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Abstract: Monitoring by institutional investors can act as an important mechanism to promote firm innovation. By investigating Chinese listed firms' patenting between 2002 and 2011, we find that the presence of institutional investors enhances firm innovation. Consistent with the monitoring view, we further find that (1) the effect of institutional investors on firm patenting mainly comes from mutual funds; (2) the effect is more pronounced when market competition is more intense; (3) the effect exists among private- and minor state-owned enterprises, but not among major state-owned enterprises. The above findings are robust when innovation quality is examined.

Keywords: Institutional investor; Firm innovation; Patenting; Mutual funds; China

JEL code: G20, G32, O31, O32, O33

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1. Introduction

Ownership structures play an important but complicated role in the innovation of listed firms, which account for a large proportion of private R&D (research and development) expenditures. On the one hand, listed firms have a natural advantage in innovation because the high risk associated with innovation can be well spread across a large number of shareholders. On the other hand, due to dispersed ownership, innovation in listed firms may be stunted due to agency problems. For example, since innovation activities are associated with high risks, the concern about being fired when innovation fails might discourage managers from investing in R&D (Kaplan and Minton, 2006; Aghion et al., 2013). Meanwhile, another agency problem emerges in some transition economies such as China where state ownership remains a strong element of corporate governance. Managers in state-owned enterprises (SOEs) have weak incentives to enhance firms' competitiveness through innovation as these public employees cannot privatize the profits but have to bear the costs of R&D, such as innovation risks and outraged laid-off workers (Megginson, 2005). With the presence of the state as a shareholder, the influence of ownership structures on listed firms' innovation is further complicated. This paper focuses on a specific force of external governance on innovation—the ownership by institutional investors—and its interaction with state ownership by examining Chinese listed firms' patenting between 2002 and 2011.

The relationship between institutional ownership and firm innovation has been examined and found to be positive by several studies on US listed firms (e.g., Francis and Smith, 1995; Bushee, 1998; Eng and Shackell, 2001; Aghion et al, 2013). However, such a relationship is rarely examined in a transition economy, where ownership structures of

listed firms are substantially different from those in developed economies. Unlike US listed firms, which are characterized by dispersed ownership and well-developed institutional investors, Chinese listed firms are characterized by concentrated ownership (e.g., state ownership) and an emergence of institutional investors.[2] This paper contributes to the literature by documenting the relationship between institutional ownership and firm innovation in China, which is the largest emerging economy in the world.

On average, state shares are about one-third of total shares for Chinese listed firms. The predominance of state ownership in China results in the coexistence of two types of listed firms, SOEs and non-SOEs. There has been evidence consistent with Megginson's (2005) argument that SOE managers have weak incentives to innovate (e.g., Hu and Jefferson, 2009; Lin et al., 2010; Boeing et al., 2016). However, it is so far unclear, both theoretically and empirically, how state ownership affects the relationship between institutional ownership and firm innovation, and through which channel if it is effective. This paper attempts to fill this gap.

As discussed in the literature, active monitoring by institutional investors can act as an important mechanism to promote firm innovation. We expect that this positive effect should be more pronounced in China, where the scattered shares that institutional investors (e.g., mutual funds) pool together used to be held by individual investors, who generally free ride on monitoring. To further motivate our research, we turn to the "career concern" hypothesis, first proposed by Holmstrom (1999) and then tested by Aghion et al. (2013). Specifically, CEOs may be concerned that once involved in innovation they will

[2] Similar to other transition economies, China's institutions are under-developed. Despite its startling economic growth, China is one of the worst countries regarding property rights protection (La Porta et al., 2004).

expose themselves to the risk of being fired for innovation-related stochastic reasons. Active monitoring by institutional investors may help to identify these stochastic reasons, thereby motivating CEOs to innovate (Aghion et al., 2013).

We postulate that compared to non-SOEs, the manager market of SOEs is less competitive due to the bureaucratic arrangement in the SOE system. Ranked as government officers, the appointment of CEOs in SOEs is very selective, and the candidates generally come from current government officers and SOE top management. Given a relatively small pool of qualified candidates, CEOs in SOEs may still hold leading positions even though they are not qualified for business administration. According to the career concern view, the incentives of institutional investors for active monitoring should be reduced since firing an unqualified CEO is a major benefit of monitoring, and this benefit vanishes when it is unlikely that such a CEO can be replaced. We thus postulate that the positive effect of institutional ownership on firm innovation should be weakened when the manager market is less competitive as in the case of the SOE manager market.

To generate a convincing proxy for the extent of firm innovation, we collect listed firms' patenting records. It is well acknowledged that patents are heterogeneous in quality. We address the quality issue in two ways. First, to generate firms' patent counts, we only count invention patents, which have the highest standards of novelty and technological inventiveness among the three types of patents granted by the SIPO (State Intellectual Property Office) of China. Second, we turn to forward citations to measure the quality of innovation output.

By regressing listed firms' patent counts on one-year lagged institutional ownership

with control for other influential factors as well as year and industry fixed effects, we find that the effect of institutional ownership is significantly positive. The relationship persists when we control for R&D investment, suggesting that the effect of institutional ownership is mainly through improving the R&D productivity. By examining different types of institutional investors, we further find that the positive effect of institutional ownership is attributed to mutual funds but not to the remaining domestic institutional investors. It is consistent with Chen et al.'s (2007) finding that "independent" institutional investors such as mutual funds tend to collect information and do active monitoring. Moreover, we find that the effect of QFII (Qualified Foreign Institutional Investor) ownership is positive, but it relies on the presence of mutual funds.

Our study is less subject to endogeneity issues compared to the US case. As a developed economy, in the US institutional ownership is already stabilized, and its variations largely result from institutional investors' portfolio adjustment. In contrast, as a transition economy, in China institutional ownership increased from only around 1% in 2001 to over 25% in 2010, and the surge was largely policy driven. To further mitigate the endogeneity concern, we show that even the exogenous increase in a firm's institutional ownership following its inclusion into the stock index has a positive effect on patenting. It is particularly so for mutual fund ownership. Additionally, the positive effect persists when we address the endogeneity problem by using firms' "internal instruments" based on GMM (Generalized Method of Moments) estimations. Overall, we confirm a causal and positive relationship from institutional ownership, particularly mutual fund ownership, to firm patenting.

Competition tends to increase innovation risks, thus making CEOs more concerned

about their career when carrying out innovation projects. The career concern hypothesis thus predicts a stronger effect of mutual funds on firm innovation when market competition becomes intensified. Consistently, we find that the effect of mutual funds on firm patenting is more pronounced when market competition is more intense.

Further examinations reveal that the positive effect of mutual funds on firm patenting is more pronounced among POEs (firms with zero state ownership) than that among either minor SOEs (firms with positive state ownership but not more than 50%) or major SOEs (firms with state ownership greater than 50%). Moreover, all our major results persist when we use citation counts instead of patent counts to measure firms' innovation output. Particularly, while mutual funds have a weak impact on the quantity of innovation (i.e., patent counts) produced by major SOEs, we find that there is no impact on these firms' actual quality of innovation (i.e., citation counts). Overall, we conclude that mutual funds enhance firm innovation both quantitatively and qualitatively for Chinese POEs and minor SOEs, but not for major SOEs.

We regard our study as an important complement to studies on institutional ownership and firm innovation. It contributes to this strand of literature in three ways. First, instead of a developed economy, we provide new evidence on the positive relationship in a transition economy. Second, by examining POEs, minor SOEs, and major SOEs separately, we highlight the important role that the competitiveness of the manager market plays on firm patenting through the career concern channel. Third, we are among the first to document the heterogeneous effects of different types of institutional investors (i.e., mutual funds, QFIIs, and other domestic institutional investors) on firm patenting.

This paper is closely related to the burgeoning literature on corporate governance and

firm innovation in China. By examining Chinese listed firms for 2001-2004, Choi et al. (2011) find that foreign ownership and business affiliation are positively related to firm patenting. In a similar vein, Shapiro et al. (2015) investigate small and medium enterprises (SMEs) in China and find that corporate governance and ownership are significantly associated with firm patenting. So far, the causality is not well established. This paper attempts to fill the gap by using a more updated and representative sample of listed firms, compared to earlier research. Additionally, our study explores the relationship between institutional ownership and firm innovation more rigorously and allows for a more causal interpretation.

This paper also enriches the literature on state ownership and firm innovation in China. Consistent with Megginson (2005), Hu and Jefferson (2009) document that patenting propensities are much lower in SOEs than private firms; Lin et al. (2010) find that government ownership and its intervention in CEO appointments are negatively associated with firms' R&D activities; Boeing et al. (2016) show that POEs obtain higher productivity returns from R&D than SOEs. Our study shows that the positive effect of institutional ownership on firm innovation barely exists among major SOEs, suggesting that major SOEs may further stunt their competitiveness improvement by insulating external governance from monitoring.

This paper also contributes to the literature on innovation activities among listed firms in China. Studies using patent data in China are limited (Guan and Yam, 2015; Dang and Motohashi, 2015; Xie and Zhang, 2015), especially regarding listed firms (e.g., Boeing 2016; Boeing et al. 2016; Choi et al., 2011). It may be because obtaining innovation-related information (e.g., information on R&D and patenting activities)

requires the matching of different data sources. Compared to the previous literature, our patenting measure is more comprehensive in the sense that we use both patent counts and citation counts to measure firms' innovation output.

The rest of the paper is organized as follows. Section 2 reviews prior literature and formulates our hypotheses. Section 3 describes the data. Section 4 shows the empirical results. Section 5 discusses policy implications. Section 6 concludes.

2. Literature review, institutional background, and hypothesis development

In this section, we first review the literature on institutional investors and firm innovation. Then, we introduce the background of China's economic transition by highlighting its special corporate governance within SOEs and its underdeveloped stock market. Last, we develop hypotheses by taking into account these special conditions.

2.1. Institutional investors and firm innovation

Characterized as highly risky, long-term, and complex, firms' innovation activities tend to be poorly performed because corporate governance is generally not well designed to reflect these characteristics. Different from conventional projects, R&D projects are associated with high uncertainty and take multiple stages to succeed. Therefore, optimal incentive contracts motivating top managers to innovate should tolerate their early failure and share firms' long-term success with them (Manso, 2011; Ederer and Manso, 2013). Since motivating innovation requires special incentive contracts, innovation activities may be poorly performed when the focus is to motivate a firm's routine activities (Holmstrom, 1999). Another major difference of R&D projects from conventional ones is their heterogeneity (Hall, 1992), which makes it more difficult for outside investors to

estimate their potential value. Subsequently, when deciding whether to start an R&D project, top managers take into account not only its contribution to the firm's long-term performance but also the difficulty of acceptance by the market due to its low visibility.

Theoretically, institutional investors, acting as an important force of corporate governance, can influence firm innovation in both directions. On the one hand, institutional investors may impede firm innovation. Stein (1988) suggests that constant pressures on delivering good short-term performance may result in managers avoiding long-term projects. Ferreira, Manso and Silva (2014) argue that the stock market may force managers to choose projects that are more visible to investors; consequently, managers may forgo R&D projects and instead adopt conventional projects. Such managerial short-termism can be further deteriorated by institutional investors acting as speculators, who care little about firms' long-term performance. As documented by Bushee (1998, 2001), short-term-focused institutional investors can force managers to sacrifice innovation for better short-term performance.

On the other hand, institutional investors may promote innovation. Compared to individual investors, institutional investors are more sophisticated and more capable of tolerating the heterogeneous risks from R&D projects by holding diversified portfolios. By pooling the scattered shares from these individual investors, institutional investors with larger ownership have more incentives to actively monitor as well as to collect costly but valuable information (Shleifer and Vishny, 1986). Particularly, there are two possible channels through which institutional investors motivate CEOs to invest more in innovation.

One possible channel is that when innovation is not fully motivated by incentive

contracts, institutional investors encourage firm innovation by insuring CEOs against the early failure of innovation projects (the "career concern view"). Specifically, a CEO may be concerned that once involved in innovation he will expose himself to the risk of being fired for innovation-related stochastic reasons (Holmstrom, 1999; Manso, 2011; Ederer and Manso, 2013). Active monitoring by institutional investors can identify these stochastic reasons, thereby motivating the CEO to innovate (Aghion et al., 2013).

The other possible channel is that CEOs prefer a quiet life, which can be regarded as a "rent seeking" activity (Hart 1983; Bertrand and Mullainathan, 2003), but institutional investors force them to innovate (the "rent seeking view"). Hicks (1935) regards a quiet life as a monopoly rent, in which CEOs tend to avoid difficult decisions and costly efforts in the absence of efficient governance. Since innovation needs extra efforts and intelligence, it is reasonable to expect that CEOs have incentives to shirk. By active involvement in a firm's daily management activities, institutional investors can force the CEO to put more efforts on innovation activities (Hart, 1983).

Empirically, the relationship between institutional ownership and firm innovation has been examined by several studies on US listed firms, and it is generally found positive (e.g., Francis and Smith, 1995; Bushee, 1998; Eng and Shackell, 2001; Aghion et al, 2013). Francis and Smith (1995) show that ownership concentration (including institutional investors) is positively associated with R&D expenditures. Eng and Shackell (2001) document a positive relationship between institutional ownership and R&D. Bushee (1998) finds that firms with higher institutional ownership are less likely to cut R&D following poor performance. Aghion et al. (2013) show that institutional ownership positively influences firms' patenting by mitigating CEOs' career concerns. They also

discover that this positive effect is more pronounced when product market competition is more intense. However, such a relationship is rarely examined in a transition economy, where stock markets and ownership structures of listed firms are substantially different from the US as well as other developed economies.

2.2. Background of China's economic transition

2.2.1. SOE reform

In the pre-reform planned economy, China's industry was dominated by SOEs, which acted as units of fulfilling production quotas rather than pursuing profits. In terms of choosing SOE top managers, Groves et al. (1995) provide the following discussion:

> "Enterprise managers were hired and fired by officials in the industrial bureaus, which were in turn organized into sectoral and geographical divisions. The entire industrial system was accountable to a national or regional planning commission, which steered the entire system through a complex system of highly specific commands that extended all the way down the hierarchy to managers at the plant level. Authority relations were complicated by the intrusive role of the Communist Party, which functioned more or less as the personnel department of this enormous corporation, maintaining dossiers and tracking managerial careers."

Since 1978, SOEs have gone through two major reforms to meet China's transition towards a market economy. In the first stage, the responsibility contract was introduced into SOEs, which increased managers' incentives while keeping the state ownership untouched (see Groves et al., 1995). In the second stage, following the policy of "grasping the large and letting go of the small (*Zhuada Fangxiao*)", since 1997 large SOEs have been corporatized and small ones have been privatized or closed (see Hsieh

and Song, 2015). Some of these large SOEs become partially privatized by selling shares to individual investors through IPOs (initial public offerings). These listed firms were generally carved out from an existing SOE, which retained a substantial proportion of shares.[3]

Despite these reforms, the system of choosing SOE managers has barely changed. Listed SOEs still satisfy the major characteristics proposed by Shleifer and Vishny (1997) well; that is, SOEs are controlled by government officers who have strong control rights but no significant cash flow rights. Two major differences from the pre-reform period are that industrial bureaus, which were in charge of managing SOEs, no longer exist, and SOEs have become more profit oriented.

Instead of industrial bureaus, SOEs are now managed by other bureaucratic agencies, such as the SASAC (State-Owned Asset Supervision and Administration Commission). Representing the interest of the state as shareholders (Naughton, 2007, p.303), these bureaus have no cash-flow rights from the shares that they manage, but exclusive rights on appointing SOE managers. According to the Corporate Law, it is the board of directors who make personnel decisions. In practice, listed SOEs' board chairman and CEO are predetermined by the associated bureaucratic agency, and the board only rubber-stamps the decision. With governments' direct control of CEO appointment, it is not surprising that SOE managers tend to give priority to bureaucrats' interests while minority stakeholders' interests are largely ignored. The major problem is that the two groups' interests may be conflicting: bureaucrats' interests are to achieve their political goals and to pursue their private benefits, which are often different from and sometimes against the goal of improving SOEs' profitability (Shleifer and Vishny, 1997).

[3] Meanwhile, private firms in China grew rapidly and some of them became listed (Chen et al., 2008).

One key factor that remains unchanged in SOEs is that their top managers are still treated as government officers; they are selected through a political process but not chosen completely based on their business acumen. Candidates generally come from the pool of current SOE managers and government officers. The selection process is similar to that in China's political system as described by Li and Zhou (2005):

> "China is a unitary state and its political system is broadly composed of five layers of state administration: the center (*zhongyang*), provinces (*sheng*), prefectures (*diqu*), counties (*xian*) and townships (*xiang*). The Central Committee of the Chinese Communist Party (CCP) acts as the headquarters of this multidivisional system, which ultimately controls the mobility of government officials within the system. This highly centralized structure of personnel control remains intact even to this day."

SOEs are regarded as part of this political system, and their political rankings can be as high as the ministerial (equivalent to provincial) level, so are SOE top managers. To be consistent with the Corporate Law, the top position in listed SOEs is the party secretary who is also appointed as the board chairman, followed by the CEO who routinely sits in the party committee.[4] It echoes the dual presence of the communist party and the government administration in China's bureaucratic hierarchy. In contrast, the selection of top managers in non-SOEs is not subject to these restrictions; thus, non-SOE managers are faced with more potential competitors to replace them. As a result, it makes the non-SOE manager market more competitive than the SOE manager market.

To meet the financial performance indicators set by the government and to secure promotion, top managers in SOEs generally choose to closely follow instructions from

[4] Wang (2014) rationalizes this due governance structure in SOEs through a political approach.

above rather than to engage in independent inquiry. With the introduction of the National Medium- and Long-Term Program for Science and Technology Development (MLP) in 2006, innovation performance indicators are included in governmental evaluations of SOEs in a top-down approach (Chen and Naughton, 2016). These indicators are specified in terms of the quantity of patent applications instead of their quality, the latter being hard to specify ex ante. Consequently, a typical SOE has incentives to "produce" the required amount of patent applications while caring little about its innovation quality. Combined with complementary patent subsidies by local governments, the MLP further stimulated SOEs to file more low-quality patent applications (Zhang and Zhong, 2016).

Under China's institutional background, China's POEs may also act differently from US firms. As Chinese entrepreneurs grew up in an opportunity-driven business environment with high political uncertainty, top managers in POEs were used to making strategies within a short-term horizon. Investment in innovation or technological specialization was less attractive to them than pursuing short-term profits by diversifying to rather unrelated industries.[5] China's recent innovation-oriented policy may also induce POEs to "produce" more low-quality patent applications to receive patent subsidies. Overall, the necessity to invest in innovation for long-term competition advantages is only gradually understood by the majority of both SOEs and POEs, even among listed firms.

2.2.2. China's stock market

It was not allowed to trade stocks in China until the Shanghai Stock Exchange (SHSE) and Shenzhen Stock Exchange (SZSE) opened in the early 1990s. A listed firm's shares

[5] One notable example is Chinese listed firms' diversification into the real estate industry during the housing boom period as documented by Rong et al. (2016).

can be classified as domestic (A-shares) and foreign according to shareholders' residency.[6] Not all A-shares are publicly tradable, but it is required that tradable A-shares account for at least 25% of total shares when a firm goes public. Non-tradable A-shares compose three different types, state shares, legal person shares, and employee shares.[7] The proportions of state shares, legal person shares, employee shares, and tradable A-shares were 28%, 29%, 0.03%, and 42%, according to Chen et al.'s (2013) calculation on non-financial listed firms in 2004.

At the early stage, tradable A-shares were mostly held by individual investors, and then institutional investors were introduced into the secondary market, among which we focus on mutual funds. Following the policy of "extraordinarily developing institutional investors" and with the introduction of open-end mutual funds, mutual funds have been growing rapidly since 2001. Figure 1 plots the time trend of institutional ownership and those of its three components, QFIIs, mutual funds, and other domestic institutional investors. Overall, there was a dramatic increase in the ownership of institutional investors during our examination period. The major contributors to the growth were mutual funds and other domestic institutional investors while the contribution of QFIIs was negligible. Mutual fund ownership increased from less than 1% in 2001 to 5% in

[6] Foreign shares include B-, N-, and H-shares. B-shares are traded domestically but separately from A-shares. They are denominated in US dollars on the SHSE and in Hong Kong dollars on the SZSE, respectively. N- and H-shares are referred to shares traded on the New York Stock Exchange and the Hong Kong Stock Exchange, respectively. About 10% of listed firms have issued at least one type of foreign shares (Chen et al., 2013).

[7] The state shares are held by the central government, local governments, and solely SOEs. The legal person shares are held by other domestic institutions including SOEs that are not solely state-owned. The employee shares are offered to employees, including workers and managers, by the listed firm, usually at a substantial discount. Non-tradable shares are transferable but not through the open markets. On average less than half of shares in listed firms are tradable, making the stock market volatile. To solve the problem, in 2005 and 2006 authorities launched the Split Share Structure Reform. We tend to believe that this reform had limited impacts on our study, given that there was at least a two-year trading-window restriction after the reform. We will come back to this issue in the later section. Tan et al. (2014) document a positive effect of the reform on firm innovation.

2007 and then was stabilized. Since the Split Share Structure Reform launched in 2005, other domestic institutional ownership began to surge and became the major contributor to the growth.

Compared to average state shares and legal person shares of about 30% each, the proportion held by any individual or institutional investor is negligible. Consequently, ownership structures in China are highly concentrated. The largest shareholder usually controls the firm effectively (Chen et al., 2008). Because state and legal person shares are non-tradable, it makes the largest shareholder almost indifferent to stock price changes.

In contrast, there are over 100 million individual investors typically holding a tiny proportion of a firm's total shares. These individual investors tend to be free riders, who have little incentives to actively participate in corporate governance (Tenev et al., 2002). Moreover, most individual investors are characterized as short-term speculators instead of long-term investors, one piece of evidence being that the annual share turnover rate was about 350% on average for 2001-2007.[8] In contrast, the NYSE (New York Stock Exchange) website reports that the annual share turnover rate on the NYSE was about 100% in 2003.

2.3. Hypothesis development

2.3.1. Gross effect

As revealed by the literature, monitoring by institutional investors has acted as an important mechanism to mitigate managerial short-termism, managerial slack, and their career concerns, thereby promoting firm innovation. This positive effect should be more pronounced in China, where the scattered shares that institutional investors pool together

[8] The annual turnover ratio is calculated as the ratio of total trading value over total tradable value of A-shares on both exchanges for a given year.

used to be held by individual investors who were less educated and were generally characterized as frequent traders thus prone to free ride.

However, there are different types of institutional investors, and apparently not all types are equally active in monitoring. For example, Bushee (1998) finds that short-term institutional investors result in managerial short-termism while long-term institutional investors reduce this tendency. Chen et al. (2007) find that "independent" institutional investors tend to collect information and do active monitoring while "grey" institutional investors tend to hold shares quietly. They define mutual funds and investment advisers as "independent", and bank trusts, pension funds, insurance companies, and other institutions as "grey." Moreover, it has been found that mutual funds positively influence Chinese listed firms' performance (Yuan et al., 2008).[9] Accordingly, we postulate that if institutional investors contribute to firm innovation in China, mutual funds that have strong incentives to monitor (i.e., independent institutional investors) should play a more important role in promoting firm innovation. We thus frame our main hypothesis as follows.

Main hypothesis: Institutional investors, particularly mutual funds, positively influence firm innovation.

There is a special type of institutional investors, QFIIs.[10] To make the domestic financial system more internationalized, China began to allow QFIIs to enter the A-share market in 2003. To become a qualified QFII, a foreign investor is required to have been managing assets of at least 10 billion US dollars. Consequently, QFIIs in China are exclusively composed of internationally well-known funds and investment banks. With

[9] The earliest related study can be traced back to Xu and Wang (1999), in which they find a positive relationship between institutional ownership and firm performance.

[10] For more information about the development of QFIIs in China, please refer to Liu et al. (2014).

rich experiences and financial prudence, these foreign institutions are supposed to enhance corporate governance in China, which has lagged behind the international standard. Moreover, cross-country studies have documented that foreign institutional investors enhance firm innovation (e.g., Bena et al., 2015; Luong et al., 2014). Accordingly, we hypothesize that the effect of QFIIs on firm innovation is positive. However, compared to an average of 3.6% in other emerging economies documented by Luong et al. (2014), QFII ownership in China is extremely low, at about 0.1% in our sample.[11] Thus, we expect that the mechanism of QFIIs influencing firm innovation in China may be different from other emerging economies.

2.3.2. Mechanism analysis

Though the career concern view and the rent seeking view both predict a positive relationship between institutional ownership and firm innovation, these two views have different predictions regarding the interaction effect between product market competition and institutional ownership. Based on the career concern view, the positive effect of institutional ownership on firm innovation should be stronger when competition is more intense (Aghion et al., 2013). The intuition is that when there are more competitors, R&D becomes more risky because the innovation output, once produced, is more likely to be replicated by competitors. This concern becomes even more critical in a transition economy like China, where the IPR (intelligent property right) is poorly enforced (e.g., Allen et al., 2005; Ang et al., 2014; Fang et al., 2015).

In contrast, from the rent seeking view, competition has two effects (Schmidt, 1997). On the one hand, more competition results in fewer economic rents for CEOs to exploit.

[11] According to Luong et al. (2014), as an average firm in emerging economies, foreign institutional ownership is much higher than domestic institutional ownership (3.6% vs. 0.7%), which presents a sharp contrast to the situation in China where the domestic institutional ownership dominates.

On the other hand, more competition raises the probability of bankruptcy, forcing CEOs to work harder. Overall, the rent seeking view predicts that when competition is more intense, there should be less managerial slack and thus institutional investors' monitoring becomes less valuable. We thus come up with two competing hypotheses.

Hypothesis 1a (Career Concern View): The positive effect of institutional (or mutual fund) ownership on firm innovation is stronger when market competition is more intense.

Hypothesis 1b (Rent Seeking View): The positive effect of institutional (or mutual fund) ownership on firm innovation is weaker when market competition is more intense.

Additionally, China's unique situation, the coexistence of POEs, minor SOEs, and major SOEs in the stock market, provides us with an ideal environment to investigate how the effect of institutional ownership on firm innovation varies with different extent of state ownership from the perspective of both views. We first compare POEs with major SOEs and then discuss minor SOEs as a hybrid of the other two.

From the career concern view, institutional investors can monitor a firm's R&D process so that when there is an R&D failure, they know whether it is due to stochastic reasons or due to CEOs' low ability. Consequently, by monitoring, institutional investors expect to benefit not only from boosted firm innovation but also from enhanced firm value if a low-ability CEO is identified and replaced. Thus, institutional investors' expected benefit from monitoring should be higher when they hold a larger proportion of the firm's stocks or when a low-ability CEO, once identified, is more likely to be replaced. The career concern view thus postulates that when an institutional investor holds a larger proportion of the firm's stocks or when a low-ability CEO is more likely to be replaced, the investor is more likely to monitor, and thus the CEO is less concerned

about his career, thereby having more incentives to innovate.[12]

Compared to POEs, CEOs in major SOEs are generally selected from the pool of SOE managers and government officials rather than from the outside manager market. Meanwhile, it is reasonable to expect that it is hard, if not impossible, for the government to accept a professional manager recommended by institutional investors as the new CEO. We thus expect that top managers in major SOEs are less likely to be fired, given that qualified candidates to replace them are limited. Consequently, the career concern view predicts a positive effect of institutional ownership on firm innovation among POEs but not among major SOEs.

Hypothesis 2a (Career Concern View): The positive effect of institutional (or mutual fund) ownership on firm innovation is stronger among POEs than among major SOEs.

The rent seeking view postulates that CEOs prefer a quiet life but institutional investors force them to innovate. However, a quiet life is more likely to happen in major SOEs than in POEs, given that CEOs in major SOEs are essentially government officers and thus less likely to be replaced. Therefore, the rent seeking view predicts a stronger effect among major SOEs.

Hypothesis 2b (Rent Seeking View): The positive effect of institutional (or mutual fund) ownership on firm innovation is stronger among major SOEs than among POEs.

Studies have found important differences in innovation behavior between major SOEs and minor SOEs (e.g., Cai and Tylecote, 2008; Boeing, 2016). Cai and Tylecote (2008) find that ownership types matter, but governments' influence over management selection

[12] Aghion et al. (2013) simply assume that the CEO market is completely competitive; that is, a firm can set a wage lower than a CEO's reservation utility so the CEO will choose to leave once found to be low-ability. Though this assumption may be a good approximation of the situation in the US, it is not so regarding the situation in China, especially when major SOEs are observed. To better reflect the situation in China, we modify Aghion et al.'s (2013) model by introducing some friction in the CEO market (not reported in the paper). Our derivation based on the modified model further confirms the above argument.

matters more. Minor SOEs, which are semi-privatized and with arms-length relationships to governments, have the highest dynamic technological capability compared to both POEs and major SOEs. By investigating the effect of government R&D subsidies on private R&D expenditures, Boeing (2016) shows that only minor SOEs do not substitute their own funds with government grants, thereby increasing their R&D intensity more than the other two firm types.

Compared to major SOEs, top managers in minor SOEs should be more likely selected by shareholders instead of administrative authorities. Though data limitation does not allow us to know exactly how top managers are elected, we shed some light on this issue by turning to Cai and Tylecote (2008). According to their manually collected data of telecommunication firms, all POEs' top managers are selected by shareholders, but major SOEs' top managers are not. Top managers in major SOEs are either selected (46.4%) or recommended/approved (53.6%) by administrative authorities while these proportions are only 10.5% and 31.6% in minor SOEs. Based on the career concern review, it is thus reasonable to postulate that the effect of institutional ownership on firm innovation among minor SOEs should lie between major SOEs and POEs, given that the selection of CEOs in minor SOEs can be regarded as a hybrid of the other two.

3. Data

Our data cover the population of Chinese domestic firms listed at the Shanghai and Shenzhen Stock Exchanges between 2001 and 2011. As suggested by Long et al. (1999), the information efficiency of China's stock markets had reached a reasonable degree before the 2000s. Data on Chinese listed firms have been widely used in high-quality

publications (e.g., Fisman and Wang, 2010; Kato and Long, 2006; Fernald and Rogers, 2002).

Our fundamental data on financial statements and capital market information are obtained from the Chinese databases, WIND and GTA CSMAR. The data on firm ownership are obtained from RESSET. In this section, we first describe in details about innovation-related measures, including patent counts, citation counts, and R&D stocks, and then we describe the sampling process and provide summary statistics.

3.1. Innovation-related measures

Our patent data come from PATSTAT.[13] We follow the approach detailed in Boeing et al. (2016) to match listed firms to patent data. Using patent data to measure firms' innovation output has the following advantages. The examination of patent applications follows a consistent and rigorous process. As a result, patent data systematically capture the progress of innovation in China. China has signed all major international conventions about intellectual property rights (Yang and Clarke, 2005).[14] Moreover, it has been documented that China is transferring to an economy of innovation from one of imitation (e.g., Cai and Tylecote, 2008; Guan et al., 2009).

We construct two measures of firms' innovation output as follows. The first measure is patent counts. The Chinese patent system grants three types of patents: innovation, utility, and design patents. Among them, innovation patents are of the highest novelty and technological inventiveness. To be granted, the application for an invention patent must meet the requirement of "novelty, inventiveness, and practical applicability." In contrast, utility or design patents only require that a similar application has not previously been

[13] April 2013 version of the EPO Worldwide Patent Statistical Database PATSTAT.
[14] These conventions include the World Intellectual Property Organization (WIPO) (1980), the Paris Convention (1985), the Madrid Agreement (1989), and the Integrated Circuits Treaty (1989).

granted.[15] We thus focus on those invention patents. Doing so also enables us to avoid double counting of invention and utility/design patents, which may be filed simultaneously for the same underlying invention.

Our patent counts are based on patent families instead of patent applications. The reason is that the number of families better reflects the number of inventions. When counting patent families, we rely on the INPADOC family definition in PATSTAT. To better reflect a firm's innovation output that is generated in a given year, we count patent families based on the priority application year.

Even though we exclusively count invention patents, the quality of these patents remains highly skewed (Gambardella et al., 2008). As documented by Li (2012), subsidies have contributed to the recent patenting expansion in China, which leads to a common concern that patent counts measure the quantity but not the quality of inventions (Dang and Motohashi, 2015). As a result, one may mistakenly conclude that a firm becomes more innovative in the presence of institutional investors, but in fact the firm only files more patent applications while the actual number of inventions remains unchanged. For example, Lei at al. (2012) show that firms in China exhibit patent filing peaks in December to meet annual patenting quotas by splitting a patentable invention into multiple applications.

As forward citations provide a reliable approximation of patent quality (Gambardella et al., 2008; Reitzig, 2004), we generate our second measure of innovation output, citation counts (i.e., citation-weighted patent counts). The rationale is that citations by

[15] These three types of patents also differ in application processing time and strength of protection. It generally takes more than one year to grant an invention patent. The processing time is about six months for utility-model patents, and even shorter for external-design patents. The term of protection is 20 years for invention patents, but only 10 years for the other two types.

subsequent patents indicate higher commercial value and technological impact of the underlying invention (Jaffe and De Rassenfosse, 2016; Hall et al., 2005; Harhoff et al., 1999; Trajtenberg, 1990). To solve the constraint that the SIPO of China does not disclose citation data, we follow Boeing (2016) and use citations generated by patent applications filed via the Patent Cooperation Treaty (PCT).[16] Specifically, we count PCT forward citations at the family level received within the first three years after the publication of the priority application. After counting citations for each patent application, we generate a firm-year's citation counts by computing the citation-weighted number of patents that the firm applied for in the given year.

Last, to measure innovation input, we obtain R&D expenditures from the WIND database for 2006-2010 and manually collect complementary information for earlier years. To generate the R&D stock, we rely on the perpetual investment method and calculate the deflated R&D stock based on an annual growth rate of R&D of 5% and an annual depreciation rate of 15%.[17] To account for the fact that some firms release no R&D expenditure (either because they conduct no R&D or because they fail to report it), we generate a zero-R&D dummy that equals one if no R&D stock can be generated, and zero otherwise.

3.2. Descriptive statistics

Our examination is restricted to firms listed on the main board of the Shanghai and Shenzhen Stock Exchanges. Specifically, our sampling process is as follows. First, we restrict the sample to the years 2001-2011 to account for an 18-month publication lag. In this way we make sure to observe those patents with a priority application date between

[16] See Boeing and Mueller (2016) for more details on the PCT system.
[17] These two rates are regarded as the standards in the literature (Hall et al., 2009).

2001 and 2011. Second, we restrict the sample to those firms with their main business in manufacturing or IT industries as innovation is of pivotal importance in these sectors. Third, taking into account that R&D expenditures affect patent applications with a short lag (Cameron and Trivedi, 2005, p.795; Griliches, 1990) and to avoid simultaneity between innovation output and firm characteristics, we forward our outcome variables, patent counts and citation counts, by one year. Accordingly, we delete observations of the year 2011. Last, we delete observations with strange or invalid values.[18] After these procedures, our final sample has 8,412 observations representing 1,248 firms.

Table 1 reports summary statistics of major variables. Each variable is defined in Appendix 1. All monetary terms are in real values (2005=100) and their units are million *yuan*. Due to our data preparation, statistics for outcome variables are calculated based on the observations from 2002 to 2011, while statistics for independent variables are from 2001 to 2010.

The distribution of patent counts is highly skewed, with a mean of 9.13 and a maximum of 5,937.[19] On average, each firm receives 1.16 citations annually while the maximum is as high as 1,697. Institutional ownership is distributed between 0% and 92.55%. To its mean of 11.09%, other domestic investors contribute 7.48, mutual funds 3.53, and QFIIs only 0.09 percentage points. To provide a first glimpse at the relationship between institutional ownership and firm patenting, in panel A of Figure 1 we present the relationship between the log of one plus patent counts and firms' institutional ownership. In panels B to D, we present the same graph but using fund, QFII, and other domestic

[18] We delete observations that show any of the following issues: (i) total sales less than or equal to zero; (ii) capital per labor less than 0.01; (iii) missing values for major variables, including capital per labor, sales, state ownership, Tobin's Q, ROA, leverage, and the Lerner Index.

[19] The observation with the largest patent stocks is ZTE, which is among the firms that also show up in other publications as largest applicants (e.g., WIPO, 2014).

institutional ownership, respectively. In all figures, a curve of the local linear regression is presented, which is estimated using the lowest smoother with a bandwidth of 0.8. Apparently, there is a positive correlation between patent counts and each ownership measure, although the estimated curve for mutual funds is steeper than that for other domestic institutional investors.

The control variables, capital per labor, sales, age, Tobin's Q, return on assets, and leverage, are winsorized at the 1% level in both tails to mitigate the influence of outliers. Our surveyed firms are relatively large with total sales at 2.6 billion *yuan*, with a high capital intensity (0.35 million *yuan* per labor), and have been listed for over six years on average. For financial variables, while the return on assets is low (3%), the leverage ratio is high (50%) and so is Tobin's Q (2.53).

We define three firm types based on state ownership: firms with no state ownership (POEs), firms with state ownership over 50% (major SOEs), and firms with state ownership no more than 50% but greater than 0% (minor SOEs). Consequently, 44% of our observations are POEs, 36% are minor SOEs, and 20% are major SOEs. The distribution is very close to that in Boeing et al. (2016) and resembles the privatization of firms in China's manufacturing industries.

In Table 2, we present firm characteristics of POEs, minor SOEs, and major SOEs, respectively. POEs and minor SOEs not only file almost twice as many patents as major SOEs but also receive twice as many citations per patent on average. It suggests that major SOEs are inferior with regard to the quantity and quality of innovation. Interestingly, institutional ownership among POEs and minor SOEs is several times higher than that among major SOEs. In the next section, we empirically investigate the

relationship between institutional ownership and firm innovation.

4. Estimation Results

In this section, we first develop the model specifications and estimate the gross and disaggregated effects of institutional ownership on firm patenting. Then, we employ several identification strategies to confirm the causality. We later analyze the mechanism and differentiate the extent of competition as well as firm types. Last, we take the quality of innovation into account.

4.1. Model specification

In our baseline model, we specify the relationship between institutional ownership and firm innovation as follows:

$$\ln(1 + Patent_{i,t}) = \alpha_1 Institution_{i,t-1} + X_{i,t-1}\beta_1 + Indu\_dummies + Year\_dummies + \varepsilon_{i,t}, \quad (1)$$

where subscripts i and t refer to firm and year, respectively. The dependent variable, $\ln(1 + Patent_{i,t})$ is the natural logarithm of one plus patent counts for firm i in year t.[20] $Institution_{i,t-1}$ is the institutional ownership of firm i at the year end t-1. $X_{i,t-1}$ represents a vector of one-year lagged firm characteristics, including ln(1+R&D stock), zero-R&D dummy, ln(capital per labor), ln(sales), ln(age), and two SOE dummies that control for minor and major SOEs. Industry dummies are defined at the 3-digit level and

[20] Count data are often estimated by Poisson or negative binominal models (Cameron and Trivedi, 2005, p.802). We employ OLS as our baseline model to make the comparability of coefficients more straightforward because our subsequent estimations (i.e., firm fixed effects, two-stage least square, and GMM) are also additive models. Our OLS specification is valid since the mean of the outcome variable is very close to 10, a benchmark proposed by Coxe et al. (2009). To address the concern that the log-transformation of the discrete patent counts influences our findings, we report estimates for Poisson and negative binomial models in the Appendix Table 1. As shown, in both specifications the coefficient on R&D stocks remains significantly positive, suggesting that our baseline model well captures firms' innovation activities.

capture time-persistent differences in patenting across industries. Year dummies capture macro-economic shocks and time trends.

If our main hypothesis is true, one should expect the coefficient on $Institution_{i,t-1}$, α_1 to be positive. Particularly, given that $X_{i,t-1}$ includes the R&D stock, the coefficient α_1 indicates whether higher institutional ownership leads to more innovation output conditional on R&D investment (i.e., R&D productivity improvement). When the R&D stock is dropped, α_1 will reflect the gross effect from both R&D productivity improvement and the increase in R&D investment.

Even though all regressors are lagged by one year to avoid simultaneity, the estimated α_1 may still be biased if institutional investors select more innovative firms for investment. To address this potential source of endogeneity, we adopt three identification strategies as follows. First, if the investment is based on cross-firm patenting differences, we can solve the problem by controlling for firm fixed effects as in the following specification:

$$\ln(1 + Patent_{i,t}) = \alpha_2 Institution_{i,t-1} + X_{i,t-1}\beta_2 + Firm\_dummies + Year\_dummies + \varepsilon_{i,t}, \quad (2)$$

where firm dummies are used to replace industry dummies.

However, endogeneity problems may still exist if institutional investors successfully predict changes in a firm's patenting performance based on unobserved firm characteristics and trade accordingly. Our second identification strategy is an IV (Instrumental Variable) estimation. Following the standard process (Aghion et al., 2013; Yuan et al., 2008), we use an index-inclusion dummy as the instrument for institutional ownership. The dummy indicates whether a stock has been included in the Shanghai 180

Index[21] or the Shenzhen Component Index; it equals one if so, and zero otherwise.

The economic rationale behind the IV is as follows. On the one hand, institutional investors often mimic the index, which implies that when a stock is included in the index, it is more likely to have higher institutional ownership. Therefore, we expect a positive correlation between the index-inclusion dummy and institutional ownership. On the other hand, a stock's inclusion in the index is because of its representativeness of a certain sector, not its patenting potential. Therefore, the exclusion condition is likely to be satisfied. Specifically, we estimate the following 2SLS (two-stage least squares) regression:

$$Institution_{i,t-1} = \gamma Index_{i,t-1} + X_{i,t-1}\delta$$

$$+Indu\_dummies + Year\_dummies + \tau_{i,t-1}, \quad (3)$$

$$\ln(1 + Patent_{i,t}) = \alpha_3 \widehat{Institution}_{i,t-1} + X_{i,t-1}\beta_3$$

$$+ Indu\_dummies + Year\_dummies + \varepsilon_{i,t}. \quad (4)$$

In equation (3), the instrument is $Index_{i,t-1}$, which indicates whether firm *i* is included in the stock index in year *t*-1. $\widehat{Institution}_{i,t-1}$ in equation (4) is the fitted value of $Institution_{i,t-1}$ from the first-stage regression in equation (3).

As sectoral representativeness and patenting potential may still be correlated for certain firms, we employ our third identification strategy, GMM estimation. Specifically, we follow Acemoglu et al. (2008) and O'Connor and Rafferty (2012) and estimate dynamic panel GMM models. The method was first developed by Anderson and Hsiao (1981). By time differencing equation (2), one can obtain:

[21] The Shanghai 180 Index was launched in July 2002 so the index-inclusion dummy is equal to zero before 2002 for firms listed in the Shanghai Stock Exchange.

$$\Delta \ln(1 + patent_{i,t}) = \alpha_2 \Delta Institution_{i,t-1} + \Delta X_{i,t-1}\beta_2 +$$

$$Year\_dummies + \Delta\varepsilon_{i,t}, \quad (5)$$

where firm dummies are dropped due to the time differencing. Since the original residual $\varepsilon_{i,t}$ is no longer included, $Institution_{i,t-2}$ is uncorrelated with $\Delta\varepsilon_{i,t}$ (assume that there is no second-order serial correlation in $\varepsilon_{i,t}$). Therefore, it can be used as an instrument for $\Delta Institution_{i,t-1}$ to obtain consistent estimates.

Though Anderson and Hsiao's (1981) method leads to consistent estimates, the efficiency of estimates can still be improved. Under the assumption that there is no high-order serial correlation in $\varepsilon_{i,t}$, not only $Institution_{i,t-2}$ but also all further lags of $Institution_{i,t-1}$ are uncorrelated with $\Delta\varepsilon_{i,t}$, and thus can be used as additional instruments. Arellano and Bond's (1991) difference-GMM estimation method uses all of these moment conditions and provides a more efficient estimator than Anderson and Hsiao (1981). We therefore estimate the difference-GMM model.[22]

4.2. Baseline estimation

First, in column (1) of Table 3, we estimate equation (1) without including institutional ownership to resemble a specification that is similar to a typical knowledge production function. Consistent with prior literature, R&D stocks are positively and significantly related to patent counts. However, R^2 and the elasticity are lower than prior findings for OECD countries (Griliches, 1990). Our elasticity—a 1% increase in the R&D stock corresponds with a 0.14% increase in patent applications—is very close to the elasticity

[22] To further improve the efficiency of Arellano and Bond's (1991) estimator, Arellano and Bover (1995) and Blundell and Bond (1998) develop the system-GMM estimator, which uses time-differenced instruments for level equation (2). These instruments are valid only if they are orthogonal to the firm fixed effect. This is unlikely the case here since the propensity of patenting is unlikely orthogonal to the firm fixed effect.

of 0.15% estimated by Hu et al. (2017) for Chinese manufacturing firms.[23]

Different from Aghion et al. (2013) who find that the effect of capital intensity is significantly positive, the coefficient on ln(capital per labor) is insignificant and tends to be negative. This seems to indicate that a positive effect is offset by a negative effect, the latter originating from a special situation in China. During our examination period, China experienced a rise in wages of unskilled labor (Liang et al., 2016; Rong et al., 2015). Consequently, more labor-intensive (hence less capital-intensive) firms had incentives to apply capital-substituting-labor strategies (Tan and Zhang, 2016), either to increase profits by product innovation or to reduce production costs by process innovation. Recent evidence suggests that the latter is of greater importance in China, as Chinese applicants file substantially more patents protecting process innovation in China compared to the US (Eberhardt et al., 2016). Additionally, firm size, which is measured by ln(sales), has a positive and significant impact on patenting as larger firms typically maintain larger patent portfolios.[24]

In columns (2) and (3), we rerun the regression by using current and two-year lagged R&D measures, respectively. In either case, the coefficient on R&D stocks barely changes, indicating a time-persistent influence of R&D stocks on firms' patent counts. We also conduct an interim test to see how our baseline model reacts to the inclusion of firm fixed effects and obtain a less significant and smaller coefficient on R&D stocks. This finding suggests that over-time variations within a firm are less important than variations across firms to explain patenting activities, as R&D expenditures within a firm

[23] Hu et al. (2017) justify a lower elasticity in China by discussing that indirect motivations other than R&D investment might be important but unobservable determinants of firm patenting in China.

[24] Since the inclusion of the zero-R&D dummy is only for the purpose of ensuring consistent estimates of the coefficient on R&D stocks, as a routine treatment in the literature its coefficient is not reported. Our results show that its coefficient is significantly positive perhaps because R&D complicacy delays a more innovative firm to prepare for reporting their R&D spending.

are smoothed over years and may not be sufficient to identify short-term changes in patenting. Nonetheless, we return to the firm fixed-effects specification as a robustness check when the effect of institutional ownership on firm patenting is estimated.

In Table 4 we introduce institutional ownership back as in the baseline model. Column (1) estimates the parsimonious model by including only year and industry dummies. The coefficient on institutional ownership is positive and significant at the 1% level. Column (2) includes all the control variables except for R&D measures, and column (3) further includes R&D measures. In either case, the coefficient on institutional ownership remains positive and significant at the 1% level. When R&D measures are included, the coefficient on institutional ownership decreases from 0.0061 to 0.0053. The drop is relatively small, suggesting that the main effect of institutional ownership is through enhanced R&D productivity instead of increases in R&D investment.[25] Besides statistical significance, its magnitude also confirms economic significance: a 10-percentage point increase in institutional ownership is associated with 5.3% more patent counts in the subsequent year. Additionally, the magnitude is comparable to previous studies. Aghion et al. (2013) show that a 10-percentage point increase in institutional ownership leads to 7% more patent counts. Not surprisingly, we also find that larger and younger firms are associated with higher patenting. It also reveals that minor SOEs are more productive in patenting, which is consistent with the finding by Cai and Tylecote (2008) that hybrid firms (i.e., minor SOEs) have the highest dynamic capacities of innovation.

We further estimate different lagged effects of institutional ownership. In column (4),

[25] We rerun the regressions by using R&D expenditures instead of R&D stocks and the major results barely change, which further confirms our argument of R&D productivity enhancement.

we use current institutional ownership as the variable of interest; in column (5), we use its two-year lagged value. Irrespective of the timing structure, the coefficient remains positive and highly significant. It is interesting to note that the coefficient becomes larger when a longer time lag is allowed for, suggesting that it takes time for institutional investors to materialize their influence on firm innovation.

4.3. Different types of institutional investors

We proceed to examine how the influence of institutional investors varies among three different institution types: mutual funds, QFIIs, and other domestic institutional investors. In columns (1) to (3) of Table 5, we estimate the effect of fund, QFII, and other domestic institutional ownership on firm patenting, respectively. The coefficient on fund ownership is positive and significant at the 1% level. Its magnitude indicates that a 10-percentage point increase in fund ownership leads to 13% more patent counts. In contrast, the coefficient on other domestic institutional ownership is insignificant. Particularly, the coefficient on other domestic institutional ownership is substantially smaller than that on fund ownership, suggesting that other domestic institutions are far less influential on firm innovation than mutual funds. This is consistent with Chen et al.'s (2007) finding that "independent" institutions such as mutual funds tend to monitor, but "grey" institutions do not.

The coefficient on QFII ownership, weakly significant at the 15% level, is large in magnitude. Since QFII ownership is relatively small, we are interested in whether its positive effect comes from its interaction with other institutional investors, which have larger shares and thus have more incentives to monitor. Column (4) includes the interaction of QFII ownership and domestic institutional ownership (the sum of fund

ownership and other domestic institutional ownership). The coefficient on the interaction term is positive but insignificant while the coefficient on QFII ownership turns negative. It indicates that QFIIs' influence is ignorable when domestic institutional investors are absent, and its influence indeed relies on the presence of domestic institutional investors. In column (5), we further examine whether the effect of QFIIs is triggered by mutual funds or other domestic institutional investors. It turns out that the effect of QFIIs relies on the presence of mutual funds but not other domestic institutions.

In summary, these findings highlight the importance of mutual funds whereas the other two types seem negligible in the context of our study. This assessment is further confirmed by two investigations discussed below. First, we examine different lagged effects of these three ownership rates in Appendix Table 2. Column (1) uses their one-year lagged value, column (2) uses their current value, and column (3) uses their two-year lagged value. Our major results persist as the coefficient on fund ownership remains nearly unchanged no matter which lagged effect is examined. In contrast, the effects of the other two are mostly insignificant.

Second, we analyze whether these correlations change over time. As mentioned, other domestic institutional ownership surged since 2006. To have a better idea of how this surge may have influenced the patenting effect of institutional ownership, in Table 6 we rerun the baseline regression for the sub-periods 2001-2006 and 2007-2010, respectively. We start with examining the gross effect of institutional ownership in columns (1) and (2). The coefficient on institutional ownership, though remaining significantly positive, is much lower in the latter period (0.014 vs. 0.0045), suggesting that the patenting effect of institutional ownership became less pronounced. The disaggregated estimation results

(columns 3 and 4) indicate that the coefficient on fund ownership is persistent over time (0.015 vs. 0.013), while the coefficient on other domestic institutional ownership turns insignificant and its magnitude is negligible in the post-2006 period. Combined with the fact that the proportion of other domestic institutional ownership has significantly increased after 2006, fund ownership thus contributes less to the gross effect of institutional ownership, which helps to explain the sharp drop of the coefficient on institutional ownership in the post-2006 period. Based on the above findings,[26] we conclude that fund ownership is the major driving force behind the gross effect of institutional ownership.[27]

4.4. Robustness tests

It is possible that the positive relationship between institutional ownership and firm patenting is driven by institutional investors selectively investing in firms with more investment opportunities. Another possibility is that there are some unobservables correlated with both institutional ownership and firm patenting. In Table 7 we aim to address these endogeneity concerns regarding institutional ownership (panel A) and fund ownership (panel B), respectively. We first address omitted observables, then turn to time-invariant unobservable confounders, and finally address time-variant unobservable confounders.

[26] We further confirm the importance of fund ownership by employing Poisson and negative binomial specifications in Appendix Table 3. While the coefficient on institutional ownership is significantly positive only for the Poisson specification, the coefficient on fund ownership remains significantly positive for both specifications.

[27] To investigate the heterogeneous effects of mutual funds, we divide mutual funds into three types based on Bushee's (1998) classification: "quasi-indexed" (funds that are widely diversified and do not trade much), "dedicated" (funds that are more concentrated but do not trade much), and "transient" (funds that are diversified but trade often). Our results show that the coefficients on dedicated and transient fund ownership are both significantly positive, and the magnitude is similar to each other. In contrast, the coefficient on quasi-indexed fund ownership is insignificant. The insignificant effect of quasi-indexed funds is consistent with our argument that active monitoring is necessary.

One important omitted variable could be market value. It is likely that market value and patent applications are positively correlated. Institutional investors may prefer to purchase high market-value firms, leading to an upward bias when estimating the effect without control for market value. We thus include Tobin's Q to control for market value, and further include leverage and return on assets to control for firms' financial structure and profitability. As shown in column (1) of panels A and B in Table 7, the positive effect of either institutional ownership or fund ownership barely changes.[28]

To address time-invariant unobservable confounders, we include firm dummies as specified in equation (2). As shown in column (2) of panels A and B, the coefficient on either institutional or fund ownership decreases but remains positive and significant at the 1% level. Therefore, it is unlikely that the positive relationship mainly comes from time-invariant unobservables that are correlated with both firm patenting and institutional or fund ownership.

To rule out the influence of time-variant unobservable confounders, we now adopt IV and GMM strategies. We first estimate the 2SLS specification of equations (3) and (4) by using the index-inclusion dummy as the instrument for institutional ownership. Columns (3) and (4) present the results for institutional ownership (panel A) and fund ownership (panel B). For the first-stage estimation (column 3), the coefficient on the index-inclusion dummy is positive and significant at the 5% and 1% level, respectively, which is consistent with our expectation that the inclusion of a firm into the stock index indeed stimulates its institutional ownership. We conduct endogeneity tests to examine whether the OLS estimates are different from the 2SLS estimates. The null hypothesis of the

[28] To control for the effect of the Split Share Structure Reform, we also rerun the regressions with the inclusion of a dummy indicating whether a firm has accomplished its reform. The major results remain unchanged, while the reform effect is positive but insignificant.

associated Hausman Chi-squared test is that there is no significant difference between these two estimates. The test statistic indicates that the 2SLS estimates are significantly different from the OLS estimates, implying serious endogeneity in the OLS model. Then, we perform the weak IV test to determine whether the instrument is sufficiently correlated with the endogenous regressor. In panel A the Cragg-Donald Wald F-statistic is lower than the critical value at the 10% significance level (Stock and Yogo, 2005), indicating that our IV for institutional ownership might be subject to the weak IV problem. In contrast, in panel B the F-statistic is well above the critical value, indicating that our IV for fund ownership is strong.

The second-stage estimation (column 4) shows that higher institutional or fund ownership is associated with significantly more patent counts. When the instrument is used, the estimated coefficient on institutional or fund ownership becomes larger, providing even stronger support for the causal relationship from institutional or fund ownership to firm patenting.

Finally, we estimate the difference-GMM specification in column (5). We use $Institution_{i,t-3}$ as well as its further lags as the instruments for $\Delta Institution_{i,t-1}$. The AR(2) test is the test for second-order serial correlation in $\Delta\varepsilon_{i,t}$ with the null hypothesis of no serial correlation. Our AR(2) test shows that there is no significant second-order autocorrelation of $\Delta\varepsilon_{i,t}$. To test the validity of our instruments, we further conduct the Hansen test of overidentification. The null hypothesis of the Hansen test is that all instruments are valid. Our Hansen test cannot reject the null hypothesis. Therefore, our GMM regression appears to be well specified. It shows that fund ownership causes significantly more patenting and the magnitude is comparable to that estimated in the

baseline model, while the effect of institutional ownership is positive but insignificant. Overall, compared to institutional ownership, the above findings make us more confident on a causal and positive effect of fund ownership on firm patenting.

4.5. Mechanism analysis

As we have discussed, the innovation effect of institutional ownership may come from either the career concern view or the rent seeking view. To examine which channel drives the result, we deepen our analysis by the following two approaches. First, we examine how the effect of institutional ownership on firm innovation would change when product market competition becomes more intense. While the career concern view predicts the effect should be strengthened when market competition is intensified, the rent seeking view predicts the opposite. Second, we examine cross-sectional differences for POEs, minor SOEs, and major SOEs. Our assumption is that, compared to those in POEs, CEOs in SOEs, especially those in major SOEs, are less likely to be replaced. Consequently, the career concern view predicts that the positive effect of institutional ownership on patenting among POEs should be more pronounced than that among SOEs. Again, the rent seeking view predicts the opposite.

4.5.1. Institutional ownership and product market competition

We first examine the interaction effect of institutional ownership and the extent of market competition, as measured by the Lerner Index.[29] From the rent seeking view, the impact of market competition and the monitoring of institutional investors are substitutes. In contrast, the career concern view regards them as complements.

In Table 8 we examine the interaction of institutional ownership and market

[29] The Lerner index is defined as $L = (P - MC)/P$, where P is the product price and MC is the marginal cost. Since, the marginal cost is very difficult to measure, it is generally substituted by the average cost (Hirschey, 1985).

competition. Columns (1) and (2) rerun the baseline regression for firms with high competition and firms with low competition (based on the median of the Lerner Index in each year), respectively. In either case, the coefficient on institutional ownership is significantly positive. However, the coefficient in column (1) is similar to that in column (2) (0.0051 vs. 0.0049), which is inconsistent with the career concern view. In columns (3) and (4), we repeat the regressions by using fund ownership. Consistent with the career concern view, the effect of mutual funds is more pronounced when competition is more intense (0.039 vs. 0.0073), and the difference is statistically significant.

Overall, though the results for institutional ownership are not consistent with the career concern view, we find consistent results when fund ownership is examined. It further supports our claim that it is fund ownership that drives the major results through the career concern channel.

4.5.2. Institutional ownership and firm types

In Table 9 we examine the heterogeneous effects of institutional ownership among POEs, minor SOEs, and major SOEs. In column (1) of panel A, we repeat the baseline regression among POEs. The coefficient on institutional ownership is positive and significant at the 1% level. Column (2) restricts the sample to minor SOEs, and the coefficient on institutional ownership is even higher than that for POEs (0.0098 vs. 0.0054). Column (3) restricts the sample to major SOEs. The coefficient is no longer significant and turns negative. These results are consistent with our expectation that the effect of institutional ownership is stronger among POEs and minor SOEs than that among major SOEs. In columns (4) to (6), we repeat the regressions by using fund ownership instead of institutional ownership. The significant and positive effect of fund

ownership persists among POEs. Its magnitude is higher than that among either minor SOEs or major SOEs, which is consistent with our expectation.

To confirm that our findings are robust to different thresholds, we change the threshold between POEs and minor SOEs and rerun the regressions on fund ownership. In columns (1) and (2) of panel B, we use 5% as the threshold; in columns (3) and (4), we use 10%. In either case, the fund effect remains highly significant and positive among POEs. These findings indicate that the effect of mutual funds is most pronounced for firms with zero or small state ownership.

4.6. The quality of innovation

As previously discussed, subsidies have contributed to China's recent patent expansion at the detriment of patent quality. To avoid that we mistakenly confirm a mechanism between innovation and the presence of institutional investors whereas only patent applications increase but actual innovation remains unchanged, we use citation counts as an alternative measure of firms' innovation output to check the robustness of our major results. As shown in summary statistics, the average citation counts are far lower than the average patent counts as only more valuable patents receive PCT citations. This requirement, though leading to a small number of citations, is necessary to ensure the quality of each citation. Therefore, by investigating citation counts, we are aiming to answer the following question: Now that we have found a positive effect of fund ownership on firm patenting, does such an effect still exist regarding firms' most valuable patenting (i.e., patents that receive PCT citations)?

In column (1) of Table 10, we first estimate the effect of fund ownership on citation counts for the full sample. Different from patent applications, which can be filed even

without having conducted formal R&D,[30] forward citations can only be received for those observations with at least one patent application filed in the given year. We thus restrict our sample to firm-years with positive patent counts. Since the dependent variable, the log of one plus citation counts is continuous but truncated at zero, we employ a Tobit model.

As shown, the coefficient on fund ownership is positive and significant at the 1% level.[31] It indicates that a 10-percentage point increase in fund ownership is associated with 16% more citation counts. Sub-period estimations deliver consistent results as shown in columns (2) and (3).

Last, we repeat the mechanism analysis and differentiate the extent of competition as well as firm types. Consistent with our previous results, columns (4) and (5) confirm that the effect of fund ownership is more pronounced when competition is more intense (0.04 vs 0.014). We then examine the fund effect for three firm types in columns (6) to (8). Consistently, the effect is more pronounced among POEs (0.021) than that among minor SOEs (0.011), and both are significant at the 1% level. In contrast, the effect is the weakest among major SOEs (0.0067) and insignificant. It seems that while mutual funds still have a weak impact on the quantity of innovation produced by major SOEs, whose governmental performance indicators are usually defined in patent counts, there is no impact on the actual quality of innovation produced by these firms.[32]

[30] Non-R&D invention is not unusual in developing countries and also exists in developed countries (Rammer et al., 2012).

[31] We rerun the regression by using institutional ownership instead of fund ownership and the major result persists.

[32] Compared to patent counts, citation counts are more likely subject to truncation bias in the later years. This issue should be partially solved by controlling for year fixed effects. As a robustness check, we rerun the regressions with the sample restricted to the years 2001-2008. The major results persist.

5. Discussion and policy implications

In this section we present several recommendations to policy makers. We first address the positive effect of institutional investors on firm innovation. Then, we discuss its heterogeneity across institutional investor types and across firm types, respectively. Last, we highlight the importance of improving R&D productivity to current China.

Consistent with prior studies on developed economies, we find that institutional investors, particularly mutual funds, positively influence firm innovation among POEs and minor SOEs, which compose the majority of Chinese listed firms. It suggests that regulatory efforts in promoting the development of mutual funds as institutional investors have generated positive impacts on firm innovation and should be carried on. It also suggests that those policy recommendations made by prior studies can also apply to transition economies, such as China. For instance, to reduce top managers' innovation risk and so to reach a higher level of innovation, government authorities might grant institutional investors, particularly mutual funds, for better board representation in listed firms. Additionally, many innovation-related policy prescriptions to solve the rent seeking problem should be taken with caution if career concerns, instead of rent seeking, are top managers' major agency problems for innovation.

Our study extends prior research in two major ways. First, we document heterogeneous effects of different institutions. Particularly, we find that independent institutions such as mutual funds are effective in promoting firm innovation while other domestic institutions, which are generally granted as grey institutions, are not. Therefore, Chinese policy makers may like to put more efforts on cultivating mutual funds as well as other independent institutions for the purpose of promoting innovation. Additionally, we

find that the positive effect of QFII ownership exists but relies on the presence of mutual funds. Consistent with Bena et al. (2015) and Luong et al. (2014), it suggests that it is beneficial to encourage QFIIs' entry to Chinese stock market. Meanwhile, to magnify their positive effect on innovation, more work should be done to induce QFIIs in China, whose shareholdings only account for a tiny proportion at the current stage, to invest in those firms with the presence of mutual funds.

Second, our study also reveals that the effect of mutual funds varies significantly across different firm types. Specifically, in contrast to POEs and minor SOEs, we do not see much of a positive effect among major SOEs. POEs and minor SOEs are generally more profit oriented, and the related manager market is more competitive; consequently, leveraged by their expertise, mutual funds have more incentives to monitor, thereby stimulating these firms' innovation. In contrast, due to their multiple targets and less competitive appointment and compensation scheme of CEOs, major SOEs' innovation can hardly benefit from the presence of mutual funds. It seems that due to their government-controlled internal governance, major SOEs are genuinely immune from external governance.[33] Consequently, without further privatization, the positive effect of mutual funds on innovation is seriously compromised among major SOEs.

Unfortunately, interest groups that oppose privatization are on the rise in China. Although major SOEs may comply with policy targets, their low-cost achievement of patent quotas has an unexpected consequence that their patent applications have become disconnected from their productivity development in recent years (Boeing et al. 2016). It

[33] This argument echoes Chan et al. (2014), whose finding suggests that state ownership may impede the effectiveness of external governance. They show that state ownership weakens mutual funds' monitoring effect on financial reporting quality. Though they argue that the mechanism is that SOEs can receive financial support from governments, making them less dependent on the capital markets, it is reasonable to expect that the SOE manager market structure may also play a role.

is also documented that relying on SOEs to pursue a top-down approach to innovation results in misallocation of resources (Wei et al., 2016). In this aspect, encouraging private firms, which are generally discriminated, to go public may be a way to better utilize the capital market in terms of promoting firm innovation. Also, it may be helpful to encourage mutual funds to hold innovative firms' stocks, which are mostly POEs and minor SOEs.

The improvement of R&D productivity is crucial to China's further growth, where innovation resources (e.g., high-quality scientific personnel) are relatively scarce. We have confirmed earlier research by Hu et al. (2017) in that the elasticity between R&D and patents is comparatively low in China. Considering the quality-quantity nexus of Chinese patents, we find that mutual funds not only have a positive effect on innovation quantity (i.e., patent counts) but also on innovation quality (i.e., citation counts), and this effect mainly comes from the enhancement of R&D productivity. Although privatization and market-oriented reforms have been slowing down in recent years, our finding suggests that the expansion of mutual funds provides an effective instrument to enhance R&D productivity for Chinese listed firms except for major SOEs.

To sum up, our study suggests that developing institutional investors, particularly mutual funds, is beneficial for firm innovation both quantitatively and qualitatively in China. Our study also suggests that this positive effect would become more pronounced were partial-privatization and market liberalization pursued more rigorously.

6. Conclusion

The beginning of the 21st century saw a rapid development in institutional investors in China's stock market. Although some studies have found that institutional investors played a positive role in firms' corporate governance (Yuan et al., 2008), it remains an open question whether the development of institutional investors has influenced firm innovation.

By investigating Chinese listed firms' patenting for 2002-2011, we find that (1) institutional ownership enhances firm patenting, (2) the effect is more pronounced when market competition is more intense, and (3) the effect exists among POEs and minor SOEs, but not among major SOEs. We also find the effect of institutional ownership on firm patenting mainly comes from mutual funds. Moreover, the above findings persist when the quality of innovation is examined.

Our results shed light on the complicacy of a general perception that financial institutions in China play no role in firm performance: even though we find that other domestic institutional investors have little influence on firm innovation, we do find that mutual funds, as a portion of domestic institutional investors, enhance firm innovation.

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Appendix 1. Variable definition

Variable	Definition
Dependent variable	
Patent count	Number of invention patent families applied for in a given priority year.
Citation count	Number of citation-weighted invention patent applications in a given priority year. We only consider PCT forward citations received by a patent application within a 3-year window since its publication date.
Variable of interest	
Institution%	Institutional ownership, defined as the sum of shares owned by all institutional investors as a percentage of the firm's total shares outstanding at the year end.
Dom. ins.%	Domestic institutional ownership, defined as the sum of shares owned by all domestic institutional investors as a percentage of the firm's total shares outstanding at the year end.
Fund%	Fund ownership, defined as the sum of shares owned by all domestic mutual funds as a percentage of the firm's total shares outstanding at the year end.
Other dom. ins.%	Other domestic institutional ownership, defined as the sum of shares owned by all domestic institutional investors except for mutual funds as a percentage of the firm's total shares outstanding at the year end.
QFII%	QFII ownership, defined as the sum of shares owned by QFIIs as a percentage of the firm's total shares outstanding at the year end.
Control variable	
Age	Number of years since the firm's IPO.
LEV	Leverage, defined as the ratio of total debts to total assets, measured at the end of the fiscal year.
ROA	Return on assets, defined as operating income before depreciation divided by total assets, measured at the end of the fiscal year.
Sales	Net sales in the fiscal year deflated to 2005 prices.
Capital per labor	Fixed assets over total employment at the end of the fiscal year deflated to 2005 prices.
R&D stock	Stock of R&D expenditures deflated to 2005 prices. To calculate the R&D stock, we rely on the perpetual investment method to calculate the R&D stock based on an annual growth rate of 5% and an annual depreciation rate of 15%.
Tobin's Q	Market value of equity plus total debts, scaled by total assets, measured at the end of the fiscal year.
Lerner Index	A firm's Lerner Index is defined as total sales minus total costs divided by total costs, measured at the end of the fiscal year.
POE	POE dummy, equal to one if the firm's state ownership is zero, and zero otherwise.
Minor SOE	Minor SOE dummy, equal to one if the firm's state ownership is positive but not more than 50%, and zero otherwise.
Major SOE	Major SOE dummy, equal to one if the firm's state ownership is greater than 50%, and zero otherwise.

Appendix Table 1. Robustness test with count models

	(1)	(2)
Dependent variable	Patent count	
Specification	Poisson	Negative binominal
ln(1+R&D stock)	.44***	.22***
	(4.1)	(4.1)
ln(Capital per labor)	-.27***	-.04
	(-2.7)	(-.73)
ln(Sales)	.9***	.62***
	(11)	(13)
ln(Age)	-.096	-.06
	(-.84)	(-.75)
Minor SOE	.03	.024
	(.18)	(.23)
Major SOE	-.34*	-.19
	(-1.9)	(-1.3)
Year dummies	Yes	
Industry dummies	Yes	
Observations	8412	8412

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively. Column (1) uses a Poisson model as follows:

$$f(patent_{i,t} \mid \mathrm{x}) = e^{-\mu}\mu^{patent_{i,t}} / patent_{i,t},$$

where $\mu = \exp(X_{i,t-1}\gamma + Indu\_dummies + Year\_dummies)$. Column (2) uses a negative binomial model as follows:

$$f(patent_{i,t} \mid \mathrm{x}) = \frac{\Gamma\left(\alpha^{-1} + patent_{i,t}\right)}{\Gamma\left(\alpha^{-1}\right)\Gamma\left(patent_{i,t}+1\right)}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\alpha^{-1}+\mu}\right)^{patent_{i,t}}.$$

Appendix Table 2. Disaggregating institutional ownership by types, lagged effects

Lagged effect of institutional ownership	(1) One-year lag	(2) Current	(3) Two-year lag
F.Fund%		.013***	
		(4)	
F.QFII%		.034	
		(.94)	
F.Other dom. ins.%		.00075	
		(.53)	
Fund%	.014***		
	(4.1)		
QFII%	.054		
	(1.4)		
Other dom. ins.%	.0019		
	(1.1)		
L.Fund%			.014***
			(3.5)
L.QFII%			.057
			(1.4)
L.Other dom. ins.%			.0038*
			(1.9)
Control variables		Yes	
Year dummies		Yes	
Industry dummies		Yes	
Observations	8412	8412	7148
Adjusted R^2	0.297	0.296	0.297

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Appendix Table 3. Robustness test of the institution effect by using count models

	(1)	(2)	(3)	(4)
Ownership type	Gross		Fund	
Specification	Poisson	Negative binominal	Poisson	Negative binominal
Institution%	.016***	.0021		
	(3.3)	(.68)		
Fund%			.04***	.02***
			(4.6)	(3.1)
Control variables		Yes		
Year dummies		Yes		
Industry dummies		Yes		
Observations	8412	8412	8412	8412

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

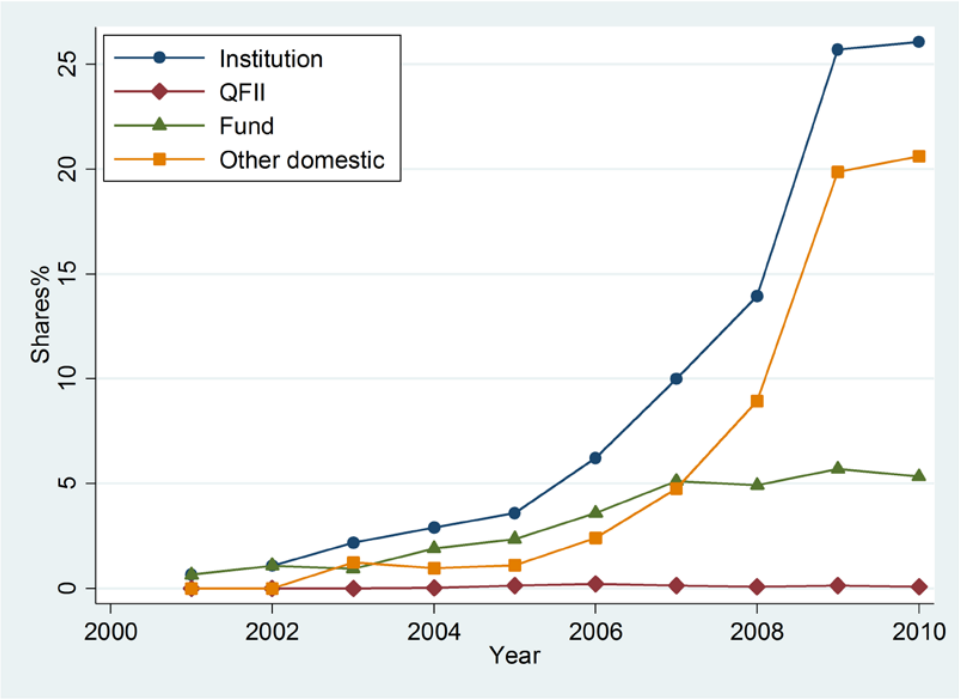
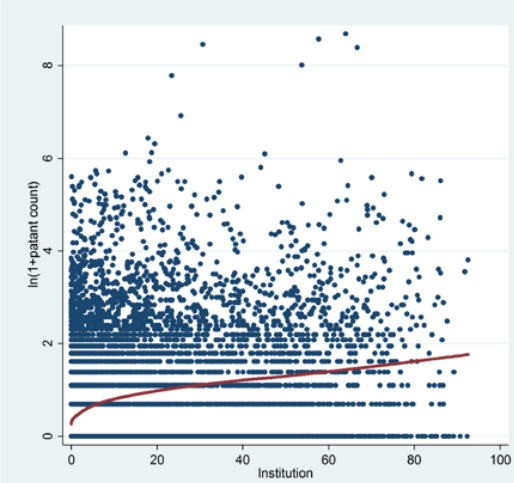
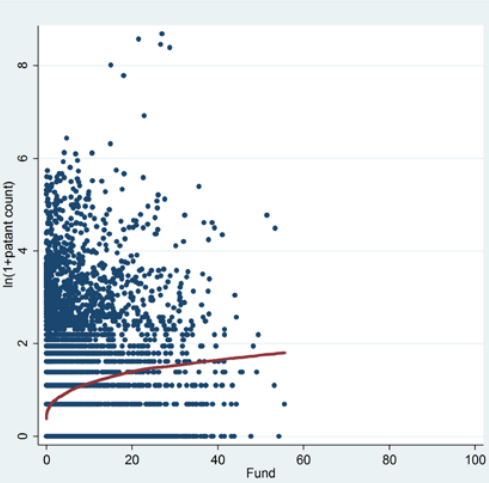


Figure 1. Time trend of institutional ownership, 2001-2010

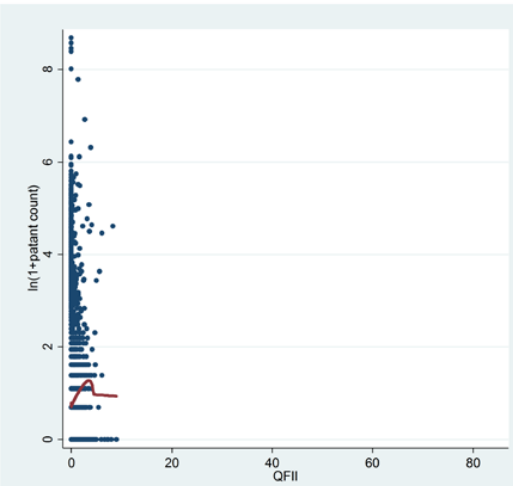
Panel A. Institutional ownership



Panel B. Fund ownership



Panel C. QFII ownership



Panel D. Other domestic institutional ownership

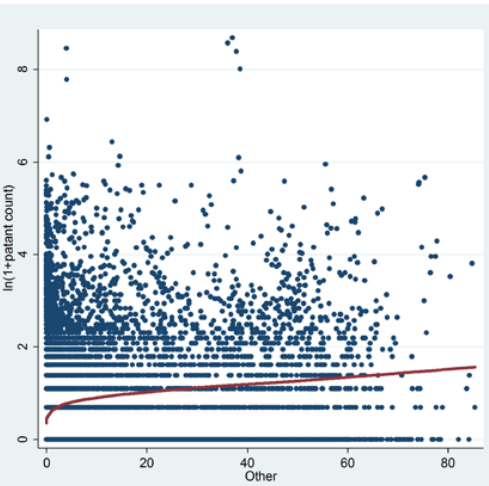


Figure 2. Regression of patent counts on institutional ownership

This figure presents the nonparametric (local linear) regressions of firms' patent counts and institutional ownership (panel A), patent counts and fund ownership (panel B), patent counts and QFII ownership (panel C), patent counts and other domestic institutional ownership (panel D), respectively.

Table 1. Descriptive statistics

	Mean	S.D.	Min.	P25	Median	P75	Max.
Patent count	9.13	122.34	0.00	0.00	0.00	3.00	5937.00
ln(1+Patent count)	0.81	1.16	0.00	0.00	0.00	1.39	8.69
Citation count	1.16	33.78	0.00	0.00	0.00	0.00	1697.00
ln(1+Citation count)	0.10	0.43	0.00	0.00	0.00	0.00	7.44
Institution%	11.09	17.11	0.00	0.22	2.86	14.39	92.55
Dom. ins.%	11.00	17.05	0.00	0.21	2.74	14.07	92.55
Fund%	3.53	6.92	0.00	0.00	0.24	3.56	55.55
Other dom. ins.%	7.48	14.27	0.00	0.00	0.80	6.57	84.76
QFII%	0.09	0.48	0.00	0.00	0.00	0.00	8.96
R&D stock (mil. *yuan*)	67.25	463.28	0.00	0.00	1.59	35.66	18229.60
Capital per labor (mil. *yuan*)	0.35	0.66	0.01	0.11	0.19	0.35	8.79
Sales (mil. *yuan*)	2564.24	6035.78	11.97	403.52	893.27	2004.74	49361.53
Age	6.75	4.39	0.00	3.00	7.00	10.00	18.00
Tobin's Q	2.53	1.79	0.88	1.39	1.97	3.01	11.21
ROA	0.03	0.09	-0.37	0.01	0.03	0.07	0.23
LEV	0.50	0.27	0.05	0.33	0.48	0.61	1.99
Lerner Index	0.03	0.26	-1.00	0.01	0.05	0.11	1.00
POE	0.44	0.50	0.00	0.00	0.00	1.00	1.00
Minor SOE	0.36	0.48	0.00	0.00	0.00	1.00	1.00
Major SOE	0.20	0.40	0.00	0.00	0.00	0.00	1.00
Observations	8412						

All monetary terms are in real values (2005=100). Patent-related variables are calculated based on the observations from 2002 to 2011. The other variables are from 2001 to 2010.

Table 2. Descriptive statistics, by firm type

	POE		Minor SOE		Major SOE	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Patent count	9.60	141.36	10.32	128.41	5.85	29.76
ln(1+Patent count)	0.87	1.17	0.82	1.18	0.64	1.11
Citation count	1.16	33.51	1.58	42.02	0.36	4.29
ln(1+Citation count)	0.10	0.43	0.11	0.45	0.08	0.37
Institution%	16.80	21.50	8.19	12.09	3.72	6.50
Dom. ins.%	16.70	21.44	8.09	12.01	3.67	6.45
Fund%	4.23	7.57	3.37	6.92	2.26	4.91
Other dom. ins.%	12.47	18.58	4.72	8.89	1.41	3.35
QFII%	0.10	0.49	0.11	0.55	0.05	0.28
R&D stock (mil. *yuan*)	81.35	622.05	55.49	276.58	57.53	291.77
Capital per labor (mil. *yuan*)	0.33	0.62	0.37	0.76	0.35	0.56
Sales (mil. *yuan*)	2111.73	4862.08	2433.55	5541.39	3822.00	8587.59
Age	6.54	4.74	7.64	4.16	5.55	3.59
Tobin's Q	2.83	1.93	2.36	1.71	2.21	1.50
ROA	0.04	0.09	0.02	0.09	0.03	0.08
LEV	0.48	0.29	0.52	0.27	0.49	0.21
Lerner Index	0.05	0.26	0.01	0.27	0.04	0.23
Observations	3694		3070		1648	

Table 3. Knowledge production function estimations

	(1)	(2)	(3)
Lagged effect of R&D	1-year lag	Current	2-year lag
F.ln(1+R&D stock)		.15***	
		(5.9)	
ln(1+R&D stock)	.14***		
	(5.5)		
L.ln(1+R&D stock)			.14***
			(4.6)
ln(Capital per labor)	-.016	-.015	-.02
	(-.65)	(-.6)	(-.77)
ln(Sales)	.29***	.28***	.31***
	(10)	(10)	(11)
ln(Age)	-.03	-.019	-.061
	(-1.1)	(-.68)	(-1.4)
Minor SOE	.065	.068	.075
	(1.4)	(1.5)	(1.5)
Major SOE	-.038	-.031	-.05
	(-.72)	(-.59)	(-.87)
Year dummies		Yes	
Industry dummies		Yes	
Observations	8412	8412	7148
Adjusted R^2	0.290	0.292	0.290

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 4. The effect of institutional ownership on firm patenting

	(1)	(2)	(3)	(4)	(5)
Lagged effect of institutional ownership	1-year lag			Current	2-year lag
Specification	Without controls	Without R&D	With R&D	With R&D	With R&D
F.Institution%				.0035***	
				(2.6)	
Institution%	.012***	.0061***	.0053***		
	(6.5)	(3.8)	(3.4)		
L.Institution%					.0074***
					(3.9)
ln(1+R&D stock)			.14***	.14***	.13***
			(5.4)	(5.4)	(4.9)
ln(Capital per labor)		-.025	-.017	-.017	-.021
		(-.99)	(-.72)	(-.69)	(-.81)
ln(Sales)		.32***	.27***	.28***	.28***
		(11)	(10)	(10)	(9.8)
ln(Age)		-.095***	-.049*	-.039	-.058
		(-3.2)	(-1.7)	(-1.3)	(-1.3)
Minor SOE		.11**	.093**	.071	.098**
		(2.3)	(2)	(1.6)	(2)
Major SOE		-.0026	-.0072	-.03	-.02
		(-.048)	(-.13)	(-.57)	(-.34)
Year dummies			Yes		
Industry dummies			Yes		
Observations	8412	8412	8412	8412	7148
Adjusted R^2	0.162	0.273	0.294	0.292	0.295

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 5. Disaggregation of institutional ownership

Institution type	(1) Fund	(2) QFII	(3) Other Domestic	(4) Interaction effects	(5) Interaction effects
Fund%	.013***				.012***
	(3.8)				(3.6)
QFII%		.06		-.013	-.028
		(1.6)		(-.3)	(-.65)
Other Dom. ins.%			.0017		.0012
			(1)		(.7)
QFII% *Fund%					.0039
					(1.1)
QFII%*Other dom. ins.%					.0021
					(.75)
QFII%*Dom. ins.%				.0032	
				(1.6)	
Dom. ins.%				.0037**	
				(2.5)	
Control variables			Yes		
Year dummies			Yes		
Industry dummies			Yes		
Observations	8412	8412	8412	8412	8412
Adjusted R^2	0.301	0.296	0.296	0.299	0.301

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 6. Institutional ownership effects, by period

	(1)	(2)	(3)	(4)
Ownership type	Gross		Disaggregated	
Period	2001-2006	2007-2011	2001-2006	2007-2011
Institution%	.014***	.0045***		
	(4)	(2.8)		
Fund%			.015***	.013***
			(3.4)	(3.5)
QFII%			.022	.13**
			(.52)	(2.4)
Other dom. ins.%			.011*	.002
			(1.9)	(1.1)
Observations	5347	3065	5347	3065
Adjusted R^2	0.261	0.252	0.260	0.258

For all regressions, all control variables, year dummies, and industry dummies are included. Robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 7. Robustness tests

Panel A. The effect of institutional ownership

	(1)	(2)	(3)	(4)	(5)
Specification	OLS	FE	2SLS		GMM
	More controls		1st-stage	2nd-stage	
Index or not			1.8**		
			(2.1)		
Institution%	.0051***	.0038***		.22*	.0034
	(3.3)	(3.6)		(2)	(1.4)
Tobin's Q	.06***				
	(4.8)				
ROA	-.76***				
	(-3.1)				
LEV	-.13				
	(-1.4)				
Other controls	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	No	Yes	Yes	No
Firm dummies	No	Yes	No	No	Yes
Observations	8412	8412	8412	8412	7148
Adjusted R^2	0.299	0.233	0.441		
Hausman Chi-squared Test				0.035	
P-value					
Cragg-Donald Wald F statistic				4.5	
P-value for AR(2) Test					.61
P-value for Hansen Test					.46

Panel B. The effect of fund ownership

	(1)	(2)	(3)	(4)	(5)
Specification	OLS	FE	2SLS		GMM
	More controls		1st-stage	2nd-stage	
Indexing or not			2.2***		
			(4.9)		
Fund%	.012***	.0087***		.18***	.014**
	(2.8)	(3.7)		(3.7)	(2.3)
Tobin's Q	.048***				
	(3.7)				
ROA	-.91***				
	(-3.7)				
LEV	-.13				
	(-1.4)				
Other controls	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	No	Yes	Yes	No
Firm dummies	No	Yes	No	No	Yes
Observations	8412	8412	8412	8412	7148
Adjusted R^2	0.301	0.233	0.212		
Hausman Chi-squared Test				0.000	
P-value					
Cragg-Donald Wald F statistic				24	
P-value for AR(2) Test					.58
P-value for Hansen Test					.49

For all regressions, robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 8. The effect of institutional ownership on firm patenting, by competition extent

	(1)	(2)	(3)	(4)
Ownership type	Institution		Fund	
Competition extent	High	Low	High	Low
Institution%	.0051**	.0049***		
	(2.1)	(2.6)		
Fund%			.039***	.0073**
			(3.8)	(2.1)
Observations	4203	4209	4203	4209
Adjusted R^2	0.280	0.317	0.294	0.316

For all regressions, all control variables, year dummies, and industry dummies are included. Robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 9. The effect of institutional ownership on firm patenting, by firm type

Panel A. Threshold, 0%-50%

	(1)	(2)	(3)	(4)	(5)	(6)
Ownership type	Institution			Fund		
Firm type	POE	Minor SOE	Major SOE	POE	Minor SOE	Major SOE
Institution%	.0054***	.0098***	.038			
	(3.1)	(3.4)	(.21)			
Fund%				.019***	.012**	.015*
				(4.1)	(2.3)	(1.7)
Observations	3694	3070	1648	3694	3070	1648
Adjusted R^2	0.257	0.333	0.120	0.264	0.331	0.356

Panel B. Alternative thresholds

	(1)	(2)	(3)	(4)
Threshold	5%		10%	
Firm type	POE	Minor SOE	POE	Minor SOE
Fund%	.015***	.013	.015***	.012
	(4.1)	(1.4)	(4.1)	(1.3)
Observations	5587	1369	5709	1247
Adjusted R^2	0.270	0.237	0.272	0.253

For all regressions, all control variables, year dummies, and industry dummies are included. Robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.

Table 10. The effect of fund ownership on citation counts

Sample	(1) Full	(2) 2001-2006	(3) 2007-2011	(4) Competition extent	(5)	(6) Firm type	(7)	(8)
				High	Low	POE	Minor SOE	Major SOE
Fund%	.016***	.019***	.015***	.04**	.014***	.021***	.011***	.0067
	(7.7)	(4.6)	(7.2)	(2.3)	(5.3)	(7.7)	(3.9)	(.27)
Observations	3413	1202	2211	1703	1710	1668	1238	507

For all regressions, all control variables, year dummies, and industry dummies are included. Robust standard errors clustered at the firm level are estimated. *t*-statistics are presented in parentheses. *, ** and *** represent the significance level of 10%, 5% and 1%, respectively.