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IPO INTERVENTION AND INNOVATION:
EVIDENCE FROM CHINA

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ABSTRACT

This paper asks whether restricting timely access to public equity markets affects innovation among firms that intend to go public. The Chinese government has suspended IPOs occasionally, exposing firms to indeterminate listing delays, which curtails timely access to equity capital and increases uncertainty. We find that suspension-induced delay substantially reduces innovation, measured using patenting activity. These effects begin during the delay period and endure for multiple years, while impacts on other firm outcomes are short-lived. Our results suggest that corporate innovation is cumulative, and that predictable, well-functioning IPO markets are important for firm value creation through innovation.

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1 Introduction

Innovation has large social benefits, but information and agency frictions create financing challenges (Aghion & Tirole 1994). This is especially true in emerging economies with less developed financial markets such as China (Cong, Lee, Qu & Shen 2018). Existing work examines the link between public markets and firm innovation: Consistent with Ferreira, Manso & Silva (2012), Bernstein (2015) finds that innovation quality declines after a firm goes public, while Atanassov, Nanda & Seru (2007) and Acharya & Xu (2017) find that public equity enables more innovation in the U.S. This paper explores a new dimension in arguably the most important emerging economy — how curbing timely and definite access to public equity in China affects firm outcomes, especially innovation.

Using a novel identification strategy, we show that indefinite IPO suspensions in China induce unexpected listing delays, which reduce innovation. The effect endures after listing, which should not occur in the absence of frictions. We argue that IPO suspension-induced delay leads to temporary capital constraints and heightened uncertainty, which are known to impede corporate investment (Froot, Scharfstein & Stein 1993, Dixit & Pindyck 1994, Almeida & Campello 2007). By generating financial constraints and uncertainty, IPO suspension-induced delay disrupts the corporate innovation process and because innovation is cumulative, the effects are persistent.

Specifically, we examine the effect of IPO delay among firms that ultimately go public on Chinese exchanges. Two facets of the IPO system in China enable causal identification. First, firms in China have little ability to time the IPO market. In China's approval-based public listing system, IPO approval takes two to three years in normal, non-suspension times. Once approved, firms take several months to complete final steps. Second, regulators have on multiple occasions suspended all IPO activity, stranding a group of approved firms. While related to the state of the market, the suspensions were not scheduled and were widely viewed as unexpected. Affected firms face a longer time between approval and listing as well as greater uncertainty about when they will list.

We use a sample of firms approved to IPO on the Shanghai or Shenzhen exchanges in the twelve months before a suspension announcement, for two suspensions from September 2008 to July 2009 and from October 2012 to January 2014. Some of the firms experience sharply greater listing delays because of their approval date (see Figure 1). Those approved early in the year are ahead in a queue and list with little delay, while the remainder must wait until the suspension ends. This suspension-induced delay is plausibly exogenous to firm-specific factors, so the suspensions offer quasi-experimental variation in timely access to public capital. Firms in the control and treatment groups are similar before approval and we verify that the order of listing closely follows the order of IPO approval.

We estimate the effect of delay in regressions that control for the listing date and firm variables such as state ownership, size, age, and industry. Our primary measure of innovation effort is the number of patent applications to China's State Intellectual Property Office (Chinese patent applications), but we also use granted Chinese patents, citations to Chinese patents, and granted global (non-Chinese) patents.[1] Treated firms, which average 16 months of delay, have 28 percent fewer Chinese patent applications than control firms, which average three months of delay. The effect persists over time. For example, four years after the approval year, the treated group has 16 percent fewer patent applications. Suspension-induced delay treatment also reduces patent quality; in the year after IPO approval, there are large significant declines in granted Chinese patents, citations to Chinese patents, and granted global (non-Chinese) patents. Meanwhile, suspension-induced delay leads to higher leverage, lower return on sales, and lower investment in tangible assets in the year following IPO approval. However, none of these effects persist after delayed firms eventually list.

Our analysis does not assume that the suspensions are unrelated to aggregate economic conditions. Instead, we show that cross-sectionally, delayed firms are more affected. For example, one specification considers the first and second years after IPO among delayed

[1] Previous work on Chinese firm innovation has primarily relied on patent counts. We are among the first to gather comprehensive data on citations for Chinese patents from global patent offices, and to our knowledge, the first that include citations to SIPO patents beyond WIPO family patents.

firms and aligns control firms so that they are considered in the same calendar time as the treatment firms. We further show that our main results are robust to instrumenting for delay with the approval date and disappear in sensible placebo tests.

We propose two potential non-mutually exclusive channels for our findings: capital constraints and uncertainty.[2] In the year following IPO approval, when delayed firms are still private but their non-delayed counterparts have listed, the effects on leverage, tangible investment and innovation are consistent with a shock to access to capital. This negative effect of financial constraints during delay on innovation complements the findings in Brown, Fazzari & Petersen (2009) and Acharya & Xu (2017). The capital constraint channel implies that in China, IPO markets are important for capital provision.

Taken alone, this capital supply mechanism implies that alternative forms of financing such as risky debt or private equity (PE) are too costly or unavailable during delay. In this case, firms with better access to debt and PE should be less affected by delay. Yet state-owned enterprises – which have advantaged access to credit – are not less affected than private firms. Firms with prior PE financing are more affected, and delayed firms are not more or less likely to receive PE. These heterogeneity results may have a variety of explanations, but they suggest that forces beyond pure financial constraints are also at play.

The second channel is uncertainty. The indefinitely long IPO suspensions create uncertainty among delayed firms about when they would be able to go public. The real options literature predicts that uncertainty yields the negative effects that we observe during the delay period on tangible and innovation investment, which are typically irreversible (Dixit & Pindyck 1994). Consistent with the suspensions creating general uncertainty about the ability of firms to access public markets and early private investors to achieve liquidity, we demonstrate that the suspensions were associated with lower VC investment in China, even among elite U.S. VC firms active in China.

[2] Window dressing is a well-known part of the IPO process. However, we show in Section 5.3.3 that window dressing before IPO is inconsistent with our evidence of depressed innovation activity both during the delay period and after IPO.

To our knowledge, this paper is the first to explore how regulatory uncertainty interacts with capital constraints to affect corporate innovation. Uncertainty is also central to how our setting differs from the literature comparing public and private firms using U.S. data, including Bernstein (2015). There, treatment coincides with the firm adjusting its investment and development strategies based on whether it will go public or remain private. In our setting, the firm does not switch gears and pursue a private firm strategy; all the firms in our sample ultimately go public. Instead, the delayed firm is uncertain about when it will be able to pursue its intended public firm strategy.

Our setting thus offers an example of government policy uncertainty negatively affecting firm outcomes, as in Baker, Bloom & Davis (2016). Our work adds an empirical corporate finance perspective to studies such as Bond & Goldstein (2015) on how policy uncertainty affects financial markets. Brunnermeier, Sockin & Xiong (2017) point out that an interventionist approach can create uncertainty for firms, which affects corporate decisions. The fact that temporary disruption has lasting effects on patenting also suggests that innovation investment is cumulative; for future investments to be NPV positive, the firm must build or maintain its R&D infrastructure today.

Beyond the work mentioned above, this paper contributes to several strands of literature. One is the relationship between going public and firm behavior. In addition to innovation, researchers have addressed investment (Pagano, Panetta & Zingales 1998, Asker, Farre-Mensa & Ljungqvist 2014, Gilje & Taillard 2016), the private benefits of control (Doidge et al. 2009), profitability (Pástor, Taylor & Veronesi 2009), and product markets (Chemmanur, He & Nandy 2009). A second strand studies the effects of government interventions in financial markets (e.g., Gertler & Karadi 2013, Cong, Grenadier & Hu 2017). A striking feature of China's financial system is active government intervention to promote financial stability, with frequent use of a wide array of policy tools, including interest rates, bank reserve requirements, stamp taxes on equity trading, and IPO suspensions and quotas. While government intervention in IPO markets is common in developing economies, relatively little is known about the effects of these interventions.[3] Third, beyond one-off interventions, this paper contributes to research on China's IPO process, which includes Tian (2011), Allen, Qian, Shan & Zhu (2015), Lee, Qu & Shen (2017), and Shi, Sun & Zhang (2018).

More broadly, our results support the importance of market-based mechanisms for Chinese firms' productivity growth, which Aghion et al. (2015) and Fang, Lerner & Wu (2017) also emphasize. We cannot speak to the welfare effects of the IPO suspensions, but our results suggest that promoting innovation may be one reason for Chinese regulators to prioritize predictable, well-functioning IPO markets.[4] While some policies explicitly aim to encourage innovation (e.g., Lerner 2009 and Howell 2017), many others may have unintended consequences for innovation. It is worthwhile to understand how Chinese market interventions affect domestic innovation for at least three reasons: corporate innovation is central to China's ongoing effort to transition from export- and infrastructure-led growth to an economy centered around high-tech industries and consumption; the Chinese government plays an especially active role in domestic financial markets; and finally, China's economy is inherently important.[5]

The remainder of the paper proceeds as follows. Section 2 provides institutional background, and Section 3 describes the data. Section 4 introduces the empirical strategies. The findings are in Section 5. Section 6 discusses potential channels. Section 7 concludes.

2 Institutional Background

In this section, we briefly describe China's public equity markets and the IPO process. Then we explain the IPO suspensions we use to identify the effect of listing delay.

[3]For discussions on IPO interventions, see here (general description), here (India), here (Mexico) , and Prasad, Vozikis & Ariff (2006) on Malaysia.

[4] There is no convincing evidence that suspensions stabilized the market, one of the supposed objectives (Packer et al. 2016 and Shi, Sun & Zhang 2018).

[5]Innovation is prominently listed as the first guiding principle of economic policy in the 13th Five-Year Plan for 2016 to 2020. See here.

2.1 The IPO Process in China

China's banking sector, traditionally the main source of capital for Chinese firms, is slowly giving way to public and private equity finance (Allen et al. 2015). In the decade after China established the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZSE) in 1990, domestic public markets primarily served state-owned enterprises (SOEs). A large literature has studied SOE performance and the political economy surrounding the new stock markets (e.g. Fan et al. 2007; see Carpenter, Lu & Whitelaw 2016 for a review).

China's public markets have recently grown dramatically, and now serve private enterprises as well as SOEs. The Chinese A share market is the second largest in the world, with about 3,000 firms listed and a total market capitalization of more than 8.2 trillion USD at the end of 2017. Domestic listings are primarily on a "main board" (SSE and SZSE) or on newer, smaller boards targeting younger firms (e.g. ChiNext or NEEQ), which have less stringent listing criteria but are too illiquid and often OTC-based to be viewed as an effective financing source for startups. As IPOs recede in importance in the U.S., they are growing in importance in China. In 2017, there were 215 IPOs on the Shanghai Stock Exchange, and 223 on the Shenzhen exchange, compared to a total of 108 in the U.S.[6]

A firm seeking to conduct its IPO in China's domestic markets must navigate an elaborate approval process administered by the China Securities Regulatory Commission (CSRC). This administrative approval-based system contrasts with the disclosure-centric, registration-based system used in the U.S. There are four central steps. First, the firm hires financial professionals such as investment bankers and accountants for "tutorship", restructuring the firm into a qualified stock share limited company and preparing the financial and compliance documents. This "restructuring period" often takes about three months but the preparation lasts $1-3$ years.[7]

Second, the firm and underwriter submit an application package to the CSRC. Firms applying for IPO form a queue based on the order of application. According to the WIND

[6] Also see here. Only 128 companies IPOed in U.S. markets in 2016 (see here).

[7] See Cao et al. (2016) and here. The official document outlining the IPO process is available in Chinese at here.

commercial database, in late 2016 there were 726 firms in the queue. The CSRC has published this list weekly since February 2012, so it is now public how many candidates are waiting for IPO approval, as well as how many have been approved recently.[8] As it takes multiple years for an application to be approved, firms cannot time their listing as they do in the U.S. and tend to apply as soon as they meet the requirements. The Stock Issuance Examination and Verification Committee (the "committee") of the CSRC then determines whether the applicant meets the regulator's listing criteria and is eligible to undertake an IPO. The CSRC's listing criteria seek to ensure that only healthy firms gain access to China's public equity markets. Applicant companies must meet stringent historical financial performance criteria to be eligible for an IPO.[9]

Third, the committee reviews the application documents and decides whether to approve the IPO.[10] Committees usually have tenures of one year, and today consist of 25 members. In 2004, the committee composition changed from primarily government officials to primarily private sector professionals (e.g. auditors, lawyers, bankers, and mutual fund managers).[11] The criteria the CSRC uses to select candidates are not public. Panels consisting of seven members are formed to oversee each IPO application, and approval requires five or more affirmative votes. This stage takes three to six months on average but is highly variable. The committee could meet multiple times and require the applicants to address numerous issues before granting the final approval document.

The committee typically rejects about 20 percent of IPO applications (Yang 2013). In

[8]The CSRC discloses the queue for application: here.

[9]Regulating IPOs is one of the major ways that the Chinese government has historically sought to protect investors. All applicants must meet the following requirements: (1) Positive net profits for the last three fiscal years prior to the application, and the cumulative net profit in the three years must exceed RMB 30 million; (2) Cumulative revenue in the three years prior to the IPO must equal at least RMB 300 million or cumulative cash flow from operation in three years prior to the IPO must be at least RMB 50 million; (3) Intangible assets cannot account for more than 20% of total assets; (4) Net assets in the year before the IPO must total at least RMB 30 million; (5) the company did not suffer any unrecovered losses at the end of its most recent fiscal period. In addition to these financial performance requirements, firms are subject to other nonfinancial requirements, such as the existence of a functioning corporate governance system and no record of illegal behavior or financial scandals.

[10]See, for example, here.

[11]From 2004 to 2006, five members, or 20 percent of the total, were audit firms' partners, with the number rising to nine, or 36 percent, in 2007. Auditors are recommended for Committee membership by the China Institute of Certified Public Accountants (the CICPA) and candidates are selected by the CSRC.

addition to considering applicants' quality, the CSRC also controls the aggregate approval rate based on market conditions (Guo & Zhang 2012). The CSRC is concerned that too many IPOs will reduce liquidity, pull down the market, or adversely affect incumbent public firms because the cap (currently about 23) on the price to earnings ratio for IPOs might draw capital from incumbent to newly listed stocks (Tian 2011).[12]

In the fourth step, after the committee grants formal approval, the firm may apply to list at one of the domestic exchanges within six months. To do so, they solicit information from institutional investors, choose an exchange, and then build the book, all with the help from underwriters. The chosen stock exchange reviews the application to ascertain compliance with exchange rules—a procedure known to be a rubber stamp because exchange rules mirror CSRC requirements. Once approved, the firm can conduct its "road show" and decide on a share subscription day. The issuer then publishes the prospectus in designated newspapers at least three days prior to the subscription day and announces the issue at least one day prior to the subscription day. Finally, it takes an average of 24 working days after the subscription day for the shares to publicly list. (See Shi et al. 2018 for more details on the listing process). The interval between approval and listing is nearly always two to five months (the average is three), except during IPO suspensions. Approved firms try to list as soon as possible because after six months, they must renew approval.[13] Very rarely do firms and the CSRC delay listing due to disagreements on share prices.

2.2 IPO Suspensions

As an extreme form of regulating the IPO market, the CSRC occasionally suspends all IPO activities beyond the application submission step. Between 1994 and 2016, there have been nine IPO suspensions. Appendix Table A.1 contains details about the two recent suspensions

[12] Based on author interviews with regulators and other stakeholders, as well as Braun & Larrain 2008.

[13] Piotroski and Zhang (2014) Piotroski & Zhang (2014)point out that 'local firms need the support and approval of local politicians and party committee(s) to apply for an IPO', and that 'political connections have an important bearing on whether a firm is granted regulatory approval to raise public capital'. In that regard, the speed of approving listing applications could depend on individual firms' political connection. However, once a firm is approved, there is little evidence that political connections affect the time from approval to listing, which is what we examine.

we analyze. The primary reason for the suspensions is that the CSRC believes an increased supply of stocks will depress overall market prices, so suspensions have generally followed market declines (see e.g., Packer et al. 2016 and Shi et al. 2018).

The suspensions exogenously imposed uncertain periods of delay on firms that were approved to IPO shortly before the suspensions were announced. We expect that delay may be costly to firms if the delay imposes capital constraints; the firm would then have to forego strategic opportunities – such as acquisitions or large investments – and long-term planning would be disrupted (Shi, Sun & Zhang 2018). We also expect that the suspensions may have increased market uncertainty about the firm, which is costly (e.g., Almeida, Campello & Weisbach 2011 and Wang & Zhu 2013). Both of these potential negative effects of the suspensions are widely recognized in Chinese and foreign media, and among practitioners.[14]

The suspensions have been announced at the same time that they started; there have not been public warnings beforehand. Similarly, the end of a suspension coincides with the announcement that it is over. While the fact of historical suspensions means that market participants know a suspension is possible after a downturn, the suspensions are not predictable.[15] For example, after October 19, 2012, the CSRC ceased holding weekly review meetings, with no initial public explanation. The financial press initially expected the suspension to be short, but instead it lasted more than a year. More generally, the suspensions are predicated on the CSRC's concern for "market stability," not on individual firms' characteristics.[16] Firms likely form some expectation of the probability of a suspension.

[14]See e.g., here, here, here, here, and here.

[15]Based on interviews with Liliang Zhu, deputy director of CSRC's department of Public Offering Supervision, Feng Yu, deputy director of CSRC Zhejiang, and George Jiang, a partner at Springs Capital. The latter noted that while many funds tend to speculate on the timing and duration of IPO suspension, few get it right. See also articles here, here, here, here, here, and here. Also quoting fund managers at Longteng Asset management and StaRock Investment, "SEC announced that IPO is about to restart. We can tell that the market has recovered from the surge in brokerage stocks and the turnover of more than one trillion. We thought it was not until 4000 points that the issuance of new shares were resumed. The restart is ahead of schedule unexpectedly."

[16]For example, the official announcements for the first two suspensions cite "consecutive abnormal falls of the SSE Composite Index" and "327 debt event that disrupted normal trading" as the reasons. The latest suspension in 2015 was due to "abnormal volatile movements in the stock market". See here, here, and here. These are also confirmed in our interviews conducted with senior CSRC officials, Shi et al. 2018, as well as the CSRC officially designated media outlet, Security Daily. For example, see Hou and Zhu, "A Review of China IPO Suspensions", Security Daily, June 19 2013, Published: A3, retrieved from here.

Our empirical strategy will focus on firms that should have similar levels of anticipation and preparation.

In sum, the suspensions and three institutional features make China an ideal setting to study how timely access to public markets affects the firm. The three features are: (1) the IPO process is sufficiently long that the firms cannot accurately foresee future market conditions or suspensions at the time of application; (2) once a listing application is approved, firms all go through a standard procedure to list with delay determined by aggregate market conditions and the CSRC's suspension decisions; and (3) there is sufficient time from approval to listing that it is possible for a suspension to affect only a subset of approved firms. Together, these features imply that firms have little ability to time their listing or an IPO suspension (Guo & Zhang 2012).

3 Data Description

In this section, we describe our data sources and the variables we use as outcomes.

3.1 Sources of Data

We collect data from nine sources to construct variables used in this paper:

1. China Securities and Regulatory Commission (CSRC): We begin with the list of firms that applied to IPO on the A-share Shenzhen and Shanghai Main Boards. CSRC provides IPO application and approval data between 2004 and 2015 for 1,567 IPOs. We focus on the main board instead of smaller and illiquid boards such as NEEQ and ChiNext to be consistent with the literature. Moreover, these boards are new relative to many IPO suspensions and there are less financial data available from the commercial databases for firms listed on these boards.

2. Hand-collected private equity investment data: We hand-collected data from IPO

prospectuses for all IPOs between 2006 and 2013.[17] This data was checked for accuracy with the commercial ChinaVenture Source and SDC VentureXpert databases.

3. China Securities Market and Accounting Research (CSMAR)/WIND: These commercial databases (the Bloomberg equivalents) provide IPO prospectus data (sometimes called "predisclosure" data), listing, and financial statement data.

4. Compustat: We supplement the Chinese sources with Compustat data for Chinese companies.

5. SDC New Issues: This database provides listing information for Chinese companies, supplementing WIND.

6. State Intellectual Property Office (SIPO): We have annual and monthly invention, design, and utility patent application and grant data. The latter two types of patent applications are rarely rejected.

7. Google Patents: We match the firms in our sample to patent and citation data using the Google Patents, which include the entire collection (over 87 million) of granted patents and published patent applications from 17 major patent offices around the world (including US from 1790, EPO and WIPO from 1978).

8. Private Capital Research Institute (PCRI): PCRI data are used to analyze the relationship between IPO suspensions and contemporaneous VC investment. PCRI data include all investments from 30 large PE/VC firms, VentureXpert, EMPEA, unquote, Venture Intelligence (India), and Startup nation (Israel). We were provided with aggregated weekly time series for China and the rest of the world, by investment stage and GP location. It includes investment values in U.S. dollars and number of deals.

[17] The investment information comes from the prospectus section entitled "发行人基本情况" ("Basic introduction of issuer"). Within this section, the sub-section entitled "发起人、主要股东及实际控制人基本情况" ("Basic introduction of major stockholders and ultimate controllers") permits ascertaining whether a major stockholder is a venture capitalist or not. A second subsection entitled "发行人的股本形成及变化" ("Equity Capital Formation and Change") provides information on investment periods, amounts, and share holdings for the major stockholders.

9. IPO Suspension Information: We hand-collect the dates for IPO suspensions from official announcements and news articles.

3.2 Summary Statistics

All firms in our sample ultimately do go public, and we focus on outcomes after application approval.[18] Our estimation sample consists of firms approved to IPO in the twelve months before a suspension announcement. Those approved early in the year were ahead in a queue and listed with little delay, while the remainder were forced to wait until the suspension ended. Our data begin in 2004. There have been four suspensions since, but the first two in 2005 and 2006 were separated by just four months, confounding efforts to define treatment and control groups. Therefore, we focus on the two suspensions from September 16, 2008 to July 10, 2009 and from October 19, 2012 to January 16, 2014.

Table 1 Panels 1-6 describe data used in our analysis. Panel 1 summarizes categorical IPO information for all 1,558 firms in the data, which includes all IPOs on the Shanghai and Shenzhen exchanges between 2004 and 2015. Table 1 Panel 2 contains continuous IPO data. IPO delay averages 4.3 months in the whole sample, with a standard deviation of 5.8 months. Our estimation sample consists of 350 firms approved to IPO in the year (365 days) prior to an IPO suspension. Remaining summary statistics focus on the estimation sample. For example, average underpricing (the difference between the closing price on the first trading day and the offer price) in our data is almost 80 percent, consistent with the literature finding large underpricing in China.

Patent applications represent firm effort to formalize intellectual property so as to temporarily monopolize it. We use the number of patent applications to reflect innovation effort, though we recognize they also represent the firm effort to codify, disclose, and protect intellectual property (Kortum & Lerner 2001, Rajan 2012). We use only invention patents, which are the analog to utility patents in the U.S.; they cover new technical solutions relating

[18] Only eighteen firms were approved and dropped out, primarily because regulators found evidence of fraud. No firm approved to IPO in China has failed to do so and listed abroad instead.

to a product, a process, or improvement.[19] Invention patent protection lasts twenty years from the application. The patent-based variables are summarized in Table 1 Panels 3 and 4.[20] In the estimation sample, the average firm files five patents in the year following IPO approval, and the number only starts to decline after the fourth year after IPO approval conditional on public listing (to 4.8), though not significantly. The sample size declines somewhat due to truncation. The numbers are slightly different when we measure as the distance from IPO, though again not significantly; in the first and second year after IPO, the average firm files 4.2 and 4.9 patent applications respectively.

We use two measures of patent quality. First, data from Google Patent permit us to observe citations to Chinese patents, which to our knowledge is new to the literature measuring innovation among Chinese firms. China's patent office (SIPO) does not disclose citation data, and prior work has primarily relied on citations to patents that Chinese firms file in foreign countries. This approach has several limitations, including selection into foreign patent filing, different standards across offices, and home country bias (Michel & Bettels 2001, Harhoff et al. 2003, Bacchiocchi & Montobbio 2010). Google Patent covers SIPO citations and is searchable for non-English patents, providing wider coverage than previous measures.[21] The average firm has 23.8 citations to granted patents that were filed in the year following IPO approval. Note that different industries have systematically different citation rates. The industry fixed effects that we include in regressions help to account for these systematic differences. However, since we are not doing cross-industry comparisons, the differences

[19] China has three classes of patents: invention, utility model, and design. Utility model patents represent new technical solutions relating to the shape, the structure, or their combination, of a product; and design patents cover new designs in relation to shapes, patterns, colors, or their combination, of a product. Applications for these two types are essentially never rejected.

[20] Patent applications in China have increased dramatically since China established formal patent law in 1985, and there are now more invention patents filed in China than in the U.S. Fang, Lerner & Wu (2017) show that while average quality may differ across countries, patents generally serve the same purpose in China as they do in the U.S., and firm patenting behavior is similar across the two countries. For example, in both countries, within-firm increases in patent stocks are associated with higher productivity, exports, and new product revenue. Interestingly, they find that SOE patents are more associated with TFP growth than private firm patents. Wei, Xie & Zhang (2016) find that the patent approval rate is not unusually high in China, and present comparisons suggesting robust improvement in Chinese patent quality over time.

[21] This complements earlier approaches in Boeing & Mueller (2016) and Rong et al. (2017), who use citations to patents filed via the Patent Cooperation Treaty (PCT). As these applications are published through WIPO, they are also included in Google Patent data.

should not confound our results. Fang, Lerner & Wu (2016) also use unscaled citations. Truncation of the citation data is a second issue, and we to some degree control for this with time fixed effects. A second measure of patent quality is the number of granted patents filed in foreign (non-Chinese) patent offices. We term these "global" patents. The average firm has 0.04 global granted patents that were filed in the year following IPO approval.

Corporate variables for the year following IPO approval and the year following actual listing are shown in Table 1 Panels 5 and 6. We follow precedent in the literature in constructing financial variables where possible, in particular Fan et al. (2007) and Piotroski & Zhang (2014). Here we explain variables whose construction may not be obvious. Leverage is the ratio of the firm's total liabilities to total assets at the fiscal year-end. Cash is also scaled by assets. Plant, property, and equipment (PPE) investment is scaled by total assets. Market share is a focal firm's share of total industry revenue.[22] Some of these variables are not available for pre-IPO years, including cash and revenue (and thus market share). We also collected data on R&D expenditure; however, these data only exist after 2007 and appear to be poor quality. We also collected data about company boards; at IPO, boards on average have 9.2 members. Finally, a commonly used accounting measure for window dressing is the volume of discretionary accruals. This reflects the flexibility and scale of firms to manage their earnings and has been used by researchers in both the U.S. and Chinese contexts (Becker et al. 1998, Hutton et al. 2009, Chen et al. 2011, Kim & Zhang 2016). We measure discretionary accruals as the residual from a Jones model, adjusted by a performance matched firm, following Jones (1991) and Brau & Fawcett (2006).

4 Empirical Strategy

This section explains how we use the IPO suspensions to identify the effect of uncertain listing delay on firm outcomes.

[22] Industry is defined using the nnindcd variable in CSMAR, which has 78 categories.

4.1 Approach

We are interested in the effect of IPO suspension-induced delay between approval and listing on firm outcomes. After approval, firms in general list as soon as they are permitted. In the absence of a suspension, the interval from approval to listing is 3.3 months.[23] However, it is possible that both the approval decision and the exact timing of listing conditional on approval may reflect firm-specific unobservables that could confound our estimates. Therefore, we do not use raw delay as our independent variable of interest except in robustness tests.

Instead, our approach exploits the fact that the approval date is highly predictive of whether a firm was forced to delay until after the suspension ended. In a naive instrumentation approach, we divide our estimation sample into treatment and control groups based only on the approval date. First, we define the estimation sample as firms approved in the 12 months before each of the two suspensions were announced. (The results are not sensitive to this definition, and Appendix Table A.2 shows that firms approved during the 12 months are not observably lower quality than firms approved at other times.) Figure 2 describes our approach graphically.[24] Each dot is an IPO, the approval date is on the horizontal axis, and delay between approval and listing is on the vertical axis. The estimation sample comprises the green and red dots to the right of the solid lines and to the left of the suspension periods.

Second, we identify the approval date that lies at the discontinuity where subsequently approved firms were delayed as a result of the suspension. This is represented by the dotted lines in Figure 2. Control firms are the red triangles on the left side of the dotted lines. The treatment firms are the green circles to the right of the dotted lines. Average delay for the control group is 3.2 months, while it is 16.3 months for the treatment group (Table 2). Our results are not sensitive to the precise location of the dotted line, and in fact grow stronger as the line is moved to the right. Figure 3 shows the same color scheme, but with the listing date on the horizontal axis.

The identification assumption is that firm-specific factors do not drive treatment as-

[23] Calculated among control and out-of-estimation-sample firms.
[24] A few outlier firms are excluded from the graph.

signment within the estimation sample. That is, we assume that among firms approved near in time to a suspension, delay is not fully predictable and is exogenous to firm characteristics. Interviews with market participants, the observable queue post-2012, and t-tests (below) lead us to believe this is the case.[25] As explained in Section 2.2, we have reason to believe that the suspensions were largely surprises. To the degree firms may have expected them, we are examining the effect of delay among firms with similar level of anticipation and preparation. As firms must have applied to IPO three or more years earlier, their position in the queue should not be related to their expectations of a suspension based on market conditions. We do not require the suspensions to be exogenous to markets.

As with any quasi-experimental strategy, it is challenging to completely rule out endogeneity in delay. The primary concern is that some firms jump the queue to avoid delay. Note that queue-jumping by politically connected or state-owned firms should bias our results against finding a detrimental effect of delay because politically connected firms and SOEs are well known to underperform relative to their counterparts along various dimensions (Fan et al. 2007, Dollar & Wei 2007, Chen et al. 2016, Whited & Zhao 2016, and Piotroski & Zhang 2014), including innovation outputs (e.g., Jefferson et al. 2006). If these firms have less delay because they jump the queue, it is even more striking to find that delay leads to underperformance. Moreover, we test in our sample whether actual listing follows the same order of approval and find that the orderings have a correlation of 0.98, which indicates almost no change in the order in the queue from approval to listing.

A second concern is that firms of a particular latent quality (such as innovativeness) complete the approval-to-listing process faster and so are less likely to be delayed. However, our treatment group is defined by the approval date, so this should not affect our estimates. Also, we show in Appendix Table A.2 Panel 1 that firms in the estimation sample do not take longer to list; after removing the suspension months, time to listing is very similar (3.16 and

[25] Based on interviews conducted with senior CSRC officials and CSRC documents, such as 中国证监会发行监管部首次公开发行股票审核工作流程 at here and here, the orders of approval and of subsequent listing are largely determined by a firm's position in the queue. Approved firms cannot anticipate the start and the end of these suspensions at the time of application because of the significant waiting time between application and approval.

3.36 months). Within the estimation sample, the control group's approval-to-listing interval averages 3.23 months.

A third concern is that regulators decide to launch an IPO suspension based on their assessment that firms approved but not yet listed are low quality. In addition to institutional evidence that overall market conditions drive suspension decisions (Section 2.2), we show that firms in the estimation sample are similar to firms outside it; if anything, they are of higher quality. Appendix Table A.2 Panel 2 shows that among observables in the year before IPO approval, estimation sample firms are not significantly different, except that they have somewhat higher patenting and earnings. It may be that the estimation sample firms are higher quality, but it is also the case that Chinese firms have increased their patenting activity over time, and the estimation sample is in general later than the non-estimation sample. In Section 4.3 we show that treatment and control firms have similar relevant ex-ante characteristics.

4.2 Specification

Our primary specification estimates variants of Equation 1, where j denotes a firm and t denotes a year. The coefficient of interest is β on whether the firm is in the treatment group, and thus is much more likely to experience long, suspension-induced IPO delay.

$$P_{jt} = \alpha + \beta Treat_j + \delta' \mathbf{V}_{jt} + \gamma Industry_j + Year_t + \varepsilon_{jt} \tag{1}$$

$\mathbf{V}_{jt}$ is a vector of controls. It includes firm age, revenue, leverage, investment, a fixed effect for the exchange (Shanghai or Shenzhen), and indicators for whether the firm is state-owned and whether it previously received private equity or venture capital financing. Following Hsieh & Song (2015), we define a firm as a state-owned enterprise (SOE) if either the state owns at least 50 percent of registered capital or if the state is reported as the controlling shareholder. We also include industry fixed effects (25 industry classes from WIND). Finally, we include an indicator for which suspension the firm was approved prior to, which is equivalent to controlling for year (12-month period before the suspension). We double cluster errors by industry and listing quarter.

The primary dependent variable (P_{jt}) is the number of Chinese patent applications in a 12-month period (e.g., the 12 months after IPO approval). We also consider the number of granted Chinese invention patents, citations to granted Chinese patents, and global non-Chinese granted patents. To investigate the general impact of listing delays, we further examine the effects of delay on a diverse array of other outcomes, such as leverage, market share, tangible investment, and earnings.

We begin by focusing on the year following approval, to examine the effect of delay while treated firms are delayed and still private. This approach compares public and private firms, which has been the approach in the literature but conflates the effects of delay and listing. We then examine the longer-term effect of listing delays. This approach considers firms at a similar stage in their lifecycle, in the sense of being after the watershed IPO event. An alternative specification considers the first and second year after IPO for delayed firms and aligns control firms so that they are considered in the same calendar year as the treatment firms. This approach considers firms at the same calendar time.

We also conduct a number of robustness tests. First, we examine heterogeneity by state ownership, VC backing, and whether a firm is in a high-tech industry. Second, we estimate the effect of continuous delay and continuous delay instrumented using the month of IPO approval. Finally, we conduct placebo and reverse causation tests to rule out several spurious alternatives to a true effect of suspension-induced delay.

4.3 Ex-ante Differences by Delay

We conduct t-tests for whether treated firms appear different ex-ante than the control group. The results are in Table 2. We first check if the treated firms would take longer to list in the absence of suspension delays. We then examine pre-IPO approval year patenting activity, firm characteristics, and financial variables in the second year prior to IPO. We report two-tailed as well as the more stringent upper and lower one-tailed tests.

As shown in Panel 1, not counting the delay due to suspensions, the approval-to-listing time for the treatment and control groups exhibit no significant difference. The average for the control is 3.23 whereas that for the treatment is 3.03. Therefore, it is not the case that absent suspensions, the treated group takes longer to list in the first place. There are also no significant differences for patent applications, grants, or citations. The two groups are not significantly different along financial dimensions either. If anything, the treated group has lower leverage. There is no evidence that the treated group is of lower ex-ante quality.

5 Results

This section first describes the effects of suspension-induced IPO delay on patent activity, starting with patent activity immediately following the suspension when delayed firms are private (Section 5.1.1). We then consider the longer-term effect multiple years after listing approval and after the delayed firms publicly list (Section 5.1.2), before showing a number of robustness tests (Section 5.1.3). Other firm outcomes are analyzed in Section 5.2.

5.1 Patent Activity

5.1.1 Immediate Effect of Suspension-induced Delay on Innovation

Suspension-induced listing delay significantly reduces firms' effort to obtain patents. We first show the raw effect visually. Figure 4 shows a local polynomial of the average patents by month around the IPO approval date. The left two plots include only firms with above-median delay (4 months), while the right two plots include only firms with below-median delay. In the top graphs, we consider only firm-months in which the firm has not yet listed. Therefore, all firms are included in months through zero, and then drop out of the sample as they list. The bottom graphs include all firm-months. For example, in the bottom left graph, all firms experience at least four months of delay. After the 4th month following IPO approval, some will have listed and some not. Figure 4 reveals that patent applications rise leading up to approval as firms ready themselves for listing. They may be doing more innovation during this period, but the patent applications could also reflect a need to increase disclosure. It is comforting that firms affected by delay (left graphs) have similar pre-approval behavior as firms that did not experience abnormal delay (right graphs). After approval, patents decline much more for delayed firms, both when we exclude post-listing months (top graphs) and when we include them (bottom graphs).

Table 3 shows estimates of Equation 1. We begin in Panel 1 with outcomes measured in the 12 months following IPO approval, to examine the effect of delay while treated firms are delayed. Average delay in the treatment group is 16.3 months, while average delay in the control group is 3.2 months (see Table 2). Therefore, this year period is almost entirely post-IPO for the control group, and pre-IPO for the treatment group. The advantage of examining this time period is that outcomes are observed around the same calendar time. The disadvantage is that we are comparing public and private firms. This has been the approach of the literature on the effect of going public on innovation. In our context, it conflates the effects of delay with treatment effects of listing. Column 1 shows that the suspension treatment reduces patent applications in the year after approval by about 28 percent with a Poisson model.[26] Columns 2 use OLS model to show that the suspension treatment reduces patents by 1.7 (the mean is 5.01 patents).

Delay also reduces patent quality. The treatment reduces granted Chinese invention patents and their citations in the year following approval by about 20 percent and 36 percent respectively in the Poisson model. Using OLS, the reduction is 0.36 grants relative to the sample mean of 1.58, and 11 citations relative to the sample mean of 23.8 citations (Table 3 Columns 3-6). For granted global utility patents, the Poisson estimation does not converge because there are too few instances of positive patents. The OLS finds that treatment reduces

[26]Here we follow the standard assumption that patenting follows a Poisson distribution as in Aghion et al. (2005). The results are robust when we use a negative binomial model.

the number of grants by 0.04 relative to the sample mean of 0.04. Overall, the results in Tables 3 provide consistent and compelling evidence that delay reduces patenting activity, the standard measure of innovation output, both in terms of quantity and quality.

Ferreira et al. (2012) predicts and Bernstein (2015) documents that innovation quality declines after public listing. Consistent with this, we observe patent applications fall in both the treatment and control groups after IPO, though the bottom right graph in Figure 4 shows that control firm patenting returns to the level at IPO after two years. We further verify in Appendix Table A.3 that our data are consistent with Bernstein (2015) by decomposing with monthly data the decline of patent citations - the measure of innovation quality used in Bernstein (2015) - into listing and delay treatments. Column 1 shows that on average, citations fall after IPO. Column 2 shows that this decline persists after controlling for delay. It is notable that the post-IPO decline established by Bernstein (2015) exists not just in the U.S. but also in China, a very different setting. Our contribution is to show that patent activity falls further among the delayed group and remains depressed even after treatment firms have listed (bottom left graph of Figure 4, and column 2 of Appendix Table A.3).

5.1.2 Longer-term Effect of Suspension-induced Delay on Innovation

We next examine the longer-term effect of listing delays. Specifically, we consider the third and fourth years following approval, conditional on the firm already having listed. The advantages here are that firms are studied at similar calendar time and are at a similar stage in their lifecycle, in the sense of being after the watershed IPO event. The disadvantage is that this approach studies outcomes long after IPO for control firms. We find that the negative effects on patenting, especially applications which proxy for innovation effort, endure for several years and after the delayed firms eventually list. Table 3 Panel 2 shows that in the third (fourth) year following approval, the delayed firms conditional on having listed average 26 (18) percent fewer patent applications in the Poisson model, and 1.2 (.91) fewer patent applications in the OLS model.

In an alternative specification, we examine the first and second year after IPO for delayed firms. We align control firms to be in the same calendar year as the treatment firms. That is, we shift the time period considered (year t) forward for control firms to make up for the suspension period. For example, many of the control firms for the 2008-2009 suspension listed in 2007. The delayed firms mostly listed in 2009. We consider the outcome (e.g. patents) for the control firms in the second or third year after their IPO, so that all firms are considered in (roughly) 2009. Again, this approach compares public firms at a similar stage in the firm lifecycle, and – importantly – we are comparing firms at the same calendar time, so the effects should not be confounded by, for example, market conditions. Effects in the year and second year after IPO are shown in Table 3 Panel 3. Treated firms have on average 34 percent fewer patents than the control group in the Poisson model and about 1.5 fewer patents in the OLS model, though these effects lose significance in the second year after IPO. These approaches either omit the most delayed firms or study outcomes long after IPO for control firms. We expect these results to be somewhat noisier than other estimates.

The longer-term effects on patent quality go in the same direction but are not significant, probably because the citation measures are noisier in the Chinese setting (e.g., Boeing & Mueller 2016). Also, the citation data suffer from truncation, especially for the 2012-13 suspension.

5.1.3 Robustness Tests

We first test for three dimensions of heterogeneity in the effect of delay on patent applications in year after IPO approval: state ownership, VC backing, and whether a firm is in a high-tech industry. The results of these interaction regressions are in Table 4 Panel 1. The effect among SOEs is smaller but not significantly so (Columns 1-2). The effect among VC-backed firms is much larger (Columns 3-4). Finally, the effect among high tech firms is larger, but insignificantly so (Columns 5-6; note that industry fixed effects absorb the independent high-tech dummy). The coefficients on the heterogeneity dummies have the signs we would expect, namely, private firms and VC-backed firms are more innovative in terms of patent applications. We find no significant differences across foreign, private Chinese, or state-backed VC.

We next estimate the effect of continuous delay, rather than the naive instrumentation approach in our main specification. In Equation 2, the coefficient of interest is β on months of delay. The other variables are the same as in Equation 1.

$$P_{jt} = \alpha + \beta MonthsDelay_j + \delta' \mathbf{V}_{jt} + \gamma Industry_j + Year_t + \varepsilon_{jt} \qquad (2)$$

Table 4 Panel 2 Columns 1-2 show this effect of continuous delay in months. Each additional month of suspension-induced listing delay is associated with a 1.3 percent reduction in patent applications in the Poisson model, and -0.067 patent less under the OLS model.

To address any concern that firms jump the queue after being approved within this continuous-delay specification, we also instrument for the months of delay using the month of IPO approval. The intuition is that if firms do not jump the queue to list after being approved, the month of approval should predict the duration of delay. The first stage consists of Equation 3, where ApprovalMonth_t is a fixed effect for the month of approval.

$$Month\hat{s}Delay_j = \alpha + \text{ApprovalMonth}_t + \delta' \mathbf{V}_{jt} + \gamma Industry_j + Year_t + \varepsilon_{jt} \qquad (3)$$

As expected from the absence of queue-jumping, the first stage is very strong, with an F-statistic of 260, well above the rule-of-thumb cutoff of ten. (We do not report the results from the first stage due to the large number of coefficients.) Instrumented delay has a significant effect on innovation, shown in Table 4 Panel 2 Column 3.

Finally, we conduct several placebo tests. First, we replace the independent variable of interest with a constructed "mock" delay that excludes the months during the IPO suspensions. For example, if a firm has 13 months of delay, of which nine occurred during a suspension, its mock delay would be four months. The goal is to test whether innovation is affected by minor differences in delay from variation in normal processing time. The results for this "mock" delay that excludes months during the IPO suspensions are in Table 4 Panel 2 Columns 4-5. The null effect demonstrates that suspension-induced delay is different from minor variation in normal processing time from approval to listing; the former affects innovation significantly, while the latter does not.

Second, we use delays (in months) in the non-estimation sample (i.e., outside the 12 months before an IPO suspension). Table 4 Panel 2 Column 6 contains this placebo test of delay outside of the estimation sample and yields no effect. This indicates that suspension-induced delays indeed drive our main findings. For example, an argument that high-quality firms tend to list faster and experience less delay would imply that the mock delayed firms should also exhibit lower number and quality of innovation, which is not the case.

Third, we examine the years before IPO approval for the treated and control groups, which is similar to testing for differences in pre-treatment characteristics. If non-suspension related factors are the primary drivers for our findings, we expect similar findings in these placebo tests as in our main specifications. Table 4 Panel 3 shows placebo tests of the effect of IPO delay on patent applications in the years before IPO approval. We do not observe any significant difference between the treated and control groups in terms of patent applications. This implies that the two groups are not ex ante different in terms of innovation effort as measured through patent applications.

Taken together, the robustness tests indicate that IPO suspensions are the main driver for the observed differences in patent activities by delay treatment status.

5.2 Other Firm Outcomes

Suspension-induced delay may also affect other firm outcomes. Table 5 Panel 1 reports the effect of IPO delay on other firm outcomes in the year after IPO approval. We find a positive effect on leverage, negative effects on tangible investment and return on sales, and no measurable effects on sales or earnings. The effects on leverage and tangible investment are consistent with the firm experiencing a negative capital shock and heightened business uncertainty as a result of delay, which helps explain why they may have less capacity for investing in innovation or commercializing existing inventions (both of which may be reflected in reduced patent applications).

Table 5 Panel 2 shows that these effects quickly dissipate after the IPO. There are additional outcomes, as we observe more corporate variables after IPO than before. For example, we observe R&D after IPO. While the effects are insignificant, the effect on R&D scaled by firm assets is very nearly significant at the .1 level, suggesting that delayed firms may invest less in R&D immediately after listing. However, as mentioned earlier, the quality of the R&D data is poor. For all of these corporate variables, we continue to find null effects when we consider multiple years after IPO approval conditional on listing (the same specification as Table 3 Panel 2). We also collected data on executive mobility and looked at personnel movements.[27] We found lower rates of tech executive entry for delayed firms after they list, but the effect was not significant at conventional levels.

6 Potential Channels

The results in Section 5 demonstrate that temporary IPO delays negatively affect innovation after listing and have short-term effects during the delay period on several real outcomes. Sections 6.1 and 6.2 discuss two potential channels for the initial disruption during delay: financial constraints (i.e., reduced capital supply) and uncertainty. Section 6.3 argues that window dressing activity cannot explain our findings. Section 6.4 explores the hypothesis that the cumulative nature of innovation leads to the enduring effect we observe.

[27]We collected data on executive mobility using the CSMAR Executive and Board Database. This is only available after IPO, and was not available for all firms. We manually translated and classified executive positions that appear more than 50 times in the database. We then examined entry and exit of holders of these positions in the years after IPO. We focus on three types of positions: finance, human resources, and technical. On average, many more executives in each category join than depart, consistent with firm management growing after IPO.

6.1 Financial Constraints

For financial constraints to be at work during suspension-induced delay, alternative forms of financing such as debt or private equity must be too costly or unavailable. Firms going public on the main Chinese boards are less constrained than young, unprofitable firms that go public in the U.S. As explained in Section 2.1, firms must meet various financial requirements, including multiple years of profitability, in order to list. Since the investment to obtain IPO approval is sunk, we expect that firms desperately in need of capital would have gone public in Hong Kong or elsewhere. At the same time, the exceedingly high valuations in China offer a powerful inducement to wait.[28]

In the absence of financial frictions, the delayed firm could fill a financing gap with debt and private equity. Frictions in these markets may make IPO markets especially important for risk capital provision in China. This is consistent with our findings that during the delay period, affected firms experience higher leverage, while patenting and tangible investment fall (Tables 3 and 5). In the year following IPO, delay is not associated with lower investment but continues to lead to higher leverage. It seems that firms are able to increase debt, but that the debt cannot be used to finance risky investments - tangible assets and innovation. These activities may be constrained by the absence of risk capital. Thus, firms appear to be in a "Goldilocks" position. They are not so constrained that they cannot raise any debt, but frictions prevent them from financing risky projects in the absence of public capital.

At the same time, if the channel were purely financial constraints, we would expect that firms with private equity investment, or that have better access to debt, would be less affected by delay. Instead, we found in Table 4 Panel 1 that VC-backed firms are more affected. We also do not find that delayed firms are more or less likely to ever receive VC investment before their IPO, suggesting that firms do not react to delay by raising money in private capital markets. We expect that SOEs will have better access to debt. For example,

[28] One recent example is online security firm 360 Security which has seen its market capitalization soar to $52 billion since it re-listed in Shanghai in late February–up from $9.3 billion when it exited the New York Stock Exchange in 2016 (here).

Cong, Gao, Ponticelli & Yang (2018) show that SOEs are advantaged in accessing credit, especially after the introduction of China's stimulus package towards the end of 2008. Table 4 Panel 1 shows that SOEs are not significantly less affected. Therefore, while a capital supply channel is part of the story, it seems unlikely to fully explain the chilling effect of delay on innovation.

6.2 Heightened Uncertainty and Instability

The suspensions, which were all of indefinite length, created uncertainty among affected firms about when they would be able to go public and what market conditions they would face. In Section 2 we provided anecdotal and industry press evidence that although there was little doubt that eventually IPOs would resume, suspension-induced delay caused market uncertainty about affected firms. The placebo tests reported in Table 4 Panels 2 and 3 show that "normal" delays of a few months during non-suspension periods do not lead to less innovation, although these short delays are also associated with lack of access to public capital markets. This is consistent with the general perception among practitioners that non-suspension-induced delays correspond to regular processing time from approval to listing, and do not create uncertainty about listing feasibility and timing.

In the literature comparing public and private U.S. firms, the firms know immediately whether they will be public or private and adjust their investment strategy accordingly. For example, Bernstein (2015) argues that the decline in patent citations that he observes after firms go public is partially intended, as public firms shift strategies to focus more on acquiring innovation and commercializing products. In our setting, the firm is unsure when it will be able to pursue its planned as-public-firm investment strategy. It does not switch gears and pursue an as-private-firm strategy, because it ultimately does plan to go public. In this way, uncertainty is a key differentiating factor for our setting.

To push further on whether there was meaningful uncertainty about the IPO market during suspensions, we examine VC investment. If IPO suspensions were perceived as short and unimportant hiatuses, contemporaneous VC investment should not be affected because of its highly illiquid nature, with portfolio companies held for multiple years before seeking liquidity through IPO. Conversely, if suspensions caused serious uncertainty about the future of IPO markets in China, VC investors may have become concerned about exit possibilities and reduced investment. We show an association between VC investment and the suspensions in Online Appendix B. Controlling for domestic market conditions and rest-of-world VC, we find that the suspensions were associated with depressed VC investment, particularly later stage VC investment, in Chinese portfolio companies. This persists among elite U.S.-headquartered VC firms active in China. While not causal, this analysis suggests that the suspensions had a chilling effect on VC.

These findings are consistent with the real options literature, which predicts that investment declines under uncertainty (Dixit & Pindyck 1994). Indeed, we find strong negative effects of delay on tangible investment and leverage in the year following IPO approval, shown in Table 5 Panel 1. Note that this exercise compares listed and unlisted firms, as non-delayed firms typically list within a few months of approval. Tangible investment likely accompanies R&D investment; both are relatively longer-term and risky relative to other types of expenditure.

The data do not permit us to pin down a precise mechanism or quantify the relative magnitudes of the alternative channels. However, our evidence suggests that both the capital supply and uncertainty channels play a role in explaining why delayed firms forego innovation investment. Financing constraints during the suspensions interact with heightened uncertainty, leading to reduced corporate innovation.[29] These mechanisms are quite different from the mechanism Bernstein (2015) describes that leads on average to lower innovation quality after listing: He focuses on agency problems in the form of career concerns after public listing, which leads publicly traded firms to pursue lower quality innovation.

[29]We cannot completely rule out that the longer-term effect on the patenting rates is an artifact of patent filings and approvals lagging investment for years. However, the fact that firms immediately experience a drop in patenting activities after the suspension cannot be attributed to this lag. Also, this alternative continues to imply a cost to restricting timely access to public markets, and has the associated policy implications.

6.3 Window Dressing

An alternative channel is that the effects of delay on innovation reflect firm window dressing behavior, or efforts to artificially and temporarily mislead the market about the firm's worth (see e.g. Stein 1989 and Jain & Kini 1994). Window dressing is almost certainly present and may help explain the run-up in patent applications that we observe two years prior to the firm's approval (Figure 4). We examine the standard measure of window dressing, discretionary accruals, in the year after IPO approval. If anything, we find that delayed firms have slightly lower, albeit statistically insignificant, discretionary accruals (Table 5 Panel 1 Column 6 and Panel 2 Column 11). It is therefore unlikely that window dressing explains the innovation decline among the treatment group.

However, firms could have exhausted window dressing resources during delays, and have less flexibility to window dress after IPO. That is, firms may maintain short-term operating performance at the expense of longer-term operating performance, which could have reduced patent activities. Yet this version of window dressing cannot explain the persistent effects on innovation that we observe during delay and several years after, jointly with the absence of a longer-term effect on operating performance. Similarly, firms may perceive a need to maintain a certain standard innovation under the CSRC's watch as they wait to list. In particular, if a firm exhausts resources for innovation during delay, we might expect it to have lower innovation after ultimately going public. However, we observe patent applications drop precipitously during the delay period (Figure 4), which directly contradicts this hypothesis. A final possible window dressing scenario is that treated firms temporarily inflate patent activities prior to the approval meetings more than control firms, and subsequently have less resources for patent activities afterward. However, Figure 4 shows that this is not the case.

6.4 Cumulative Nature of Innovation

The evidence is most consistent with capital constraints and increased uncertainty during delay leading the firm to reduce investment in innovation. The remaining question is why delay has lasting effects on innovation, unlike, for example, tangible investment or return on sales. It seems that something is different about innovation. The most natural explanation is that innovation investments are cumulative, such that investing today sets the stage for continuing to have positive NPV investment opportunities in the future. That is, the productivity of firms' future innovation investment depends on whether it remains at the frontier today and maintains its R&D infrastructure. This relates to the literature showing how innovation capability depends on years of accumulated expertise and infrastructure (e.g., Feldman & Florida 1994, Bates & Flynn 1995). New innovations build upon and complement prior innovation (Chang 1995).

This is analogous to an individual's investment in education to build human capital, as Cunha & Heckman (2007) formalize. Attending third grade offers little in the way of labor market returns, but it is crucial to ultimately attending college. A child who misses a year of schooling may fall permanently behind her peers. Similarly, falling behind in the corporate innovation process may have persistent effects. Uncertain listing delay causes a firm to pause its innovation investment, disrupting its ability to build or maintain an innovative, entrepreneurial culture in the sense of Gompers, Lerner & Scharfstein (2005). The temporary disruption has effects on the firm's innovation infrastructure that last for multiple years. More broadly, short-term treatments are known to have enduring effects on people (e.g., Drago, Galbiati & Vertova 2009). Our results suggest that short-term treatments can also have enduring effects on firms.

7 Conclusion

How access to public markets affects firms is difficult to study; the ideal experiment would observe the same economy with and without well-functioning public markets. China's IPO suspensions provide a quasi-experiment in an important economy. We find that temporary listing delay imposed by IPO suspensions causes reduced innovation measured by patenting effort. The effects on innovation are economically significant and endure for years after listing. Meanwhile, effects on other corporate outcomes do not outlast the delay period. The evidence is most consistent with heightened uncertainty about delayed firms created by the interventions, combined with financing constraints due to the lack of access to public equity capital, disrupting the corporate innovation process. The enduring negative effects point to the cumulative nature of corporate innovation.

Previous literature has examined the impact of listing in environments where the firm's demand to list, while perhaps dependent on market conditions, determines its public status. In contrast, our approach exploits a regulatory shock to listing opportunities. Our findings therefore have policy implications, particularly in light of how crucial private firm innovation is to China's future growth. Our results suggest that – from the perspective of firms seeking public financing – it is valuable to be able to predictably list in a timely manner. Therefore, China's innovation ecosystem could potentially benefit if regulators focused on fostering accessible IPO markets with transparent rules and minimal uncertainty-generating intervention. One approach could be to move toward a registration-based, disclosure-oriented listing process.

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Table 1: Summary Statistics

Panel 1: Categorical IPO data

	N
IPOs in Shanghai/Shenzhen (2004-2015)	1,558
IPOs in Shanghai	290
IPOs in Shenzhen	1,268
State-owned (SOE)	241
Venture backed	634
Private Foreign VC director on board	33
State-backed Chinese VC director on board	150
Private Chinese VC director on board	206

Panel 2: Continuous IPO data (Listing less approval date, months)

	N	Mean	Median	S.d.	Min	Max
Whole sample						
IPO delay in months (time approval to listing)	1558	4.3	2.3	5.8	0.43	43.4
Estimation sample†						
IPO delay in months (time approval to listing)	350	7.7	3.7	8.1	0.63	36.63
Market cap at listing	350	3313	913	15141	145	220000
IPO proceeds	350	1369	463	5413	121	66276
Price-to-book ratio first day of trading	350	12.0	10.2	8.9	1.5	108.3
IPO underpricing††	350	-0.77	-0.8	0.08	-0.88	-0.3

Panel 3: Annual patent data in year following IPO approval for estimation sample

	N	Mean	Median	S.d.	Min	Max
Chinese invention patent applications	350	5.01	3	6.73	0	43
Chinese granted invention patents	350	1.58	1	2.06	0	13
Citations to granted Chinese invention patents	350	23.8	7	46.5	0	616
Granted global (non-Chinese) utility patents	350	0.04	0	0.33	0	5

Panel 4: Annual Chinese invention patent applications in later years

	N	Mean	Median	S.d.	Min	Max
In 3rd year after IPO approval if public	342	5.09	3.5	6.63	0	44
In 4th year after IPO approval if public	320	4.83	3	6.14	0	40
In year after IPO	350	4.24	2	5.59	0	34
In second year after IPO	350	4.85	3	8.79	0	113

Panel 5: Corporate data in year following IPO approval for estimation sample

	N	Mean	Median	S.d.	Min	Max
PPE Investment$^{\pm}$	350	0.13	0.1	0.11	0	1.12
Leverage$^{\pm}$	350	0.76	0.52	0.94	0.03	11.34
Revenue	350	6013	551	48662	65	840000
Return on sales	350	0.79	1.07	0.49	0.02	1.52
Earnings‡‡	350	724	72	7763	5.83	140,000
Discretionary accruals	340	0.07	0.05	0.14	-0.44	0.62

Panel 6: Corporate data in year following IPO for estimation sample

	N	Mean	Median	S.d.	Min	Max
PPE Investment$^{\pm}$	350	0.13	0.1	0.12	0	1.12
R&D/Assets	350	0	0	0.01	0	0.05
R&D Expenditure	350	1.45	0	5.65	0	54.4
Leverage$^{\pm}$	350	0.54	0.34	0.8	0.01	11.3
Revenue	350	1244	630	1691	64.6	13335
Employees	350	2516.4	997	6443.09	63	59996
Payroll	350	178	61.1	511	5.11	5504
Market share*	350	2.47	0.37	6.34	0.02	40.3
Return on sales	350	1.16	1.13	0.11	1.01	1.58
Earnings‡	350	752	75.4	7776	5.83	140000
Cash/Assets	346	0.39	0.38	0.19	0.03	0.92
Board size	350	9.23	9	2.09	5	17
Discretionary accruals	340	0.07	0.05	0.14	-0.44	0.62

Note: This table contains summary statistics about all IPOs on the Shenzhen and Shanghai exchanges between 2004 and 2015. Panel 1 contains categorical data about the IPOs for the whole sample. Panel 2 describes continuous IPO data, including the time between IPO approval and listing (delay). †Estimation sample consists of firms approved to IPO in the year before either 2008-9 or 2012-14 suspension. ††IPO underpricing is defined as $\frac{OpeningPrice - OfferPrice}{OfferPrice}$. Currency-denominated variables are in million RMB throughout. Panel 3 contains patent data in year after IPO approval, and Panel 4 contains patent data in subsequent years. Panel 5 describes corporate variables in the year after IPO approval (many variables are unavailable until after IPO). Panel 6 describes corporate variables in the year after IPO. $^{\pm}$Investment and leverage calculated as fraction of total assets. ‡Equivalent to net income, in nominal RMB. *Revenue of firm i in year t scaled by total revenue of industry in year t; Industry is CSRC industry (2 digits if in manufacturing, 1 digit otherwise).

Table 2: T-tests for differences by treatment status

Panel 1: Delay (months approval to listing)

	Control		Treatment			
	N	Mean	N	Mean	Diff†	2-tailed p-value
Delay (months approval to listing)	232	3.23	118	16.3	-13.1	0.00
Mock delay (months approval to listing omitting months during IPO suspensions)	232	3.23	118	3.03	0.20	0.71

Panel 2: Outcome variables in year before IPO approval

	Control		Treatment			
	N	Mean	N	Mean	Diff†	2-tailed p-value
Chinese invention patent applications	232	4.69	118	4.24	0.46	0.70
Granted Chinese invention patents	232	1.98	118	2.04	-0.06	0.94
Citations to Chinese invention patents	232	22.0	118	23.1	-1.08	0.85
Granted global utility patents	232	0.04	118	0.02	0.02	0.35
PPE investment	232	0.15	118	0.14	0.00	0.81
Leverage	232	1.24	116	1.15	0.09	0.57
Revenue	232	1450	118	1769	-319	0.53
Return on sales	232	0.19	118	0.19	0.00	0.97
Earnings	232	172	118	158	14	0.27
Discretionary accruals	232	0.000	118	0.014	-0.01	0.21

Note: This table summarizes t-tests for differences of means across treatment and control groups. We show all variables that we observe in the year before IPO approval. The sample is that used in estimation: firms approved to IPO in the 12 months before an IPO suspension. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, it is 1 for firms approved on or after June 5, 2008 (April 24, 2012).

Table 3: Effect of suspension-induced IPO delay on patent activity

Panel 1: Patents filed in year after IPO approval

Dependent variable:	Chinese invention patent applications		Granted Chinese invention patent applications		Citations to granted Chinese invention patents		Granted global (non-Chinese) utility patents
Model:	Poisson	OLS	Poisson	OLS	Poisson	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated	-.33***	-1.7***	-.22**	-.36*	-.45***	-11**	-.041*
	(.11)	(.59)	(.11)	(.2)	(.17)	(5.1)	(.023)
Controls†	Y	Y	Y	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y	Y
N	350	350	350	350	350	350	350
[Pseudo]-R^2	.14	.14	.1	.13	.2	.11	.072

Note: This panel shows the effect of IPO delay on patenting in the year after IPO approval, within the estimation sample of firms approved in the 12 months before an IPO suspension. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, it is 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

Panel 2: Patents filed in 3rd and 4th years after IPO approval if firm has listed

Dependent variable:	Chinese invention patent applications in 3rd year after IPO approval		Chinese invention patent applications in 4th year after IPO approval	
Model:	Poisson	OLS	Poisson	OLS
	(1)	(2)	(3)	(4)
Treated	-.26*	-1.2**	-.18*	-.91*
	(.14)	(.56)	(.095)	(.5)
Controls†	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y
N	320	320	342	342
[Pseudo]-R^2	.11	.12	.12	.11

Note: This panel shows the effect of IPO delay on patent applications in the 3rd and 4th year after approval conditional on the firm having already listed (that is, comparison is within public firms). Before this restriction, the sample is the estimation sample of firms approved in the 12 months before an IPO suspension. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, is it 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

Panel 3: Patents filed in year of and 2nd years after IPO

Dependent variable:	Chinese invention patent applications in year after IPO		Chinese invention patent applications in 2nd year after IPO	
Model:	Poisson	OLS	Poisson	OLS
	(1)	(2)	(3)	(4)
Treated	-.34***	-1.5**	-.34	-1.4
	(.13)	(.57)	(.24)	(1.4)
Controls†	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y
N	350	350	350	350
[Pseudo]-R^2	.13	.13	.29	.43

Note: This panel shows the effect of IPO delay on patent applications in the year after IPO and 2nd year after IPO, but aligning control firms on the calendar year of the treated firms, so that patents are compared within the same calendar year. This means that control firms are on average further past their IPO than treated firms. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, is it 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

Table 4: Robustness in effect of suspension-induced IPO delay on patenting

Panel 1: Heterogeneity in effect on patent applications in year after IPO approval

Dependent variable: Chinese invention patent applications

Model:	Poisson	OLS	Poisson	OLS	Poisson	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
Treated·State Owned	.26	1				
	(.36)	(2)				
Treated·VC/PE Backed			-.44**	-2.6**		
			(.21)	(1)		
Treated·High Tech					-.085	-.88
					(.27)	(1)
Treated	-.36***	-1.8***	-.065	-.31	-.26	-1
	(.11)	(.58)	(.2)	(.92)	(.25)	(.96)
State Owned	-.075	-.69				
	(.26)	(1.4)				
VC/PE Backed			.41**	2.5**		
			(.17)	(.94)		
Controls†	Y	Y	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y
N	350	350	350	350	350	350
[Pseudo]-R^2	.15	.14	.14	.15	.14	.14

Note: This panel shows the effect of IPO delay on patenting in the year after IPO approval, within the estimation sample of firms approved in the 12 months before an IPO suspension. Treatment is interacted with indicators for the firm being state-owned, VC/PE-backed, and in a high tech industry. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, is it 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

Panel 2: Continuous delay and patent applications in year after IPO approval

Dependent variable: Chinese invention patent applications

				Placebo tests		
			Instrument for delay with approval date	Delay exclusive of suspensions		Excluding pre-suspension periods
Model:	Poisson	OLS	IV (2SLS)	Poisson	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
Delay (months)	-.013*	-.067*	-.12**			-.071
	(.0073)	(.039)	(.059)			(.047)
Mock delay (months)				.012	.064	
				(.014)	(.072)	
Controls†	Y	Y	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y
N	350	350	350	350	350	1199
[Pseudo]-R^2	.14	.13	.13	.14	.13	.11
First stage F-test±			266			

Note: This panel shows the effect of IPO delay on patenting in the year after IPO approval, within the estimation sample of firms approved in the 12 months before an IPO suspension. Columns 1-2 show the effect of continuous delay in months. In column 3, we instrument for continuous delay with the approval date. Columns 4-5 are placebo tests that use "mock" delay that excludes months during the IPO suspensions. Column 6 is a placebo test that uses delay outside of the estimation sample, during periods other than the 12 months before an IPO suspension. †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. ±The Cragg-Donald F-statistic for the excluded instrument (delay) being significantly different from zero. *** indicates p-value<.01.

Panel 3: Placebo tests using pre-approval years

Dependent variable:	Chinese invention patent applications in year before IPO approval		Chinese invention patent applications in 2nd year before IPO approval	
Model:	Poisson	OLS	Poisson	OLS
	(1)	(2)	(3)	(4)
Treated	.032	.051	-.037	-.32
	(.15)	(.74)	(.2)	(1.1)
Controls†	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y
N	350	350	350	350
[Pseudo]-R^2	.28	.53	.24	.42

Note: This panel shows placebo tests of the effect of IPO delay on patent applications in the years before IPO approval. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, is it 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

Table 5: Effect of suspension-induced IPO delay on corporate outcomes

Panel 1: Effect in year after IPO approval

Dependent variable:	PPE investment	Leverage	Revenue	Return on Sales	Earnings	Discretionary accruals
	(1)	(2)	(3)	(4)	(5)	(6)
Treated	-.038***	.23*	-287	-.56***	-14	-.014
	(.013)	(.12)	(2726)	(.094)	(240)	(.015)
Controls	Y	Y	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y
N	350	350	350	350	350	340
R^2	.14	.38	.18	.5	.91	.12

Note: This panel shows the effect of IPO delay on other firm outcomes in the year after IPO approval, within the estimation sample of firms approved in the 12 months before an IPO suspension. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, is it 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

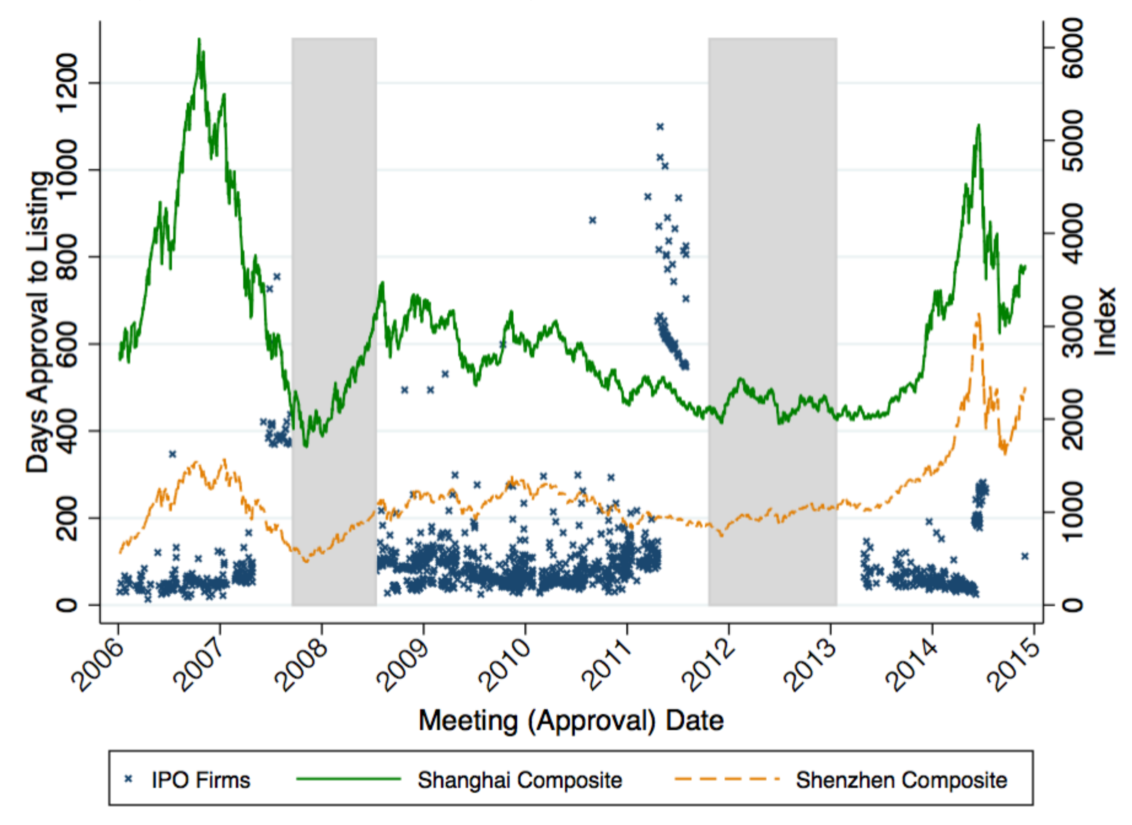
Panel 2: Effect in year after IPO

Dependent variable:	PPE investment	R&D/ assets	Log R&D	Leverage	Revenue	Board size
	(1)	(2)	(3)	(4)	(5)	(6)
Treated	-.011	-.0019	-1.1	-.13	211	.55
	(.018)	(.0012)	(1.9)	(.22)	(5740)	(.37)
Controls	Y	Y	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y
N	350	339	339	350	347	350
R^2	.16	.14	.18	.45	.21	.27

Dependent variable:	Market share	Return on sales	Earnings	Cash/ assets	Discretionary accruals
	(7)	(8)	(9)	(10)	(11)
Treated	.13	.016	-65	.029	.016
	(.26)	(.016)	(721)	(.031)	(.021)
Controls	Y	Y	Y	Y	Y
Industry f.e.	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y
N	345	350	350	335	339
R^2	.46	.33	.24	.34	.16

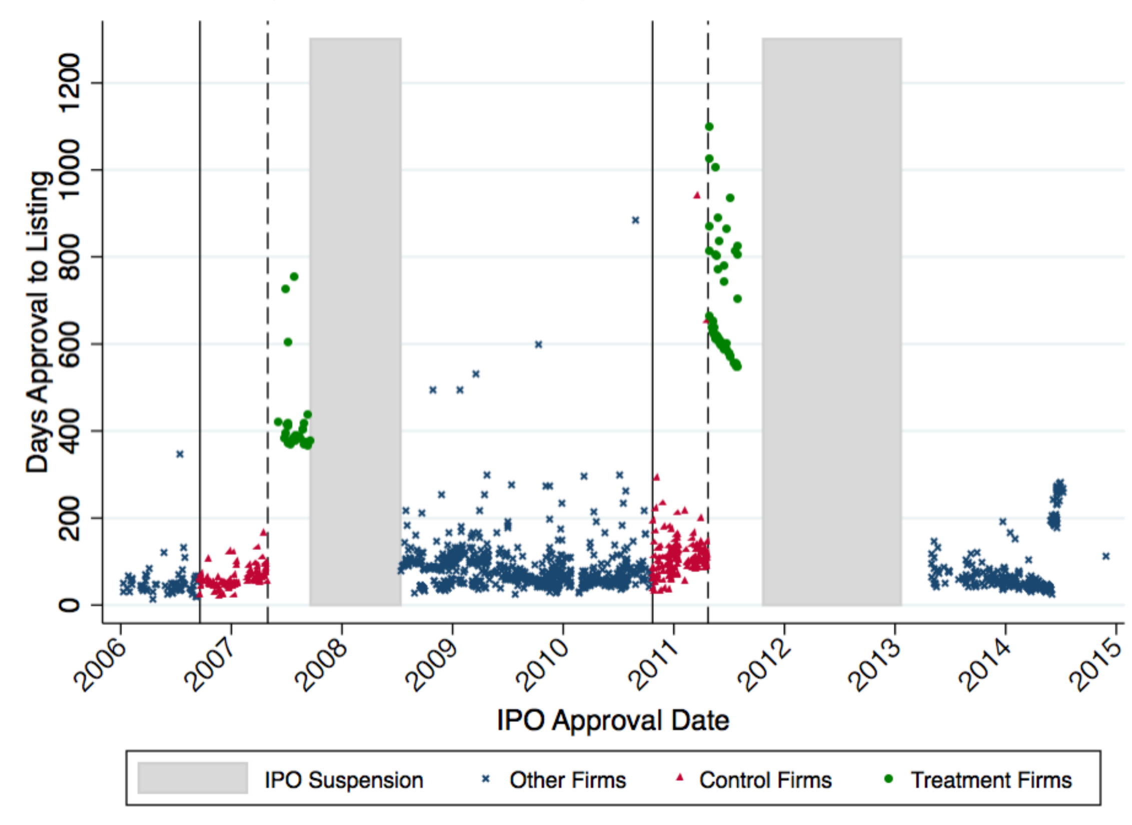
Note: This panel shows the effect of IPO delay on other outcomes in the year after delayed firms IPO, within the estimation sample of firms approved in the 12 months before an IPO suspension. We naively instrument for delay with a "Treated" indicator that is defined by an observed discontinuity in delay. For the 2008-9 (2012-14) suspension, is it 1 for firms approved on or after June 5, 2008 (April 24, 2012). †Controls are revenue, leverage, total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo for Poisson models. Errors clustered by industry-quarter. *** indicates p-value<.01.

Figure 1: IPO Delay and Shanghai and Shenzhen Composite Indices



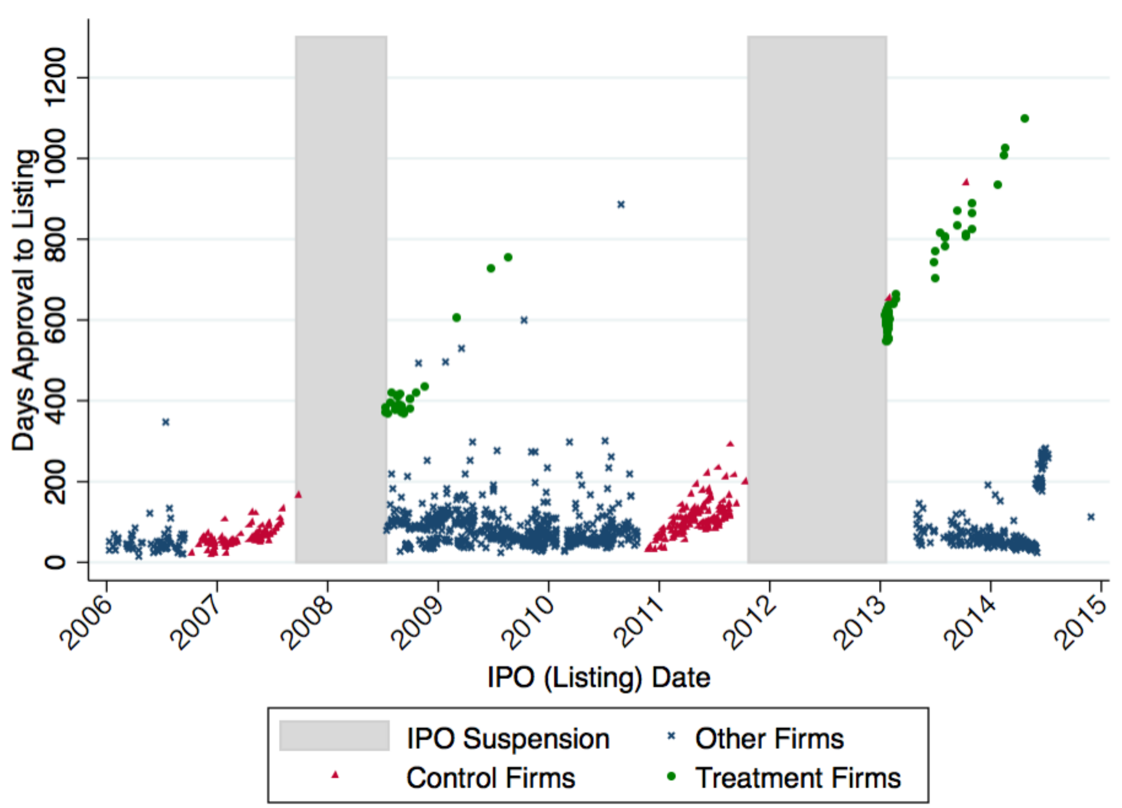
Note: This figure shows the delay (days between IPO approval and listing) for all IPO firms. Each IPO firm is a point. It also shows as lines the Shanghai and Shenzhen composite indices daily close (SHCOMP:IND and SZCOMP:IND in Bloomberg, respectively).

Figure 2: Empirical Design - IPO Approval Date



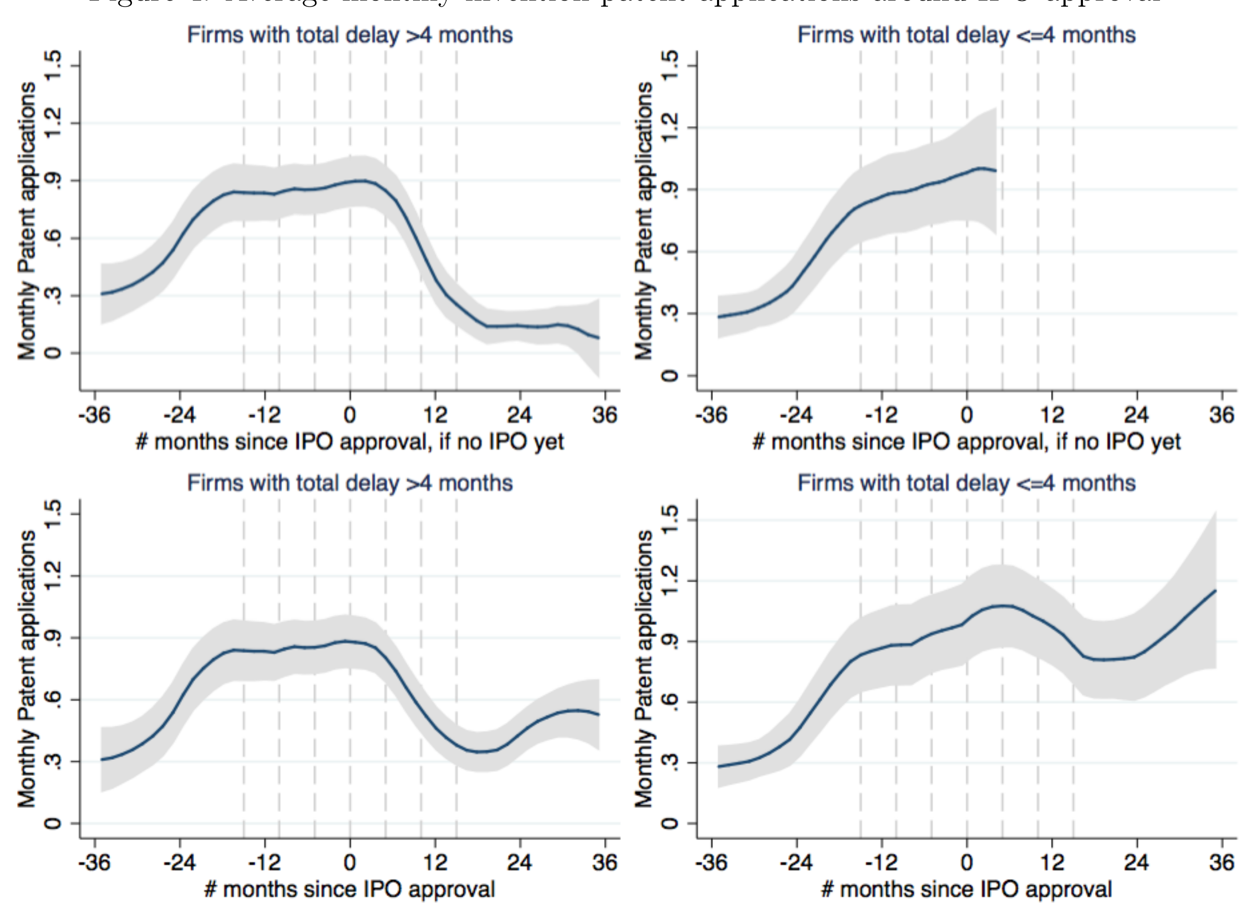
Note: This figure shows the delay (days between IPO approval and listing) for all IPO firms. The x-axis is the date of IPO approval. Each IPO firm is a point. The sample used in analysis (estimation sample) are those firms to the right of the solid vertical lines and to the left of the suspension periods. These are firms approved to IPO in the 12 months before the suspension. They are divided into treatment and control groups based on the observable discontinuity in delay. Red triangles are control firms, and green circles are treated firms.

Figure 3: Empirical Design - IPO Date



Note: This figure shows the delay (days between IPO approval and listing) for all IPO firms. The x-axis is the date of IPO (listing). Each IPO firm is a point. The sample used in analysis (estimation sample) are those firms symbolized by red triangles or green circles. These are firms approved to IPO in the 12 months before the suspension. They are divided into treatment and control groups based on the observable discontinuity in delay. Red triangles are control firms, and green circles are treated firms.

Figure 4: Average monthly invention patent applications around IPO approval



Note: This figure shows Chinese invention patent applications by the month around the committee approval date. We sort firm-months around the month that a firm was approved to IPO. In the top graphs, firms drop out of the sample as they list, and all firms are included at month zero and before. In the bottom graphs, all firms have delay of more than 4 months, but in any given month since IPO approval after the 4th month, some will have listed and some not. We use a local polynomial with Epanechnikov kernel using Stata's optimal bandwidth; 95% confidence intervals shown.

Appendix A to IPO Intervention and Innovation: Evidence from China

(for Online Publication)

Table A.1: IPO Suspensions

Suspension start - end	Rationale	Details
Dec 15, 2008 to July 10, 2009	Global Financial crisis and prolonged decline in market index.	The United States Subprime Mortgage Crisis triggered the international financial crisis, which resulted in a record low of 1802.33 points of A shares on September 18th, 2008. Under this context, the IPOs witnessed a suspension again.
Nov 2, 2012 to Jan 17, 2014	Bearish aggregate market conditions	Bearish market conditions despite the fact that indexes in Europe and in the US are performing well; CSRC started the biggest inspection of financial reporting for IPO firms.

Note: Sourced from CSRC Officially Designated Media Outlet. Hou and Zhu, "A Review of China IPO Suspensions", Security Daily, June 19 2013, Published: A3, retrieved from here. See also Finance Daily, here.

Table A.2: T-tests for differences by sample status (firms approved in year before suspensions vs. all other firms)

Panel 1: Delay (months approval to listing)

	Outside estimation sample		Estimation sample			
	N	Mean	N	Mean	Diff†	2-tailed p-value
Delay (months approval to listing)	1208	3.31	350	7.65	-4.35	0.00
Mock delay (months approval to listing omitting months during IPO suspensions)	1208	3.36	350	3.16	0.19	0.48

Panel 2: Outcome variables in year before IPO approval

	Outside estimation sample		Estimation sample			
	N	Mean	N	Mean	Diff†	2-tailed p-value
Chinese invention patent applications	1208	2.21	350	4.54	-2.33	0.00
Granted Chinese invention patents	1208	0.69	350	2.00	-1.31	0.00
PPE investment	1208	0.12	350	0.14	-0.02	0.00
Leverage	1208	1.37	350	1.42	-0.05	0.77
Revenue	1208	1610	350	2194	-584	0.20
Return on sales	1208	0.17	350	0.19	-0.01	0.22
Earnings	1208	147	350	195	-48.0	0.05
Discretionary accruals	1208	0.02	350	0.00	0.01	0.03

Note: This table summarizes t-tests for differences of means across the estimation sample and all IPOs outside of the estimation sample. We show all variables that we observe in the year before IPO approval. We do not have citation or global patent data outside of the estimation sample, so they are not included.

Table A.3: Effect of IPO and delay on monthly patent citations after IPO approval, comparing listed and unlisted firms (Bernstein comparison)

Sample: Firm-months in the 36 months after IPO approval

Dependent variable: Citations to granted Chinese invention patents

	(1)	(2)
Public (=1 if month is in or after IPO month)	-.69***	-1.7***
	(.16)	(.25)
Delay so far (months) (=total delay once Public=1)		-.13***
		(.018)
Controls†	Y	Y
Industry f.e.	Y	Y
Quarter of approval f.e.	Y	Y
N	14586	14586
R^2	.042	.047

Note: This table shows the effect of being public and delay so far on patent quality using monthly patent data and a negative binomial model †Controls are total investment that year, age, market cap, IPO proceeds, and indicators for being state-owned, VC-backed, and the exchange (SH/SZ). The R^2 is pseudo. Errors clustered by firm. *** indicates p-value<.01.

Appendix B to IPO Intervention and Innovation: Evidence from China
(for Online Publication)

Market Uncertainty Test: Effect on Contemporaneous VC

Our model predicts that if the suspensions generated uncertainty in the market about the future of IPOs in China, they would have depressed contemporaneous VC investment. VC returns depend on IPOs for liquidity events. During a suspension, investors who believed China's IPO market could be jeopardized in the medium term, perhaps through a change in IPO regulations or stringent future restrictions on the number of IPOs, might be expected to reduce investment activity. Anecdotal evidence suggests this occurred. According to a KPMG/CB Insights report following the 2012-2014 IPO suspension,

> "There are approximately 800 companies still waiting for IPO listing approvals in China. This has affected the overall deal flow, particularly for Series B and C investors considering their exit strategies" (Insights 2016).

Conversely, if the suspensions were perceived as short term hiatuses, we would not expect an effect. This is because VC investments are typically illiquid and held for three to ten years.

B.1 Empirical Approach

We are interested in the effect of an IPO suspension on VC investment. This exercise relates to Gompers, Kovner, Lerner & Scharfstein (2008), who document that VCs react rationally to public market signals about fundamentals. In Equation 3 below, we estimate an association between periods of IPO suspension and contemporaneous VC, using data at monthly and weekly frequencies. Controlling for the market indices, as well as VC investment in the rest of the world (outside mainland China), help give the coefficient of interest on the indicator for an IPO suspension being in effect (β_1) a more causal interpretation. Nonetheless, a conservative interpretation is to view the specification as testing for correlation.

Specifically, the dependent variable is either the amount or number of deals of early or later stage VC investment. Controls include either the Shenzhen and Shanghai (SZ and SH, respectively) indices, or an overall China market index. We also control for PCRI's rest-of-world VC investment at the relevant stage (early or late). Let $1 \mid IPO\ Suspension_t$ be an indicator for the IPO market being suspended in month or week t.

$$VC\ China_t = \alpha + \beta_1 \left(1 \mid IPO\ Suspension_t\right) + \gamma_1 SH\ Index_t + \gamma_2 SZ\ Index_t + \gamma_3 VC\ ROW_t + \varepsilon_t \quad (4)$$

Disturbances are likely autocorrelated, leading to underestimated standard errors. Therefore, our preferred approach uses heteroskedasticity and autocorrelation consistent (HAC) standard errors (specifically, Newey-West errors). Note that this analysis is one of correlation, not causation. The suspensions themselves were not exogenous to Chinese economic conditions. For example, it may be that during IPO suspensions it is more difficult for private equity investors to fundraise from limited partners. While we control for the market index and show similar results for elite U.S. VCs who likely do not face such fundraising cycles, we cannot rule out this channel.

B.2 Results

We find a correlation between the suspension periods and depressed VC investment in China. Figure 12 (13) shows later stage VC in in mainland Chinese (rest-of-world) portfolio companies. Appendix Figures B.1-4 show weekly frequencies and investment in real 2010 RMB. The negative correlation between suspension periods and VC investment in China is obvious, especially for the 2012-14 suspension.

Table B1 confirms this visual evidence in regression estimates, using versions of Equation 4. In Panel 1, the dependent variable is weekly early stage VC investment in nominal USD. Columns 1-3 use Newey-West standard errors with an optimal lag. While a naive regression (column 1) has a strong negative coefficient on the indicator for months in which an IPO suspension was in effect, the coefficient falls and loses significance with controls for market indices and VC investment in the rest of the world (columns 2 and 3). With less stringent error assumptions (columns 4 and 5), these effects are significant at the 10% level, and imply that the suspensions reduce weekly early stage investment by about $25 million, relative to a mean of $74 million. We are surprised to find evidence of any effect at all on early stage VC investment, as these investments are illiquid and typically held for 3-8 years (Gompers & Lerner 2004).

There is a much stronger relationship for later stage investment. In our more stringent specifications (Table B1 panel 2 columns 2-3), we find that the suspensions appear to reduce weekly later stage investment by about $53 million, relative to a mean of $181 million, significant at the 5% and 1% levels, respectively. Excluding the 2009 suspension (which was associated with the global financial crisis) leads the coefficients to increase to -$64 million. We find similar results for both early and late stage investment using real 2010 RMB, and using monthly rather than weekly data.

We turn to investment by the location of the VC firm in Table B2. Panel 1 considers investment by China-located general partners (GPs) only, and continues to find the reduction in investment, particularly for later stage investment. The aggregate correlations we measure could arise from a capital supply shock; GPs may have more difficulty raising funds during suspensions and so reduce their contemporaneous investment. If this were the case, we would not expect elite foreign firms' investments in China to be affected by the suspensions. They presumably have greater access to capital in general, and their access to capital should be less sensitive to Chinese markets in particular. In Appendix Table B.2 panel 2, the dependent variable is the number of VC deals in Chinese companies by elite U.S. VCs active in China. As the PCRI data do not include GP-level investments, we constructed this time series using data from pedata.cn, which is only available from 2005. The sample is thus smaller. Even so, columns 1-2 suggest that IPO suspensions decrease the number of elite U.S. VC deals in China by a bit more than three deals, relative to a mean of 63.5. However, this effect is less robust than the results in Table 10.

We conduct several robustness tests in Table B3. First, a placebo test in columns 1-2 examines the effect of the suspensions on VC investment outside of China. As expected, we find no statistically significant effect, though the coefficients are negative. In columns 3-6, we confirm our main results using the alternative data source, pedata.cn, which is only available from 2005. We continue to find a strong reduction in overall and later stage VC investment, of about 26 deals relative to a mean of 152. We confirm that the result is specific to VC in Table B4, where we show no effect of the suspensions on monthly aggregate bank lending.

In sum, this analysis suggests that the suspensions created uncertainty about the overall regulatory environment and the future of IPOs in China, and had a chilling effect on VC investment.

Table B.1: IPO Suspensions and Contemporaneous VC Investment

Panel 1: Early Stage VC Investment

Dependent variable: Weekly early stage VC investment in Chinese portfolio companies*

						Excluding 2009 suspension	
Standard error model:		Newey-West		Robust		NW	Robust
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
IPO suspension in effect	-67***	-26	-25	-26*	-25*	-27	-27*
	(18)	(17)	(15)	(15)	(14)	(20)	(16)
Shenzhen index†		.37***		.37***		.37***	.37***
		(.061)		(.054)		(.062)	(.054)
Shanghai index†		-.084***		-.084***		-.084***	-.084***
		(.02)		(.019)		(.021)	(.019)
China index††			.11***		.11***		
			(.022)		(.014)		
VC inv. rest of world‡		-.0034	-.0016	-.0034*	-.0016	-.0044	-.0044*
		(.0024)	(.0026)	(.0021)	(.0023)	(.0028)	(.0024)
N	960	860	915	860	915	820	820
R^2	.0053	.12	.066	.12	.066	.12	.12

Panel 2: Later Stage VC Investment

Dependent variable: Weekly later stage VC investment in Chinese portfolio companies*

						Excluding 2009 suspension	
Standard error model:		Newey-West		Robust		NW	Robust
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
IPO suspension in effect	-111***	-56**	-53***	-56***	-53***	-64**	-64***
	(23)	(24)	(20)	(17)	(15)	(28)	(19)
Shenzhen index†		.45***		.45***		.46***	.46***
		(.093)		(.095)		(.094)	(.096)
Shanghai index†		-.038		-.038		-.04	-.04
		(.028)		(.03)		(.029)	(.03)
China index††			.22***		.22***		
			(.032)		(.029)		
VC inv. rest of world‡		-.0014	.0005	-.0014	.0005	-.00079	-.00079
		(.0072)	(.0063)	(.0076)	(.0067)	(.0093)	(.0099)
N	960	860	915	860	915	820	820
R^2	.012	.2	.17	.2	.17	.2	.2

Note: This table shows OLS estimates of the relationship between VC investment and IPO suspensions, using variants of: $VC_m = \alpha + \beta_1 (1 \mid IPO\ Suspension_m) + X_m + \varepsilon_m$. *Data from PCRI; nominal USD value of early stage VC investment in mainland China companies. †Monthly average of daily closing price for Shenzhen/Shanghai composite. ††Monthly overall China market index. ‡Monthly VC investment in all portfolio companies located outside of China (source: PCRI). Newey-West standard errors, with optimal lag of 4 (identified using lag order selection statistics via Stata's varsoc command). *** indicates p-value<.01.

Table B.2: Effect of IPO Suspensions on Contemporaneous Investment by China-located VCs and top US VCs

Panel 1: China-Located VCs; all models use Newey-West standard errors

Dependent variable:	Monthly # VC deals by mainland China GPs[††]	Monthly VC investment (USD) by mainland China GPs[††]		
		Early stage	Later stage	All Excluding 2009 suspension
	(1)	(2)	(3)	(4)
IPO suspension in effect	-1.4*	-81	-146***	-37*
	(.76)	(52)	(53)	(19)
Shenzhen index[†]	.0053	1.3***	1.2***	.18*
	(.0043)	(.22)	(.2)	(.092)
Shanghai index[†]	.00026	-.27***	-.19***	-.017
	(.0013)	(.067)	(.064)	(.028)
N	222	222	222	212
R^2	.08	.52	.56	.11

Panel 2: Elite US VCs active in China; all models use Newey-West standard errors

Dependent variable: Monthly # VC deals in mainland Chinese companies by elite US VCs[‡]

				Excluding 2009 suspension
	(1)	(2)	(3)	(4)
IPO suspension in effect	-3.3*	-3.8*	-3.4	-2.2
	(1.9)	(2.2)	(2.3)	(2.1)
Shenzhen index[†]	.015***			.015***
	(.0041)			(.0042)
Shanghai index[†]	-.0042***			-.0039***
	(.0014)			(.0014)
China index[††]		.002	.0023	.002*
		(.0012)	(.0015)	(.001)
Monthly # VC deals by top US VCs in US companies			.039	
			(.047)	
N	127	127	124	117
R^2	.27	.092	.1	.125

Note: This table contains OLS regression estimates of the relationship between VC investment and whether the government has suspended IPOs. Data is monthly. We use variants of: $VC_m = \alpha + \beta_1 (1 \mid IPO\ Suspension_m) + X_m + \varepsilon_m$. [†]Monthly average of daily closing price for the Shenzhen/Shanghai composite index. [††]Data from PCRI. [‡]Data from pedata.cn (sample smaller as data starts in 2005). Newey-West standard errors, with optimal lag of 4 (identified using lag order selection statistics via Stata's varsoc command). *** indicates p-value<.01.

Table B.3: Robustness Tests of Effect of IPO Suspensions on Contemporaneous VC Investment, Newey-West Standard Errors

	Placebo test		Alternative data source: Monthly number of VC deals in China*			
Dependent variable:	VC investment rest of world‡		Total	By mainland GPs	Early stage	Later stage
	(1)	(2)	(3)	(4)	(5)	(6)
IPO suspension in effect	-1119	-1147	-29*	-31*	-2.7	-26**
	(1426)	(1408)	(15)	(18)	(8.3)	(11)
Shenzhen index	-2.1		.18***	.29***	.11***	.082***
	(3.1)		(.034)	(.043)	(.021)	(.021)
Shanghai index	3.1		-.051***	-.094***	-.035***	-.019***
	(2.1)		(.009)	(.011)	(.0061)	(.0065)
China index		2.7**				
		(1.2)				
N	222	234	127	127	127	127
R^2	.043	.037	.42	.49	.4	.29

Note: This table contains OLS regression estimates of the relationship between VC investment and whether the government has suspended IPOs. Data is monthly. We use variants of: $VC_m = \alpha + \beta_1 (1 \mid IPO\ Suspension_m) + X_m + \varepsilon_m$. *Data from pedata.cn. This variable is the monthly number of VC deals in mainland Chinese portfolio companies. ‡Monthly VC investment (nominal USD) in all portfolio companies located outside of China (source: PCRI). Newey-West standard errors, with optimal lag of 4 (identified using lag order selection statistics via Stata's varsoc command). *** indicates p-value<.01.

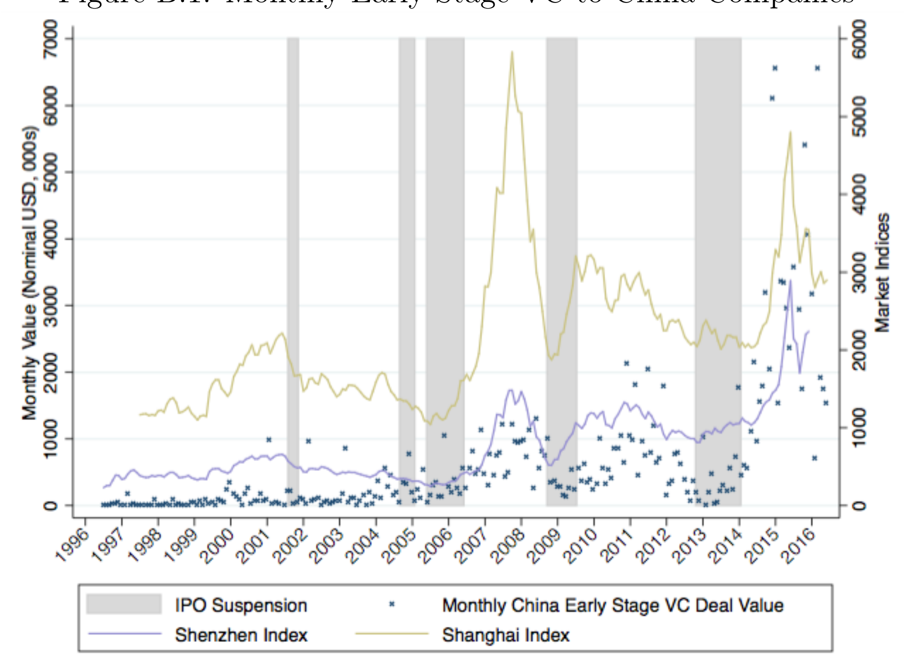
Table B.4: Effect of IPO Suspensions on Contemporaneous Monthly Aggregate Bank Lending to Non-Financial Firms, Newey-West Standard Errors

Dependent variable: Monthly aggregate bank lending to non-financial firms in China*

	(1)	(2)
IPO suspension in effect	1358.68	1234.41
	(825.68)	(822.80)
Shenzhen index†	2.166***	
	(.602)	
Shanghai index†	-1.216***	
	(.265)	
China index††		-0.544.
N	108	108
R^2	.16	.07

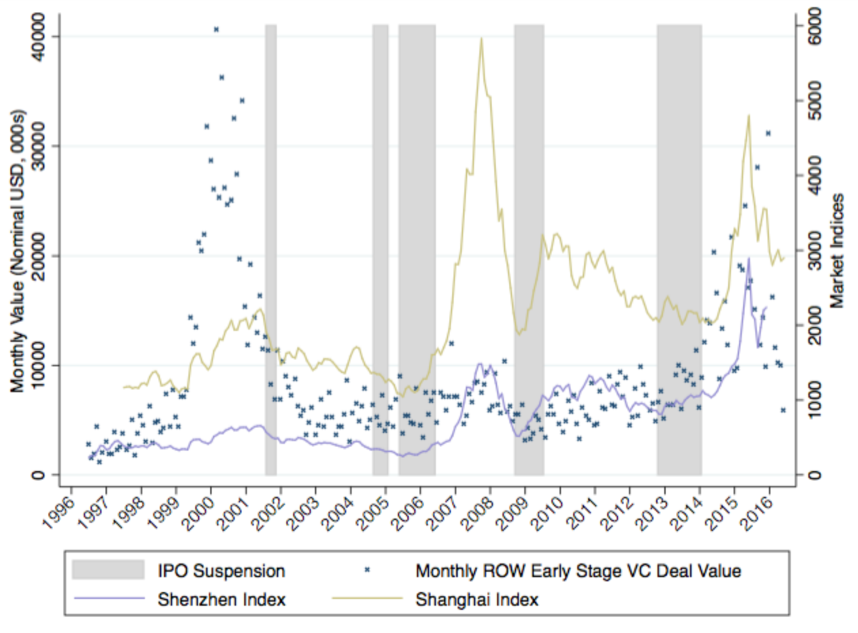
Note: This table contains OLS regression estimates of the relationship between bank lending and whether the government has suspended IPOs. Data is monthly. We use variants of: $VC_m = \alpha + \beta_1 (1 \mid IPO\ Suspension_m) + X_m + \varepsilon_m$. *Data from WIND; this variable is the value in nominal USD †Monthly average of daily closing price for the Shenzhen/Shanghai composite index. ††Monthly overall China market index, based on Shanghai and Shenzhen indices. Newey-West standard errors, with optimal lag of 4 (identified using lag order selection statistics via Stata's varsoc command). *** indicates p-value<.01.

Figure B.1: Monthly Early Stage VC to China Companies



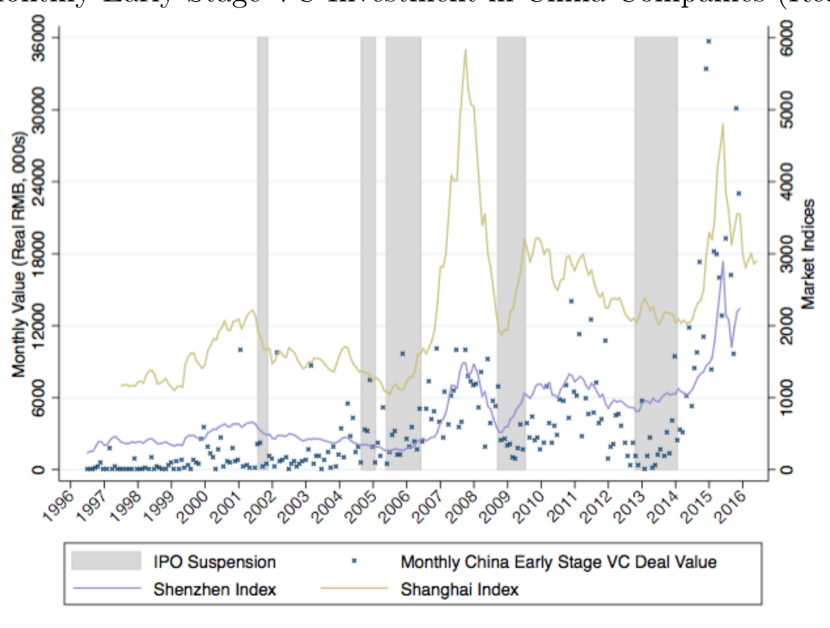
Note: Each point is the monthly value of VC investments in mainland China-based portfolio companies in nominal USD. Only seed and early stage VC investment included.

Figure B.2: Monthly Early Stage VC to Non-China (Rest of World) Companies



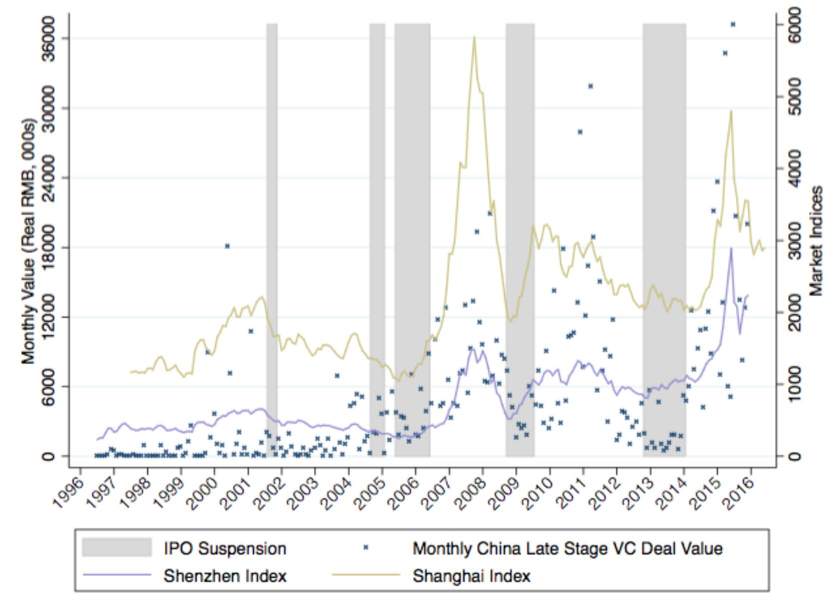
Note: Each point is the monthly value of VC investments in non-China-based portfolio companies in nominal USD. Only seed and early stage VC investment included.

Figure B.3: Monthly Early Stage VC Investment in China Companies (Real 2010 RMB)



Note: Each point in this figure is the total value of VC investments in China-based portfolio companies in a given month in real 2010 RMB. Only seed and early stage VC investment included.

Figure B.4: Monthly Later Stage VC Investment in China Companies (Real 2010 RMB)



Note: Each point in this figure is the total value of VC investments in China-based portfolio companies in a given month in real 2010 RMB. Only growth/expansion stage VC investment included.