition information from http://www.airlines.org/Pages/m_About.aspx.

of which involve bankruptcies, 13 are mergers and acquisitions, and 6 are strategic alliances. Out of the 1,840 IPO firms, 1,115 firms experience airline restructuring events during their incubation periods, accounting for 60.6% of our sample.

4.2 Summary Statistics

Table 1 provides summary statistics of the variables, for the full sample, and for the subsample of firms whose incubation periods overlap with airline restructuring events, respectively. Panel A presents the IPO firm-level descriptive statistics of VC staging, investment characteristics, and entrepreneurial firm characteristics during the incubation period. For the full sample, an average IPO firm receives 4.8 rounds of financing from its VC investors, and receives investments from 7.9 VC investors across all financing rounds. When receiving its first round of VC financing, an average firm has 0.2 patents and is 3.2 years old. During a firm's incubation period, which averages around 4.3 years, its VCs invest into 19 other IPO firms. During the same period, there are 225 firms that went public from the same state. There are on average 76 daily flights (inbound plus outbound) between VC domiciles and IPO firm headquarters. Furthermore, the descriptive statistics of the variables in the subsample in which the frequency of direct flights during firms' incubation periods varies because of airline restructuring activities are comparable to those in the full sample.

Panel B reports the IPO firm-year level descriptive statistics for innovation and control variables during the period after a firm goes public. For the full sample, an average firm has 1.9 granted patents per year during the five year period after the IPO, with each patent receiving 7.1 future citations. Regarding other variables, an average IPO firm has book value assets of $121 million, R&D-to-assets ratio of 16%, ROA of -11%, leverage ratio of 14%, and 19% of shares held by institutional investors.

Panel C reports the geographic distribution of IPO firms and VCs. Our sample firms are distributed among 42 states and VCs are distributed among 39 states.[17] We observe that 41% of our sample firms are headquartered in California, followed by Massachusetts (11.0%), Texas (5.6%), New York (4.3%) and New Jersey (3.5%). California is also the state where the most VCs reside (35.8% of our sample VCs), followed by New York (18.7%), Massachusetts (14.2%), Connecticut (5.3%), and Illinois (3.5%).

[17] We are unable to identify information on home state for 6 sample entrepreneurial firms and 177 VCs.

5. VC STAGING AND IPO FIRM INNOVATION

5.1 OLS and IV Regressions

We first explore the leashing hypothesis versus agency hypothesis in a naïve OLS panel regression framework. Specifically, we estimate the following model:

$$Innovation = \beta_0 + \beta_1(\#of\ Rounds) + \Omega' Z + \alpha_{IPO\ Year} + \alpha_{Industry} + \alpha_{VC\ State} + \alpha_{Firm\ State} + \varepsilon$$

The dependent variable is one of our two innovation variables, patent counts or citations per patent, measured during the five year period post IPO. *# of Rounds* is the key variable of interest, measured by the number of VC financing rounds before the firm goes public. A higher number indicates a greater intensity of VC stage financing. *Z* is a vector of control variables described in Section 3.3. $\alpha_{IPO\ Year}$ captures IPO year fixed effects (Lerner, 1994), $\alpha_{Industry}$ captures IPO firm's industry fixed effects, $\alpha_{VC\ State}$ captures VC firm's state fixed effects, and $\alpha_{Firm\ State}$ captures IPO firm's state fixed effects. We cluster standard errors at the IPO firm level.

Column 1 of Table 2 reports the results estimating the above equation, with $ln(Patents)$ as the dependent variable. The coefficient estimate of *# of Rounds* is close to zero and statistically insignificant. This finding suggests that the intensity of VC staging does not appear to be related to the innovation output of the entrepreneurial firms after they go public. In column 2, we control, additionally, the two measures capturing local shocks, *Local IPO Market* and *Local VC Market.* In columns 3 and 4, the dependent variable is $ln(Citations)$. In all cases, the coefficient for *# of Rounds* is close to zero and statistically insignificant.

The results in Table 2 are not surprising given that VC's staging decision is endogenous to entrepreneurial firms' characteristics, including their innovation potentials, which are unobservable to researchers. Therefore, the coefficient estimates of *# of Rounds* are likely biased.

To address the identification concern and to establish causality, we construct an instrumental variable for VC's financing rounds during IPO firms' incubation period using the daily number of inbound and outbound domestic direct flights between cities where VC and entrepreneurial firm are located. As explained in Section 3.2, we also use a refined instrument that is based on the number of direct flights being affected by airlines' restructuring events.

In Table 3, we present the regression estimates for our 2SLS analysis, in which the instrumental variable, *Direct Flight,* is constructed for the full sample. Panel A reports the first-stage regression estimates with *# of Rounds* as the dependent variable. The main independent variable is the constructed instrument, *Direct Flight*. Control variables are the same as those in the OLS regressions reported in Table 2. Robust standard errors are clustered at the IPO firm level.

Consistent with the intuition for the instrument construction and in light of Tian (2011), column 1 of Panel A shows that the coefficient estimate of *Direct Flight* is negative, and is significant at the 1% level. More frequent direct flights allow for the ease of VC monitoring, substituting the need for splitting funding to more financing rounds to alleviate the hold-up problem, thus saving the costs associated with staging for VCs. The Stagier and Stock (1997) *F*-statistics of the first-stage in IV estimation is 17.63, suggesting that the instrument is highly correlated with the endogenous right-hand-side variable in the second stage, and that it does not appear to suffer from the weak instrument problem.

In column 2, we control, additionally, two measures for local shocks that affect IPO firms and investing VCs during firms' incubation period. We observe that *Direct Flight* continues to be negatively related to *# of Rounds*. The coefficient estimate on *Direct Flight* suggests that one standard deviation (50.4) increase in the number of daily direct flights is associated with a drop of 0.3 financing rounds (= -0.006×50.4), which is equivalent to 10.3% of the standard deviation of *# of Rounds*.

Panel B reports the second-stage regression estimates, with firm's post-IPO innovation output variables as the dependent variable and the predicted values of the number of financing rounds as the independent variable. The coefficient estimates of instrumented *# of Rounds* are negative and significant in all four columns. The results suggest that VC staging is negatively related to an IPO firm's innovation, in terms of both patent quantity and quality. This finding suggests that more frequent interference by VCs during an IPO firm's incubation period, captured by a larger number of VC financing rounds, are detrimental to nurturing firm innovation. This finding is consistent with the leashing hypothesis, but is inconsistent with the agency hypothesis.

Importantly, the effects we document are not only statistically significant, but also economically sizable. When we consider only the variation in the number of VC financing rounds due to the frequency of direct flights between the cities where VCs and their entrepreneurial firms reside, one additional financing round—which brings the number of rounds from the sample mean (4.8 rounds) to the 66th percentile—leads to a 28.3% decrease in the number of patent applications that are eventually granted. This change brings the patent counts from the sample mean (1.9 patents) to 1.4, or from the 82nd percentile to the 77th percentile.

5.2 Airline Direct Flights Subject to Restructuring

In Table 4, we undertake our 2SLS analysis using the refined IV based on the subsample of VC-IPO firm pairs in which the frequency of direct flights is affected by airline restructuring events: bankruptcies, mergers and acquisitions, and strategic alliances. As discussed before, the variation in the frequency of direct flights caused by an airline company restructuring events is plausibly exogenous, as it is driven by the airline company's own restructuring plans and strategic re-alignments rather than by local economic conditions or the market size of the business and leisure travels that may be related with an IPO firm's innovation.

Panel A of Table 4 repeats the same set of first-stage regressions as in Panel A of Table 3, but restricts to the subsample of VC-IPO firm pairs in which the IPO firm's incubation period experiences airline restructuring events. We observe from columns 1 and 2 of Panel A that the coefficient estimates of the instrument, *Direct Flight*, are negative and significant at the 1% level, regardless of whether or not we include additional controls for local shocks to firms and VCs. The Stagier and Stock (1997) *F*-statistics suggest that we are able to reject the null hypothesis that the instrument is weak.

In Panel B of Table 4, we report the second-stage regression results in the refined IV setting. We observe similar findings: the coefficient estimates of instrumented *# of Rounds* are negative and significant at the 5% level in all columns. The estimates are still strongly supportive of a negative effect of VC staging on IPO firms' subsequent innovation output. For instance, one additional financing round—which brings the number of rounds from the subsample mean (5.3 rounds) to the 76th percentile—leads to a 27.2% decrease in the number of patent filings that are eventually granted. This change brings the patent counts from the subsample mean of 2.3 to 1.6, effectively reducing innovation output from the 79th percentile to the 74th percentile level.

Comparing the results obtained from the OLS analysis in Table 2 and the 2SLS analysis in Tables 3 and 4, the OLS biases the coefficient estimate of *# of Round* upward, which suggests that some omitted variables simultaneously make a firm more innovative and more likely to receive a larger number of VC financing rounds. An example of such an omitted variable could be the entrepreneurial firm's technology complexity. For instance, a new venture in the early stage of developing a new and complex technology is, by nature, very difficult for the VC investor to evaluate. Therefore, the venture is likely to receive multiple financing rounds from the VC (Gompers, 1995). Meanwhile, the development of this technology, once successful, is likely to result in many innovative products and patents. This positive correlation between staging and firm innovativeness caused by omitted variables is the main driving force that biases the coefficient estimate upward. Once we use the IV to clean up the correlation between VC staging and the omitted variable left in the residual term, the endogeneity of VC staging is largely mitigated and the coefficient estimate decreases, i.e., becomes negative.

6. CROSS-SECTIONAL ANALYSES

In this section, we examine how VC staging affects IPO firm innovation output differently in the cross section in the 2SLS framework. We use the cross-section variation in an IPO firm's innovation difficulty and VC's industry experience to further identify the possible causal effect of VC staging on IPO firm innovation output.

In these sets of analyses, we use the refined IV and focus on the subsample of VC-IPO firm pairs in which the frequency of direct flights is affected exogenously by airline restructuring events, such as bankruptcies, mergers and acquisitions, and strategic alliances. To save space, we only tabulate the second-stage results.

6.1 Innovation Difficulties

Our analysis so far demonstrates that a tighter leash, or more excessive interference, by VC investors during IPO firms' incubation period degrades the quantity and quality of their innovation. If VC staging indeed induces short-termist behaviors of entrepreneurs and impedes innovation, then a natural cross-sectional implication is that VC staging should be particularly detrimental in industries in which innovation is difficult to achieve. The intuition is that a tight leash hampers innovation incentives especially when the process to innovate is long and the resources demanded are large so that early failures are more likely to be observed. As a result, it forces entrepreneurs to focus more on short-term performance targets, instead of leaving enough room to allow them to engage in long-term innovative projects.

We split our sample of IPO firms based on the degree of innovation difficulty in the industry to which they belong. Following the work of Hall, Jaffe, and Trajtenberg (2005), we classify our sample into two categories based on patent technology class: more demanding industries that include pharmaceutical, medical instrumentation, chemicals, computers, communications, and electrical industries, and less demanding industries that include software programming, internet applications, and other low-tech industries. In drug and electronics industries, the innovation process is typically long, failure risk is high, and resources demanded are larger. On the other hand, fostering innovations is less difficult and resource demanding in software and low-tech industries.

Table 5 reports the 2^{nd}-stage of the 2SLS estimates for the two subsamples. For brevity, control variables and various fixed effects are included in the regressions but are not tabulated. We observe that the coefficient estimates of *# of Rounds*—instrumented by *Direct Flight* that varies due to airline restructuring—are negative and significant in more demanding industries. By contrast, VC staging does not seem to significantly affect innovation, both statistically and economically, in industries where innovation is less difficult to achieve. The evidence suggests that the effect of VC staging on firm innovation is more detrimental in industries in which innovation is more difficult to achieve, which is consistent with our conjecture.

6.2 Industry Expertise

Next, we examine how the effect of VC staging on entrepreneurial firms' post-IPO innovation output varies with the extent of industry expertise of VC investors. The intuition is as follows: if VC investors are more experienced with the industry to which their portfolio firms belong, they would have a better understanding about the business and innovative nature of the entrepreneurial firm. Consequently, their excessive interference in the entrepreneurial firm reflected in staged capital infusions should be less detrimental to these firms' innovation output. On the other hand, if a VC is less experienced with the industry in which the entrepreneurial firms operate, the downsides of keeping a tight leash dominate. Therefore, its frequent interferences should have a more negative effect on their innovation output.

We measure a VC's industry expertise on a rolling 10-year window basis. For each sample entrepreneurial firm, we identify the industry experience of an investing VC at the time when the firm receives the VC's first investment. A VC's industry experience is computed by dividing the total number of entrepreneurial firms that the VC has invested in an industry in the previous 10 years by the total number of entrepreneurial firms that the VC has invested in all the industries during the same 10-year period.[18] This measure thus captures a VC's experience in a specific industry at the time when it makes the initial investment into the entrepreneurial firm. We then compute the industry expertise of the entire VC syndicate for each entrepreneurial firm by weighted-averaging the industry expertise of each VC in the syndicate using its investment amount.

A higher value of this measure suggests that a VC has more experience and exposure in the industry to which the entrepreneurial firm belongs. Using total proceeds instead of total number of entrepreneurial firms to compute a VC's industry expertise does not alter our findings.

Based on the industry expertise of VC syndicate, we divide our IPO firm sample into the "more experienced" and "less experienced" subsamples. The "more experienced" subsample contains IPO firms that involve VCs with above-sample 60th percentile industry experience, whereas the "less experienced" subsample contains IPO firms that involve VCs with below-40th percentile industry experience. We choose these cutoffs to split the sample because VCs' industry expertise values are clustered at the median value. We expect that stage financing is mostly detrimental among the entrepreneurial firms whose VCs are less experienced with the industry to which they belong, and the negative effect should not prevail among firms whose VCs are more experienced about the nature and challenge of the industry where they operate.

Table 6 reports the 2nd-stage estimates of the 2SLS regressions for the subsamples in which VCs are less experienced in their entrepreneurial firm's industry (columns 1 through 4) and VCs are more experienced in their entrepreneurial firm's industry (columns 5 through 8), respectively. The coefficient estimates of instrumented *# of Rounds* are negative and significant for the "less experienced VCs" subsample, but are insignificant for the "more experienced VCs" subsample. The magnitudes of the coefficient estimates are much larger in the "less experienced VCs" subsample. The evidence suggests that VC staging negatively affects innovation output in IPO firms when VCs are less experienced in the industries in which their portfolio firms operate,

[18] Industry classification is based on the "sub1" industry classifications defined in the VentureXpert database Specifically, the industries include: Agriculture/Forestry/Fish, Biotechnology, Business Service, Communications, Computer Hardware, Computer Other, Computer Software, Construction, Consumer Related, Financial Services, Industrial/Energy, Internet Specific, Manufacturing, Medical/Health, Other, Semiconductor/Electrics, Transportation, and Utilities.

but this effect is absent if the VC investors have expertise in the IPO firm's industry. The evidence is consistent with our conjecture.

Overall, the cross-sectional tests further lend credence to our causal inferences of the negative effect of VC staged capital infusions on firm innovation. While the documented results could be driven by VCs endogenously choosing to stage less in more innovative firms, our tests suggest that the negative relation is unlikely to be entirely driven by this alternative selection argument. Instead, coupled with our results from identification tests reported in Section 5, there appears a treatment effect at least partially in play.

7. EXTENSIONS AND ROBUSTNESS

7.1 Ease of Monitoring or Intensity of Interference?

We instrument VC stage financing using the frequency of direct flights during an entrepreneurial firm's incubation period. We argue that more frequent direct flights allow for easy access by VCs to the entrepreneurial firm they fund, which reduces the need for stage financing to mitigate the hold-up problem, leading to a reduced intensity of the VC's leashing on the firm, which, in turn, spurs firm innovation.

One possible alternative argument, however, is that the frequency of direct flights may affect a firm's innovation output via the ease of monitoring or lower information acquisition costs instead of through a lower level of VC interference intensity. To test the validity of this argument, one may be tempted to run a reduced form regression in which the innovation outcome variable is regressed on the number of direct flights and check whether the coefficient estimate of the direct flight variable is statistically significant. However, such an empirical design cannot address the concern. This is because the coefficient estimate of the direct flight variable in the reduced form regression is by definition positive and significant, given the negative coefficient estimate of the direct flight variable in the 1^{st}-stage and the negative coefficient estimate of the instrumented VC staging variable in the 2^{nd}-stage. Therefore, to address this concern, we have to rely on an alternative empirical design.

VC monitoring can affect not only a firm's innovation but also its routine operations. Therefore, if the frequency of direct flights merely portrays the ease of VC monitoring, then we should expect to observe that the outcomes of an IPO firm's routine operations, such as ROA and asset turnover, are improved if VCs can monitor the entrepreneurial firms with less cost in the presence of more direct flights. We thus estimate a reduced form OLS regression below:

$$Operation = \beta_0 + \beta_1(Direct\ Flight) + \Omega' Z + \alpha_{IPO\ Year} + \alpha_{Industry} + \alpha_{VC\ State} + \alpha_{Firm\ State} + \varepsilon$$

where the dependent variable is either *ROA* or *Asset Turnover* and *Direct Flight* is the key variable of interest. If *Direct Flight* merely captures the ease of VC monitoring, its coefficient estimate should be both positive and significant.

Panel A of Table 7 reports the coefficient estimates of the OLS panel regression examining the effect of *Direct Flight* on a firm's operating performance, measured from year t to year $t + 5$ after the firm goes public. We observe that *Direct Flight* is insignificantly related to either ROA or Asset Turnover, regardless whether it is based on the entire sample of direct flights, or a subsample of direct flights that are affected by airline restructuring. In most cases, the coefficient estimates are negative.

In Panel B of Table 7, we focus on an alternative measure for performance: post-IPO survival rate. Bhattacharya, Borisov, and Yu (2013) find that the first three years after IPO are crucial to a firm's long-term survival. The mortality rates of U.S. public firms initially increase, peaking at three years after a firm goes public, and then decrease with age. If the variation in the frequency of direct flights captures the ease of VC monitoring, then we expect that VC stage financing both negatively and significantly affects an IPO firm's propensity for involuntary delisting.

Following Bhattacharya, Borisov, and Yu (2013), we construct a dummy for involuntary delisting that equals one if an IPO firm is delisted due to liquidation, delisting, and/or permanent trading halts (CRSP delisting codes 400-490 or 500-591) in a year after IPO, and zero otherwise. Panel B reports the marginal effects of the coefficient estimates from the probit regression, with the involuntary delisting dummy as the dependent variable. The coefficient for *Direct Flight* is positive, albeit insignificant.

The results in Table 7 suggest that the frequency of direct flights is not merely a proxy for the ease of monitoring and information acquisition. Instead, it apparently affects innovation output through its effect on a VC's staging incentives.

7.2 Why not Abandon Staging?

Our finding that more intensive stage financing leads to less innovation activities by IPO firms sheds light on a previously neglected adverse consequence of VC staging—the induced short-termism of the entrepreneurial firms. A natural question is why not VCs abandon stage financing to avoid this negative consequence on their portfolio firm's innovation. One plausible reason is that, as we discussed in the introduction, staging is a mechanism that VCs discipline entrepreneurs and it helps to mitigate the hold-up and information asymmetry problems. Another plausible reason is that entrepreneurial firms' post-IPO innovation productivity does not affect a VC investor's performance because it has already exited from these firms after they go public. Therefore, a VC investor would not take its portfolio firm's post-IPO innovation productivity into consideration in the first place when it makes staging decisions.

To test the above conjecture, we regress the post-IPO innovation output on the number of VC financing round in the incubation period. Specifically, for each entrepreneurial firm, we run a reduced form OLS regression as follows:

$$Innovation = \beta_0 + \beta_1(\#\ of\ Rounds) + \alpha_{IPO\ Year} + \varepsilon$$

where innovation output is measured by $ln(Patents)$ and $ln(Citations)$, respectively. We then generate the predicted values of $ln(Patents)$ and $ln(Citations)$. By construction, the predicted values of these variables capture the innovation component of an IPO firm that is affected by the extent of its VC's pre-IPO staging.

Next, we examine whether a VC's future performance is affected by the post-IPO innovativeness of its portfolio firms arising from its pre-IPO staging intensity. We regress the VC's performance, measured as future fund raising and successful exit rate, on the average predicted innovation quality of the firms taking public by the VC in the past:

$$VC\ Performance = \beta_0 + \beta_1(Predicted\ Innovation) + \Omega^{'}\ Z + \alpha_{IPO\ Year} + \varepsilon$$

A VC's future fund raising is computed as the natural logarithm of one plus the total amount of fund raised between year $t + 1$ and year $t + 5$. A VC's future successful exit rate is the fraction of entrepreneurial firms backed by the VC that has gone public or been acquired in the same five-year period. The key dependent variable *Predicted Innovation*, is computed by averaging the predicted value of the natural logarithm of one plus the number of patents or citation counts from all the firms taken public by the VC in the previous five years (i.e., from year $t - 5$ to $t - 1$). We include VC firm fixed effects and year fixed years to take into account unobserved VC characteristics and time-varying economic trend that may affect a VC's subsequent performance. In addition, we control for a VC's past performance, measured by the natural logarithm of one plus the total amount of fund raised, and the fraction of entrepreneurial firms backed by the VC that have gone public or been acquired in the previous five years. We bootstrap the standard errors as our main independent variable is a generated variable.

Table 8 reports the results from the second stage regressions. In columns 1 and 2, the dependent variable is a VC's future fund raising, and in columns 3 and 4 is a VC's successful exit rate. We observe that the post-IPO innovativeness of entrepreneurial firms due to a VC's pre-IPO staging intensity does not significantly affect the VC's own future fund raising or successful exit rate. This finding suggests that the effect of VC staging on an entrepreneurial firm's innovation quality does not affect the VC's own future performance after it successfully exits its investment from the firm. This finding helps explain why VCs keep using staging to finance their portfolio firms even though staging hurts these firms' post-IPO innovation.

7.3 Alternative Data Structure

Since the number of financing rounds an IPO firm receives before it goes public is time-invariant for each IPO firm in our baseline panel regressions, an alternative way of analyzing the data is to run cross-sectional regressions. We estimate the effect of VC staging on innovation in a cross-sectional data framework and report the 2SLS results in Table 9. Unlike previous tables in which the observation unit is IPO firm-year, the observation unit in Table 9 is IPO firm.

We impose an arbitrary three-year threshold to facilitate comparisons of innovation-output across IPO firms because some IPO firms get acquired or delisted a few years after IPO. The dependent variables are thus the total number of granted patents generated by each IPO firm within the first three years after IPO and the average number of citations each of these patents receives.

The independent variable is the total number of financing rounds an IPO firm receives during its incubation period. The values of all control variables are measured either as of the venture's first VC financing round year or the venture's IPO year.

Table 9 reports the 2^{nd}-stage estimates of the 2SLS regression results in the full sample (columns 1 through 4) and in the subsample based on the refined IV from airline restructuring (columns 5 through 8), respectively. The coefficient estimates of instrumented *# of Rounds* are negative and significant in all columns, consistent with the implications of the leashing hypothesis. The evidence suggests that our main results are robust to an alternative way of constructing the data.

7.4 Alternative Sample Specifications

Our sample includes firms located in cities without direct flight services, and one potential concern is that the results are simply driven by the systemic difference between firms with and without direct flight services to their investing VCs. In an alternative specification, we exclude firms that have never had direct flight services to where their VCs are located during the incubation period. This restricted sample thus compares firms that have direct flight services available, but with varying degrees of frequency of daily direct flights. This restricted sample also allows us to address the concern that VC investors may choose to fly corporate jets to visit the entrepreneurial firms instead of taking commercial flights. This is because, in our setting, as long as not all VCs and entrepreneurial firms use corporate jets to visit each other, the variation in direct flight frequency allows us to distinguish between those that are affected by the availability and frequency of direct flights and those that are not. By restricting to the subsample where direct flights are available to all the VC-entrepreneurial firm pairs, we focus our attention to the group of VC-entrepreneurial firm pairs that are least affected by the availability of corporate jets and explore the within-group variation. We find similar results (not tabulated): more frequent direct flight is associated with a smaller number of financing rounds, which subsequently, leads to more innovation output.

Our sample also includes firms that are located in the same state as their VCs. While many airlines offer direct flights between cities within the same state, it is possible that in some cases, due to the close proximity, VCs may rely on driving instead of air travel to visit their entrepreneurial firms. In our main analysis, we address this potential issue by assigning the maximum number of direct flights in the sample to VC-firm pairs that are located within driving distance. As a robustness check, we exclude firms whose VCs are located within the same state during their incubation periods, and re-estimate our results (not tabulated). In this subsample, we continue to observe that a larger number of VC financing rounds causes poorer innovation output.

8. CONCLUSIONS

In this paper, we aim to tackle the question that whether VC investors' tight leashes on entrepreneurs promote or impede technological innovation by examining the effects of VC stage financing on IPO firms' innovation output. Using plausibly exogenous variation in the frequency of direct flights between VCs and entrepreneurs that is caused by airline restructuring, we find IPO firms financed by a larger number of VC financing rounds are significantly less innovative and this negative effect appears causal. We further show that VC staging is more detrimental to firm innovation when innovation is more difficult to achieve and when VC investors are less experienced in the industry in which entrepreneurs operate. Our paper contributes to the literature by uncovering a previously under-recognized adverse consequence of keeping entrepreneurs on a tight leash—it stifles innovation. Compared to other costs associated with VC staging as identified in the literature, the cost of stifled innovation can be much more substantial. More importantly, our findings indicate that entrepreneurial firms' short-termism may still arise even in a private market populated with long-term and sophisticated investors.

While the VC market and the risky and long-term nature of innovation are part of our research design to help explore whether and how entrepreneurial firms' short-termism may arise in the absence of investors with short-term investment horizons, we acknowledge that two important caveats need to be borne in mind when interpreting or generalizing our results. First, while we show a negative effect of VC staging on firm innovation, consistent with the leashing hypothesis, we cannot rule out the possible positive role played by VC staging in promoting firm innovation, as suggested by the agency hypothesis. This is because our evidence reflects only the net effect of VC staging on firm innovation. A tight leash kept by VCs could play both a positive role (by mitigating agency and hold-up problems) and a negative role (by imposing short-term pressures on entrepreneurs to meet stage targets) in motivating firm innovation. However, in practice, the former is dominated by the latter so that we observe a net negative effect of VC staging on firm innovation. Second, although we show one particular adverse effect of VC staging, we are agnostic about how VC stage financing, a unique feature of VC investment, affects entrepreneurial firm performance in many other ways. Hence, our finding should not be interpreted as evidence that VC staging are overall detrimental to firm performance or social welfare. Further, while venture capital is a key ingredient of the capital market and our paper examines its influence on newly public firms' incentives to innovate, a proper evaluation of the overall effect of the financial and capital investment system on a nation's innovation productivity and competitive advantage is beyond the scope of this paper and calls for future research.

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Appendix
Variable Definitions and Data Sources

Innovation Measures (Data Source: NBER Patent Data)	
$ln(Patents)$	Natural logarithm of one plus the total number of patents a firm filed (and eventually granted) in a given year. The total number of patents is winsorized at the 99th percentile.
$ln(Citations)$	Natural logarithm of one plus the total number of citations received on the patents that a firm filed (and eventually granted), scaled by the number of the patents filed (and eventually granted) by the firm. The total number of citation counts per firm is winsorized at the 99th percentile.
$ln(Patents\ at\ 1st\ Round)$	Natural logarithm of one plus the total number of patents a firm filed (and eventually granted) before or at the time when it receives the first round of VC financing. The total number of patents is winsorized at the 99th percentile.
$ln(Citations\ at\ 1st\ Round)$	Natural logarithm of one plus the total number of citations received on the patents a firm filed (and eventually granted) before or at the time when it receives the first round of VC financing. The total number of citation counts per firm is winsorized at the 99th percentile.
VC and Project Characteristics (Data Source: VentureXpert)	
# of Rounds	The total number of financing rounds an entrepreneurial firm receives from investing VCs prior to its IPO. Winsorized at the 1st and 99th percentiles.
Firm Stage	A dummy variable that equals one if an entrepreneurial firm is in its seed/startup or early stage, and zero if is in its expansion, late, or buyout/acquisition stage, when it receives the first round of VC financing
Fund Raising	The natural logarithm of one plus the amount of fund (in millions of dollars) raised by a VC firm within a previous five-year period.
Incubation Period	The length of time between the date when an entrepreneurial firm receives its first VC financing and the date of its IPO. Winsorized at the 1st and 99th percentiles.
Local VC Market	Total number of IPO firms that VCs invest during an IPO firm i's incubation period, excluding firm i itself. Winsorized at the 1st and 99th percentiles.
Successful Exit	The fraction of entrepreneurial firms backed by a VC that have gone public or been acquired during a previous five-year period.
VC Syndication Size	The number of VCs that invested in the entrepreneurial firms. Winsorized at the 1st and 99th percentiles.
VC Reputation	The weighted average of reputation of firm i's lead VC firms. A VC firm's reputation is measured by the dollar market value of all companies taken public by the VC firm from the

	beginning of calendar year 1980 until a given calendar year then normalized by the aggregate market value of all VC-backed companies that went public from the beginning (Nahata, 2008).
IPO Firm Characteristics (Data Sources: COMPUSTAT and SDC)	
Size	Natural logarithm of book value of total assets (COMPUSTAT data item #6), which is measured at the end of the fiscal year. Total assets are winsorized at the 1^{st} and 99^{th} percentiles.
Firm Age	The difference between current year and the firm's founding year. Winsorized at the 1^{st} and 99^{th} percentiles.
R&D	Research and development (R&D) expenditure (data item #46), scaled by book value of total assets (#6) measured at the end of fiscal year. This variable is set to 0 if missing. Winsorized at the 1^{st} and 99^{th} percentiles.
ROA	Return on assets ratio defined as operating income before depreciation (#13), scaled by book value of total assets (#6), measured at the end of the fiscal year. Winsorized at the 1^{st} and 99^{th} percentiles.
PPE	Property, plant & equipment (#8), scaled by book value of total assets (#6) measured at the end of the fiscal year.
Leverage	Book value of debt (#9 + #34) divided by book value of total assets (#6), measured at the end of the fiscal year. Winsorized at the 1^{st} and 99^{th} percentiles.
Local IPO Market	Total number of firms that are headquartered in the same state as IPO firm i and went public during firm i's incubation period, excluding firm i itself. Winsorized at the 1^{st} and 99^{th} percentiles.
Institutional Ownership	Institutional holdings of shares of a firm during the year, calculated as the arithmetic mean of the four quarterly institutional holdings reported through form 13F.
Industry Concentration	The Herfindahl index of the industry where a firm operates, measured at the end of the fiscal year. Industry classification is based on the two-digit SIC code.
Instrumental Variable (Data Sources: Bureau of Transportation Statistics and Wikipedia)	
Direct Flight	The number of direct flights (inbound and outbound) between the airports where VC and the entrepreneurial firm are located. Computed as the sum of direct flights during the incubation period scaled by the length of incubation period, weighted by investment amounts of VCs.

Table 1
Descriptive Statistics

This table reports the summary statistics for variables constructed based on the sample of U.S. firms which went public from 1980 to 2004. The unit of analysis is IPO firm in Panel A, and is IPO firm-year in Panel B. "# of Patents at 1st Round" is the total number of patents a firm filed (and eventually granted) before or at the time when it receives the first round of VC financing. "# of Citations at 1st Round" is the total number of citations received on the patents a firm filed (and eventually granted) before or at the time when it receives the first round of VC financing. "# of Patents" is the total number of patents a firm filed (and eventually granted) in a given year after IPO; "# of Citations" is the total number of citations received on the patents that a firm filed (and eventually granted), scaled by the number of the patents filed (and eventually granted) by the firm; "Assets" is the book value of total assets (COMPUSTAT data item #6). These variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers on the results. The rest of the variables are defined in Appendix. Panel C reports the geographic distribution of sample IPO firms and VCs.

Panel A: IPO Firm-level Variables

	25th	Mean	Median	75th	Standard Deviation	# of obs.
Full Sample						
# of Rounds	2	4.75	4	6	2.94	1,840
Firm Stage	0	0.70	1	1	0.46	1,816
# of Patents at 1st Round	0	0.21	0	0	1.05	1,840
# of Citations at 1st Round	0	2.48	0	0	12.62	1,840
VC Reputation	0	0.02	0.00	0.02	0.03	1,840
VC Syndication Size	3	7.88	7	11	5.59	1,840
Incubation Period	2.05	4.25	3.55	5.58	3.08	1,840
Firm Age	0.33	3.18	1.37	4.00	4.55	1,837
Local IPO Market	45	225.05	135	358	226.51	1,834
Local VC Market	2.67	19.41	13.2	26.33	23.91	1,835
Direct Flights	23.27	76.24	85.67	128	50.38	1,668
Subsample for Airline Restructuring						
# of Rounds	3	5.34	5	7	2.94	1,115
Firm Stage	1	0.75	1	1	0.43	1,094
# of Patents at 1st Round	0	0.19	0	0	1.00	1,115
# of Citations at 1st Round	0	2.36	0	0	12.47	1,115
VC Reputation	0	0.02	0.00	0.02	0.03	1,115
VC Syndication Size	5	8.87	8	12	5.35	1,115
Incubation Period	2.44	4.59	3.97	6.07	3.04	1,115
Firm Age	0.27	2.70	1.07	3.16	4.13	1,113
Local IPO Market	62	276.29	196	460	246.19	1,115
Local VC Market	4.21	18.73	13.62	25.62	21.48	1,115
Direct Flights	21.41	68.23	66.99	127.68	46.81	1,078

Table 1 continued.

Panel B: IPO Firm-year Level Variables

	25th	Mean	Median	75th	Standard Deviation	# of obs.
Full Sample						
# of Patents	0	1.89	0	1	5.15	10,755
# of Citations	0	7.12	0	3.75	16.89	10,755
Assets (Millions)	20.66	121.01	50.14	113.45	230.97	9,131
R&D	0	0.16	0.10	0.21	0.20	9,916
ROA	-0.26	-0.11	0.01	0.14	0.39	9,055
PPE	0.06	0.18	0.12	0.22	0.17	9,128
Leverage	0.00	0.14	0.04	0.19	0.22	9,106
Industry Concentration	0.03	0.05	0.04	0.05	0.06	9,940
Institutional Ownership	0	0.19	0.07	0.33	0.25	10,755
Asset Turnover	0.31	0.83	0.72	1.12	0.80	8,540
Involuntary Delisting	0	0.05	0	0	0.22	10,755
Subsample for Airline Restructuring						
# of Patents	0	2.25	0	2	5.70	6,451
# of Citations	0	7.42	0	4.95	17.31	6,451
Assets (Millions)	23.99	130.17	56.05	124.95	233.54	5,492
R&D	0	0.18	0.12	0.25	0.22	5,924
ROA	-0.33	-0.16	-0.05	0.12	0.41	5,438
PPE	0.05	0.16	0.10	0.19	0.16	5,491
Leverage	0.00	0.13	0.03	0.16	0.21	5,475
Industry Concentration	0.02	0.04	0.04	0.05	0.03	5,934
Institutional Ownership	0	0.21	0.08	0.36	0.26	6,451
Asset Turnover	0.24	0.76	0.63	1.04	0.82	5,062
Involuntary Delisting	0	0.05	0	0	0.22	6,451

Table 1 continued.

Panel C: Geographic Distribution of IPO Firms and VCs

State	# of IPO Firms	% of IPO Firms	# of VC	% of VCs
AL	9	0.49%	6	0.06%
AZ	17	0.93%	22	0.20%
CA	752	41.00%	3,859	35.76%
CO	52	2.84%	160	1.48%
CT	28	1.53%	572	5.30%
DC	4	0.22%	44	0.41%
DE	4	0.22%	21	0.19%
FL	39	2.13%	45	0.42%
GA	54	2.94%	102	0.95%
IA	2	0.11%	24	0.22%
ID	3	0.16%	0	0.00%
IL	38	2.07%	376	3.48%
IN	7	0.38%	34	0.32%
KS	5	0.27%	4	0.04%
LA	2	0.11%	12	0.11%
MA	202	11.01%	1,535	14.23%
MD	35	1.91%	169	1.57%
ME	2	0.11%	10	0.09%
MI	8	0.44%	39	0.36%
MN	47	2.56%	183	1.70%
MO	11	0.60%	43	0.40%
MS	3	0.16%	1	0.01%
MT	2	0.11%	0	0.00%
NC	21	1.15%	57	0.53%
ND	1	0.05%	0	0.00%
NE	2	0.11%	3	0.03%
NH	9	0.49%	27	0.25%
NJ	64	3.49%	349	3.23%
NV	2	0.11%	4	0.04%
NY	79	4.31%	2,016	18.68%
OH	15	0.82%	84	0.78%
OK	7	0.38%	11	0.10%
OR	20	1.09%	22	0.20%
PA	56	3.05%	217	2.01%
RI	2	0.11%	56	0.52%
SC	3	0.16%	0	0.00%
TN	15	0.82%	53	0.49%

TX	103	5.62%	341	3.16%
UT	6	0.33%	15	0.14%
VA	31	1.69%	39	0.36%
WA	62	3.38%	224	2.08%
WI	10	0.55%	11	0.10%
Total	1,834	100%	10,790	100%

Table 2
The Effect of VC Staging on Innovation: OLS Regressions

This table reports the OLS panel regression analyses examining the effect of "# of Rounds" on IPO firms' innovation outcomes. The dependent variables are "$ln(Patents)$" and "$ln(Citations)$" for each entrepreneurial firm from year t to year $t+5$ after IPO, respectively. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC codes. Robust standard errors clustered at IPO firm level are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	$ln(Patents)$		$ln(Citations)$	
	(1)	(2)	(3)	(4)
# of Rounds	0.006	0.005	0.003	0.002
	(0.008)	(0.008)	(0.012)	(0.012)
VC Reputation	0.143	-0.009	0.267	0.124
	(0.495)	(0.499)	(0.773)	(0.790)
VC Syndication Size	0.006	0.005	0.019***	0.019***
	(0.004)	(0.004)	(0.006)	(0.006)
Incubation Period	-0.007	-0.011	-0.018**	-0.012
	(0.006)	(0.008)	(0.008)	(0.012)
Stage	0.144***	0.145***	0.275***	0.282***
	(0.033)	(0.034)	(0.052)	(0.052)
$ln(Patents\ at\ 1st\ Round)$	0.190*	0.191*	-0.077	-0.089
	(0.109)	(0.108)	(0.125)	(0.126)
$ln(Citations\ at\ 1st\ Round)$	0.047	0.048	0.212***	0.214***
	(0.041)	(0.040)	(0.057)	(0.057)
Firm Age	-0.010***	-0.010***	-0.012**	-0.012**
	(0.003)	(0.003)	(0.005)	(0.005)
Size	0.157***	0.155***	0.099***	0.097***
	(0.015)	(0.015)	(0.021)	(0.021)
R&D	0.600***	0.588***	0.641***	0.635***
	(0.089)	(0.089)	(0.133)	(0.132)
ROA	0.162***	0.156***	0.115	0.111
	(0.044)	(0.044)	(0.071)	(0.071)
PPE	0.065	0.075	0.074	0.070
	(0.090)	(0.090)	(0.146)	(0.145)
Leverage	-0.113**	-0.110*	-0.251***	-0.246***
	(0.057)	(0.058)	(0.095)	(0.095)
Industry Concentration	0.882***	0.932***	0.339	0.354
	(0.253)	(0.255)	(0.508)	(0.509)
Institutional Ownership	0.052	0.048	0.164*	0.161*
	(0.063)	(0.063)	(0.085)	(0.085)
Local IPO Market		0.040		-0.042

		(0.042)		(0.059)
Local VC Market		0.022*		0.022
		(0.012)		(0.018)
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	8,294	8,294	8,294	8,294
R Squared	0.281	0.282	0.239	0.240

Table 3
The Effect of VC Staging on Innovation: Instrumental Variable (IV) Analysis

This table reports the 2SLS panel regression analyses examining the effect of VC's staged financing on IPO firms' innovation outcomes. We instrument "# of Rounds" with the frequency of direct flights between VC domiciles and IPO firm headquarters, "Direct Flight". Panel A reports the first-stage results, which generate the fitted (instrumented) value of "# of Rounds" for use in the second-stage regressions. Panel B reports the results from the second-stage regressions. The dependent variables are "$ln(Patents)$" and "$ln(Citations)$" for each entrepreneurial firm from year t to year $t+5$ after its IPO, respectively. Adjusted R squared is reported for the first-stage regressions. Since it is not meaningful in the second stage of 2SLS, we report root MSE instead. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC codes. First-stage F-test refers to the Stagier and Stock (1997) F-test of the first-stage in IV estimation. Robust standard errors clustered at IPO firm level are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: First-stage Regression of Direct Flight on Number of Financing Rounds

Dependent variable	# of Rounds	
	(1)	(2)
Direct Flight	-0.006***	-0.006***
	(0.001)	(0.001)
VC Reputation	1.115	0.139
	(1.729)	(1.721)
VC Syndication Size	0.306***	0.300***
	(0.013)	(0.013)
Incubation Period	0.243***	0.239***
	(0.026)	(0.037)
Firm Stage	0.266**	0.278**
	(0.127)	(0.126)
$ln(Patents\ at\ 1st\ Round)$	-0.118	-0.145
	(0.217)	(0.212)
$ln(Citations\ at\ 1st\ Round)$	-0.130	-0.119
	(0.101)	(0.096)
Firm Age	-0.002	-0.002
	(0.013)	(0.013)
Size	-0.037	-0.049
	(0.041)	(0.040)
R&D	0.275	0.210
	(0.268)	(0.268)
ROA	-0.351**	-0.388***
	(0.145)	(0.145)
PPE	-0.958***	-0.901***
	(0.338)	(0.334)
Leverage	0.191	0.207
	(0.198)	(0.194)

Industry Concentration	-1.405	-1.165
	(1.362)	(1.376)
Institutional Ownership	-0.093	-0.133
	(0.176)	(0.177)
Local IPO Market		0.051
		(0.149)
Local VC Market		0.162***
		(0.040)
Industry Fixed Effects	Yes	Yes
IPO Year Fixed Effects	Yes	Yes
Firm State Fixed Effects	Yes	Yes
VC State Fixed Effects	Yes	Yes
First-stage F-test	17.63	15.95
# of obs.	7,577	7,577
R Squared	0.574	0.578

Panel B: The Effect of VC Staging on IPO Firm's Innovation

Dependent variable	$ln(Patents)$		$ln(Citations)$	
	(1)	(2)	(3)	(4)
# of Rounds (Instrumented)	-0.283***	-0.310***	-0.308**	-0.339**
	(0.104)	(0.114)	(0.126)	(0.138)
VC Reputation	0.663	0.190	1.023	0.499
	(0.797)	(0.823)	(1.049)	(1.076)
VC Syndication Size	0.092***	0.096***	0.111***	0.117***
	(0.032)	(0.035)	(0.039)	(0.042)
Incubation Period	0.058**	0.060**	0.050*	0.066*
	(0.025)	(0.029)	(0.030)	(0.035)
Firm Stage	0.225***	0.236***	0.365***	0.386***
	(0.057)	(0.061)	(0.072)	(0.077)
$ln(Patents\ at\ 1st\ Round)$	0.168	0.153	-0.099	-0.129
	(0.133)	(0.132)	(0.146)	(0.149)
$ln(Citations\ at\ 1st\ Round)$	0.005	0.007	0.169***	0.172***
	(0.050)	(0.050)	(0.065)	(0.066)
Firm Age	-0.011**	-0.011**	-0.015**	-0.015**
	(0.005)	(0.005)	(0.007)	(0.007)
Size	0.150***	0.143***	0.068***	0.060**
	(0.020)	(0.021)	(0.024)	(0.025)
R&D	0.617***	0.589***	0.586***	0.565***
	(0.126)	(0.127)	(0.164)	(0.165)
ROA	0.043	0.015	0.001	-0.029
	(0.069)	(0.075)	(0.095)	(0.100)
PPE	-0.103	-0.096	-0.090	-0.099
	(0.169)	(0.174)	(0.230)	(0.233)
Leverage	-0.033	-0.020	-0.118	-0.101
	(0.088)	(0.091)	(0.124)	(0.127)
Industry Concentration	0.618	0.711	-0.061	-0.001
	(0.487)	(0.521)	(0.728)	(0.759)
Institutional Ownership	0.000	-0.023	0.108	0.082
	(0.085)	(0.089)	(0.103)	(0.106)
Local IPO Market		0.040		-0.047
		(0.068)		(0.083)
Local VC Market		0.083***		0.094***
		(0.027)		(0.035)
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	7,577	7,577	7,577	7,577
Root MSE	0.934	0.960	1.374	1.397

Table 4
The Effect of VC Staging on Innovation: Airline Restructuring Related

This table reports the 2SLS panel regression analyses examining the effect of VC's staged financing on IPO firms' innovation outcomes. The IV analyses are conducted based on the subsample where variations in frequencies of direct flights between VC domiciles and IPO firm headquarters are due to airline restructuring activities such as bankruptcies, mergers and acquisitions, and/or strategic alliances. We instrument "# of Rounds" with the frequency of direct flights between VC domiciles and IPO firm headquarters, "Direct Flight". Panel A reports the first-stage results, which generate the fitted (instrumented) value of "# of Rounds" for use in the second-stage regressions. Panel B reports the results from the second-stage regressions. The dependent variables are "$ln(Patents)$" and "$ln(Citations)$" for each entrepreneurial firm from year t to year $t+5$ after its IPO, respectively. Adjusted R squared is reported for the first-stage regressions. Since it is not meaningful in the second stage of 2SLS, we report root MSE instead. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC codes. First-stage F-test refers to the Stagier and Stock (1997) F-test of the first-stage in IV estimation. Robust standard errors clustered at IPO firm level are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: First-stage Regression of Direct Flight on Number of Financing Rounds

Dependent variable	# of Rounds	
	(1)	(2)
Direct Flight	-0.008***	-0.008***
	(0.002)	(0.002)
VC Reputation	3.900	2.821
	(3.380)	(3.401)
VC Syndication Size	0.265***	0.261***
	(0.017)	(0.017)
Incubation Period	0.330***	0.326***
	(0.036)	(0.054)
Firm Stage	0.353**	0.372**
	(0.166)	(0.167)
$ln(Patents\ at\ 1st\ Round)$	0.311	0.260
	(0.319)	(0.307)
$ln(Citations\ at\ 1st\ Round)$	-0.228	-0.208
	(0.152)	(0.148)
Firm Age	-0.004	-0.005
	(0.018)	(0.018)
Size	0.004	-0.003
	(0.052)	(0.051)
R&D	0.388	0.351
	(0.329)	(0.331)
ROA	-0.435**	-0.461**
	(0.194)	(0.194)
PPE	-0.710	-0.642

	(0.464)	(0.459)
Leverage	0.039	0.073
	(0.231)	(0.229)
Industry Concentration	-0.861	-0.782
	(2.110)	(2.161)
Institutional Ownership	-0.070	-0.091
	(0.215)	(0.214)
Local IPO Market		0.019
		(0.221)
Local VC Market		0.142**
		(0.057)
Industry Fixed Effects	Yes	Yes
IPO Year Fixed Effects	Yes	Yes
Firm State Fixed Effects	Yes	Yes
VC State Fixed Effects	Yes	Yes
First-stage F-test	15.34	14.05
# of obs.	4,798	4,798
R Squared	0.560	0.562

Panel B: Second-stage Regression of the Effect of VC Staging on IPO Firm's Innovation

Dependent variable	$ln(Patents)$		$ln(Citations)$	
	(1)	(2)	(3)	(4)
# of Rounds (Instrumented)	-0.272**	-0.294**	-0.296**	-0.311**
	(0.110)	(0.120)	(0.131)	(0.140)
VC Reputation	2.323	1.808	4.078**	3.726*
	(1.496)	(1.542)	(1.888)	(1.921)
VC Syndication Size	0.076**	0.080**	0.088**	0.090**
	(0.030)	(0.032)	(0.036)	(0.037)
Incubation Period	0.078**	0.085**	0.071*	0.099**
	(0.034)	(0.040)	(0.041)	(0.047)
Firm Stage	0.258***	0.278***	0.383***	0.411***
	(0.075)	(0.081)	(0.093)	(0.098)
$ln(Patents\ at\ 1st\ Round)$	0.399**	0.375**	0.054	0.002
	(0.195)	(0.189)	(0.209)	(0.203)
$ln(Citations\ at\ 1st\ Round)$	-0.047	-0.040	0.140	0.152*
	(0.071)	(0.069)	(0.095)	(0.092)
Firm Age	-0.012*	-0.013*	-0.015	-0.016
	(0.007)	(0.007)	(0.010)	(0.010)
Size	0.158***	0.154***	0.031	0.029
	(0.025)	(0.026)	(0.031)	(0.032)
R&D	0.637***	0.625***	0.378*	0.377*
	(0.153)	(0.156)	(0.193)	(0.194)
ROA	0.052	0.027	-0.022	-0.041
	(0.089)	(0.096)	(0.122)	(0.127)
PPE	-0.067	-0.047	-0.067	-0.069
	(0.192)	(0.196)	(0.260)	(0.260)
Leverage	-0.040	-0.020	-0.180	-0.157
	(0.110)	(0.112)	(0.148)	(0.149)
Industry Concentration	-0.303	-0.275	-0.373	-0.329
	(0.781)	(0.824)	(1.274)	(1.303)
Institutional Ownership	0.011	-0.003	0.039	0.030
	(0.100)	(0.102)	(0.118)	(0.119)
Local IPO Market		-0.005		-0.157
		(0.097)		(0.108)
Local VC Market		0.081**		0.072*
		(0.033)		(0.041)
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	4,798	4,798	4,798	4,798
Root MSE	0.950	0.971	1.369	1.378

Table 5
Industry-level Innovation Diffculties

This table reports the 2SLS panel regression analyses examining how the effect of "# of Rounds" on innovation outcomes varies with the degree of difficulty to innovate. The IV analyses are conducted based on the subsample where variations in frequencies of direct flights between VC domiciles and IPO firm headquarters are due to airline restructuring activities such as bankruptcies, mergers and acquisitions, and/or strategic alliances. As in Hall, Jaffe, and Trajtenberg (2005), more demanding industries include pharmaceutical, medical instrumentation, chemicals, computers, communications, and electrical industries, and the rest are classified as less demanding industries, which include software programming, internet applications, and other low-tech industries. The dependent variables are "$ln(Patents)$" and "$ln(Citations)$" for each entrepreneurial firm from year t to year $t+5$ after its IPO, respectively. We instrument "# of Rounds" with "Direct Flight", the frequency of direct flights between VC domiciles and IPO firm headquarters. For brevity, the first-stage regression in which the fitted (instrumented) value of "# of Rounds" is generated for use in the second-stage regressions is not tabulated. Control variables are included in the regressions but not reported. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC codes. Robust standard errors clustered at IPO firm level are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	More Demanding Industries				Less Demanding Industries			
Dependent variable	$ln(Patents)$		$ln(Citations)$		$ln(Patents)$		$ln(Citations)$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Rounds (Instrumented)	-0.327**	-0.347**	-0.354**	-0.371**	-0.110	-0.126	-0.167	-0.189
	(0.136)	(0.143)	(0.154)	(0.161)	(0.142)	(0.169)	(0.234)	(0.271)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	2,742	2,742	2,742	2,742	2,056	2,056	2,056	2,056
Root MSE	1.103	1.123	1.459	1.471	0.580	0.589	1.136	1.143

Table 6
VCs' Industry Experience

This table reports the 2SLS panel regression analyses examining how the effect of "# of Rounds" on innovation outcomes varies with VCs' industry experience. The IV analyses are conducted based on the subsample where variations in frequencies of direct flights between VC domiciles and IPO firm headquarters are due to airline restructuring activities such as bankruptcies, mergers and acquisitions, and/or strategic alliances. For each VC that has invested in a sample entrepreneurial firm, we compute its industry experience at the time of its first investment into the firm by dividing the total number of entrepreneurial firms it has invested in an industry in the previous 10 years by the total number of entrepreneurial firms that the VC has invested in all the industries during the same period. We then compute the industry experience of the VC syndicate for each sample IPO firm by weighted-averaging the industry experience of each VC of the syndicate by the dollar amount of its total investment into the firm. A VC syndicate is "more experienced" ("less experienced") if its experience in the industry where the entrepreneurial firm belongs to is above (below) the sample's 60^{th} (40^{th}) percentile, where industry classification is based on "sub1" industries defined in the VentureXpert database. The dependent variables are "$ln(Patents)$" and "$ln(Citations)$" for each entrepreneurial firm from year t to year $t+5$ after its IPO, respectively. We instrument "# of Rounds" with "Direct Flight", the frequency of direct flights between VC domiciles and IPO firm headquarters. For brevity, the first-stage regression in which the fitted (instrumented) value of "# of Rounds" is generated for use in the second-stage regressions is not tabulated. Control variables are included in the regressions but not reported. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC code. Robust standard errors clustered at IPO firm level are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	Less Experienced VCs				More Experienced VCs			
Dependent variable	$ln(Patents)$		$ln(Citations)$		$ln(Patents)$		$ln(Citations)$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Rounds (Instrumented)	-0.359**	-0.401*	-0.429**	-0.443*	-0.192	-0.292	-0.201	-0.289
	(0.179)	(0.223)	(0.209)	(0.253)	(0.129)	(0.178)	(0.160)	(0.215)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	1,745	1,745	1,745	1,745	2,025	2,025	2,025	2,025
Root MSE	1.032	1.099	1.476	1.483	0.813	0.902	1.264	1.306

Table 7
Post-IPO Operating Performance

This table reports the panel regression analyses examining the effect of the frequency of direct flights during IPO firms' incubation periods on their operating performance from year t to year $t + 5$ after its IPO. The independent variable of interest is "Direct Flight", which is the number of total daily direct flights between VC domicile and IPO firm headquarter during the firm's incubation period. We multiple this number by 100. In Panel A, we estimate an OLS regression. The dependent variable is "ROA" in columns 1 through 4, "Asset Turnover" in columns 5 through 8. In Panel B, we estimate a probit regression, and report the marginal effects of the coefficient estimates. The dependent variable is "Involuntary Delisting", a dummy variable equal to one if an IPO firm is delisted due to liquidation, delisting, and/or permanent trading halts (CRSP delisting codes 400-490 or 500-591) in a year after IPO, and zero otherwise. In columns 1, 2, 5 and 6 in Panel A and columns 1 and 2 in Panel B, the analyses are based on the full sample. For the rest, the analyses are based on the subsample where variations in frequencies of direct flights between VC domiciles and IPO firm headquarters are due to airline restructuring activities such as bankruptcies, mergers and acquisitions, and/or strategic alliances. Control variables are included in the regressions but not reported. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC code. Robust standard errors clustered at IPO firm level are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: ROA and Asset Turnover

Dependent variable	ROA				Asset Turnover			
	All Direct Flights		Airline Restructuring		All Direct Flights		Airline Restructuring	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Direct Flight (× 100)	-0.011	-0.008	0.002	0.006	-0.033	-0.038	-0.006	-0.012
	(0.013)	(0.012)	(0.019)	(0.018)	(0.035)	(0.034)	(0.044)	(0.043)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	6,932	6,932	4,367	4,367	6,963	6,963	4,387	4,387
R Squared	0.425	0.427	0.436	0.440	0.308	0.309	0.308	0.311

Table 7 continued.

Panel B: Involuntary Delisting

	All Direct Flights		Airline Restructuring	
	(1)	(2)	(3)	(4)
Direct Flight (× 100)	0.003	0.003	0.006	0.004
	(0.007)	(0.007)	(0.009)	(0.009)
Control Variables	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	8,013	8,013	5,125	5,125
Pseudo R Squared	0.045	0.047	0.041	0.046

Table 8
Entrepreneurial Firms' Innovation and VC Performance

This table reports the panel regression analyses examining the effect of entrepreneurial firms' innovation activities on their VC's subsequent performance from year $t+1$ to year $t+5$ after their IPO. The dependent variable in columns 1 and 2 is "Fund Raising", computed as the natural logarithm of total capital raised by a VC in the subsequent five-year period, and in columns 3 and 4 is "Successful Exit", computed as the fraction of entrepreneurial firms backed by the VC that have gone public or been sold to the third party in the subsequent five-year period. We regress "$ln(Patents)$" and "$ln(Citations)$" for each entrepreneurial firm that have gone public during the period of year $t-5$ to year $t-1$, respectively, on "# of Rounds", and compute the predicted values of the number of patents filed that are eventually granted and citations per patent. "Predicted $ln(Patents)$" and "Predicted $ln(Citations)$" are then computed by averaging, respectively, the predicted numbers of patents filed that are eventually granted, and the predicted number of citations received per patent, by all the firms that are backed by the same VC and that have gone public from year $t-5$ to year $t-1$. "Past Successful Exit" is the fraction of entrepreneurial firms backed by the same VC that have gone public or been acquired from year $t-5$ to year $t-1$. "Past Fund Raising" is the natural logarithm of total fund raised by the VC between year $t-5$ and year $t-1$. Bootstrapped standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Dependent Variable	Fund Raising		Successful Exit	
	(1)	(2)	(3)	(4)
Predicted $ln(Patents)$	-0.068		0.010	
	(0.094)		(0.010)	
Predicted $ln(Citations)$		-0.091		0.001
		(0.059)		(0.006)
Past Successful Exit	-0.261	-0.260	-0.071***	-0.071***
	(0.183)	(0.167)	(0.027)	(0.025)
Past Fund Raising	0.100***	0.096***	0.004	0.003
	(0.019)	(0.018)	(0.003)	(0.003)
VC Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	3,663	3,663	3,282	3,282
R Squared	0.759	0.759	0.576	0.576

Table 9
Cross-Sectional Regression

This table reports the 2SLS cross-sectional regression analyses examining the effect of "# of Rounds" on innovation outcomes. The dependent variables are "$ln(Patents)$" and "$ln(Citations)$", respectively, each summed over year t to year $t+3$ after an firm's IPO. We instrument "# of Rounds" with "Direct Flight", the frequency of direct flights between VC domiciles and IPO firm headquarters. Columns 1 through 4 present the results based on the full sample. Columns 5 through 8 present the results based on the subsample where variations in frequencies of direct flights between VC domiciles and IPO firm headquarters are due to airline restructuring activities such as bankruptcies, mergers and acquisitions, and/or strategic alliances. For brevity, the first-stage regression in which the fitted (instrumented) value of "# of Rounds" is generated for use in the second-stage regressions is not tabulated. Control variables are included in the regressions but not reported. Robust standard errors are in parentheses. Definitions of variables are in Appendix. Industry classification is based on 2 digit SIC code. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	All Direct Flights				Airline Restructuring Related			
Dependent variable	$ln(Patents)$		$ln(Citations)$		$ln(Patents)$		$ln(Citations)$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Rounds (Instrumented)	-0.402**	-0.452**	-0.386**	-0.439**	-0.401**	-0.442**	-0.366*	-0.380*
	(0.160)	(0.180)	(0.195)	(0.218)	(0.172)	(0.192)	(0.190)	(0.206)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	1,526	1,526	1,526	1,526	978	978	978	978
Root MSE	1.219	1.276	1.491	1.540	1.226	1.274	1.426	1.435