

Does Going Public Affect Innovation?

Shai Bernstein*

Stanford University

July 3, 2014

Abstract

This paper investigates the effects of going public on innovation by comparing the innovative activity of firms that went public with firms that withdrew their IPO filing and remained private. NASDAQ fluctuations during the book-building phase are used as an instrument for IPO completion. Using patent-based metrics, I find that the quality of internal innovation declines following the IPO and firms experience both an exodus of skilled inventors and a decline in productivity of remaining inventors. However, public firms attract new human capital and acquire external innovations. The analysis reveals that going public changes firms' strategies in pursuing innovation.

*Stanford University, e-mail: shaib@stanford.edu. I am deeply grateful to Fritz Foley, Josh Lerner, Andrei Shleifer, and Jeremy Stein for their invaluable comments. I also thank Philippe Aghion, Effi Benmelech, Laura Field, Paul Gompers, Robin Greenwood, Sam Hanson, Oliver Hart, Victoria Ivashina, Dirk Jenter, Bill Kerr, Jacob Leshno, Gustavo Manso, Ramana Nanda, Francisco Perez-Gonzalez, David Scharfstein, Antoinette Schoar, Amit Seru, Adi Sunderam, Rick Townsend and Jeff Zwiebel for helpful comments. I am grateful to seminar participants at Chicago University, Columbia University, Dartmouth College, Entrepreneurial Finance and Innovation Conference, Harvard Business School, Hebrew University, London Business School, London School of Economics, NBER Productivity Lunch, Northwestern University, Searle Conference on Innovation and Entrepreneurship, Stanford University, Tel-Aviv University, University of British Columbia and University of Pennsylvania for helpful comments and suggestions. Andrew Speen provided superb research assistance. I am grateful for funding from the Ewing Marion Kauffman Foundation.

1. Introduction

Does the transition to public equity markets affect innovation? This question is particularly relevant given the the critical role of innovation in promoting economic growth (Solow 1957) and the prevalence of technological firms in the initial public offerings (IPOs) market over the last decades.¹ Although a large body of research examines the performance of firms around their IPO, little is known about the effects of going public on innovation. This paper's main contribution is to show that going public affects three important dimensions of innovative activity: internally generated innovation, productivity and mobility of individual inventors, and acquisition of external innovation.

Theoretically, in frictionless financial markets, selling equities publicly should have no bearing on subsequent innovative activity. With financial frictions, however, the transition to public equity markets provides firms with better access to capital. This can improve innovative activity in particular, because such activity is likely more sensitive to financing constraints than other forms of investments (Arrow 1962; Hall and Lerner 2010). Alternatively, it has long been recognized that a stock market listing can increase the scope for agency problems, which may undermine firm incentives to innovate (Berle and Means 1932; Jensen and Meckling 1976).

Ultimately, the long-run effects of going public on innovation is an empirical question. Estimating these effects, however, is challenging due to an inherent selection bias associated with the decision to go public. A standard approach in the literature uses within-firm variation to study the dynamics of firm outcomes around the IPO. But, as noted by Jain and Kini (1994), firms choose to go public at a specific stage in their life cycle, and therefore this approach may produce biased estimates of the IPO effect. For instance, firms may choose to go public following an innovative breakthrough, as argued by Pastor, Taylor, and Veronesi (2009).² In this case, the post-IPO performance may reflect reversion to the mean

¹In the last 40 years, approximately 40 percent of all firms that went public were technological firms.

²Chemmanur, He, and Nandy (2010) find that firms go public following productivity improvements.

thereby mixing life cycle effects with the IPO effect.

To estimate the effect of going public on innovation and overcome this selection bias, I construct a dataset of innovative firms that filed for an initial registration statement with the SEC in an attempt to go public, and either completed or withdrew their filing. Combined with standard patent-based metrics, this sample allows me to compare the innovative activity of firms that went public with that of private firms that are at a similar stage in their life cycle, namely, intended to go public. However, comparing complete and withdrawn IPO filings introduces a new bias associated with the decision of firms to withdraw the IPO filing and remain private.

To address this concern, I use NASDAQ fluctuations in the two months following the IPO filing date as an instrument for IPO completion, relying on filers' sensitivity to aggregate stock market movements during the book-building phase. Consistent with prior literature, I find that these short-run NASDAQ fluctuations strongly predict IPO completion and the effect is concentrated at market declines.³ In the analysis, the IPO effect is identified from differences in long-run (five years) of innovation between firms that filed to go public in the same year, but experienced different post-filing NASDAQ returns.⁴

For the instrument to be valid, it needs to satisfy the exclusion restriction condition; i.e., that two-month NASDAQ returns relate to long-run innovation measures only through the IPO completion choice. I present a variety of evidence supporting the validity of the instrument (see section 3.C for a detailed discussion). Its validity can be further illustrated using a placebo test. While the reduced form analysis shows that the instrument significantly explains the long-run five years of innovation, the concern is that it may affect innovation through other channels. If this is the case, then two-month NASDAQ returns should explain long-run innovation also outside the book-building phase. The placebo test reveals that

³See for example Benveniste et al. (2003), Busaba, Benveniste and Guo (2000), Busaba (2006), Dunbar (1998), Dunbar and Foerster (2008), Edelen and Kadlec (2005), and Hanley (1993).

⁴The reduced-form results of the paper can be illustrated using a simple means comparison of the post-IPO innovation of firms that experienced a NASDAQ drop and other same-year filers. Such cross-tabulation of the results is discussed in section 4.A.1.

outside the book-building phase, when ownership choice is fixed, NASDAQ returns have no effect on long-run innovation. This finding is consistent with the notion that short-term NASDAQ returns during the book-building phase affect long-run innovation only through the IPO completion choice.

Using this instrumental variables approach, I find a significant link between public ownership and innovation: going public causes a substantial decline of approximately 40 percent in innovation novelty as measured by patent citations. At the same time, I find no change in the scale of innovation, as measured by the number of patents. These results suggest that the transition to public equity markets leads firms to reposition their R&D investments toward more conventional projects.

Having shown that going public affects the composition of innovative relative to conventional projects, I proceed to study the effects of going public on individual inventors' productivity and mobility over time. I find that the quality of innovation produced by inventors who remained at the firm declines following the IPO and key inventors are more likely to leave. The firms that went public are also more likely to generate spinout companies, suggesting that inventors who left remain entrepreneurial. These effects are partially mitigated by the ability of public firms to attract new inventors.

I also find a stark increase in the likelihood that newly public firms acquire companies in the years following an IPO. To better understand whether these acquisitions are used for purchasing new technologies, I collect information on targets' patent portfolios. I find that public firms acquire a substantial number of patents through M&A: acquired patents constitute almost a third of firms' total patent portfolio in the five years following the IPO. The acquired patents are of higher quality than the patents produced internally following the IPO.

These results illustrate that the transition to public equity markets affects the strategies firms employ in pursuing innovation. While publicly traded firms generate more incremental innovation internally, they also rely more heavily on acquiring technologies externally. This

shift takes place during a substantial inventor turnover after the IPO.

What leads to these changes? It may be that stock market listing increases the scope for agency problems, leading firms to pursue less innovation following the IPO (Berle and Means 1932; Jensen and Meckling 1976). Alternatively, agency problems may be concentrated in private firms that pursue too much innovation. Finally, it may be the case that the results are not driven by an agency problem. Rather, the improved access to capital allows firms to focus on commercialization after the IPO. Such a strategy is not viable to firms that remained private and therefore focus on innovation only. I discuss these hypotheses in detail in Section 5. I find supportive evidence toward a managerial career concerns hypothesis, consistent with recent papers that explore agency problems in public equity markets (see, e.g., Aghion, Van Reenen, and Zingales 2013; Asker, Farre-Mensa, and Ljungqvist 2014; Fisman et al. 2013; and Gao, Harford, and Li 2014).

The paper is related to several strands of the literature. First, the IPO literature explores firm behavior following the IPO, and documents a decline in firm performance measures such as profitability and productivity (Chemmanur, He, and Nandy, 2010; Degeorge and Zeckhauser, 1993; Jain and Kini, 1994; Mikkelson, Partch, and Shah, 1997; Pagano, Panetta, and Zingales, 1996; Pagano, Panetta, and Zingales, 1998; and Pastor, Taylor, and Veronesi, 2009). This paper's contribution to the literature is twofold. First, it proposes an identification strategy to isolate the IPO effect. Second, it focuses on firms' innovative activities around the IPO.⁵

This analysis focuses on the ex-post consequences of becoming a publicly traded firm on innovation, illustrating a complex trade-off between public and private ownership structures. In that regard, the paper is also related to a growing literature that compares the behavior of public and private firms along various dimensions such as investment sensitivity (e.g., Asker, Farre-Mensa, and Ljungqvist, 2014; Sheen 2009), debt financing and borrowing costs

⁵Aggarwal and Hsu (2013) examine similar question in the context of venture capital-backed biotechnology firms. Similarly to this paper they find a post-IPO long-run decline in innovation quality. This study differs from Aggarwal and Hsu (2013) by its focus on a cross-industry analysis and the use of an identification strategy that exploits NASDAQ fluctuations as an instrument for IPO completion.

(Saunders and Steffen, 2011; and Brav, 2009), dividend payouts (Michaely and Roberts, 2012), and CEO compensation (Gao, Lemmon, and Li, 2013).

This work also contributes to a growing literature that explores the role of governance, capital structure, and ownership on corporate innovation. For example, Seru (2014) explores the effects of Mergers and Acquisitions on innovation, while Lerner, Sorensen, and Stromberg (2011) examine the impact of Private Equity investments. Aghion, Van Reenen, and Zingales (2013) explore the importance of institutional investors and concentrated ownership. This paper is also connected to the theoretical literature on the organization of R&D (e.g., Aghion and Tirole, 1994) and more broadly to empirical work on the boundaries of the firm (e.g., Robinson 2008, Beshears 2013, and Seru 2014).

The rest of the paper proceeds as follows. Section 2 describes the data and presents summary statistics and Section 3 presents the empirical strategy. Section 4 provides the main results and Section 5 discusses potential channels. Section 6 concludes.

2. Data

The data in this analysis is constructed from several sources combining information on IPO filings, patents, and hand-collected financial information and other firm characteristics.

2.A IPO Filings

To apply for an IPO, a firm is required to submit an initial registration statement to the SEC (usually S-1 form), which contains the IPO filer’s business and financial information. Following the submission of the S-1 form, filers engage in marketing the equity issuance to investors (the “book-building” phase) and have the option to withdraw the IPO filing by submitting the RW form. Filing withdrawals are common in IPO markets, as approximately 20 percent of all IPO filings are ultimately withdrawn.

I collect all IPO filings using Thomson Financial’s SDC New Issues database. The sample

starts in 1985, when SDC began covering withdrawn IPOs systematically, and ends in 2003 since the analysis explores the innovative outcomes of firms in the five years after the IPO filing. Following the IPO literature, I exclude IPO filings of financial firms (SIC codes between 6000 and 6999), unit offers, closed-end funds (including REITs), ADRs, limited partnerships, special acquisition vehicles, and spin-offs. I identify 5,583 complete IPOs and 1,599 withdrawn IPO filings in the period of 1985 - 2003.

2.B Patent Data

2.B.1 Measuring Innovative Activity

An extensive literature on the economics of technological change demonstrates that patenting activity reflects the quality and extent of firm innovation. While the literature acknowledges that patents are not a perfect measure,⁶ their use as a measure of innovative activity is widely accepted (Hall, Jaffe, and Trajtenberg, 2001; Lanjouw, Pakes, and Putnam, 1998). Importantly for this analysis, patent information is available for both public and private firms, unlike R&D expenditures, and allows measuring firm innovative output along several dimensions.

The most basic measure of innovative output is a simple count of number of patents granted. However, patent counts cannot distinguish between breakthrough innovation and incremental discoveries (e.g., Griliches, 1990). The second metric, therefore, reflects the importance or novelty of a patent by counting the number of citations a patent receives following its approval. Patent citations also capture the economic importance of the innovation, as it correlates with firm's market value (Hall, Jaffe, and Trajtenberg, 2005). Moreover, Kogan et al. (2012) show that the stock market strongly and favorably react to the approval of patents who are eventually highly cited. Moreover, they show that such patents predict firm productivity, and capital and labor flows from non-innovative to innovative firms within the industry.

⁶For example, inventions may be protected by trade secrets.

Both citation rates and patent counts vary over time and across technologies. Variations may stem from changes in the importance of technologies or from changes in the patent system. Therefore, a comparison of raw patents and citations is only partially informative. To adjust for these variations, I follow Hall, Jaffe, and Trajtenberg (2001) and scale each patent citation count by the average citations of matched patents. Matched patents are defined as patents that are granted in the same year and in the same technology class. Similarly, to adjust for variations in patent counts, each patent is weighted by the average number of patents granted by firms in the same year and technology class. Hence, patents that were granted in technologies in which firms issue more patents receive less weight. The *scaled patent count per year* is a simple sum of the scaled patents a firm generates in a year.

The final measures, Originality and Generality, use the distribution of citations to capture the fundamental nature of research (Trajtenberg, Henderson, and Jaffe, 1997). A patent that cites a broader array of technology classes is viewed as having greater originality. A patent that is being cited by a more technologically varied array of patents is viewed as having greater generality.⁷ Similarly to patent counts and citations, *scaled originality* and *scaled generality* are normalized by the corresponding average originality or generality of all patents granted in the same year and technology class.

2.B.2 Patent Data Sources

The patent data is obtained from the National Bureau of Economic Research (NBER) patent database, which includes detailed information on more than 3 million patents submitted to the U.S. Patent and Trademark Office (USPTO) from 1976 to 2006 (Hall, Jaffe, and Trajtenberg, 2001).

I use the NBER bridge file to COMPUSTAT to match patents to firms that completed

⁷The originality (generality) measure is the Herfindahl index of the cited (citing) patents, used to capture dispersion across technology classes. I use the bias correction of the Herfindahl measures, described in Jaffe and Trajtenberg (2002) to account for cases with a small number of patents within technological categories.

the IPO filing, and manually match patents to withdrawn IPO filings.⁸ I restrict the sample to firms with at least one successful patent application in the period of three years before and five years after the IPO filing. This yields 1,488 innovative firms that went public and 323 that withdrew the IPO application.

The goal is to collect information on firms' innovative activity in the five years after the IPO filing regardless of whether they are acquired or go public in a second attempt, to avoid biases that may arise from truncating firm activity. After all, firm exits are yet another consequence of the IPO effect that influences firms' innovative paths. Collecting patent information subsequent to firm exits is feasible since in most cases, even if a firm is acquired, its patents are still assigned to the acquired rather than the acquiring company.⁹

I calculate the number of citations a patent receives in the calendar year of its approval and in the subsequent three years. This time frame is selected to fit the nature of the sample. Since many of the IPO filings in the sample occur toward the end of the 1990s, increasing the time horizon of citation counts will reduce sample size. Further motivating the selected citations horizon is that citations are concentrated in the first few years following a patent's approval and there is a considerable serial correlation in citation rates (Akcigit and Kerr, 2013).

Since the NBER patent database ends in 2006, I supplement it with the Harvard Business School (HBS) patent database, which covers patents granted through December 2009. This enables calculating the citations of patents granted toward the end of the sample. Overall, the sample consists of 39,306 granted patents of firms that went public (henceforth 'IPO firms') and 4,835 granted patents of firms that withdrew their filing (henceforth 'withdrawn

⁸Since withdrawn firms are not included in COMPUSTAT, I match these firms based on company name, industry, and geographic location, all of which are available in SDC and IPO registration forms. In ambiguous cases where firm names are similar but not identical, or the location of the patentee differs from the SDC records or SEC registration statements, I conduct web and FACTIVE searches to verify matches.

⁹In 90% of the firm-year observations in the five years after the IPO filing, firms are either independent, or acquired and produced a patent under the previous assignee name. In the remaining firm-years, a firm was acquired and no patent was assigned to it. Hence, the acquired firm either did not generate additional patents, or any patents generated were assigned to the acquiring company. To identify missing patents in these remaining years, I use inventor identifiers and geographic location to locate patents that were produced by the inventors of the acquired rather than the acquiring company.

firms’).

Table 1 compares the patenting activity of withdrawn and IPO firms in the three years prior to the IPO filing. I find no significant differences across any of the patenting measures. Since a value of one in the scaled citations measure implies that a firm is producing patents of average quality, it is interesting to note that both IPO firms and withdrawn firms produce patents that are substantially more cited than comparable patents in the years leading to the IPO filing (80 percent higher for withdrawn firms and 89 percent higher for IPO firms). This evidence suggests that firms that select to go public are likely to do so following innovative breakthroughs, raising concerns of post-IPO mean reversion, regardless of the IPO effect. This further motivates the empirical approach in this paper.¹⁰

2.C Financial Information and Firm Characteristics

The analysis of private firms is complicated due to data limitations. While patents are useful in capturing the innovative activity of both public and private firms, no financial information is readily available for withdrawn firms in standard financial databases. To partially overcome this constraint, I collect withdrawn firms’ financial information from initial registration statements, by downloading the S-1 forms from the SEC’s EDGAR service, which is available from 1996. I collect financial information for IPO firms from COMPUSTAT and CapitalIQ.

Additional information on firm characteristics is collected from various sources. I obtain data on venture capital (VC) funding from SDC, VentureXpert, and registration statements. I supplement the data with information on firms’ age at the time of the IPO filing and its underwriters’ ranking obtained from registration forms, VentureXpert, Jay Ritter’s webpage, and the SDC database. Finally, I collect information on firms’ exits, i.e., events in which

¹⁰In Panel A of Table A.1 in the Appendix, I summarize the distribution of IPO filings, patent applications and awards over time. Panels B and C provide the distribution of firms across industries and of patents across technology classes. The majority of the firms in the sample are concentrated in technological industries such as electronic equipment, software, drugs, and medical equipment. Similarly, most patents are concentrated in industries that rely on intellectual property, such as computer, drugs, and electronics industries.

firms were acquired, went public in a second attempt (for withdrawn firms), or filed for bankruptcy. I use COMPUSTAT and CapitalIQ to search for acquisitions and bankruptcies, and the SDC database to identify second IPOs of withdrawn firms. I perform extensive checks to verify the nature of private firms' exits using the Deal Pipeline database, Lexis-Nexis and web searches.

Table 1 compares the characteristics of IPO firms and withdrawn firms at the time of filing. I find no significant differences in firm size (measured by log firm assets) and R&D spending (normalized by firm assets). However, withdrawn firms have a higher cash-to-assets ratio and have lower net income to assets. I also find no significant differences in the reputation of lead underwriter, which is often considered as a proxy for firm quality.¹¹ Moreover, there is no significant difference in firm age at the time of filing.¹²

There are stark differences, however, in the NASDAQ fluctuations that firms experience after the IPO filing. Specifically, firms that went public experienced on average a 3 percent increase in the two-month NASDAQ returns following the IPO filing, while firms that selected to withdraw experienced, on average, a sharp drop of 6 percent over a similar period. However, the differences in NASDAQ returns in the three months prior to the IPO filing are fairly small (5 percent increase for firms that ultimately remained private versus 7 percent for those that went public). These differences provide further motivation for using NASDAQ fluctuations as a variation that affects IPO completion choices. I discuss this in detail in the next section.

Table 1 also describes firm exit events in the five years following the IPO filing. I find that 29 percent of the withdrawn firms and 24 percent of the IPO firms are being acquired over this period, and the difference between the two groups is insignificant. Only 2 percent

¹¹The literature often uses the reputation of the lead underwriter as a proxy for firm quality, based on the rationale that higher-quality firms are more likely to be matched with a higher-quality underwriter. The underwriter ranking is based on a scale of 0 to 9, where 9 implies highest underwriter prestige. The ranking is compiled by Carter and Manaster (1990), Carter, Dark, and Singh (1998), and Loughran and Ritter (2004). I use the rating that covers the particular time period when the firm went public. If the rating for that period is not available, I employ the rating in the most proximate period.

¹²Firm age is calculated from founding date. The firm age of issuers that went public is kindly available at Jay Ritter's webpage. I collected firms' age of issuers that remained private from IPO prospectuses.

of both IPO and withdrawn firms went bankrupt. Additionally, 18 percent of the withdrawn firms ultimately go public in a second attempt in the five years following the IPO filing.

The resulting small fraction of withdrawn firms that return to public equity markets in a second attempt was highlighted in the literature (Dunbar and Foerster, 2008; Busaba, Beneviste, and Guo, 2001). Several explanations exist for the low fraction of second attempt IPOs. It may be the case that returning to the IPO markets in a second attempt is difficult as the window of opportunities may close due to the boom and bust nature of the IPO markets (Ibbotson and Ritter 1995). Brau and Fawcett (2006) find that the most important signal when going public is a firm’s past historical earnings. If going public requires several years of fast growth to attract investors’ attention, such growth may be difficult to regenerate in a second attempt. Finally, Dunbar and Foerster (2008) suggest that there are reputational costs associated with the decision to withdraw which prevent firms from returning to equity markets.

3. Empirical Strategy

3.A Empirical Design

Identifying the effects of going public on innovation and firm outcomes in general is challenging due to inherent selection issues that arise from the decision of firms to go public. This concern is evident in Figure 1 which presents the within-firm changes in innovation quality, measured by scaled citations, in the years around the IPO.¹³ Firms experience a monotonic decline in patents’ novelty that starts two years before the IPO event, and continues in the five years thereafter. Due to the selection of firms to go public, post-IPO performance could

¹³The chart’s estimates and confidence intervals are taken from a regression that runs scaled citations as a dependent variable on a series of dummy variables indicating the the relative year around the IPO in which a patent application was submitted (year zero is the year of the IPO and the omitted category). The specification is estimated using OLS and includes firm and year fixed effects. The estimates are reported in the second column of Table A.2 in the Appendix. Table A.2 also reports the within-firm changes in originality, generality and number of patents around the IPO event.

be driven by reversion to the mean and life cycle effects, rather than the actual effect of becoming a publicly traded firm.

What is a reasonable counterfactual for firms that went public? Simply comparing post-IPO innovation to an average private firm may generate biased estimates, as most private companies are fundamentally different and will never to go public. This is evident in Table 1 as pre-filing innovation quality of firms that went public is 80% higher than the average innovation in the respective technological classes. To overcome this concern, I focus only on firms that submitted initial registration statement to the SEC in an attempt to go public.

I compare the long-run innovation of firms that went public with firms that filed to go public in the same year, but ultimately withdrew their filing and remained private. This approach is similar to Seru (2014) who compares complete and cancelled M&A deals.¹⁴ This setup is attractive as it allows the comparison of the post-IPO performance of firms that went public with that of private firms at a similar stage in their life cycle. My baseline specification of interest is

$$(1) \quad Y_i^{post} = \alpha_1 + \beta_1 IPO_i + \gamma_1 Y_i^{pre} + X_i' \delta_1 + \nu_k + \mu_t + \varepsilon_{1i}$$

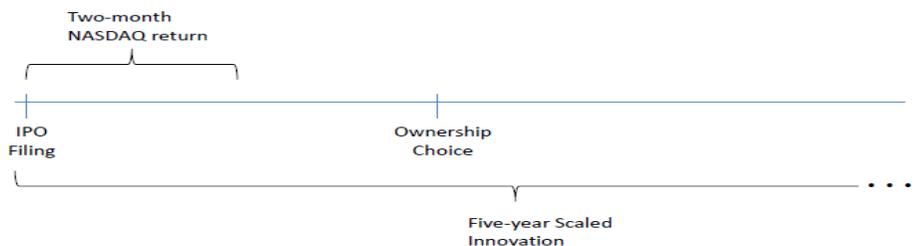
Y_i^{post} is the average innovative performance in the five years following the IPO filing: average scaled citations, average scaled originality/generalizability and average scaled number of patents per year. Y_i^{pre} is the equivalent measure in the three years prior to the IPO filing. IPO_i is the dummy variable of interest, indicating whether a filer went public or remained private. Under the null hypothesis that going public has no effect on innovation, β_1 should not be statistically different from zero. This model includes industry (ν_k) and IPO filing year (μ_t) fixed effects.

If the decision to withdraw an IPO filing is related to unobserved innovation policy or innovative opportunities (captured in the error term), then β_1 estimate may be biased.

¹⁴Seru (2014) uses news reports to identify deals that were cancelled due to reasons exogenous to innovation policy of the firm.

Therefore, I instrument for the IPO completion choice using NASDAQ returns in the first two months of the book-building phase. The decision to use a two-month window is somewhat arbitrary. One could use the NASDAQ returns during the entire period of the book-building phase. However, since the length of the book-building phase is often correlated with the likelihood to withdraw, I choose a fixed window that is sufficiently shorter than the average length of the book-building period.

The figure below illustrates the time line of the IPO filing and the NASDAQ fluctuations during the book-building phase. On average, the ownership choice is made within four months following the IPO filing. The firm-level innovation is measured over the five-year horizon after the IPO filing.¹⁵



To implement the instrumental variables approach, I estimate the following first-stage regression:

$$(2) \quad IPO_i = \alpha_2 + \beta_2 NSDQ_i + \gamma_2 Y_i^{pre} + X_i' \delta_2 + \nu_k + \mu_t + \varepsilon_{2i}$$

where $NSDQ_i$ is the instrumental variable. The second-stage equation estimates the impact of IPO on firm innovative activity:

$$(3) \quad Y_i^{post} = \alpha_3 + \beta_3 \widehat{IPO}_i + \gamma_3 Y_i^{pre} + X_i' \delta_3 + \nu_k + \mu_t + \varepsilon_{3i}$$

where \widehat{IPO}_i are the predicted values from (2). If the conditions for a valid instrumental variable are met, β_3 captures the causal effect of an IPO on innovation outcomes. I

¹⁵The results of the analysis remain unchanged if innovation measures are calculated from the ownership choice date rather than IPO filing date, as patent filings during the book-building period are rare.

implement the instrumental variable estimator using two-stage least squares. I also use a quasi-maximum likelihood (QML) Poisson model to estimate the IV specification (Blundell and Powell, 2004), which is the standard estimation method used in the innovation literature and count data analysis more generally.

It is important to note that the estimates in the instrumental variables analysis is coming only from the *sensitive* firms (Imbens and Angrist, 1994). In other words, the estimates are coming only from those firms that would alter their IPO completion decision if experienced a NASDAQ drop, and therefore, sensitive to changes in the instrument. In section I of the Appendix, I provide a simple example to illustrate this point. In the next section I discuss the necessary assumptions that need to hold for the instrument to be valid.

3.B NASDAQ Fluctuations and IPO Completion

For the instrument to be valid, it must strongly affect IPO completion choice. Indeed, issuers are highly sensitive to stock market fluctuations during the book-building phase (Benveniste et al., 2003; Busaba, Benveniste, and Guo, 2001; Dunbar, 1998; Dunbar and Foerster, 2008; Edelen and Kadlec, 2005). This sensitivity is also illustrated in Figure 1 which plots the fraction of monthly filings that ultimately withdrew against the two months of NASDAQ returns calculated from the middle of each month, which approximates the stock market fluctuations during the initial part of the book-building phase.¹⁶ Consistently, a survey by Brau and Fawcett (2006) finds that CFOs that withdrew an IPO registration recognized that market conditions played a decisive role in their decision.

Why wouldn't firms simply wait for more favorable market conditions? There are several reasons. First, a filing registration automatically expires 270 days after the last amendment of the IPO filing, which limits the time to complete the IPO filing (Lerner, 1994). Additionally, waiting is costly: as long as the application is pending, firms cannot issue private placements, and are forbidden to disclose new information to specific investors or banks. In fact, firms

¹⁶The correlation of the two plots equals -0.44, or -0.34 if considering only the pre-2000 period. Both correlations are significantly different from zero at the 0.01% level.

are required to update the registration statement periodically to reflect the current affairs of the company. These considerations lead firms to withdraw at an even earlier date prior to the automatic expiration of the IPO filing.

The first-stage results, presented in Table 2, demonstrate the effect of NASDAQ returns during the book-building phase on IPO completion. The dependent variable is equal to one if a firm completed the IPO filing, and zero otherwise. All specifications include filing year and industry fixed effects using OLS. In column (1), I find that the coefficient of the two-month NASDAQ returns equals 0.704 and is significant at 1 percent. A decline of one standard deviation in NASDAQ returns translates into a decline of 8.72 percent in the likelihood of completing the IPO. Moreover, the F -statistic equals 47.79 and exceeds the threshold of $F = 10$ which suggests that the instrument is strong and unlikely to be biased towards the OLS estimates (Bound, Jaeger, and Baker, 1995; Staiger and Stock 1997).

In column (2) I control for the three-month NASDAQ returns prior to the IPO filing, the location of the filer within the IPO wave, the number of pre-filing patents, and a VC-backing dummy variable. The coefficient remains highly statistically significant, suggesting that the instrument is almost orthogonal to the added control variables, confirming the findings in Table 2. Moreover, in columns (3) and (4) I limit the sample to pre-2000 years, and results remain similar. In columns (5) and (6) I calculate the NASDAQ returns over the entire book-building period.¹⁷ The coefficient is still significant at 1 percent, but the magnitude of the coefficient somewhat declines.¹⁸ In columns (7) and (8), I construct a dummy variable that equals one if the firm did not experience a NASDAQ drop. A firm is said to experience a NASDAQ drop if the two-month NASDAQ returns following the IPO filing are among the lowest 25 percent of all filers within the same year. The dummy variable in column (7) is highly statistically significant, reflecting a 10.6 percent increase in IPO completion

¹⁷When the IPO withdrawal date is not available, I calculate it as the 270 days after the last IPO filing amendment (Lerner 1994)

¹⁸The weaker effect may reflect the importance of the first months in the book-building period, where most of the marketing efforts are concentrated. This is consistent with Welch's (1992) argument of "information cascades": later investors are more likely to rely on earlier investors' choices, leading to the rapid success or failure of the equity offering.

likelihood. Column (8) adds the additional control variables and results remain unchanged.

Figure 3 illustrates the non-parametric relation between the two-month NASDAQ fluctuations and the likelihood of completing the IPO filing. The figure shows that as long as the NASDAQ fluctuations are negative, there is a positive and monotonic association between NASDAQ returns and the likelihood of completing the IPO filing. When NASDAQ returns are positive, filers become less sensitive to market conditions and the likelihood of completing an IPO filing becomes more or less stable around 85 percent.

Overall, the first-stage results indicate that NASDAQ fluctuations have a strong effect on IPO completion, and the effect is concentrated in market declines. Moreover, the two-month NASDAQ effect seems to be orthogonal to the added control variables.

3.C The Exclusion Restriction Condition

The instrument not only needs to affect IPO completion choice, but importantly, it must satisfy the exclusion restriction. That is, it should not affect the scaled innovation measures through any channel other than the decision to complete the IPO filing.¹⁹ Formally, this requires that the instrument must be uncorrelated with the residuals in equation (1). To alleviate concerns about the exclusion restriction, I take several steps:

- (1) Comparing observables - I explore whether significant differences in observables occur between firms that experienced a NASDAQ drop and other firms that filed to go public in the same year. A firm is said to have experienced a NASDAQ drop if the two-month NASDAQ returns after the IPO filing are within the bottom 10 percent (or bottom 25 percent) of filers in a given year. Using both thresholds in Table 3, I find no significant differences between the two sets of firms across a list of observables such as firm financial information at the time of filing, age, VC backing, IPO filing

¹⁹These two requirements are sufficient if treatment effects are homogeneous. In case of heterogeneous treatment effects, monotonicity is also required to estimate a local average treatment effect. In other words, it is required that, other things equal, there is no firm whose likelihood to complete the IPO filing increases as NASDAQ returns decline.

characteristics, and importantly, all innovation measures in the three years before the IPO filing. These findings are not surprising given that similar firms are likely to cluster and attempt to go public at the same time in an attempt to exploit information spillovers (Beneveniste et al. 2003).

- (2) Within year comparison - In the analysis, I compare the long-run innovative activity of firms that filed to go public in the same year, but experienced different short-term NASDAQ fluctuations during the book-building phase. Firms that filed to go public in the same year are likely to be similarly exposed to changes in long-run innovation opportunities, if reflected by NASDAQ returns, since R&D expenditure is a slow-moving process (Hall, Griliches, and Hausman 1986; Lach and Schankerman, 1989).
- (3) Additional controls - To further address concerns about within-year compositional shifts, I control also for the three-month NASDAQ returns leading to the IPO filing, and for firms' location within the IPO wave.²⁰
- (4) Scaled innovation measures - Any aggregate changes, such as changes in innovative opportunities, should affect both sample firms and all other firms doing research in the same technology. Since scaled innovation measures are expressed in terms relative to all patents granted in the same year and technology class, these measures are not likely to be affected by aggregate changes if such are reflected by the instrument.²¹
- (5) Placebo test - column (1) of Table 4 illustrates a statistically significant correlation between the two month post-filing NASDAQ returns and the long-run scaled citations.²²

²⁰I follow Beneveniste et al. (2003) definition of location within the IPO wave. A firm is defined as a "pioneer" if its filing is not preceded by filings in the same Fama-French industry in the previous 180 days (using all IPO filings, irrespective of patenting activity). "Early followers" are those that file within 180 days of a pioneer's filing date.

²¹Consider for example a firm that submitted an IPO filing in 1995 and was awarded a patent three years later in 1998 in the fiber optics technology. The novelty of the patent is scaled by the average novelty of all patents granted in 1998 in the fiber optics technology. If the two-month NASDAQ returns following the IPO filing reflected a change in innovative opportunities in fiber optics in coming years, this change should affect the novelty of all patents within this technology class. Hence, relative patent novelty is unlikely to be affected by the instrument, even if the instrument reflects changes in innovative opportunities.

²²This result is also reported in Table 6 column (2), when discussing the main results of the paper.

If the exclusion restriction is violated, then the two-month NASDAQ returns affect long-run innovation through alternative channels other than the ownership channel. Such alternative channels should be apparent also when exploring NASDAQ returns *outside* the book-building phase, when firms' ownership choice is fixed. Using this setting as a placebo test, I find in column (2) that the two-month NASDAQ returns immediately following the IPO completion choice do not predict long-run innovative performance. In columns (3) and (4), I similarly find that in the year before (or year after) the IPO filing, the two-month NASDAQ returns are insignificant and do not correlate with long-run innovation. In columns (5) to (7) I repeat the analysis by including both post-filing NASDAQ returns and NASDAQ returns outside the book-building phase. In contrast to the NASDAQ returns following the IPO filing, outside the book-building window they are not correlated with long-run innovation. These findings are consistent with the notion that short-run NASDAQ returns affect long-run innovation only through its impact on firms' ownership choice.

- (6) Innovation trends test - I also investigate directly whether the instrument can explain changes in aggregate long-run innovative trends in filers' core technologies, using all patents granted by the U.S. Patent and Trademark Office. The results, reported in Table A.3 in the Appendix, show that the instrument does not predict changes in innovative trends.

4. Results

4.A Internal Innovation

In this section I use the instrumental variables approach, described in Section 3, to study the effects of going public on internally generated firm innovation.

4.A.1 Simple Illustration of Reduced Form Results

Before proceeding to the multivariate analysis, I illustrate the results by a simple comparison of the post-IPO innovative performance of firms that experienced a NASDAQ drop relative to other filers within the same year. This comparison is equivalent to the reduced-form estimation in which the instrument is binary and equals one if a firm experienced a NASDAQ drop. This approach is attractive because of its simplicity and absence of any distributional or functional form assumptions.

A firm is said to have experienced a NASDAQ drop if the two-month NASDAQ returns after the IPO filing are within the bottom 25 percent of filers in a given year. Column (6) of Table 3 illustrates that there are no significant differences between the two groups in any of the firm characteristics and innovation measures at the time of the IPO filing. However, as illustrated in Table 5, the likelihood that the IPO will be completed declines by 11.1 percent for firms that experienced low NASDAQ returns.

In Table 5 I find a strong correlation between two-month NASDAQ declines and subsequent five-year innovative performance, arguably through the impact of NASDAQ returns on IPO completion choice. Firms that experienced NASDAQ declines produce patents with higher average scaled citations and generate patents with higher average scaled originality. The difference in patent quality is also apparent when one considers the most-cited patent produced after the IPO filing (rather than the average citation rates). I find no differences in the number of patents produced following the IPO filing. These results are similar to the ones presented in the multivariate analysis which makes use of the continuous value instrument.

4.A.2 Multivariate Analysis

The first set of results explores the effect of IPO on innovation novelty. The dependent variable is the average scaled citations in the five years following the IPO filing, controlling for equivalent measure in the three years prior to the IPO filing. All specifications follow

the model described in Section 3.A, controlling for filing year and industry fixed effects. Additionally, I control for the three-month pre-IPO filing NASDAQ returns, VC-backing dummy variable, and location within the IPO wave. Robust standard errors are reported in parentheses.

In column (1) of Table 6, I report the endogenous OLS model and find no differences between IPO firms and withdrawn firms as the IPO coefficient is insignificant. Column (2) presents the reduced-form estimation, obtained by substituting the endogenous IPO variable with the instrument. I find a statistically significant and negative correlation between two-month NASDAQ returns and average scaled citations in the subsequent five years, arguably through the impact of the instrument on IPO completion choice.²³ This result corresponds to the findings in Table 5. In column (3), I report the estimates of the two-stage least squares. The coefficient of the IPO variable is significant and equals -0.831, implying that average scaled citations of IPO firms drops after the event by 43.51 percent ($=0.83/1.91$, when 1.91 is the average number of scaled citations in pre-event years). In column (4) I use the quasi maximum likelihood (QML) Poisson model to estimate the IV specification. The estimates are similar to column (3), as the coefficient of interest is significant, negative, and of a similar magnitude.²⁴

It is interesting to note that the OLS coefficient overestimates the effect of going public on the quality of innovation, compared to the IV estimate. This suggests that the selection bias associated with the decision to complete the IPO filing is positive, and on average, more innovative firms are more likely to complete the IPO filing.

In Table 7 I explore whether the decline in patent citations is associated with a change in the nature of projects. Columns (1)-(3) provide the results with respect to average scaled

²³This negative correlation contradicts the notion that two-month NASDAQ returns predict long-run innovation opportunities. If that was the case, one would expect positive correlation between short-run NASDAQ returns and long-run innovation.

²⁴It would be interesting to report how such changes in innovation quality vary with changes in firm R&D expenditure. While such information is not available for privately held firms, I find that in the five years after the IPO, the average R&D spending of publicly traded firms almost doubles, although its share relative to total assets remain constant. While I cannot distinguish between spendings on research versus development, this suggests that after the IPO, R&D spending remain an important objective for new publicly traded firms.

originality. The two-stage least squares estimates presented in column (3) demonstrate that the post-filing average originality of firms that completed the IPO significantly declines as the IPO coefficient equals -0.137 reflecting a decline of 13 percent ($= -\frac{0.13}{1.06}$, the average scaled originality in pre-event years is 1.06). These findings suggest that issuers who remained private produce patents that rely on a broader set of technologies. In columns (4)-(6) I repeat the analysis this time with respect to average scaled generality measure, and results demonstrate no significant effects.

The decline in innovation novelty may be driven by an increase in the scale of innovation, measured by number of patents. In that case, addition of low-quality innovative projects may generate the results rather than a repositioning of research to lower impact topics. The analysis in Table 8 addresses this conjecture by exploring changes in innovative scale.²⁵

The endogenous model in column (1) indicates that IPO firms produce significantly more patents per year following the IPO filing with a 37.75 percent increase relative to the pre-IPO average. Column (2), however, indicates that the above effect is insignificant when the reduced form specification is estimated. The 2SLS estimate in column (3) indicates that the coefficient of the IPO variable is insignificant and the magnitude declines to 28.17 percent. In fact, when using the IV Poisson specification in column (4), the coefficient of the IPO variable is close to zero and insignificant.

4.A.3 Robustness Checks and Interpretation

In this section I summarize several supplemental analyses that test the robustness of the findings and interpretation. I start by exploring whether the decline in average innovation quality of IPO firms can be driven by lower patenting threshold after the IPO. This may lead to the addition of low-quality patents and hence lower average patenting quality. Therefore, I

²⁵One complication in this analysis is coming from the attrition problem that may arise due to patent approval lags, particularly toward the end of the sample. Such patents may have not been approved yet and therefore are not considered in the analysis. In that regard, scaling patent counts is important not only to account for variations in patent filings across technologies but also to correct for variations in patent approvals, thus alleviating the attrition problem. The attrition problem is further mitigated by the fact that patent approval lags are likely to affect similarly both IPO firms and withdrawn firms.

explore the best (most-cited) patent, which is unlikely to be affected by such addition of low-quality patent filings. I find that the quality of the best patent of IPO firms declines as well, with a comparable magnitude to the decline in the average innovation quality reported in Table 6. This evidence, which is reported in Table A.4 of the Appendix, suggests that going public affects the entire patent distribution rather than simply driving average performance down by the addition of low-quality projects.²⁶

Cash-rich firms may be less cited because citing firms may face higher litigation risk. This may mechanically generate the results in the paper. To test this concern, I focus on patents approved before the IPO-filing and explore whether the yearly citation rates change once firms become publicly traded (relative to firms that withdrew the filing). In Table A.5 of the Appendix, I find that changes in citation rates of existing inventions cannot be explained by the transition to public equity markets.

I also explore whether the results are mostly driven by the internet bubble years. As illustrated in Table 4, the instrument strongly predicts IPO completion even when all firms that filed during the internet bubble onward are excluded. I re-estimate the innovation novelty regressions after excluding all firms that filed to go public on 1999 onward. Naturally, standard errors increase due to the decline in sample size, but the results, reported in Table A.6 in the Appendix, remain significant and qualitatively the same.

In the analysis I collect information on the innovative trajectory of firms in the five years following the IPO filing. To carefully interpret the results, it is natural to wonder how the endogenous transition of 18% of the withdrawn firms to public equity markets affect

²⁶A reversed concern might be that publicly traded firms are more likely to rely on trade secrets, while withdrawn firms rely on patents. This may explain the results only if best inventions of public firms are kept secret, leading to disclosure of only the worst ones. It is not immediately clear why public firms will selectively rely on trade secrets. The literature shows that higher-quality innovations are in fact more likely to be patented (Anton and Yao, 2004; Moser 2007), and variations in patenting seem to be mostly explained by the nature of technologies across industries and their risk of being reverse engineered (Moser 2007). Controlling for industry fixed effects and focusing on industries with high patenting intensity may alleviate such concerns. Moreover, since shareholders of public firms may have weaker incentives to monitor the firm (as ownership is more dispersed, and stock is liquid), patenting may be a useful strategy to ease stock market pressures and illustrate innovative progress. In fact, it might be the case that private firms are more likely to rely on trade secrets to avoid patenting and litigation expenses.

the estimates. I repeat the instrumental variables analysis, but now using an endogenous variable that equals one if a firm went public in the two (or three) years after the IPO filing, regardless of whether it withdrew in the first attempt. This implies that if a firm withdrew its filing, and returned back to the IPO markets in the first two (three) years after the filing, this firm would be considered as part of the treatment group only (and not the control group).²⁷ As reported in Table A.7 in the Appendix, these specifications generate estimates that are similar to those reported in the paper.

Finally, it is also important to understand whether the estimates are driven by changes in firms that withdrew their IPO filing and remained private or by those that went public. For example, withdrawn firms may choose to increase their innovation in order to successfully go public in a second attempt, rather than IPO firms that experience a decline in innovation. However, I find that all IPO filers experienced a decline in scaled innovation measures, both firms that experienced a NASDAQ drop (and thus are more likely to remain private) and firms that did not experience a NASDAQ drop.²⁸ But the decline is more substantial among those that ended up going public. Similarly, changes in acquisition of external innovation, as discussed in section 4.C, are driven by those firms that went public rather than those that remained private.²⁹

4.B Inventor Mobility and Productivity Changes

A substantial portion of the R&D investment is in the form of wages for highly educated scientists and engineers, who encompass the firm's knowledge. It is therefore only natural to explore whether going public leads to inventors' mobility and productivity changes following the IPO.

²⁷I also explore an endogenous variable that is the fraction of years in the 5 years after the IPO filing in which the firm is public. If a firm went public in first attempt then it equals one and if withdrew and never returned in a second attempt then it equals zero. If a withdrawn firm went public three years following the initial filing, then variable equals 2/5. Using this endogenous variable generate similar results.

²⁸This decline is evident in Table 5 in which the post-filing scaled citations of firms that experienced a NASDAQ drop (and thus are more likely to remain private) are substantially smaller than their pre-filing scaled citations (as reported in Table 3).

²⁹These results are reported in Table A.9, Panel D, of the Appendix.

4.B.1 Inventor Level Data

The patent database provides an interesting opportunity to track inventors' mobility across firms, as each patent application includes both the name of the inventor and its assignee (most often the inventor's employer). The analysis of inventor-level data is, however, complicated for several reasons. First, patents are associated with inventors based on their name and geographic location. Inventors' names are unreliable, as first names can be abbreviated and different inventors may have similar or even identical names. Second, attempting to detect inventor mobility using patents is necessarily inexact. While it is possible to infer that an inventor changed firms (e.g., patented for company A in 1987 and for company B in 1989), the precise date of the relocation is unavailable. Additionally, transitions in which inventors did not produce patents in the new location are not observable. Hence, this method identifies relocations of the more creative inventors who patent frequently and presumably matter the most.

To overcome the hurdle of name matching, I use the Harvard Business School patenting database, which includes unique inventor identifiers. The unique identifiers are based on refined disambiguation algorithms that separate similar inventors based on various characteristics (Lai, D'Amour, and Fleming, 2009). When patent applications include multiple inventors, I attribute a patent equally to each inventor. Overall, I have information on approximately 36,000 inventors in my sample. I restrict the analysis to inventors that produced at least a single patent both before and after the IPO filing and explore the patenting behavior of inventors in the three years before and five years after the IPO filing. I identify three inventor types:

1. Stayer – an inventor with at least a single patent before and after the IPO filing at the same sample firm.
2. Leaver – an inventor with at least a single patent at a sample firm before the IPO

filing, and at least a single patent in a different company after the IPO filing.³⁰

3. Newcomer – an inventor that has at least a single patent after the IPO filing at a sample firm, but no patents before, and has at least a single patent at a different firm before the IPO filing.

Out of the 36,000 inventors in my sample, I can classify 16,108 inventors by the above categories.³¹ These inventors account for approximately 65 percent of the patents in the sample.

4.B.2 Inventor Level Analysis

I explore changes in inventor level activity using the instrumental variables approach introduced in Section 3.A. I start by investigating changes in innovation quality of stayers. Then, I examine inventor mobility by studying inventors' likelihood to leave, spinout a company, or join the firm following the IPO filing.

The results are reported in Table 9, when the unit of observation is at the level of the inventor. In columns (1) I explore changes in stayers' productivity. I focus on the set of inventors that remained at the firm, and the dependent variable is the average scaled citations produced by inventors in the five years after the IPO filing. I control for the inventor's pre-IPO filing citations per patent, as well as filing year and industry fixed effects, and the other standard controls. Standard errors are clustered at the level of the firm, to allow for correlations between inventors in the same firm. I estimate the 2SLS-IV in column (1), and find that the IPO coefficient equals -1.094 and this effect is statistically significant at a 1 percent level. The magnitude is large, corresponding to a 48 percent decline in inventors' innovation novelty in IPO firms relative to the pre-IPO filing period.³² These findings suggest

³⁰I verify that all inventor relocations are not mistakenly associated with acquisitions and name changes.

³¹An inventor can be classified as both a stayer and a leaver. In these cases, I classify her as a leaver. The results do not change in a meaningful way if I classify her as a stayer instead.

³²Results are similar when using a Poisson specification, as reported in Table A.9 in the Appendix.

that the decline in IPO firms' innovative activity could at least partially be attributed to the change in quality of innovation produced by inventors who remained at the firm.

To estimate whether going public may affect inventors' departure, I focus on inventors that produced patents at the firm before the IPO filing, and explore their likelihood to leave. In column (2), I run a similar specification to the one reported in column (1) but now the dependent variable equals one if the inventor is classified as a leaver, and zero if an inventor is a stayer. The 2SLS-IV estimates illustrate that inventors in IPO firms are 18 percent more likely to leave the firm after the IPO, and the coefficient is statistically significant at 1 percent.³³ This result demonstrates that the decline in the quality of innovation of IPO firms is potentially driven also by the departure of inventors.

Does the increased inventor departure rate also translate into higher rate of spinouts? I follow Agrawal, Cockburn, Galasso and Oettl (2012). I identify all patents produced by leavers post-departure and the firms to which these patents were assigned. An assigned firm is considered a spin-out if the number of applied patents before the leaver's patent is zero.³⁴ This approach provides an approximation of whether a leaver started a new company. While not perfect, inaccuracies are similarly likely to affect leavers of IPO and withdrawn firms.

I repeat the specification of column (2), focusing on inventors that produced patents in a sample firm before the IPO filing, and explore their likelihood to create a spinout. The 2SLS-IV estimate reported in column (3) of Table 9 illustrates that IPO firms are 9.5% more likely to generate spinouts, compared to withdrawn firms, suggesting that IPO firms' leavers remain entrepreneurial following their departure. This result is also consistent with the finding that leavers of IPO firms generated higher quality pre-IPO patents relative to the

³³A natural concern regarding the validity of the instrument in this setup is that NASDAQ returns may also reflect changes in the labor market conditions and thus correlate with the likelihood that an inventor will leave the firm. However, since the empirical exercise compares firms that filed in the same year, it may be reasonable to assume that employees of firms that filed to go public in the same year will face similar labor market conditions in the five years following the IPO filing. In the Appendix, Table A.9, I show that results remain the same even if restricting the sample to stayers and *late* leavers. The time lag between the IPO filing event and the late relocations may reduce the likelihood that the two-month NASDAQ change is correlated with future labor market conditions.

³⁴In the Appendix, Table A.9, I verify that the results are similar if the number of pre-leaver patent is one, rather than zero.

stayers, in contrast to the case of withdrawn firms (reported in Table A.8 in the Appendix).

Finally, I explore whether IPO firms are more likely to attract new inventors. In column (4) I restrict the analysis to inventors that generated post-filing patents in a sample firm and as a dependent variable I use an indicator that an inventor is a newcomer. Using the 2SLS-IV specification I find that IPO firms are substantially more likely to hire new inventors. The magnitude of the coefficient is large, corresponding to a 38.8 percent increase.³⁵

The results reveal that the transition to public equity markets has important implications for the human capital accumulation process, as it shapes firms' ability to retain and attract inventors. Following the IPO, there is an exodus of inventors leaving the firm, and importantly, more spinouts are generated following their departure. Additionally, going public affects the productivity of the inventors who remained at the firm. The average quality of patents produced by stayers decline substantially at IPO firms. However, the effect is partially mitigated by the ability of IPO firms to attract new inventors who produce patents of higher quality than the inventors who remained at the firm.

4.C Acquisition of External Technologies

In this section, I explore how the transition to public equity markets affects firms' reliance on external technologies purchased through mergers and acquisitions.³⁶ I collect information on all acquisitions conducted by IPO and withdrawn firms using the SDC database.³⁷ In Table A.10 in the Appendix, I find that IPO firms exhibit a sharp increase in M&A activity in the five years following the IPO, while there is no meaningful effect for withdrawn firms.

Acquisitions, however, are used for a variety of reasons. The question remains whether acquisitions are used to buy external technologies. I collect information on patents generated by target firms in the years prior to the acquisition, by matching acquisition targets to the

³⁵The results remain the same when focusing on late newcomers, as reported in Table A.9 in the Appendix.

³⁶Firms may enhance their innovative activity through other external venues such as joint-ventures and strategic alliances (Seru 2014, Robinson 2008).

³⁷Approximately half of all deals reported on SDC are made by private acquirers (Netter, Stegemoller and Wintoki, 2011). Nevertheless, to further alleviate concerns about limited coverage of private acquirers, I search CapitalIQ and Lexis-Nexis for additional acquisitions made by sample firms.

NBER patents database.³⁸ Approximately 7,500 patents were acquired through mergers and acquisitions in the five years following the IPO filing, relative to approximately 30,000 patents produced. In Table A.10 in the Appendix, I show that before the IPO filing both withdrawn and IPO firms rarely acquire external patents through M&A. Following the IPO, however, the fraction of external patents in IPO firms' portfolio increases to 31 percent while it remains small for withdrawn firms (8 percent).

Similar patterns arise when using the instrumental variable approach. In Table 10, the dependent variable is the number of external patents bought through mergers and acquisitions in the five years following the IPO filing. All specifications follow the model described in Section 3.A, controlling for filing year and industry fixed effects. I also add all additional control variables previously mentioned. I estimate the 2SLS-IV in column (3), and find that IPO firms acquire 3.276 more patents per year compared to withdrawn firms.

The identifying assumption here is that changes in short term NASDAQ fluctuations are going to equally affect the likelihood to acquire external patents of two firms that attempt to go public in the *same* year. To further alleviate concerns about the exclusion restriction, I also control for the industry acquisition intensity in the five years following the IPO filing.³⁹ I add this control variable in column (4), and both coefficient and standard errors remains similar. In Table A.10 in the Appendix, I show that similar results can be illustrated also by simple averages comparison between firms that experienced a NASDAQ drop and other filers in the same year, similarly to the approach taken in Table 5 in the paper.

Given the increased reliance on external patents, it is interesting to compare the external and internal patents of IPO firms. In Table A.10 in the Appendix, I find that, on average, external patents exhibit higher quality than patents generated internally, measured by av-

³⁸A complication arises since approximately 30 percent of the acquisition targets are of firm subsidiaries. In these cases, it is difficult to identify whether assigned patents are generated by the parent firm or by the subsidiary. Therefore, I collect patent information on independent firms only. Given that almost all of the subsidiaries are acquired by IPO firms, the results underestimate the true contribution of acquisitions to the IPO firms' patent portfolio and provide only a lower bound.

³⁹Industry acquisition intensity is defined as the total volume of acquisitions within an industry normalized by the total market value of all firms in that industry

erage scaled citations.⁴⁰ Overall, the results suggest that going public leads to enhanced reliance on external technologies.

5. Potential Channels

The empirical findings thus far illustrate that the transition to public equity markets changes firm strategy when pursuing innovation. Following the IPO, firms experience a decline in innovation quality, substantial inventor turnover, and an increase in the acquisition of external innovation.

In this section, I discuss several potential explanations for the findings. Following the IPO, various characteristics of the firm change, therefore, multiple potential stories may arise. I focus on four such explanations. The corporate finance literature has long argued that public ownership entails agency problems between managers and shareholders due to the increased separation of ownership and control (Berle and Means 1932, Jensen and Meckling 1976). Therefore, the first two hypotheses are based on agency-problems that lead publicly traded firms to conduct too little innovation. Specifically, motivated by Aghion, Van Reenen, and Zingales (2013), I focus on managerial career concerns and the quiet life hypotheses. It may be the case, however, that agency problems are more pervasive in private firms, leading to too much innovation. I discuss this alternative story under the excessive innovation hypothesis.

Finally, I consider the case in which the results are not driven by an agency problem. One such explanation is that firms go public at the peak of their innovation, therefore, the quality of innovation declines due to mean reversion. However, such a story can be ruled out by the empirical design. I therefore consider an alternative story, under the agency-free hypothesis, motivated by the assumption that commercialization is capital-intensive, and

⁴⁰In Table A.11 in the Appendix, I explore the IPO effect on overall innovation quality, captured by both internal and external patents. The decline in innovation quality is still substantial and statistically significant. However, the magnitude of the decline is somewhat smaller, consistent with the finding that external patents are of higher quality, when compared to internal innovation.

thus feasible only following the IPO.

I discuss these hypotheses in detail below, and then provide some suggestive empirical evidence in an attempt to differentiate between these alternative stories.

5.A Hypotheses

5.A.1 Career Concerns Hypothesis

The first hypothesis is based on a variation of the career concerns story (Holmstrom 1982). Under this hypothesis, the principal-agent problem occurs between the shareholders and the manager. Specifically, the manager gains private benefits from retaining her job, and needs to choose whether to innovate or not. Innovation carries a risk for the CEO: As innovation is highly uncertain and may go wrong for purely stochastic reasons, shareholders may mistakenly attribute innovation failures to managerial skill, potentially costing the manager job. Therefore, the manager is concerned about the impact of innovation on investors perception of her ability, generating a natural aversion to innovation.

Increased monitoring may allow investors to distinguish between unlucky negative draws and managerial skill (Aghion, Van Reenen, and Zingales 2013). In private ownership, where ownership is concentrated, investors have a greater incentive to monitor the manager. Such increased monitoring insulates the manager from adverse reputational consequences of innovation, thus leading to more innovation. In public ownership, dispersed ownership leads to lower incentives to monitor and thus may dissuade the manager from innovating.⁴¹

An additional prediction of such a model is that an entrenched manager, whose job is more secured, may be willing to innovate relatively more after the IPO, as innovation does not expose the manager to as much risk of losing her job.

⁴¹This hypothesis is also consistent with Stein (1989) short-termism model.

5.A.2 Quiet Life Hypothesis

Another hypothesis that relies on an agency problem between the shareholders and the manager is when innovation is a difficult task (for example, may require deviating from standard routines), and managers bear a private cost when pursuing it. Therefore managers prefer to refrain from innovating, similarly to the “quiet life” hypothesis of Bertrand and Mullainathan (2003). As ownership is more concentrated in private companies, investors are more likely to carefully monitor the manager and ensure that the manager innovates by threatening that she may lose her job otherwise. Under public ownership, investors have weaker incentives to monitor, allowing the manager to innovate less. Moreover, a more entrenched manager will choose to innovate less following the IPO, as her job is more secured, in contrast to the career concerns hypothesis.

5.A.3 Excessive Innovation Hypothesis

Maybe private firms innovate too much? Consider the case in which entrepreneurs gain private benefits from innovation, as opposed to commercialization. Moreover, assume that the entrepreneur is the largest owner and has control over the firm, when the firm is private. In that case, the entrepreneur may choose to focus too much on innovation, not necessarily contributing to firm value. Hence, the principal-agent problem here arises between the entrepreneur, who is the largest shareholder, and minority shareholders.⁴² In publicly traded firms, the entrepreneur is no longer the largest shareholder, has less control, and therefore can no longer pursue excessive innovation.

5.A.4 Agency-Free Hypothesis

Under the last hypothesis, firms choose to go public at a stage in which they plan to commercialize existing innovation. This assumption alone cannot yet explain the results, as

⁴²In a sense, this hypothesis is similar to the case of family firms, who may pursue various objectives other than those that maximize shareholder value (Bennedsen, Pérez-González, and Wolfenzon 2010).

all firms in the sample are attempting to go public. However, if commercialization is capital intensive (more than innovation), then only firms that successfully completed the IPO can pursue such strategy. If the focus on commercialization leads firms to innovate less, this may explain the decline in innovation quality. In contrast, firms that remained private, do not have the resources to commercialize and thus continue to innovate. Importantly, for this hypothesis to hold, it is necessary to assume that some limited resource, such as managerial attention, prevents firms from pursuing commercialization and innovation strategies simultaneously, despite the improved access to capital following the IPO.

5.B Empirical Tests

This section provides some suggestive empirical evidence in an attempt to distinguish between the alternative hypotheses.

5.B.1 Excessive Innovation Hypothesis

The excessive innovation hypothesis posits that when the entrepreneur has control, private firms may conduct too much innovation that may not necessarily contribute to firm value. To explore this hypothesis, I compare firms that went public with a set of private firms in which the entrepreneur has no control. Specifically, I consider the case of private firms that are owned by venture capital firms and managed by a professional manager (that is, a non-founder manager). These private firms are likely to suffer the least from agency problems that lead to excessive innovation. I repeat the main instrumental variables analysis and explore the IPO effect relative to such private firms (as reported in table A.12 in the appendix). I find that even in this case, such private companies conduct significantly higher quality innovation in the years following the IPO, relative to firms that went public. Moreover, inventors in such private firms are significantly less likely to leave. While this evidence is suggestive, it hints that it may not be the case that private firms over-invest in innovation, as conjectured by the excessive innovation hypothesis, as companies that are likely to suffer

the least from agency problems produce higher quality innovation.

5.B.2 Agency-Free Hypothesis

Can the agency-free hypothesis explain the results? If improved access to capital allows firms to focus on commercialization and thus cause a decline in innovation quality, then such a decline should be less apparent in firms that already have significant resources at the time of the IPO, or raised little capital through the IPO. Such firms may be the largest firms that went public, the firms that had most cash (relative to assets) at the time of the IPO, and firms that raised the least capital through primary shares. Such a decline should be less apparent also in firms that face lower commercialization costs, such as firms in the software and services industries. I repeat the main instrumental variables approach, and explore the effect of IPO on each of the groups outlined above, as reported in table A.13 in the Appendix. In all cases I still find a significant decline in innovation quality. While this evidence is not conclusive, it suggests that the access to capital and the potential ability to pursue commercialization, does not seem to explain the decline in innovation quality.

In fact, in light of the evidence in the literature that innovation is economically important (e.g., Hall, Jaffe, and Trajtenberg 2005; Kogan et al. 2012), it may be surprising if firms choose not to pursue innovation after the IPO.⁴³ For example, Kogan et al. (2012) find that high quality innovation predicts firm productivity, and capital and labor flows from non-innovative to innovative firms within the industry. Indeed, when reading firm intentions at the time of the IPO, as disclosed in the “use of proceeds” paragraph in the prospectus, I find that 75% of the firms state they intend to use the proceeds from the IPO also for technological

⁴³One may be concerned that these results, discussed by the literature, do not apply to the particular life cycle stage of firms in the years after the IPO. However, in the Appendix I replicate these findings and find that innovation is economically important also in the years after the IPO. In tables A.14 and A.15 in the Appendix I find that innovation is correlated with long-run post-IPO buy-and-hold returns, and with risk-adjusted returns, when applying the Brav and Gompers (1997) methodology. Moreover, in table A.16 in the appendix, I use Kogan et al. (2012) measure of market reaction to patent approvals. I find that markets react strongly and favorably to patents produced by firms in the years following the IPO. Moreover, the economic importance of patents following the IPO (relative to firm market capitalization) is similar to the one described by Kogan et al. (2012) using all patents from 1926-2010. This is illustrated in table A.16, when comparing columns (4) and (5). I am grateful to the authors for sharing their data.

development and innovation.⁴⁴ When repeating the main instrumental variables strategy, but now restricting the sample only to firms that stated intention to innovate, I find results similar to the main findings, as reported in table A.18 in the Appendix.⁴⁵

5.B.3 Career Concerns and Quiet Life Hypotheses

In light of this evidence, I consider the alternative view in which publicly traded firms are prone to under-invest in innovation due to agency problems that arise between management and shareholders. Consistent with the main results, both the quiet life and career concerns hypotheses suggest that innovation will decline following the IPO. These hypotheses, however, yield different predictions when interacted with managerial entrenchment. Innovation may improve under the career concerns hypothesis but decline under the quiet life hypothesis. These contrasting effects of managerial entrenchment were previously discussed by Fisman et al. (2014).

I explored the interaction of going public with managerial entrenchment in an attempt to distinguish between these two hypotheses. As a proxy for managerial entrenchment I use cases in which the CEO is also the chairman of the board (Shleifer and Vishny 1989). I hand collect this information from IPO prospectuses, available through the SEC Edgar system from 1996. In Table A.19 in the Appendix, I repeat the main instrumental variables analysis to explore the effect of IPO on firm innovation separately for entrenched and non-entrenched CEOs. I find that firms with non-entrenched managers experience a significant decline in innovation quality following the IPO, and inventors are more likely to leave. In contrast, such an effect does not exist for firms with entrenched management. These results support the career concerns hypothesis.

⁴⁴I manually collect this information for all firms filed to go public from 1996 (the first year SEC Edgar system became available). Firms rarely provide the specific amounts planned to be used for each objective, but rather state broadly the planned uses of the proceeds.

⁴⁵I also find IPO firms triple R&D expenditure in the five years following the IPO. Also relative to firm size R&D expenditure increases. Moreover, the median R&D expenditure is three times larger than the median relative capital expenditure, and almost 10 times larger than the relative expenditure on advertisement (scaled by firm assets). The results are reported in table A.17 in the Appendix.

5.C Discussion

Overall, this section offers suggestive evidence that agency problems between management and shareholders, in the form of career concerns, lead publicly traded firms to pursue lower quality innovation. That said, it is important to interpret these findings with caution in light of the suggestive nature of the tests in this section.

These results are consistent with recent evidence that explores agency problems in public equity markets in various settings.⁴⁶ For example, Gao, Harford, and Li (2014) find that public firms are more likely to replace a CEO, relative to private firms, and such events are more sensitive to firm contemporaneous performance. Moreover, subsequent performance following CEO departure is more modest in public firms. Relatedly, Aghion, Van Reenen and Zingales (2013), find that institutional investors in public firms lead to more innovation, and the likelihood of CEO turnover following a revenue drop is lower. These papers are consistent with the career concerns hypothesis, which may lead managers to select more incremental, and less risky projects.

If the results are driven by agency problems, then why do firms go public? This question goes back to Jensen and Meckling (1976) and can be rephrased more broadly as there are many additional costs associated with the decision to go public. Underwriting direct expenses, underpricing, increased transparency, and short-term market pressures, are just a few examples. These costs are balanced by various motivations that lead firms to go public such as improved access to capital, providing liquidity and diversification to investors and insiders, enhancing firm reputation, among others (see for example discussions in Pagano, Panetta, and Zingales 1998; and Ritter and Welch 2002). An example of such benefits is illustrated in the paper by the increased ability of firms, following the IPO, to acquire external innovation, and attract new inventors. These are two important mitigating forces that alleviate the decline in internal innovation, and the departure of existing employees.

⁴⁶See for example Aghion, Van Reenen and Zingales (2013); Asker, Farre-Mensa, and Ljungqvist (2014); Fisman et al. (2013); and Gao, Harford, and Li (2014).

6. Conclusion

In this paper, I investigate an important yet understudied aspect of initial public offerings, namely, the effect on firm innovation. The findings in this paper reveal a complex trade-off between public and private ownership forms. Following the transition to public equity markets internal innovation becomes less novel, in comparison with firms that withdrew their IPO filing and remained private. In addition, firms experience an exodus of skilled inventors. However, due to an increased access to capital, IPO firms can rely on acquisitions of technologies as an additional source of generating innovation and also attract new human capital. These results suggest that going public changes the strategies that firms employ when pursuing innovation. I propose four potential explanations of these findings, and find suggestive evidence that supports managerial career concerns.

The results also draw attention to the effects of IPO on both the ability of firms to retain and attract human capital and on the productivity of the remaining inventors. Seru's (2014) study of the impact of mergers on innovation has found that mergers affect mostly the productivity of inventors remaining at the firm, rather than affecting their likelihood to leave. The difference in results suggests that productivity changes that coincide with various corporate events such as mergers and IPOs are nuanced, heterogeneous, and require better understanding.

Finally, corporate managers, bankers, and policy makers alike have expressed concerns that the recent dearth of IPOs marks a breakdown in the engine of innovation and growth (Weild and Kim, 2009). The recent passage of the Jumpstart Our Business Startups (JOBS) act aims to ease the process of younger, fast-growing companies to raise funds through the IPO market. This paper illustrates that, beyond raising capital, going public affects firms' internal project selection, human capital, and outsourcing strategies, therefore has important implications towards the optimal timing in which a firm should go public.

REFERENCES

- [1] Aggarwal, Vikas, and David Hsu. 2013. "Entrepreneurial Exits and Innovation." *Management Science*, 60(4), 867-887.
- [2] Aghion, Philippe, and Jean Tirole. 1994. "The management of innovation." *The Quarterly Journal of Economics* 109, 1185-1209.
- [3] Aghion, Philippe, John Van Reenen, and Luigi Zingales. 2013. "Innovation and institutional ownership." *American economic review*, 103 (1). 277-304.
- [4] Agrawal, Ajay K., Iain M. Cockburn, Alberto Galasso, and Alexander Oettl. 2012. "Why are some regions more innovative than others? The role of firm size diversity." NBER Working Paper.
- [5] Akcigit, Ufuk, and William R. Kerr. 2013. "Growth Through Heterogeneous Innovations." NBER Working Paper.
- [6] Anton, James J., and Dennis A. Yao. 2004. "Little patents and big secrets: Managing intellectual property." *RAND Journal of Economics* 1-22.
- [7] Arrow, Kenneth J. 1962. "Economic welfare and the allocation of resources for invention." *The Rate and Direction of Inventive Activity*, Princeton University Press and NBER.
- [8] Asker, John, Joan Farre-Mensa, and Alexander Ljungqvist. 2014. "Corporate Investment and Stock Market Listing: A Puzzle?" Unpublished working paper, New York University.
- [9] Bennedsen, M., Pérez-González, F., and Wolfenzon, D. 2010. "The governance of family firms." *Corporate governance: A synthesis of theory research and practice*. 371-389.
- [10] Benveniste, Lawrence M., Alexander Ljungqvist, William J. Wilhelm Jr, and Xiaoyun Yu. 2003. "Evidence of information spillovers in the production of investment banking services." *The Journal of Finance* 58 (2): 577-608.
- [11] Berle, Adolf A., and Gardiner C. Means. 1932. "The Modern Corporation and Private Property." New York, Macmillan.
- [12] Bertrand, Marianne, and Sendhil Mullainathan. 2003. "Enjoying the quiet life? Corporate governance and managerial preferences." *Journal of Political Economy* 111, 1043-1075.
- [13] Beshears, John. 2013. "The performance of corporate alliances: Evidence from oil and gas drilling in the gulf of mexico." *Journal of Financial Economics*, 110(2), 324-346.
- [14] Blundell, Richard W., and James L. Powell. 2004. "Endogeneity in semiparametric binary response models." *Review of Economic Studies* 71 (3): 655-679.

- [15] Bound, John, David A. Jaeger, and Regina M. Baker. 1995. "Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak." *Journal of the American statistical association*: 443-450.
- [16] Brau, James C., and Stanley E. Fawcett. 2006. "Initial public offerings: An analysis of theory and practice." *The Journal of Finance* 61 (1): 399-436.
- [17] Brav, Alon, and Paul A. Gompers, 1997. "Myth or reality? The longrun underperformance of initial public offerings: Evidence from venture and nonventure capitalbacked companies." *The Journal of Finance* 52, 1791-1821.
- [18] Brav, Omer. 2009. "Access to capital, capital structure, and the funding of the firm." *The Journal of Finance* 64 (1): 263-308.
- [19] Busaba, Walid Y. 2006. "Bookbuilding, the option to withdraw, and the timing of IPOs." *Journal of Corporate Finance* 12 (2): 159-186.
- [20] Busaba, Walid Y., Lawrence M. Benveniste, and Re-Jin Guo. 2001. "The option to withdraw IPOs during the premarket: empirical analysis." *Journal of Financial Economics* 60 (1): 73-102.
- [21] Carter, Richard B., Frederick H. Dark, and Ajai K. Singh. 1998. "Underwriter reputation, initial returns, and the long-run performance of IPO stocks." *The Journal of Finance* 53 (1): 285-311.
- [22] Carter, Richard B., and Steven Manaster. 1990. "Initial public offerings and underwriter reputation." *Journal of Finance*: 1045-1067.
- [23] Chemmanur, Thomas J., Shan He, and Debarshi K. Nandy. 2010. "The going-public decision and the product market." *Review of Financial Studies* 23 (5): 1855.
- [24] Degeorge, Francois, and Richard Zeckhauser. 1993. "The reverse LBO decision and firm performance: Theory and evidence." *Journal of Finance*: 1323-1348.
- [25] Dunbar, Craig G. 1998. "The Choice between Firm-Commitment and Best-Efforts Offering Methods in IPOs: The Effect of Unsuccessful Offers." *Journal of Financial Intermediation* 7 (1): 60-90.
- [26] Dunbar, Craig G., and Stephen R. Foerster. 2008. "Second time lucky? Withdrawn IPOs that return to the market." *Journal of Financial Economics* 87 (3): 610-635.
- [27] Edelen, Roger M., and Gregory B. Kadlec. 2005. "Issuer surplus and the partial adjustment of IPO prices to public information." *Journal of Financial Economics* 77 (2): 347-373.
- [28] Ferreira, Daniel, Gustavo Manso, and Andre C. Silva. 2010. "Incentives to innovate and the decision to go public or private." *Review of Financial Studies*, Forthcoming.

- [29] Fisman, Raymond J., Rakesh Khurana, Matthew Rhodes-Kropf, and Soojin Yim. 2013. "Governance and CEO turnover: Do something or do the right thing?" *Management Science* 60, 319-337.
- [30] Gao, Huasheng and Hsu, Po-Hsuan and Li, Kai. 2014. "Managerial Short-Termism and Corporate Innovation Strategies." Unpublished working paper, University of British Columbia.
- [31] Gao, Huasheng, Michael L. Lemmon, and Kai Li. 2013. "A comparison of CEO pay in public and private US firms." Unpublished working paper, University of British Columbia.
- [32] Griliches, Zvi. 1990. "Patent Statistics as Economic Indicators: A Survey." *Journal of Economic Literature* 28: 1661-1707.
- [33] Hall, Bronwyn H., Zvi Griliches, and Jerry A. Hausman. 1986. "Patents and R&D: Is there a lag?" *International Economic Review* 27 (2): 265-283.
- [34] Hall, Bronwyn H., Adam Jaffe, and Manuel Trajtenberg. 2001. "The NBER patent citation data file: Lessons, insights and methodological tools." NBER Working Paper 8498.
- [35] ———. 2005. "Market value and patent citations." *RAND Journal of Economics* 36 (1): 16-38.
- [36] Hall, Bronwyn H., and Josh Lerner. 2010. "The financing of R&D and innovation." In *Handbook of the Economics of Innovation*, ed. Bronwyn H. Hall and Nathan Rosenberg, 609-639. Elsevier-North Holland.
- [37] Hanley, Kathleen W. 1993. "The underpricing of initial public offerings and the partial adjustment phenomenon." *Journal of Financial Economics* 34 (2): 231-250.
- [38] Holmstrom, Bengt. 1982. "Managerial incentive problems - A dynamic perspective." in *Essays in Economics and Management in honor of Lars Wahlbeck*, Helsinki: Swedish School of Economics.
- [39] Ibbotson, Roger, and Jay R. Ritter, 1995, *Initial public offerings*, in Robert A. Jarrow, Vojislav Maksimovic, and William T. Ziemba, eds.: *Handbooks of Operations Research and Management Science* (Amsterdam: North-Holland)
- [40] Imbens, Guido W., and Joshua D. Angrist. 1994. "Identification and estimation of local average treatment effects." *Econometrica: Journal of the Econometric Society*: 467-475.
- [41] Jaffe, Adam B., and Manuel Trajtenberg. 2002. "Patents, citations, and innovations: A window on the knowledge economy." MIT Press Books.
- [42] Jain, Bharat A., and Omesh Kini. 1994. "The Post-Issue Operating Performance of IPO Firms." *The Journal of Finance* 49 (5): 1699 - 1726.

- [43] Jensen, Michael, and William H. Meckling. 1976. "Theory of the firm: Managerial behavior, agency costs and ownership structure." *Journal of Financial Economics* 3, 305-360.
- [44] Kogan, Leonid, Dimitris Papanikolaou, Amit Seru, and Noah Stoffman. 2012. "Technological innovation, resource allocation, and growth." National Bureau of Economic Research working paper.
- [45] Lach, Saul, and Mark Schankerman. 1989. "Dynamics of R & D and Investment in the Scientific Sector." *The Journal of Political Economy*: 880-904.
- [46] Lai, Ronald, Alexander D'Amour, and Lee Fleming. 2009. "The careers and co-authorship networks of US patent-holders, since 1975." Unpublished Working Paper, Harvard University.
- [47] Lanjouw, Jean O., Ariel Pakes, and Jonathan Putnam. 1998. "How to count patents and value intellectual property: The uses of patent renewal and application data." *The Journal of Industrial Economics* 46 (4): 405-432.
- [48] Lerner, Josh. 1994. "Venture capitalists and the decision to go public." *Journal of Financial Economics* 35 (3): 293-316.
- [49] Lerner, Josh, Morten Sorensen, and Per Strömberg. 2011. "Private Equity and Long-Run Investment: The Case of Innovation." *The Journal of Finance* 66 (2):445-477.
- [50] Loughran, Tim, and Jay R. Ritter. 2004. "Why has IPO underpricing increased over time." *Financial Management* 33 (3): 5-37.
- [51] Michaely, Roni, and Michael R. Roberts. 2012. "Corporate dividend policies: Lessons from private firms." *Review of Financial Studies* 25: 711-746.
- [52] Mikkelson, Wayne H., Megan M. Partch, and Kshitij Shaw. 1997. "Ownership and Operating Decisions of Companies that Go Public." *Journal of Financial Economics* 44 (3): 281-307.
- [53] Moser, Petra. 2007. "Why don't inventors patent?" National Bureau of Economic Research Working Paper.
- [54] Netter, Jeffry, Mike Stegemoller, and M. Babajide Wintoki. 2011. "Implications of data screens on merger and acquisition analysis: A large sample study of mergers and acquisitions from 1992 to 2009." *Review of Financial Studies* 24, 2316-2357.
- [55] Pagano, Marco, Fabio Panetta, and Luigi Zingales. 1996. "The stock market as a source of capital: Some lessons from initial public offerings in italy." *European Economic Review* 40, 1057-1069.
- [56] Pagano, Marc, Fabio Panetta, and Luigi Zingales. 1998. "Why do firms go public? An empirical analysis." *Journal of Finance* 53: 27-64.

- [57] Pástor, Lubos, Lucian Taylor, and Pietro Veronesi. 2009. “Entrepreneurial learning, the IPO decision, and the post-IPO drop in firm profitability.” *Review of Financial Studies* 22 (8): 3005.
- [58] Ritter, Jay R., and Ivo Welch. 2002. “A review of IPO activity, pricing, and allocations.” *The Journal of Finance* 57, 1795-1828.
- [59] Robinson, David. 2008. “Strategic alliances and the boundaries of the firm.” *Review of Financial Studies* 21, 649-681.
- [60] Saunders, Anthony, and Sascha Steffen. 2011. “The costs of being private: Evidence from the loan market.” *Review of Financial Studies*, 24(12), 4091-4122.
- [61] Seru, Amit. 2014. “Firm boundaries matter: Evidence from conglomerates and R&D activity.” *Journal of Financial Economics*, 111(2), 381-405.
- [62] Sheen, Albert. 2009. “Do public and private firms behave differently? An examination of investment in the chemical industry.” Unpublished working paper, UCLA.
- [63] Shleifer, Andrei, and Robert W. Vishny. 1989. “Management entrenchment:: The case of manager-specific investments.” *Journal of Financial Economics* 25 (1): 123–139.
- [64] Solow, Robert M. 1957. “Technical Change and the Aggregate Production Function.” *Review of Economics and Statistics* 39 (3): 312–320
- [65] Staiger, Douglas, and James H. Stock. 1997. “Instrumental Variables Regression with Weak Instruments.” *Econometrica* 65 (3): 557-586.
- [66] Stein, Jeremy C. 1989. “Efficient capital markets, inefficient firms: A model of myopic corporate behavior.” *The Quarterly Journal of Economics* 104 (4): 655–669.
- [67] Trajtenberg, Manuel, Rebecca Henderson, and Adam Jaffe. 1997. “University versus corporate patents: A window on the basicness of invention.” *Economics of Innovation and New Technology* 5 (1): 19–50.
- [68] Weild, David, and Edward Kim. 2009. “A wake-up call for America.” Grant Thornton: Capital Markets Series.
- [69] Welch, Ivo. 1992. “Sequential sales, learning, and cascades.” *Journal of Finance*: 695–732.

Table 1 - Summary Statistics

Table provides key summary statistics, comparing firms that went public with firms that withdrew IPO filing and remained private. All variables are defined in section II of the Appendix. Average innovative measures are calculated over the three years up to (and through) the IPO filing year. Financial information and IPO characteristics are at the time of the IPO filing. Firm exits such as acquisition, bankruptcy and second IPO, are calculated over the five years after the IPO filing. *, **, and *** indicate that differences in means are statistically significant at the 10%, 5%, and 1% levels.

	<u>Complete</u>			<u>Withdrawn</u>			Difference
	Mean	Median	S.D.	Mean	Median	S.D.	
Innovation Measures in the 3 years before IPO Filing							
Citations	12.69	7.25	21.60	10.91	6.00	16.83	1.78
Scaled Citations	1.89	1.41	1.73	1.80	1.31	1.94	0.09
Number of Patents	8.20	2.00	50.06	7.00	2.00	15.00	1.21
Scaled Number of Patents	2.96	0.85	11.16	2.72	0.93	5.07	0.24
Generality	0.45	0.47	0.21	0.46	0.50	0.22	-0.01
Originality	0.47	0.50	0.21	0.48	0.49	0.23	-0.01
Scaled Best patent	4.30	2.89	5.71	4.00	2.49	4.92	0.31
Financial Information at IPO filing (from 1996)							
Log Total Assets	3.07	2.91	0.05	2.97	2.93	0.11	-0.09
R&D / Assets	0.29	0.21	0.31	0.29	0.19	0.31	0.01
Net Income / Assets	-0.31	-0.11	0.48	-0.44	-0.21	0.47	0.13***
Cash / Assets	0.28	0.20	0.26	0.36	0.32	0.29	-0.08***
IPO Characteristics							
Lead Underwriter Ranking	8.16	9.00	1.27	8.17	9.00	1.33	-0.01
Firm age	11.94	8.00	10.98	11.14	7.00	10.38	0.80
VC-Backed	0.46	0.00	0.50	0.51	1.00	0.50	-0.05*
Post-filing NASDAQ returns	0.03	0.03	0.11	-0.06	-0.05	0.14	0.09***
Pre-filing NASDAQ returns	0.07	0.06	0.12	0.05	0.05	0.16	0.02***
Pioneer	0.02	0.00	0.14	0.03	0.00	0.17	-0.01
Early follower	0.05	0.00	0.22	0.07	0.00	0.26	-0.02
Firm exits in the five years after the IPO							
Bankruptcy	0.02	0.00	0.17	0.02	0.00	0.15	0.00
Acquisition	0.24	0.00	0.42	0.29	0.00	0.46	-0.05
Second IPO	-	-	-	0.18	0.00	0.36	-

Table 2 - First Stage

Table reports the first-stage estimation of the instrumental variables analysis. The dependent variable is a dummy variable that equals to one if a firm completed the IPO filing, and zero otherwise. *NASDAQ returns* variable is constructed differently across specifications. In *Two Months* specification (columns (1) to (4)), NASDAQ returns are the two-month returns after the IPO filing date. In columns (5) and (6), *All* specification indicates that NASDAQ returns are calculated over the entire book-building period, i.e., from the date of the initial registration statement to the completion or withdrawal dates. Finally, *Binary* in columns (7) and (8) uses a dummy variable and is equal to one if a firm did not experienced a NASDAQ drop. A firm is said to have experienced a NASDAQ drop if the two-month NASDAQ returns from the date of the IPO filing are within the bottom 25 percent of all filers in the same year. In columns (3) and (4) the sample is restricted to IPO filings before the year 2000. When control variables are included, the following variables are added to the specification: three-month NASDAQ returns prior to the IPO filing, number of patents in the three years before the IPO filing, VC-backed dummy, Pioneer and Early Follower variables. All variables are defined in section II of the Appendix. The estimated model is Ordinary Least Squares (OLS), and robust standard errors are calculated in parentheses. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample	Full	Full	Pre-2000	Pre-2000	Full	Full	Full	Full
Instrument	Two Months	Two Months	Two Months	Two Months	All	All	Binary	Binary
NASDAQ returns	0.704*** (0.102)	0.763*** (0.106)	0.690*** (0.128)	0.723*** (0.132)	0.381*** (0.080)	0.400*** (0.081)	0.106*** (0.022)	0.111*** (0.022)
Observations	1,801	1,801	1,458	1,458	1,801	1,801	1,801	1,801
R-squared	0.138	0.149	0.082	0.089	0.127	0.136	0.124	0.134
Filing year FE	yes							
Industry FE	yes							
Control variables	no	yes	no	yes	no	yes	no	yes
F-stat	47.79	52.03	28.9	29.9	22.63	24.13	24.16	25.99

Table 3 - NASDAQ Drops and Firm Characteristics

Table presents differences in firm characteristics and innovative performance between IPO filers that experienced a NASDAQ drop and other filers in the same year. A firm is said to experience a NASDAQ drop if the two month NASDAQ returns it experienced following the IPO-filing is at the bottom of the distribution of all IPO filers in the same year. In column (1), *Bottom 10%* defines all firms that experienced the lowest 10% NASDAQ returns of all IPO filers within a year, and *Top 90%* in column (2) captures the remaining firms. In column (4), *Bottom 25%* defines all firms that experienced the lowest 25% NASDAQ returns within a year, and *Top 75%* captures all remaining firms. All variables are defined in section II of the Appendix. *, **, and *** indicate that differences in means are statistically significant at the 10%, 5%, and 1% levels.

	(1)	(2)	(3)	(4)	(5)	(6)
NASDAQ Returns Threshold:	Bottom	Top	Difference	Bottom	Top	Difference
	10%	90%		25%	75%	
Pre-Filing Financials Information						
Total Assets	3.16	3.06	0.104	3.13	3.05	0.077
R&D / Assets	0.26	0.26	0.007	0.26	0.26	-0.002
Net Income / Assets	-0.32	-0.33	0.008	-0.34	-0.33	-0.014
Cash / Assets	0.32	0.28	0.036	0.30	0.29	0.013
Sales / Assets	0.86	0.89	-0.024	0.85	0.90	-0.051
IPO Characteristics						
Lead Underwriter Ranking	8.22	8.09	0.124	8.19	8.08	0.110
Firm age at filing	11.87	11.81	0.068	11.10	12.05	-0.946
VC backed	0.46	0.49	-0.029	0.49	0.50	-0.011
Pre-Filing Patents Characteristics:						
Citations	13.38	12.48	0.905	12.63	12.57	0.064
Scaled Citations	1.81	1.87	-0.070	1.92	1.85	0.072
Number of Patents	8.53	7.92	0.603	6.97	8.32	-1.354
Scaled Number of Patents	3.21	2.88	0.330	2.67	2.99	-0.326
Scaled Generality	1.11	1.12	-0.020	1.14	1.12	0.023
Scaled Originality	1.03	1.07	-0.039	1.06	1.07	-0.017
Scaled Best Patent	4.06	4.26	-0.197	4.45	4.17	0.277

Table 4 - Placebo Test

Table reports a placebo test to assess validity of instrumental variable exclusion restriction condition. The dependent variable is the average scaled citations in the five years after the IPO filing. *Returns following IPO-filing* are the two-month NASDAQ returns calculated from the IPO filing date. *Returns following IPO outcome* are the two-month NASDAQ returns calculated from either the date of the equity issuance or the date of the IPO filing withdrawal. When the date of IPO filing withdrawal is not available, 270 days subsequent to the last amendment of the IPO filing is assumed (Lerner 1994). *Returns in year before IPO-filing* are the two-month NASDAQ returns calculated from a year before the IPO filing. *Returns in year after IPO-filing* are the two-month NASDAQ returns calculated from a year after the IPO filing. The variables included in the regressions are pre-filing average scaled citations, pre-filing number of patents, Pioneer, Early follower, VC-backed variable, and the three-month NASDAQ returns before the IPO filing. All variables are defined in section II of the Appendix. The estimated model is Ordinary Least Squares (OLS), and robust Standard errors are reported in parentheses. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable	Scaled Citations	Scaled Citations	Scaled Citations	Scaled Citations	Scaled Citations	Scaled Citations	Scaled Citations
Returns following IPO-filing	-0.498** (0.239)				-0.482** (0.237)	-0.495** (0.237)	-0.509** (0.241)
Returns following IPO outcome		0.207 (0.251)			0.162 (0.248)		
Returns in year before IPO-filing			0.201 (0.254)			0.193 (0.252)	
Returns in year after IPO-filing				0.006 (0.096)			0.037 (0.094)
Observations	1079	1079	1079	1079	1079	1079	1079
R-squared	0.242	0.240	0.239	0.239	0.242	0.242	0.242
Filing year FE	yes	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes	yes
Control variables	yes	yes	yes	yes	yes	yes	yes

Table 5 - Reduced Form

Table reports differences in the five-year innovative performance following the IPO filing between filers that experienced a NASDAQ drop and other filers in the same year. A firm is said to have experienced a NASDAQ drop if the two-month NASDAQ returns after the IPO filing are within the bottom 25 percent of all filers in the same year. *IPO* is a dummy variable that is equal to one if a firm completed its IPO filing, and zero otherwise. All variables are defined in section II of the Appendix. *, **, and *** indicate that the difference in means is statistically significant at the 10%, 5%, and 1% levels.

	<u>NASDAQ Drop</u>			<u>No NASDAQ Drop</u>			Difference
	Mean	Median	S.D.	Mean	Median	S.D.	
IPO	0.74	1.00	0.44	0.85	1.00	0.36	-0.111***
Scaled Citations	1.12	0.88	1.21	0.99	0.81	0.86	0.134**
Scaled Number of Patents	5.56	1.91	12.42	5.91	1.49	16.64	-0.351
Scaled Generality	1.10	1.10	0.67	1.10	1.09	0.67	-0.005
Scaled Originality	1.09	1.09	0.39	1.04	1.06	0.43	0.047*
Scaled Best Patent	3.61	2.10	4.66	2.89	1.94	3.13	0.721***

Table 6 - Innovation Novelty

Table reports the effect of an IPO on innovation novelty. The dependent variable is the average scaled citations in the five years after the IPO filing. *IPO* is a dummy variable equals to one if a firm completed the IPO filing, and zero otherwise. *NASDAQ returns* variable is the two-month NASDAQ returns calculated from the IPO filing date. Control variables included in the regressions are: pre-filing average scaled citations, pre-filing average scaled number of patents per year, Pioneer, Early follower, VC-backed dummy, and the three-month NASDAQ returns before the IPO filing. All variables are defined in section II of the Appendix. In columns (1) and (2) the estimated model is Ordinary Least Squares (OLS), and Two-stage Least Squares (2SLS) in column (3). Column (4) estimates the instrumental variables approach using a quasi maximum likelihood Poisson model. In all specifications, marginal effects are reported. *Magnitude* is the ratio of the *IPO* coefficient to the pre-filing average of scaled citations. Robust Standard errors are reported in parentheses. The standard errors in column (4) are corrected using the delta method. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	Scaled Citations	Scaled Citations	Scaled Citations	Scaled Citations
Model	OLS	OLS	2SLS-IV	Poisson-IV
IPO	-0.019 (0.069)		-0.831** (0.409)	-0.980** (0.427)
NASDAQ returns		-0.498** (0.239)		
Magnitude	-1.02%	-	-43.51%	-52.41%
Observations	1,079	1,079	1,079	1,079
R-squared	0.239	0.242	0.128	0.148
Filing year FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Control variables	yes	yes	yes	yes

Table 7 - Fundamental Nature of Research

Table reports the effect of an IPO on the fundamental nature of research. In columns (1) to (3) the dependent variable is the average Scaled Originality in the five years after the IPO filing, and in columns (4) to (6) it is average Scaled Generality. *IPO* is a dummy variable equals to one if a firm completed the IPO filing, and zero otherwise. *NASDAQ returns* variable is the two-month NASDAQ returns calculated from the IPO filing date. In columns (1) to (3) I control for the pre-filing average scaled originality, and in columns (4) to (6) I control for the corresponding generality measure. Additional control variables are: pre-filing average scaled citations, pre-filing average scaled patents per year, Pioneer, Early follower, VC-backed variable, and the three-month NASDAQ returns before the IPO filing. All variables are defined in section II of the Appendix. The estimated model is OLS, and two-stage least squares in columns (3) and (6). *Magnitude* is the ratio of *IPO* coefficient to the pre-filing average of scaled originality or scaled generality per patent. Robust Standard errors are reported in parentheses. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Scaled Originality	Scaled Originality	Scaled Originality	Scaled Generality	Scaled Generality	Scaled Generality
Model	OLS	OLS	2SLS - IV	OLS	OLS	2SLS - IV
IPO	-0.006 (0.010)		-0.137** (0.068)	-0.001 (0.016)		-0.087 (0.092)
NASDAQ returns		-0.081** (0.036)			-0.050 (0.051)	
Magnitude	-0.10%	-	-13%	0%	-	-8%
Observations	1,079	1,079	1,079	1,079	1,079	1,079
R-squared	0.231	0.234	0.102	0.226	0.226	0.206
Filing year FE	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes
Control variables	yes	yes	yes	yes	yes	yes

Table 8 - Innovation Scale

Table reports the effect of an IPO on innovation scale. The dependent variable is the average scaled number of patents per year in the five years after the IPO filing. *IPO* is a dummy variable equals to one if a firm completed the IPO filing, and zero otherwise. *NASDAQ returns* variable is the two-month NASDAQ returns calculated from the IPO filing date. Control variables included in regressions are: pre-filing average scaled citations, pre-filing average scaled number of patents per year, Pioneer, Early follower, VC-backed variable, and the three-month NASDAQ returns before the IPO filing. All variables are defined in section II of the Appendix. The estimated model is OLS in columns (1) and (2), and two-stage least squares in column (3). Columns (4) estimate the specification using a quasi maximum likelihood Poisson model. In all specifications, marginal effects are reported. *Magnitude* is equal to the ratio of the *IPO* coefficient, divided by the pre-filing scaled number of patents per year. Robust Standard errors are reported in parentheses. In columns (4) standard errors are corrected using the delta method. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	Scaled Patents	Scaled Patents	Scaled Patents	Scaled Patents
Model	OLS	OLS	2SLS - IV	Poisson IV
IPO	0.268*** (0.066)		0.200 (0.474)	0.002 (0.662)
NASDAQ returns		0.127 (0.305)		
Magnitude	37.75%		28.17%	0.28%
Observations	1,801	1,801	1,801	1,801
R-squared	0.184	0.178	0.184	0.168
Filing year FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Control Variables	yes	yes	yes	yes

Table 9 - Inventor Mobility and Innovative Productivity

Table reports the effects of an IPO on inventors' mobility and innovative activity. Inventors are classified into three categories: stayers, leavers and newcomers, as defined in the text. In column (1) the sample is restricted to stayers and the dependent variable is the average scaled citations after the IPO filing. In columns (2) and (3), the sample includes stayers and leavers, and the dependent variable equals to one if inventor left the firm or generated a spinout respectively. In column (4) the sample includes stayers and newcomers, and the dependent variable equals to one if the inventor joined the firm. *IPO* is a dummy variable equals to one if a firm completed the IPO filing, and zero otherwise. The instrument is the two-month NASDAQ returns calculated from the IPO filing date. In all specifications I control for the inventor's pre-IPO filing average scaled citations and scaled number of patents. Additional control variables are: Pioneer, Early follower, VC-backed variable, and the three-month NASDAQ return before the IPO filing. All variables are defined in section II of the Appendix. All models are estimated using two-stage least squares. *Magnitude* is equal to the *IPO* coefficient, divided by the pre-filing average scaled citations. Robust Standard errors are reported in parentheses. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	Citations of stayers	Likelihood to leave	Likelihood of Spinout	Likelihood to hire
Model	2SLS - IV	2SLS - IV	2SLS - IV	2SLS - IV
IPO	-1.094** (0.457)	0.183*** (0.062)	0.095** (0.048)	0.388*** (0.078)
Magnitude	-47.94%	-	-	-
Observations	6657	8773	8773	11678
R-squared	0.203	0.017	0.03	0.058
Filing year FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Control Variables	yes	yes	yes	yes

Table 10 - Acquisition of External Technologies

Table reports the effects of an IPO on number of external patents acquired through mergers and acquisitions. The dependent variable is the average number of external patents acquired per year in the five years after the IPO filing. *IPO* is a dummy variable equals to one if a firm completed the IPO filing, and zero otherwise. *NASDAQ returns* variable is the two-month NASDAQ returns calculated from the IPO filing date. Control variables included in regressions are: pre-filing average scaled citations, pre-filing average scaled number of patents per year, Pioneer, Early follower, VC-backed variable, and the three-month NASDAQ returns before the IPO filing. All variables are defined in section II of the Appendix. The estimated model is OLS in columns (1) and (2), and two-stage least squares in column (3) and (4). Column (4) controls also for industry acquisition intensity, defined as the total volume of acquisitions within an industry normalized by the total market value of all firms in that industry. Robust Standard errors are reported in parentheses. *, **, and *** indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	External Patents	External Patents	External Patents	External Patents
Model	OLS	OLS	2SLS-IV	2SLS-IV
IPO	0.630*** (0.154)		2.603** (1.277)	2.489* (1.288)
NASDAQ returns		1.636** (0.785)		
Observations	1,801	1,801	1,801	1,801
R-squared	0.366	0.365	0.347	0.350
Filing year FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Control variables	yes	yes	yes	yes
Acquisition Propensity	no	no	no	yes

Figure 1 - Quality of Innovation around the IPO Event

The figure presents changes in patent quality, measured by scaled citations, in the years around the IPO. The chart estimates and confidence intervals are taken from the following specification:

$$Y_{it} = \beta_0 + \sum_{\substack{k=-3 \\ k \neq 0}}^{k=5} \gamma_k \text{EventYear}_{i,k} + \tau_i + \mu_t + \varepsilon_{i,t}$$

The unit of observation is at the patent level and the dependent variable is scaled citations. $\text{EventYear}_{i,k}$ is a dummy variable indicating the relative year around the IPO in which a patent application was submitted (year zero is the year of the IPO and the omitted category). The specification is estimated using OLS and includes firm fixed effects (τ_i) and year fixed effects (μ_t). Standard errors are clustered at the firm level. The estimates are reported in the second column of Table A.2 in the Appendix.

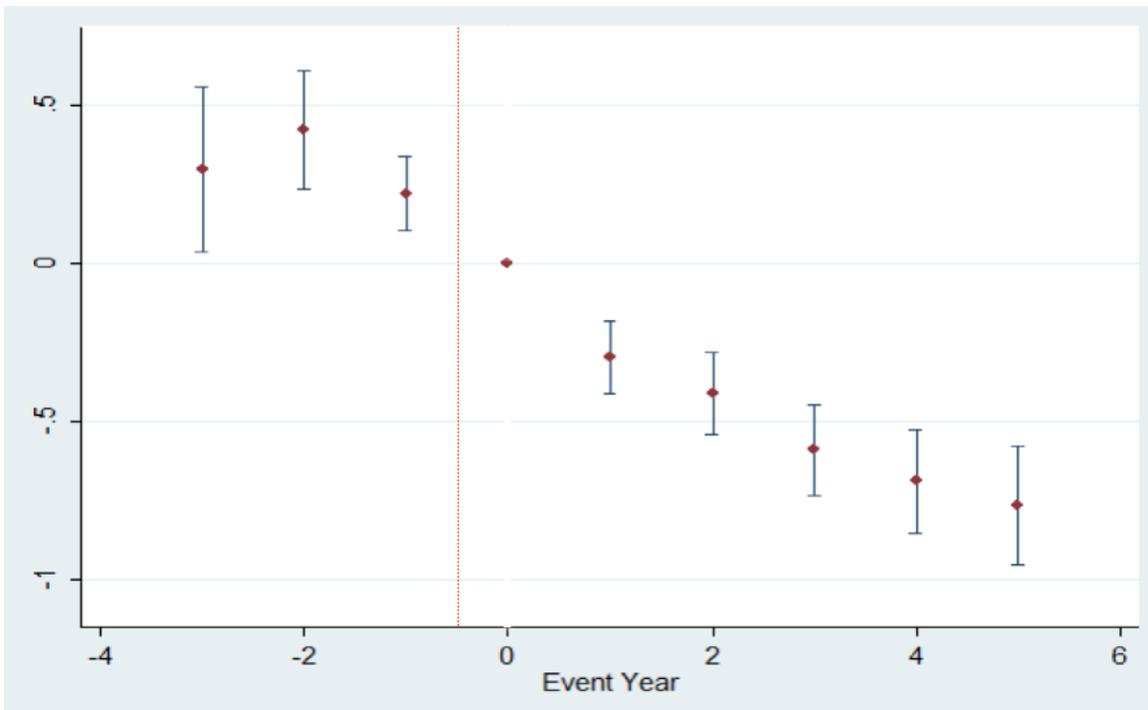


Figure 2 - NASDAQ Fluctuations and IPO Withdrawals

The figure illustrates the sensitivity of IPO filings to NASDAQ fluctuations. The sample includes all IPO filings from 1985 through 2003 in the United States, after excluding unit investment trusts, Closed-end funds, REITs, Limited partnerships, and financial companies. Overall there are 8563 IPO filings, with 6958 complete registrations and 1605 withdrawn registrations. The dashed line is the fraction of monthly filings that ultimately withdrew their registration. The solid line is the two-month NASDAQ returns calculated from the middle of each month. The correlation of the two plots is -0.44, and -0.34 before 2000. Both correlations are significantly different from zero at 0.01% level.

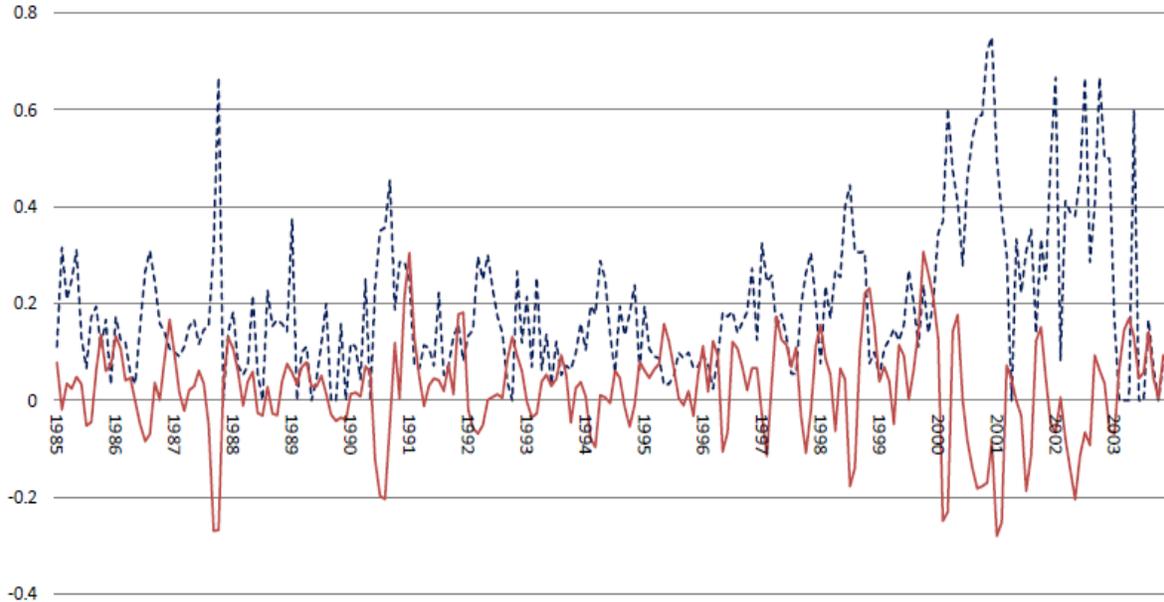


Figure 3 - Two-month NASDAQ fluctuations and IPO completion likelihood

The figure presents the non-parametric association of the two-month post-IPO filing NASDAQ returns and the likelihood to complete the IPO filing of firms in the sample.

