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The effect of institutional ownership on firm innovation: Evidence from Chinese listed firms

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ABSTRACT

Monitoring by institutional investors can act as an important mechanism to promote firm innovation. By investigating the patenting behavior of Chinese listed firms between 2002 and 2011, we find that the presence of institutional investors enhances firm innovation. Consistent with this 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 product market competition is more intense; (3) the effect exists among private- and minority state-owned enterprises, but not among majority state-owned enterprises. The above findings remain robust when innovation quality is examined.

1. Introduction

Ownership structures play an important but complicated role in the level of innovation in 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 conducting innovation because the high risk associated with innovation can be spread across a large number of shareholders. On the other hand, with 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 transition economies such as China where state ownership remains a key element of corporate governance. Managers in state-owned enterprises (SOEs) have few incentives to enhance firm competitiveness through innovation as these public employees do not benefit much from R & D but have to bear its costs such as innovation risks and the outrage of laid-off workers (Megginson, 2005). With the presence of the state as a shareholder, the influence of ownership structures on innovation in listed firms is further complicated. This paper focuses on a specific force of external governance on innovation—ownership by institutional investors—and how it interacts with state ownership by examining the patenting behavior of Chinese listed firms 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 has rarely been 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.[1] This paper contributes to the existing literature by documenting the relationship between institutional ownership and firm innovation in China, the largest emerging economy in the world.

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[1] 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).

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On average, state shares make up about one-third of total shares for Chinese listed firms. The strong presence of state ownership in China results in the coexistence of two types of listed firms, SOEs and non-SOEs. There is some evidence to support Megginson's (2005) argument that SOE managers have few 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. This paper attempts to fill this gap.

As discussed in the literature, active monitoring carried out 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 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 are generally selected from a pool of current government officers and SOE top management. Given this relatively small pool of qualified candidates, CEOs in SOEs may hold leading positions even though they are not qualified for business administration. According to the career concern view, the incentive for institutional investors to engage in active monitoring should be reduced since firing an unqualified CEO is a major benefit of monitoring, and this benefit vanishes if it is unlikely that such a CEO will be replaced. We thus postulate that the positive effect of institutional ownership on firm innovation should be weakened when the factor market for managers is less competitive as in the case for SOEs.

To generate a convincing proxy for 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 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 positive effect of institutional ownership is mainly realized through improving R & D productivity. By examining different types of institutional investors, we further find that the positive effect of institutional ownership can be 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 carry out active monitoring. Moreover, we find that QFII (Qualified Foreign Institutional Investor) ownership has a positive effect, but this effect relies on the presence of mutual funds.

One may be concerned about reverse causality; that is, institutional investors may tend to invest in firms with more innovation. Our study is less subject to this endogeneity problem compared to the US case. As a developed economy, in the US institutional ownership is already stabilized, and its variations result largely from institutional investors adjusting their portfolios. In contrast, as a transition economy, in China institutional ownership increased from around 1% in 2001 to over 25% in 2010, and this surge was largely driven by government policy. 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. This is particularly the case for mutual fund ownership. Additionally, the positive effect persists when we address endogeneity by using firms' "internal instruments" based on GMM (Generalized Method of Moments) estimations. Overall, we confirm a causal and positive effect of institutional ownership, particularly mutual fund ownership, on firm patenting.

Stronger product market competition tends to increase the risk of imitation by competitors, 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 product market competition intensifies. 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 (private-owned enterprises with zero state ownership) than among either minority SOEs (enterprises with positive state ownership but not more than 50%) or majority SOEs (enterprises with more than 50% state ownership). Moreover, all our major results persist when we use citation counts instead of patent counts to measure firms' innovation output. Particularly, for majority SOEs, while mutual funds have a weak impact on the quantity of innovation (i.e., patent counts), there is no impact on the 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 minority SOEs, but not for majority SOEs.

We regard our study as an important complement to studies on institutional ownership and firm innovation. It contributes to this strand of the literature in three ways. First, instead of investigating another developed economy, we provide new evidence on the positive relationship between institutional ownership and firm innovation in a transition economy. Second, by examining POEs, minority SOEs, and majority 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 between 2001 and 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-sized enterprises (SMEs) in China and find that corporate governance and ownership are significantly associated with firm patenting. However, the actual causality has not been well established so far. Our study attempts to fill this 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 in private firms; Lin et al. (2010) find that government ownership and its intervention in CEO appointments are negatively related to firms' R & D activities; Boeing et al. (2016) show that POEs experience higher returns on productivity from R & D than SOEs. Our study shows that the positive effect of institutional ownership on firm innovation barely exists among majority SOEs, suggesting that majority SOEs may stunt their innovation 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 (e.g., 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 remainder of the paper is organized as follows. Section 2 reviews prior literature and formulates our hypotheses. Section 3 describes the data. Section 4 presents the empirical results. Section 5 discusses the policy implications of our findings. 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 provide background information on China's economic transition by highlighting the particular governance structures within SOEs as well as China's underdeveloped stock market. Finally, we develop several hypotheses, taking these special conditions into account.

2.1. Institutional investors and firm innovation

Characterized as high risk, long-term, and complex, firms' innovation activities tend to be poorly executed because corporate governance is generally not designed to be compatible with these characteristics. Unlike conventional projects, R & D projects are associated with high uncertainty and require multiple stages to succeed. Therefore, optimal incentive contracts intending to motivate 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 executed if the focus is primarily on motivating 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. Consequently, when deciding whether to launch an R & D project, top managers take into account not only the project's 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 the constant pressure to deliver a good short-term performance may result in managers avoiding risky long-term projects. Ferreira et al., 2014 argue that pressures from the stock market may force managers to choose projects that are more visible to investors. Consequently, managers may forgo R & D projects and instead pursue more conventional ones. Such managerial short-termism can be further exacerbated by institutional investors acting as speculators, who show little interest in 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 associated with R & D projects due to their 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). There are two possible channels in particular through which institutional investors motivate CEOs to invest more in innovation.

One possible channel is that when innovation is not being fully encouraged by means of 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 an innovation project, 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 from 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 extra efforts in the absence of efficient governance. Since innovation demands extra efforts and intelligence, it is reasonable to expect that CEOs have incentives to shirk innovation projects. By being actively involved 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 has generally been found to be 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 a higher percentage of institutional ownership are less likely to cut R & D expenditures 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 the more intense product market competition is. However, such a relationship has rarely been examined in a transition economy in which stock markets and ownership structures of listed firms are substantially different from the US and 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, whose main function was to fulfill production quotas rather than pursue 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 comply with China's transition towards a market economy. In the first stage, the responsibility contract was introduced into SOEs, which increased incentives for managers while leaving 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 either

been privatized or shut down (see Hsieh and Song, 2015). Some of these large SOEs became partially privatized by selling shares to individual investors through IPOs (initial public offerings). These listed firms were generally carved out from existing SOEs, which retained a substantial proportion of shares.[2]

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); that is, SOEs are controlled by government officers with strong rights of control but no significant rights over cash flow. Two major differences from the pre-reform period are that industrial bureaus, which were once 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, however, the board chairman and CEO of listed SOEs are selected by the associated bureaucratic agency, and the board merely rubber-stamps the decision. With direct governmental control of CEO appointments, it is not surprising that SOE managers tend to give priority to the interests of bureaucrats while minority stakeholders' interests are largely ignored. The major problem is that the interests of these two groups may be conflicting: bureaucrats are generally interested in achieving their political goals and pursuing any private benefits, goals which are often different from and sometimes against the goal of improving the profitability of SOEs (Shleifer and Vishny, 1997).

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 entirely based on their business acumen. Candidates generally come from a 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 their top managers. In line with the Corporate Law, the top position in a listed SOE is the party secretary who is also appointed as the board chairman, followed by the CEO who routinely sits in the party committee.[3] This arrangement echoes the dual presence of the Communist Party and the government administration in China's bureaucratic hierarchy. In contrast, the selection of executives 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, the factor market for non-SOE managers is more competitive than the market for SOE managers.

To meet the financial performance targets set by the government and to secure promotion, executives in SOEs generally choose to closely follow instructions from 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 become strongly emphasized 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 rather than their quality, the latter being hard to specify ex ante. Consequently, a typical SOE has an incentive to "produce" the required amount of patent applications while caring little about its innovation quality. Combined with complementary patent subsidies offered by local governments, the MLP further stimulated SOEs to file more low-quality patent applications (Zhang and Zhong, 2016).

Given 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, executives 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.[4] China's recent innovation-oriented policy may also induce POEs to "produce" more low-quality patent applications in order to receive patent subsidies. Overall, the necessity to invest in innovation to gain long-term competitive advantages is only gradually being understood by the majority of both SOEs and POEs, even among listed firms.

We can further divide SOEs into two types based on the level of state ownership, minority SOEs and majority SOEs. Compared to majority SOEs, executives in minority SOEs should be more likely to have been selected by shareholders instead of administrative authorities. Though we do not know exactly how executives are selected due to limited data, we are able to shed some light on this issue by turning to Cai and Tylecote (2008). According to their manually collected data of telecommunication firms, all executives at POEs are selected by shareholders, but the executives at majority SOEs are not. Executives in majority 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 minority SOEs.

2.2.2. China's stock market

Trading stocks was illegal in China until the Shanghai Stock Exchange (SHSE) and Shenzhen Stock Exchange (SZSE) opened in the early 1990s. A listed firm's shares can be classified as domestic (A-shares) and foreign depending on shareholders' country of residence.[5] Not all A-shares are publicly tradable, but tradable A-shares must account for at least 25% of total shares when a firm goes public. Non-tradable A-shares comprise three different types, state shares, legal person shares, and employee shares.[6] 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

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

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

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

[5] Foreign shares include B-, N-, and H-shares. B-shares are traded domestically but separately from A-shares. They are priced in US dollars on the SHSE and in Hong Kong dollars on the SZSE, respectively. N- and H-shares refer 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).

[6] State shares are held by the central government, local governments, and solely SOEs. Legal person shares are held by other domestic institutions including SOEs that are not solely state-owned. 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 this problem, in 2005 and 2006 authorities launched the Split Share Structure Reform. We tend to believe that this reform has had a limited impact 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 a later section. Tan et al. (2014) document a positive effect of the reform on firm innovation.

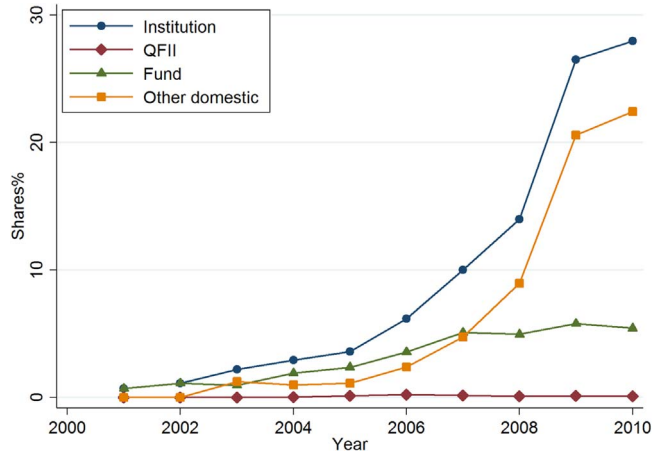

Fig. 1. Time trend of institutional ownership, 2001–2010.

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. Fig. 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 ownership by 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 2001–5% in 2007 and then stabilized. Since the Split Share Structure Reform launched in 2005, other forms of domestic institutional ownership began to surge and became the major contributor to 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. Usually, the largest shareholder effectively controls the firm (Chen et al., 2008). Because state and legal person shares are non-tradable, it makes the largest shareholder almost entirely 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 can be characterized as short-term speculators rather than long-term investors. This is evidenced by an annual share turnover rate of about 350% on average for 2001–2007.[7] In contrast, the NYSE (New York Stock Exchange) website reports an annual share turnover rate on the NYSE of about 100% for 2003.

2.3. Hypothesis development

2.3.1. Gross effect

As revealed by the literature, monitoring by institutional investors acts as an important mechanism to mitigate managerial short-termism, managerial slack, and career concerns, thereby promoting firm innovation. This positive effect should be more pronounced in China, where the scattered shares once held by individual investors, who are less educated and generally characterized as frequent traders thus prone to free ride, have been pooled together by institutional investors.

However, there are different types of institutional investors, and not all types appear to be 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 engage in active monitoring while "grey" institutional investors tend to hold shares passively. 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).[8] 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.[9] 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 a wealth of 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.[10] 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 offer 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 will be stronger the more intense product market competition is, as argued by Aghion et al. (2013). The intuition is that when there are more competitors, R & D becomes more risky because the related innovation, once released to the public, is more likely to be imitated by competitors.[11] Making things even worse, such imitation is sometimes hard to identify (e.g., a firm's ongoing innovation is stolen by its competitor), and outsiders may simply regard it as an R & D failure of the affected firm. With a higher likelihood of imitation, more competition thus implies a higher risk to the CEO's reputation when innovating, making him more concerned about his career. Such a concern is supposedly more prominent in a transition economy like China, where IPRs (intellectual property rights) are poorly enforced (e.g., Allen et al., 2005; Ang et al., 2014; Fang et al., 2015) and thus imitation occurs more frequently. Given that

[7] 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.

[8] 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.

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

[10] According to Luong et al. (2014), for the average firm in an emerging economy, 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 domestic institutional ownership dominates.

[11] Such a Schumpeterian aspect is commonly predicted in the literature on endogenous growth (e.g., Romer, 1990; Grossman and Helpman, 1991), in which competition extent is proxied by the likelihood of imitation and such a higher likelihood results in a lower monopoly rent that a firm can appropriate from its innovation.

R & D is more risky when competition is more intense, institutional investors thus have more influence on firm innovation through the career concern channel. We therefore present the following hypothesis.

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

In contrast, from the rent-seeking view, competition tends to weaken the effect of institutional ownership on firm innovation. Generally, more competition increases the probability of bankruptcy; to escape from bankruptcy, CEOs have to work harder (e.g., Hart, 1983; Schmidt, 1997; Bertrand and Mullainathan, 2003). Given that there is less managerial slack when competition is more intense, institutional investors' monitoring thus becomes less influential. We turn to a stylized model set up by Aghion et al. (2013) to illustrate the case with the presence of innovation. They assume that the CEO obtains private benefit B by keeping the job while engaging in innovation imposes a private cost I to him. They also assume that the institutional investor monitors with possibility m, which is an increasing function of the proportion of stock shares held by the institution. Through monitoring, the institution can figure out whether the CEO is actually innovating and will fire him if he is not. Additionally, the CEO may lose his job if the innovation is imitated by a competitor, which happens with possibility π. Consequently, the CEO chooses to innovate if $B-I > (1-\pi)(1-m)B$. It implies that the higher the monitoring possibility m, the more likely the CEO is to innovate. However, when imitation possibility π is higher, it will reduce the marginal effect of monitoring possibility m on the CEO's net benefit from engaging in innovation (i.e., $B-I-(1-\pi)(1-m)B$). Consequently, unlike the career concern view, the rent-seeking view predicts that more competition will weaken the effect of institutional ownership on firm innovation. We thus come up with a competing hypothesis.

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

Additionally, China's unique situation, namely the coexistence of POEs, minority SOEs, and majority 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 levels of state ownership, from the perspective of both the career concern and rent-seeking view. We first compare POEs with majority SOEs and then discuss minority 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 competence. Consequently, by monitoring, institutional investors expect to benefit not only from boosted firm innovation but also from enhanced firm value if an incompetent CEO is identified and replaced. Thus, the expected benefit for institutional investors from monitoring should be higher the larger the proportion of the firm's stocks they hold or the more likely an incompetent CEO, once identified, is to be replaced. The career concern view thus postulates that the larger the proportion of the firm's stocks an institutional investor holds or the more likely an incompetent CEO is to be replaced, the more likely the investor is to monitor the firm's activities. The CEO is thus less concerned about his career, thereby having more incentives to innovate.[12]

[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 does not accurately reflect the situation in China, especially when majority SOEs are concerned. 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.

Compared to POEs, CEOs in majority SOEs are generally selected from a pool of SOE managers and government officials rather than from the external manager market. Meanwhile, it is reasonable to expect that it is unlikely, if not impossible, that the government will accept a professional manager recommended by institutional investors as the new CEO. We thus expect that executives in majority 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 majority SOEs.

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

The rent-seeking view postulates that CEOs prefer a quiet life but institutional investors force them to innovate. Hicks (1935) in particular suggests that enjoying a quiet life is "the best of all monopoly profits" for CEOs. With poor corporate governance, CEOs may prefer to avoid making tough decisions such as restructuring business lines or doing innovation. Consistent with this prediction, it has been found that when under less threat of being replaced due to protections under anti-takeover law, CEOs tend to avoid either closing a plant or creating a new one (Bertrand and Mullainathan, 2003) and tend to engage in less innovation (Atanassov, 2013). It suggests that on average CEOs are better characterized as enjoying a quiet life than empire-building when the threat of being fired is low. As we have discussed, compared to POEs, majority SOE executives are faced with less competition thus are under less threat of being replaced. It is thus reasonable to assume that CEOs are more likely to enjoy a quiet life in majority SOEs. From the rent-seeking view, it leaves more room for institutional investors to force majority SOE managers to innovate; that is, the effect of institutional ownership on firm innovation will be stronger among majority SOEs.

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

Studies have found important differences in innovation behavior between majority SOEs and minority SOEs (e.g., Cai and Tylecote, 2008; Boeing, 2016). Cai and Tylecote (2008) find that ownership types matter, but governmental influence over management selection matters more. Minority SOEs, which are semi-privatized and with arms-length relationships to governments, have the highest dynamic technological capability compared to both POEs and majority SOEs. By investigating the effect of government R & D subsidies on private R & D expenditures, Boeing (2016) shows that only minority SOEs do not substitute their own funds with government grants, thereby increasing their R & D intensity more than the other two firm types.

As we have discussed, compared to majority SOEs, executives in minority SOEs are more likely to be selected by shareholders instead of administrative authorities. Based on the career concern review, it is thus reasonable to postulate that the effect of institutional ownership on firm innovation among minority SOEs should lie somewhere between that of majority SOEs and POEs, given that the selection process for CEOs in minority SOEs can be regarded as a hybrid of the processes in the other two types.

3. Data

Our data cover all 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 the Chinese database RESSET. In this section, we first describe innovation-related measures, including patent counts, citation counts, and R & D stocks, in detail, 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. China has signed all major international conventions regarding 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: invention, utility, and design patents. Among them, invention 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 granted.[15] We thus focus on invention patents. Doing so also enables us to avoid double counting of invention and utility/design patents, since these may be filed simultaneously for the same underlying invention.

Our patent counts are based on patent families rather than patent applications because the number of families better reflects the number of inventions. When counting patent families, we rely on the INPADOC family definition in PATSTAT. To appropriately reflect a firm's innovation output 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 surge in China, which gives rise to a common concern that patent counts measure the quantity but not the quality of inventions (Dang and Motohashi, 2015). This concern is further supported by Lei et al. (2012), who 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 a result, one may mistakenly conclude that a firm becomes more innovative in the presence of institutional investors, when in fact the firm is simply filing more patent applications while the actual number of inventions remains unchanged.

As forward citations provide a reliable approximation of patent quality (Gambardella et al., 2008; Reitzig, 2004), we use citation counts (i.e., citation-weighted patent counts) as our second measure of innovation output. The rationale is that citations by subsequent patents indicate a 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 find a way around the fact 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.[17] 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 data on 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 R & D growth rate of 5% and an annual depreciation rate of 15%.[18] To account for the fact that some firms do not release any data on R & D expenditures (either because they do not conduct 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 analysis 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 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 for the year 2011. Last, we delete observations with strange or invalid values.[19] After these procedures, our final sample has 8412 observations representing 1248 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 method of data preparation explained above, 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 5937.[20] On average, each firm receives 1.16 PCT citations annually while the maximum is as high as 1697. Institutional ownership is distributed between 0% and 92.55%. To the mean of 11.09%, other domestic investors contribute 7.48, mutual funds 3.53, and QFIIs only 0.09 percentage points.

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. The surveyed firms are relatively

[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).

[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.

[16] See Boeing and Mueller (2016) for more details on the PCT system.

[17] As suggested by one referee, there is an alternative approach of standardization to account for possible truncation bias when citation counts are used as the dependent variable; that is, one can standardize citation counts using the mean and standard deviation of all citations received by the patents published in the same year (e.g., Guan et al., 2017; Cannella and McFadyen, 2013). If we follow this approach, 90% of our observations, which have zero citations, will have the standardized citation counts valued below zero, making the Tobit specification no longer applicable. We thus stick to our current approach of using a three-year citation window to deal with truncation bias.

[18] These two rates are regarded as the standards in the literature (Hall et al., 2009).

[19] 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.

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

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
Minority SOE	0.36	0.48	0.00	0.00	0.00	1.00	1.00
Majority 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		Minority SOE		Majority 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	

large with total sales at 2.6 billion *yuan*, with a high capital intensity (0.35 million *yuan* per labor), and have on average been listed for over six years. 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 the level of state ownership: firms with no state ownership (POEs), firms with state ownership over 50% (majority SOEs), and firms with state ownership no more than 50% but greater than 0% (minority SOEs). Consequently, 44% of our observations are POEs, 36% are minority SOEs, and 20% are majority 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 the firm characteristics of POEs, minority SOEs, and majority SOEs, respectively. POEs and minority SOEs not only file almost twice as many patents as majority SOEs but also receive on average twice as many citations per patent. It suggests that majority SOEs are inferior with regard to the quantity and quality of innovation. Interestingly, institutional ownership among POEs and minority SOEs is several times higher than among majority 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 product market 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:

Table 3
Knowledge production function estimations.

Lagged effect of R & D	(1) 1-year lag	(2) Current	(3) 2-year lag
F.ln(1 + R & D stock)		0.15***	
		(5.9)	
ln(1 + R & D stock)	0.14***		
	(5.5)		
L.ln(1 + R & D stock)			0.14***
			(4.6)
ln(Capital per labor)	−0.016	−0.015	−0.02
	(−0.65)	(−0.6)	(−0.77)
ln(Sales)	0.29***	0.28***	0.31***
	(10)	(10)	(11)
ln(Age)	−0.03	−0.019	−0.061
	(−1.1)	(−0.68)	(−1.4)
Minority SOE	0.065	0.068	0.075
	(1.4)	(1.5)	(1.5)
Majority SOE	−0.038	−0.031	−0.05
	(−0.72)	(−0.59)	(−0.87)
Year dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	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.

$$\ln(1 + Patent_{i,t}) = \alpha_1 \ \text{Institution}_{i,t-1} + X_{i,t-1}\beta_1 + \text{Indudummies} + \text{Yeardummies} + \varepsilon_{i,t}, \quad (1)$$

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.[21] $Institution_{i,t-1}$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 minority and majority SOEs. Industry dummies are defined at the 3-digit level and 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 $Institution_{i,t-1}$,$\alpha_1$to be positive. Particularly, given that $X_{i,t-1}$ includes the R & D stock, the coefficient $\alpha_1$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, $\alpha_1$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 $\alpha_1$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:

$$\ln(1 + Patent_{i,t}) = \alpha_2 \ \text{Institution}_{i,t-1} + X_{i,t-1}\beta_2 + \text{Firmdummies} + \text{Yeardummies} + \varepsilon_{i,t}, \quad (2)$$

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[22] 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:

$$Institution_{i,t-1} = \gamma \ \text{Index}_{i,t-1} + X_{i,t-1}\delta + \text{Indudummies} + \text{Yeardummies} + \tau_{i,t-1}, \quad (3)$$

$$\ln(1 + Patent_{i,t}) = \alpha_3 \ \hat{\text{Institution}}_{i,t-1} + X_{i,t-1}\beta_3 + \text{Indu\_dummies} + \text{Year\_dummies} + \varepsilon_{i,t}. \quad (4)$$

In Eq. (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 Eq. (4) is the fitted value of $Institution_{i,t-1}$ from the first-stage regression in Eq. (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

[21] 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 A1. As shown, in both specifications the coefficient on R & D stocks remains significantly positive, suggesting that our baseline model well captures firms' innovation activities. Additionally, when we estimate the negative binomial model, the alpha is 3.62, indicating that the variance of the count exceeds its mean (i.e., overdispersion). In contrast, the null assumption of the Poisson distribution is that the variance of the count equals its mean. Therefore, the negative binomial specification is more appropriate for our data.

[22] 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.

Table 4
The effect of institutional ownership on firm patenting.

Lagged effect of institutional ownership	(1) 1-year lag	(2)	(3)	(4) Current	(5) 2-year lag
Specification	Without controls	Without R & D	With R & D	With R & D	With R & D
F.Institution%				0.0035***	
				(2.6)	
Institution%	0.012***	0.0061***	0.0053***		
	(6.5)	(3.8)	(3.4)		
L.Institution%					0.0074***
					(3.9)
ln(1 + R & D stock)			0.14***	0.14***	0.13***
			(5.4)	(5.4)	(4.9)
ln(Capital per labor)		−0.025	−0.017	−0.017	−0.021
		(−0.99)	(−0.72)	(−0.69)	(−0.81)
ln(Sales)		0.32***	0.27***	0.28***	0.28***
		(11)	(10)	(10)	(9.8)
ln(Age)		−0.095***	−0.049*	−0.039	−0.058
		(−3.2)	(−1.7)	(−1.3)	(−1.3)
Minority SOE		0.11**	0.093**	0.071	0.098**
		(2.3)	(2)	(1.6)	(2)
Majority SOE		−0.0026	−0.0072	−0.03	−0.02
		(−0.048)	(−0.13)	(−0.57)	(−0.34)
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	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.

O'Connor and Rafferty (2012) and estimate dynamic panel GMM models. The method was first developed by Anderson and Hsiao (1981). By time differencing Eq. (2), one can obtain:

$$\Delta \ln(1 + patent_{i,t}) = \alpha_2 \Delta \text{Institution}_{i,t-1} + \Delta X_{i,t-1}\beta_2 + \text{Year dummies} + \Delta\varepsilon_{i,t}, \quad (5)$$

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.[23]

4.2. Baseline estimation

First, in column (1) of Table 3, we estimate Eq. (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 of 0.15 estimated by Hu et al. (2017) for Chinese manufacturing firms.[24]

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 particular situation in China. During our examination period, China experienced a rise in wages for unskilled labor (Liang et al., 2016; Rong et al., 2015). Consequently, more labor-intensive (hence less capital-intensive) firms had more incentives to apply capital-substituting-labor strategies (Tan and Zhang, 2016), either to increase profits through product innovation or to reduce production costs through process innovation. Recent evidence suggests that the latter is of greater importance in China, as Chinese applicants file substantially more patents protecting process innovation 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.[25]

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 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

[23] 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 Eq. (2). These instruments are valid only if they are orthogonal to the firm fixed effect. This is unlikely to be the case here since the propensity of patenting is unlikely orthogonal to the firm fixed effect.

[24] 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.

[25] 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 when it comes to reporting their R & D expenditures.

Table 5
Disaggregation of institutional ownership.

Institution type	(1) Fund	(2) QFII	(3) Other domestic	(4) Interaction effects	(5) Interaction effects
Fund%	0.013***				0.012***
	(3.8)				(3.6)
QFII%		0.06		−0.013	−0.028
		(1.6)		(−0.3)	(−0.65)
Other Dom. ins.%			0.0017		0.0012
			(1)		(0.7)
QFII% *Fund%					0.0039
					(1.1)
QFII%*Other dom. ins.%					0.0021
					(0.75)
QFII%*Dom. ins.%				0.0032	
				(1.6)	
Dom. ins.%				0.0037**	
				(2.5)	
Control variables	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	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.

robustness check when the effect of institutional ownership on firm patenting is estimated.

In our estimations, we adjust standard errors by clustering at the firm level. It has the feature to remain robust in the presence of heteroscedasticity and the presence of autocorrelation within firms. As a robustness check, we rerun the regressions of columns 1–3 in Table 3 by a method proposed by Cameron et al. (2011), in which standard errors are robust to heteroscedasticity and two-way clustered by both firms and years. The estimated standard errors only change in a negligible manner.

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 results from enhanced R & D productivity rather than increased R & D investment.[26] 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. This 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 levels of patenting. It also reveals that minority SOEs are more productive in patenting, which is consistent with the finding by Cai and Tylecote (2008) that hybrid firms (i.e., minority SOEs) have the highest dynamic capacity for innovation.

We further estimate different lagged effects of institutional ownership. In column (4), 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.[27]

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)–(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. Specifically, 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

[26] 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.

[27] As one referee correctly pointed out, considering the sequence of the cause and effect of institutional ownership on firm innovation, one should expect the effect to be more pronounced with a lag of three or four years. We thus rerun the regression of column 3 in Table 4 with institutional ownership lagged by three and four years, respectively. As expected, the magnitude of the coefficient on institutional ownership increases further. Specifically, with a three-year lag, the coefficient increases to 0.012; it goes up to 0.016 with a four-year lag. However, in the interest of receiving more efficient estimates, we choose the specification with a one-year lag as the baseline. Compared to our baseline specification, using the most demanding specification with a four-year lag results in a loss of 3317 observations. This loss accounts for 39% of total observations and seems disproportional to the gains.

Table 6
Institutional ownership effects, by period.

Ownership type	(1) Gross	(2)	(3) Disaggregated	(4)
Period	2001–2006	2007–2011	2001–2006	2007–2011
Institution%	0.014***	0.0045***		
	(4)	(2.8)		
Fund%			0.015***	0.013***
			(3.4)	(3.5)
QFII%			0.022	0.13**
			(0.52)	(2.4)
Other dom. ins.%			0.011*	0.002
			(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.

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 negligible 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 tends to rely more on the presence of mutual funds than 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 supported by two investigations discussed below. First, we examine different lagged effects of the three types of ownership in Appendix Table A2. 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 with the coefficient on fund ownership remaining 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 from 2006 onwards. 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 by 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 becomes 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,[28] we conclude that fund ownership is the major driving force behind the gross effect of institutional ownership.[29]

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.

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 controlling 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.[30]

To address time-invariant unobservable confounders, we include firm dummies as specified in Eq. (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 Eqs. (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

[28] We further confirm the importance of fund ownership by employing the negative binomial specification in Appendix Table A3. While the coefficient on institutional ownership turns insignificant (column 1), the coefficient on fund ownership remains significantly positive (column 2), which further confirms our argument that it is mutual funds that really matter.

[29] 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.

[30] 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 carried out such reform. The major results remain unchanged, while the reform effect is positive but insignificant.

Table 7
Robustness tests.

Specification	(1) OLS with more controls	(2) FE	(3) 2SLS 1st-stage	(4) 2SLS 2nd-stage	(5) GMM
Panel A. The effect of institutional ownership					
Index or not			1.8**		
			(2.1)		
Institution%	0.0051***	0.0038***		0.22*	0.0034
	(3.3)	(3.6)		(2)	(1.4)
Tobin's Q	0.06***				
	(4.8)				
ROA	−0.76***				
	(−3.1)				
LEV	−0.13				
	(−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 P-value				0.035	
Cragg-Donald Wald F statistic				4.5	
P-value for AR(2) Test					0.61
P-value for Hansen Test					0.46
Panel B. The effect of fund ownership					
Indexing or not			2.2***		
			(4.9)		
Fund%	0.012***	0.0087***		0.18***	0.014**
	(2.8)	(3.7)		(3.7)	(2.3)
Tobin's Q	0.048***				
	(3.7)				
ROA	−0.91***				
	(−3.7)				
LEV	−0.13				
	(−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 P-value				0.000	
Cragg-Donald Wald F statistic				24	
P-value for AR(2) Test					0.58
P-value for Hansen Test					0.49

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.

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 in the stock index stimulates the level of institutional ownership. We conduct endogeneity tests to examine whether the OLS estimates are different from the 2SLS estimates. The null hypothesis of the 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 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 higher 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

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

Ownership type	(1) Institution	(2)	(3) Fund	(4)
Competition extent	High	Low	High	Low
Institution%	0.0051**	0.0049***		
	(2.1)	(2.6)		
Fund%			0.039***	0.0073**
			(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.

Ownership type	(1) Institution	(2)	(3)	(4) Fund	(5)	(6)
Firm type	POE	Minority SOE	Majority SOE	POE	Minority SOE	Majority SOE
Panel A. Threshold, 0%–50%						
Institution%	0.0054***	0.0098***	0.038			
	(3.1)	(3.4)	(0.21)			
Fund%				0.019***	0.012**	0.015*
				(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

Firm type	(1) 5% POE	(2) Minority SOE	(3) 10% POE	(4) Minority SOE
Panel B. Alternative thresholds				
Fund%	0.015***	0.013	0.015***	0.012
	(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.

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 stem from either the career concern view or the rent-seeking view. To examine which channel drives the result, we deepen our analysis using 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 intensifies, the rent-seeking view predicts the opposite. Second, we examine cross-sectional differences for POEs, minority SOEs, and majority SOEs. Our assumption is that, compared to those in POEs, executives in SOEs, especially those in majority 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.[31] 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 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 the more intense the competition (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.

[31] 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).

Table 10
The effect of fund ownership on citation counts.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Competition extent		Firm type		
Sample	Full	2001–2006	2007–2011	High	Low	POE	Minority SOE	Majority SOE
Fund%	0.016***	0.019***	0.015***	0.04**	0.014***	0.021***	0.011***	0.0067
	(7.7)	(4.6)	(7.2)	(2.3)	(5.3)	(7.7)	(3.9)	(0.27)
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.

4.5.2. Institutional ownership and firm types

In Table 9 we examine the heterogeneous effects of institutional ownership among POEs, minority SOEs, and majority 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 minority 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 majority 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 minority SOEs than among majority 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. As expected, its magnitude is higher than that among either minority SOEs or majority SOEs.

To confirm that our findings are robust to different thresholds, we change the threshold between POEs and minority 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 limited 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 when in reality only patent applications are increasing while 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. Though it leads to a small number of citations, this requirement 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 that fund ownership has a positive effect on firm patenting, is such an effect still distinguishable when it comes to 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. Unlike patent applications, which can be filed even without conducting any formal R & D,[32] 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.[33] 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 among minority SOEs (0.011), and both are significant at the 1% level. In contrast, the effect is the weakest among majority SOEs (0.0067) and insignificant. It seems that while mutual funds still have a weak impact on the quantity of innovation produced by majority SOEs, whose governmental innovation-related performance indicators are usually defined in terms of patent quantity, there is no impact on the actual quality of innovation produced by these firms.[34]

5. Discussion and policy implications

In this section we present several recommendations for 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 present-day China.

Consistent with prior studies on developed economies, we find that institutional investors, particularly mutual funds, positively influence firm innovation among POEs and minority 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 had a positive impact on firm innovation and should be continued. Our findings also suggest that those policy recommendations made by prior studies can also be applied to transition economies, such as China. For instance, to reduce the innovation risk for executives and in doing so to achieve a higher level of innovation, government authorities could grant institutional investors, particularly mutual funds, greater board representation in listed firms. Additionally, many innovation-related policy suggestions intended to solve the rent-seeking problem should be implemented with caution if career concerns, instead of rent-seeking, are in fact the major agency problems for executives regarding innovation.

Our study extends prior research in two major ways. First, we document heterogeneous effects of different institutions. In particular, we find that independent institutions such as mutual funds are effective in promoting firm innovation while other domestic institutions, which

[32] Non-R & D inventions are not unusual in developing countries and also exist in developed countries (Rammer et al., 2012).

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

[34] Compared to patent counts, citation counts are more likely to be 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.

are generally regarded as grey institutions, are not. Therefore, Chinese policy makers may like to concentrate 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 is dependent 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 in China to promote QFIIs, whose shareholdings currently only account for a tiny proportion, to invest in firms with mutual fund ownership.

Second, our study also reveals that the effect of mutual funds varies significantly across different firm types. Specifically, in contrast to POEs and minority SOEs, we do not see much of a positive effect among majority SOEs. POEs and minority SOEs are generally more profit-oriented, and the manager market for these types of firms is more competitive; consequently, leveraged by their expertise, mutual funds have more incentives to monitor, thereby stimulating innovation in these firms. In contrast, due to their multiple targets and the less competitive appointment and compensation scheme for CEOs, majority SOEs' innovation benefits little from the presence of mutual funds. It seems that, due to their government-controlled internal governance, majority SOEs are genuinely immune from external governance.[35] Consequently, without further privatization, the positive effect of mutual funds on innovation is seriously compromised in majority SOEs.

Unfortunately, interest groups that oppose privatization are on the rise in China. Although majority SOEs may comply with policy targets by meeting patent quotas at the low cost, it has had an unexpected consequence in that their patent applications have become disconnected from their productivity development in recent years (Boeing et al., 2016). It has also been documented that relying on SOEs to pursue a top-down approach to innovation results in the misallocation of resources (Wei et al., 2017). In this respect, encouraging private firms, which are generally discriminated against in the banking system, 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 stocks of innovative firms, most of which are POEs and minority SOEs.

Improving R & D productivity is crucial to continued economic growth in China, a country where innovation resources (e.g., highly qualified scientific personnel) are relatively scarce. We have confirmed the results of 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 findings suggest that the expansion of mutual funds serves as an effective instrument to enhance R & D productivity for Chinese listed firms, except for majority SOEs.

In summary, 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 to be 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 play 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 between 2002 and 2011, we find that (1) institutional ownership enhances firm patenting, (2) this effect is more pronounced when market competition is more intense, and (3) this effect exists among POEs and minority SOEs, but not among majority 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 the 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 after 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.

[35] 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 capital markets, it is reasonable to expect that the SOE manager market structure may also play a role.

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.
Minority SOE	Minority SOE dummy, equal to one if the firm's state ownership is positive but not more than 50%, and zero otherwise.
Majority SOE	Majority SOE dummy, equal to one if the firm's state ownership is greater than 50%, and zero otherwise.

Table A1
Robustness test with count models.

Dependent variable	(1) Patent count	(2)
Specification	Poisson	Negative binominal
ln(1 + R & D stock)	0.44***	0.22***
	(4.1)	(4.1)
ln(Capital per labor)	−0.27***	−0.04
	(−2.7)	(−0.73)
ln(Sales)	0.9***	0.62***
	(11)	(13)
ln(Age)	−0.096	−0.06
	(−0.84)	(−0.75)
Minority SOE	0.03	0.024
	(0.18)	(0.23)
Majority SOE	−0.34*	−0.19
	(−1.9)	(−1.3)
Year dummies	Yes	Yes
Industry dummies	Yes	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:

$f(\text{patent}_{i,t}|\text{x}) = e^{-\mu}\mu^{\text{patent}_{i,t}}/\text{patent}_{i,t}!$,

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

$$f(patent_{\text{i,t}}|\text{X}) = \frac{\Gamma(\alpha^{-1} + patent_{\text{i,t}})}{\Gamma(\alpha^{-1})\Gamma(patent_{\text{i,t}} +)}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\alpha^{-1}+\mu}\right)^{patent_{\text{i,t}}}.$$

Table A2
Disaggregating institutional ownership by type, lagged effects.

Lagged effect of institutional ownership	(1) One-year lag	(2) Current	(3) Two-year lag
F.Fund%		0.013***	
		(4)	
F.QFII%		0.034	
		(0.94)	
F.Other dom. ins.%		0.00075	
		(0.53)	
Fund%	0.014***		
	(4.1)		
QFII%	0.054		
	(1.4)		
Other dom. ins.%	0.0019		
	(1.1)		
L.Fund%			0.014***
			(3.5)
L.QFII%			0.057
			(1.4)
L.Other dom. ins.%			0.0038*
			(1.9)
Control variables	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	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.

Table A3
Robustness test of the institution effect by using the negative binominal model.

Ownership type	(1) Gross	(2) Fund
Institution%	0.0021	
	(0.68)	
Fund%		0.02***
		(3.1)
Control variables	Yes	Yes
Year dummies	Yes	Yes
Industry dummies	Yes	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.

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