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The real effect of partial privatization on corporate innovation: Evidence from China's split share structure reform☆

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ABSTRACT

We examine the real effect of partial privatization on corporate innovation. To establish causality, we explore plausibly exogenous variation in the expectation of further partial privatization generated by China's split share structure reform, which mandatorily converts non-tradable shares into freely tradable shares and opens up the gate to the further privatization of state-owned enterprises. We find that partial privatization prospects have a positive effect on corporate innovation. A better alignment of the interests of government agents with those of private shareholders and improved stock price informativeness appear to be two plausible underlying mechanisms. Our paper sheds new light on the real effects of partial privatization.

1. Introduction

Privatization — namely, the deliberate sale of state-owned enterprises (SOEs) or government assets to private economic agents — has attracted a lot of attention and spurred debate over its economic impact among academics, practitioners, and policy makers in the past a few decades. Advocates claim that privatization enhances productivity and economic efficiency by removing market frictions, improving risk sharing, lowering agency costs, and facilitating efficient resource allocation. Critics, however, argue that privatization leads to social and economic instability, lower national economic growth, increases in the expropriation of minority shareholders by large shareholders, and sales of state-owned assets at excessively low prices.[1] Given the intensive debate on privatization, we explore

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[1] See, e.g., Megginson (2010), for a comprehensive survey of the privatization literature.

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the real effect of privatization on technological innovation, which is arguably the most crucial driver of a country's economic growth and a firm's competitive advantage (Solow, 1957; Romer, 1986; Porter, 1992).

Specifically, we examine how partial privatization, in which the government remains the controlling owner, affects corporate innovation. Understanding the impact of partial privatization is important because most large privatization transactions begin with a partial sale of equity (Jones et al., 1999). In the case of China, all listed SOEs are partially privatized, but the state retains control of the firms. In this paper, we contribute to the debate about the economic consequences of privatization by focusing on how the expectation of further partial privatization affects corporate innovation.

Privatization can spur corporate innovation for at least two reasons. First, it mitigates the conflict of interest between government agents (i.e., controlling shareholders and managers) and private shareholders. Although in theory SOEs are owned by all people in a country, they are controlled by government agents. A primary concern about state ownership is that government agents could use their control rights to engage in rent-seeking or politically motivated resource allocations (Shleifer, 1998). Better interest alignment, induced by the expectation of further partial privatization, could lead to the more efficient allocation of resources to innovative projects. Second, after privatization, more information about SOEs becomes available from the stock market (Gupta, 2005; Ben-Nasr and Cosset, 2014). The additional information could be used by shareholders to monitor managers and allow managers to make more informed corporate investments, such as in technological innovation.

There are, however, a few alternative arguments that suggest privatization could impede corporate innovation. First, innovation activities not only generate financial returns to corporations but also benefit the society as a whole (Griliches, 1992; Hall, 1996). Because SOEs have more social responsibility than non-SOE firms (Gan et al., 2008), they may have more incentives to invest in innovations that further social welfare. Consistent with this view, Hall (1996) points out that the gap between private and social returns to innovative activities is the principal argument for government intervention in industrial innovation. After privatization, therefore, the reduction in government influence on SOEs could adversely affect their innovation activities. Second, SOEs face increased pressure from the financial market after privatization because stock market participants pay more attention to SOEs' financial performance than governments do. The existing literature has shown that short-term pressure from the financial market has negative effects on innovation outcomes. For example, He and Tian (2013) find that analysts exert too much pressure on managers to meet short-term targets, impeding firms' investment in long-term innovative projects. Chemmanur and Tian (2018) show that pressures from hostile takeovers alter managers' incentives and stifle corporate innovation. Third, in the case of partial privatization, since the government remains the controlling owner, the impact of privatization on innovation outcomes may only be cosmetic.

Although there are likely merits to both sides of these arguments, in practice it is difficult to identify the causal effect of privatization on corporate innovation due to endogeneity concerns. First, there is a concern about selection bias: a sample of traditional share issue privatizations (SIPs) that is commonly used in the literature tends to be biased toward the very largest firms sold through privatization programs. Second, comparing the innovation output of fully or partially privatized firms and SOEs could result in misleading conclusions because of the fundamental but unobservable differences between these two groups of firms. Finally, expected changes in a firm's innovation output may cause its inclusion in the privatization program, leading to a reverse causality concern. Therefore, a correlation between privatization and innovation output may tell us little about the causal effect of privatization.

To tackle these endogeneity issues and establish causality, we explore plausibly exogenous variation in partial privatization expectations generated by a quasi-natural experiment in China: the split share structure reform (hereafter, the share reform) that commenced in 2005. The share reform allows previously non-tradable shares, including those of SOEs held by the Chinese government, to be freely traded on stock exchanges. Thus, it effectively removes the legal and technical obstacles to transferring state-owned shares to public investors on the stock market and opens up the gate to further privatization. Before the share reform, government agents in charge of SOEs were prohibited from selling state-owned shares. After the share reform, further sales of state-owned shares became a valid option for them. In this sense, the share reform created an expectation that there would be further privatization. Taking advantage of this unique setting, we attempt to conduct an empirical study that examines the causal effect of privatization prospects on firm innovation.[2]

The share reform in China has three important features that offer a unique opportunity to examine the effect of partial privatization on firm innovation. First, the share reform was initiated for reasons other than the enhancement of technological innovation. It, therefore, represents a quasi-natural experiment that is exogenous to firm innovation. Second, the share reform is mandatory: no firms can endogenously choose whether and when to convert non-tradable shares. Finally, while the share reform is carried out simultaneously on both SOEs and non-SOEs, it generates expectations of further privatization only on the part of SOEs, because the transfer from state to private ownership can occur only in SOEs. We can, therefore, use non-SOEs as a benchmark for evaluating the innovation performance of SOEs. In Section 3, we provide more a detailed discussion of the share reform.

We use a difference-in-differences (DiD) approach to study how the innovation output of SOEs changes surrounding the share reform compared with that of non-SOEs. As has now become standard in the innovation literature (He and Tian, 2018), we use patent-based information collected from the State Intellectual Property Office of China (SIPO) to construct innovation proxies. After

[2] In the existing literature, Li et al. (2011) and Liao et al. (2014) treat the share reform as a privatization event. Consistent with this view, press reports suggest that people who are key decision makers and opinion leaders in the share reform view the share reform as evolving from the intention to privatize more state-owned shares. For example, Cui (2018) reports the interview with Mr. Fulin Shang, who was in charge of the share reform as the Chairman of the China Securities Regulatory Commission. Dr. Sheng Hua, who is a finance professor recognized by the state for having exerted substantial influence on the share reform, provides a memoir of the split share structure reform (Hua, 2010). Both Mr. Shang's and Dr. Hua's account of the event suggests that the share reform evolves from the government's intention to further privatize state-owned shares.

performing a variety of diagnostic tests to ensure that the parallel trend assumption, the key identifying assumption of the DiD approach, is not violated, we find a positive effect of privatization prospects on firm innovation in both univariate and multivariate tests. Our regression results suggest that the expectation of further privatization leads to a 13.4% greater increase in patent quantity and an 11.5% greater increase in patent quality for SOEs than for non-SOEs.

We then perform robustness checks and placebo tests to make sure that our baseline results are not driven by reverse causality or by chance. First, although the share reform constitutes an exogenous shock to the privatization expectation, there is still a concern that our baseline results might be driven by reverse causality. That is, changes in innovation productivity could trigger the share reform. Our discussion on the institutional background of the share reform in Section 3 suggests that this alternative argument is unlikely to be true. Nevertheless, we provide further evidence against the reverse causality argument by examining the dynamics of innovation output surrounding the share reform (Bertrand and Mullainathan, 2003). We do not find a prior trend in innovation output, but observe a larger increase in innovation output for SOEs than for non-SOEs only after the share reform. Second, to address the concern that our DiD results could have been driven by chance, we run a placebo test that randomly and artificially assigns our sample firms to SOE and non-SOE groups and repeats the DiD regressions based on this simulated sample. We find that the DiD estimates obtained from this placebo test are zero, on average. The evidence suggests that it is unlikely that our baseline results are driven by chance.

Next, we explore two plausible underlying mechanisms through which the expectation of further privatization encourages firm innovation: better alignment of the interests of government agents with those of private shareholders and improved stock price informativeness. To this end, we examine how cross-sectional variation in conflicts of interest, as measured by related-party transactions, and stock price informativeness affect our main results. We find that the effect of the share reform is more pronounced for firms that can potentially benefit more through these two channels. Specifically, we observe that the DiD estimates are statistically and economically larger for firms with more related-party transactions and lower stock price informativeness before the reform. We also confirm that, after the share reform, SOEs experience larger reductions in related-party transactions and larger increases in stock price informativeness than non-SOEs. Taken together, our evidence suggests that better interest alignment and improved stock price informativeness are two plausible underlying mechanisms through which the expectation of further privatization spurs innovation.

In the final part of the paper, we investigate how local institutions affect the post-reform innovation performance of SOEs. A contemporaneous paper by Fang et al. (2017) examines the innovation performance of firms that switch from SOE to privately controlled status. They find that the increase in innovation output is larger among firms that enjoy better local intellectual property rights (IPR) protection. A potential concern regarding their findings is that local IPR protection could be highly correlated with other local institutions. To address this concern, we use the provincial level marketization index constructed by the National Economic Research Institute (NERI) in our tests. The marketization index is widely regarded as a meaningful measure of a province's progress toward the market economy (Lin et al., 2016; Wang et al., 2008; Fan et al., 2011). It comprises several component sub-indexes, among which is a sub-index for intellectual property protection and a sub-index for government-market relation. The correlations of the overall marketization index with the IPR protection sub-index and the government-market relation sub-index are 0.86 and 0.91, respectively. Thus, low marketization provinces tend to have poorer IPR protection and more government intervention.

We find that SOEs in provinces that have low levels of marketization before the reform experience a larger increase in innovation output than those in high marketization provinces. The evidence is consistent with the interest alignment channel. Firms in low marketization provinces are subject to more government intervention and are therefore more seriously affected by the conflict of interest between government agents and private investors. These firms benefit more from the share reform, which aligns government agents' interests with the interests of private shareholders. Consistent with this view, we also find that firms from the provinces with weaker local institutions, as measured by the IPR protection sub-index or by the government-business relationship sub-index, experience a larger increase in innovation output.

The above findings are different from the evidence documented by Fang et al. (2017), who find that formal institutions encourage innovation in firms that switch from state ownership to private control. There are a few plausible explanations for this discrepancy.[3] First, the majority of the transactions in their study are related-party transactions, such as management buyout (MBO) or other related-party buyouts. Technological innovation could be a reason for the buyouts if the target is in a location with high IPR protection. Second, by Chinese law, the impact of local IPR protection on local corporate innovation is likely to be very small. Generally, a Chinese court's jurisdiction is based on the defendant's domicile, a jurisdictional doctrine that is commonly characterized as “plaintiff accommodating defendant.”[4] According to the Chinese Supreme Court, patent infringement cases shall be “under the jurisdiction of the court of the place where the infringing act is committed or of the place of domicile of the defendant.”[5] Thus, if a company located in a province with high IPR protection has its patent rights infringed by another company located in a province with low IPR protection, the case will most probably be under the jurisdiction of the low-IPR-protection province. In other words, better local IPR protection is more likely to prevent local companies from infringing other companies' patent rights than to protect their

[3] In addition, Galasso and Schankerman (2014) and William (2013) provide evidence that intellectual property rights for existing technologies may actually hinder subsequent innovation.

[4] Civil Procedure Law of the People's Republic of China (promulgated by the National People's Congress on April 9, 1991, last revised by the Standing Committee of National People's Congress on June 27, 2017, effective June 27, 2017), available at http://www.npc.gov.cn/englishnpc/Law/2007-12/12/content_1383880.htm.

[5] Several provisions of the Supreme People's Court on Issues Concerning Applicable Laws to the Trial of Patent Controversies (promulgated by the Supreme People's Court on June 19, 2001, effective July 1, 2001), available at http://en.pkulaw.cn/display.aspx?cgid=35745&lib=law.

patent rights from being infringed by companies in other provinces. Third, large and small Chinese firms may rely on different mechanisms for protections against ex-post expropriation of innovation investment. Our sample consists of listed firms that are substantially larger than those in Fang et al. (2017). Given their size and importance in the local economy, larger Chinese firms could protect their intellectual property rights by establishing political ties and other informal relationships with local authorities.

The third explanation is consistent with the argument that informal mechanisms play an important role in supporting China's economic development (Allen et al., 2005). The Chinese government treats large and small SOEs differently during its economic reform process. Many small SOEs are sold or closed, but large SOEs are corporatized and partially privatized. This “dual-track” system is a unique feature of China's economic reform. To paint a complete picture of the economic reform in China, it is important to take the differences between these two sectors into account. The evidence we document suggests that China's stellar economic growth cannot be achieved using a one-size-fits-all formula. Instead, different sectors of the Chinese economy rely on different mechanisms for growth.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 presents background information about China's split share structure reform. Section 4 describes the sample selection and reports summary statistics. Section 5 presents the main results. Section 6 discusses possible mechanisms. Section 7 examines how local institutions alter our main results. Section 8 concludes.

2. Relation to the existing literature

Our paper is related to the literature on privatization. There is a large strand of literature on the impact of privatization in both transition and non-transition economies.[6] Shleifer (1998) points out that the primary concern over state ownership is that government agents may use their control rights to engage in rent-seeking and politically motivated resource allocation. Consistent with this view, Megginson et al. (1994) find that firms that divested through SIPs experience significant improvements in operating performance. Goyal et al. (2014) show that firms are able to pay higher dividends after privatization largely because their operating performance improves and their agency costs go down. Gupta (2005) finds that privatization in India has a positive effect on firm profitability, productivity, and investment. Ben-Nasr and Cosset (2014) find that state ownership is associated with lower firm-level stock price informativeness.

A few recent studies examine the consequences of China's split share structure reform. Firth et al. (2010) find that state and mutual fund ownership have contrasting effects on the compensation ratio. Li et al. (2011) show that the compensation size is positively associated with the gain from risk-sharing and they highlight the role of risk-sharing in China's privatization. Chen et al. (2012) find that the share reform leads to better incentive alignments between controlling and minority shareholders and relaxes financial constraints. Liao et al. (2014) show that the expectation of further privatization generated by the reform positively affects the profitability and governance of SOEs.

Our paper is also related to the emerging literature on motivating firm innovation. The empirical literature shows that various firm characteristics and economic forces can affect managerial incentives to invest in innovation. For example, institutional investors (Aghion et al., 2005; Aghion et al., 2013; Gu et al., 2017; Luong et al., 2017; Brav et al., 2018; He and Tian, 2019), corporate venture capital (Chemmanur et al., 2014), bankruptcy laws (Acharya and Subramanian, 2009), labor power (Acharya et al., 2013; Bradley et al., 2017), stock liquidity (Fang et al., 2014), shareholder litigation (Lin et al., 2017), policy uncertainty (Bhattacharya et al., 2017), insider trading (Levine et al., 2017), technology spillovers (Byun et al., 2019), financial innovation (Chang et al., 2019), customers' feedback (Chu et al., 2019), financial market development and liberalization (Hsu et al., 2014; Moshirian et al., 2020), financial reporting frequency (Fu et al., 2020), and failure tolerance (Manso, 2011; Tian and Wang, 2014) have all been found to affect managers' and employees' incentives to innovate.[7] However, there has been a paucity of evidence on whether a causal relation exists between privatization and firm innovation. Our paper contributes to this line of research by providing a rigorous empirical analysis of how the expectation of further privatization affects innovation.

Two contemporaneous studies examine the relation between state ownership and corporate innovation. Cao et al. (2020) find that SOEs generate substantially more patent output per dollar of R&D spending than non-SOEs. Fang et al. (2017) find that privatized firms that enjoy better local IPR protections increase innovation output more than those with poorer IPR protections. Our study differs from that of Fang et al. (2017) in the following important respects. First, Fang et al. (2017) focus on privatizations in which corporate control changes mainly through private transactions, whereas we study how the expectation of further sales of state-owned shares in public financial markets affects innovation. Second, Fang et al. (2017)'s experiment design does not allow them to identify the causal relationship between privatization and innovation partly because an SOE's decision to change control and its innovation potential are endogenously determined, and partly because they do not include non-SOEs as a control group. Third, Fang et al. (2017) examine a sample of relatively small firms whereas we focus on publicly listed firms, which may rely on alternative mechanisms to protect the returns to their investment in corporate innovation.

[6] Megginson and Netter (2001) and Megginson (2010) provide excellent surveys of this literature.

[7] See He and Tian (2018, 2020) for a survey of the literature on finance, institutions, and corporate innovation.

3. Institutional background of China's split share structure reform in 2005

As in many other countries, the privatization process in China begins with a partial sale of equity in the stock market.[8] The first milestone in China's privatization process was the establishment of the Shanghai Stock Exchange and the Shenzhen Stock Exchange in the early 1990s, which allowed approved firms to go public and issue exchange-listed tradable shares. By allowing SOEs to sell newly issued stocks to private investors through the stock market, the government effectively transfers a minority stake in these enterprises to private owners. To minimize the political opposition and economic risks associated with the reform, the Chinese government initially imposes a split share structure on listed firms.[9] Under the split share structure, about two-thirds of domestically listed A-shares are not publicly tradable, although holders of these shares have the same voting and cash flow rights as holders of tradable shares. Typically, state and legal persons are holders of non-tradable shares, while domestic institutional investors, individual investors, and foreign individual investors are holders of tradable shares. To maintain its influence over SOEs, the government retains substantial ownership in the majority of listed SOEs by holding non-tradable shares of these firms. Hence, although the share issue privatization in the 1990s is considered the first wave of privatization in China, it was at best partial privatization because it transferred only a small portion of SOE ownership to the public.

Beginning in the late 1990s, the Chinese government launched several attempts to privatize more state-owned shares, all of which failed due to adverse stock market reactions.[10] These attempts caused adverse market reactions because they were viewed as breaching the agreement between the Chinese government and public investors on the non-tradability of state-owned shares.[11] After unsuccessful early attempts, the Chinese government realized that the legacy dual share structure was an important obstacle to further privatization.

In April 2005, the Chinese government initiated the split share structure reform, the second major milestone in China's privatization process. The share reform involves mandatory conversion of all non-tradable shares into shares that are freely tradable on stock exchanges, subject to shareholder approval and appropriate compensation to holders of tradable shares.[12] The share reform specifies a time period during which large (and typically controlling) shareholders of Chinese listed firms are required to convert their previously non-tradable shares into tradable shares. By the end of 2011, 99% of firms in our sample had completed their reforms. Table 1 Panel A reports the number of firms that completed the share reform in each year.

By removing the split share structure as an obstacle to transferring state-owned shares to public investors on the stock market, the share reform opened the gate to further privatization. Before the share reform, government agents in charge of SOEs, such as controlling shareholders and senior executives, were legally and contractually not allowed to sell additional state-owned shares on the stock market. Since the share reform, they can reasonably expect to sell state-owned shares on the market when necessary. In this sense, the share reform leads to an increase in privatization expectation. This greater ability to sell shares will, in turn, alter corporate decision making, including their decisions about innovation.

The share reform provides a unique opportunity to examine the effect of privatization on firm innovation because of its three important features. First, the share reform was initiated for reasons other than the enhancement of technological innovation. According to the blueprint for the share reform, *Some Opinions of the State Council on Promoting the Share Reform, Opening, and Steady Growth of Capital Markets*, issued by the State Council on January 31, 2004, the goals of the share reform were to optimize ownership structure, improve corporate governance, increase capital returns, and promote financial market development. As noted earlier, the share reform aimed to resolve the split share structure that stemmed from the transition of China's economy from a planned economy to a market-oriented economy, rather than to promote or discourage innovation. As such, the share reform constitutes a quasi-natural experiment that is exogenous to firm innovation.

Second, the share reform is mandatory. The China Securities Regulatory Commission (CSRC) set August 2005 as the starting date and all Chinese firms were expected to finish the reform by the end of 2006 (Firth et al., 2010). The share reform does not allow firms to choose whether or when to convert non-tradable shares. Instead, the actual timing of the conversion was based on the amount of time required to implement and complete the reform procedures — i.e., the time it would take to communicate with shareholders and to obtain the necessary votes.

Finally, the share reform was carried out simultaneously for both SOEs and non-SOEs, allowing us to use non-SOEs as a benchmark for evaluating the innovation performance of SOEs. Through the share reform, both types of firms converted non-tradable

[8] Most privatization programs begin with a partial sale of equity in the stock market (Gupta, 2005). The government can choose to sell more shares later if the situation allows. The speed of the process depends on social, economic, and political factors. Take India's privatization program, which started in 1991, for example. From 1991 to 1999, the federal government sold an average of just 19.2% of equity in 40 of 258 industrial, financial, and service sector firms and majority stakes in none. Dinc and Gupta (2011) attribute the slow speed partly to resistance from politicians.

[9] Deng Xiaoping, the chief architect of China's economic reform, repeatedly emphasizes that China should "cross the river by feeling the stones" (i.e., China should implement economic reforms step by step through trial and error). By legally ensuring initial state control over most listed firms, the split share structure minimizes the potential political opposition and economic risks associated with the reform.

[10] As Hua (2010) points out, the Chinese government decided in 1999 to privatize more state-owned shares as a means of funding social security accounts.

[11] Liao et al. (2014) suggest that the fundamental reason why the market reacted so negatively to the early attempts is that these attempts "directly breached previous IPO and SEO agreements on the non-tradability of state-owned shares" (p. 405). They further support that argument by pointing out that "investors refused to accept the notion of privatizing state-owned shares without completely legitimizing their trading rights and compensating tradable shareholders" (p. 405).

[12] Please refer to Liao et al. (2014) for a detailed discussion of the negotiation process.

Table 1
Variable definitions and summary statistics.

Panel A: The number of firms that complete the share reform each year.

Year	# of Firms	Cumulative percentage (%)	# of SOEs	Cumulative percentage (%)	# of Non-SOEs	Cumulative percentage (%)
2005	217	16.83	117	14.61	100	20.49
2006	890	85.88	587	87.89	303	82.58
2007	112	94.57	65	96.00	47	92.21
2008	29	96.82	13	97.63	16	95.49
2009	20	98.37	8	98.63	12	97.95
2010	4	98.68	0	98.63	4	98.77
2011 and beyond	7	99.22	5	99.25	2	99.18
Total	1289		801		488	

Panel B: Variable definitions.

Variable	Definition
Pat	Total number of invention and utility model patent applications filed (and eventually granted) by a firm in a given year
InvPat	Total number of invention patent applications filed (and eventually granted) by a firm in a given year
Post	An indicator variable that takes the value of one for years after a firm completes the share reform and zero otherwise
SOE	An indicator variable that takes the value of one for firms with more than 25% government ownership as of the fiscal year end prior to the share reform
Leverage	(Long term debt - Cash)/(Market value of equity + Long term debt- Cash)
Tangibility	PP&E/Total assets
Profitability	Return on total assets (ROA)
Sales	Sales in millions of RMB
SalesGrowth	Annual sales growth rate
Age	Number of years since the firm's IPO
Patent Growth	Patent growth, defined as the mean value of (Pat_t-Pat_{t-1}) in the 3-year period before the share reform
TotCites	The logarithm of one plus the number of future citations received by the invention patents applied by a firm in a year that are eventually granted
AvgCites	The logarithm of one plus the average number of future citations received by the invention patents applied by a firm in a year that are eventually granted
RelatedTrans	Total amount of related-party transactions scaled by lagged total assets
PreRelatedTrans	Average *RelatedTrans* calculated using the most recently available four years of data before the share reform
Info	The logit transformation of *1- R^2*, where R^2 is obtained from estimating the regression model specified in *Eq.(3)* using daily stock returns
PreInfo	Average *Info* calculated using the most recently available four years of data before the reform

Panel C: Summary statistics

Variable	N	25th	Median	Mean	75th	S. D.
Pat	13,977	0.000	0.000	7.312	3.000	31.390
InvPat	13,977	0.000	0.000	2.267	1.000	10.800
SOE	13,977	0.000	1.000	0.629	1.000	0.483
Cash (Mil RMB)	13,977	99.97	245.50	574.49	561.34	1057.0
LT debt (Mil RMB)	13,977	1.217	50.10	523.26	272.76	1528.7
Leverage	13,977	−0.133	−0.045	−0.082	0.003	0.235
Tangibility	13,977	0.152	0.265	0.293	0.416	0.185
Profitability	13,977	0.009	0.030	0.023	0.055	0.082
SalesGrowth	13,977	−0.016	0.144	0.248	0.333	0.689
Age	13,977	5.000	8.000	8.266	11.000	4.206
Sales (Mil RMB)	13,977	400.80	977.60	2995.00	2382.00	6717.0

This table presents the share reform sample, the variable definitions and descriptive statistics for the sample firms. Panel A reports the number of firms that complete the share reform in each year. Panel B defines all variables used in our analyses. Panel C reports the descriptive statistics for the sample firms. The sample consists of 13,977 firm-year observations for 1289 non-financial firms over the 12 year period from 2000 to 2011. We require that the sample firms be listed on the Shanghai and Shenzhen Stock Exchanges at the end of 2004, the year prior to the share reform. All variables are winsorized at 1% and 99%.

shares to tradable shares. However, the non-tradable shares of SOEs were held mainly by entities affiliated with the government and those of non-SOEs were held mainly by private investors. Thus, the removal of the split share structure generated an expectation of future privatization (i.e., the future transfer of equity stakes from the government to private investors) only for SOEs, not for non-SOEs. By comparing the post-reform innovation output of SOEs (i.e., the treatment firms) with those of non-SOEs (i.e., the control firms), we can separate out the net effect of privatization on corporate innovation, uncontaminated by other unobservable firm

characteristics or economic conditions.

A potential concern about our empirical strategy is that the selection of state-owned firms or industries that were being privatized might not have been random. While this is a reasonable concern and a challenge faced by all privatization studies, we mitigate the concern by including firm fixed effects in all regressions to absorb time-invariant unobservable firm characteristics that may be correlated with the selection of state-owned firms.

4. Sample construction and descriptive statistics

We obtain information about our sample firms from several sources. Financial information about Chinese listed firms is retrieved from the China Stock Market & Accounting Research (CSMAR) database. Corporate ownership data used for identifying SOEs are obtained from the CSMAR database and the China Center for Economic Research (CCER) database. Patent grant information is obtained from the State Intellectual Property Office of China (SIPO). Following the procedure in Bessen (2009), we match patent data and firm financial data by firm name. We manually check for matching accuracy. We provide more details about the matching procedure in the Appendix.

Our final sample consists of 13,977 firm-year observations for 1289 non-financial firms, including 801 SOEs and 488 non-SOEs, over a 12-year period between 2000 and 2011. Our sample period starts in 2000 because that is the year in which China adopted a consistent and unified set of accounting standards for publicly traded firms. Because our purpose is to examine the differential effects of the share reform on existing SOEs and non-SOEs, we require that the sample firms be listed on the Shanghai or Shenzhen Stock Exchange at the end of 2004, the year prior to the commencement of the share reform. By the end of 2011, all sample firms except for 6 SOEs and two non-SOEs had completed their share reforms.

4.1. Measuring innovation

There are three types of patents under Chinese patent law: invention patents, utility model patents, and design patents. Chinese invention patents are granted for a new technical solution relating to a product, a process, or an improvement, which is similar to the description of U.S. utility patents. Chinese utility model patents are granted for new and practical technical solutions related to the shape and/or structure of a product, which is similar to the description of European and Japanese utility model patents. Utility model patents protect new, functional aspects of a product that do not meet the higher inventiveness level required for an invention patent. Chinese design patents are granted for new designs related to the shape, pattern or their combination, or the combination of color, shape, and/or pattern that is aesthetically pleasing and industrially applicable. In other words, a design patent protects the “look” of a product that makes it recognizable. The SIPO database covers all three types of patents. For each patent, SIPO provides information on patent application date, application ID, publication ID, granting date, and patent ID, along with the names of inventors and applicants.

Because design patents involve limited technological advancements, we construct our innovation outcome measures using only invention and utility model patents. We extract invention and utility model patent applications filed by (and eventually granted to) our sample firms, including those filed by their subsidiaries, from the SIPO database and use them to construct two measures of a firm's innovative outcome.[13] Our first measure of innovation output is *Pat,* defined as the total number of invention and utility model patents that are applied for by a firm and eventually granted to a firm in a year. We define the variable by application year rather than by granting year, because previous research shows that the application year is better able to capture the actual time of innovation (Griliches et al., 1988). To address the concerns related to variable skewness, we use the natural logarithm of one plus *Pat* as the main innovation outcome measure in our analysis.

A potential concern about this variable is that it measures only the quantity, not the quality of innovation. It is possible that, after the share reform, firms may have switched to the strategy of producing a larger number of patents at the expense of quality. If so, an increase in *Pat* does not necessarily mean that a firm's innovation performance improved. We therefore need a measure that captures patent quality. The existing innovation literature uses the number of future citations a patent receives as a measure of patent quality, assuming that more influential and higher-impact patents receive a larger number of subsequent citations. A practical difficulty we face in this study is that the SIPO database does not provide sufficient and reliable information on citations of Chinese patents. Therefore, we choose to measure a patent's quality based on its originality. According to Chinese patent law, invention patents are the most original of the three types of patents. We, therefore, use *InvPat*, defined as the number of invention patent applications filed by (and eventually granted to) a firm in a year as a proxy for a firm's innovation quality. To address issues related to skewness, we use the natural logarithm of one plus *InvPat* in our analysis. If we observe significant post-reform improvements using both *Pat* and *InvPat*, it helps to mitigate the concern that firms switched to a strategy of producing a larger number of low-quality patents. In Section 5.5 and the Internet Appendix, we use alternative measures of patent quality for robustness checks.

4.2. Defining SOEs and control variables

We define a firm's SOE status based on its state ownership information in the year prior to the firm's share reform. We obtain

[13] Our data cover all Chinese patents granted by the end of September 2014. Following Hirshleifer et al. (2012), we end our sample period three years before the last year in our patent database to address potential truncation issues.

ownership information from the CSMAR database. We first identify privately run firms by matching our sample firms with the CCER privately run firm database and label them as non-SOEs. We then check whether the largest controlling shareholders of the remaining firms are affiliated with the Chinese government by manually searching their background information through annual reports and the public press.[14] We identify a firm in our remaining sample as an SOE if its largest shareholder is affiliated with the Chinese government and holds at least 25% of the firm's outstanding shares.[15] This procedure identifies 801 SOEs and 488 non-SOEs in our sample.

As discussed in Section 3, China's secondary privatization is featured with the mandatory conversion of non-tradable shares of listed firms to tradable shares. We define the share reform completion year as the year in which a firm's non-tradable share conversion proposal is finalized. Following the innovation literature, we control for a vector of firm and industry characteristics that may affect a firm's innovation output. Our control variables include firm size, age, leverage, asset tangibility, profitability (measured by ROA), and sales growth rate. Table 1 Panel B provides detailed definitions of the variables used in our analysis.

4.3. Descriptive statistics

Table 1 Panel C reports summary statistics for our sample. To mitigate the effect of outliers, we winsorize all variables at the 1st and 99th percentiles. On average, our sample firms generate 7.3 patents per year, 2.3 of which are invention patents. Invention patents in China are equivalent to utility patents in the US system. He and Tian (2013) report that an average US firm in their sample generates 9.8 utility patents per year. Thus, Chinese listed firms appear to produce fewer patents than US-listed firms. A typical sample firm has been listed on the exchanges for 8 years and has annual sales of RMB 3 billion (about $450 M). It has an ROA of 2.3% and a sales growth rate of 24.8% per year. Following Bates et al. (2009), we define net leverage variable as net debt (i.e., long-term debt minus cash) scaled by the sum of net debt and market value of equity. The mean net leverage of our sample firms is −8.2%, suggesting that Chinese listed firms tended to hold slightly more cash than long-term debt during our sample period.[16]

In Fig. 1, we present the innovation output of SOEs and non-SOEs surrounding the share reform. The solid line in Panel A represents the average total number of invention and utility model patents produced by SOEs, and the dashed line displays the number of invention and utility model patents produced by non-SOEs. The number of patents trends closely in parallel for the two groups in the four years leading up to the share reform, suggesting that the parallel trend assumption of the DiD approach is likely satisfied. However, the gap between the two lines widens after the share reform because SOEs increase their patent generation at a faster pace than non-SOEs. Panel B displays the number of invention patents produced by the two groups of firms. Non-SOEs increase their invention patents at a relatively stable rate over time. The number of invention patents produced by SOEs initially grows at a slower rate than non-SOEs. However, SOEs increase their invention patent production more rapidly after the share reform, which widens the difference in invention patent counts between these two groups of firms. The figures in both panels show that, after the share reform, SOEs enhance their innovation productivity more than non-SOEs.

5. Main results

A standard approach to evaluating the effect of privatization on innovation is to run an OLS estimation that regresses a firm's innovation output variable on a variable that captures the privatization program in China. As we discussed before, however, this approach suffers from sample selection and endogeneity concerns. First, a sample of traditional SIPs is likely to be biased toward the very largest firms sold during the privatization program, causing a selection bias concern. Second, there are fundamental but unobservable differences between SOEs and non-SOEs. These differences could be related to innovation output, leading to spurious or biased inferences. Third, changes in a firm's innovation output could cause it to be included in the privatization program, raising concerns about reverse causality. Therefore, a correlation between privatization and innovation output obtained from a naïve OLS regression tells us little about the causal effect of privatization on innovation.

Our identification strategy is to exploit the plausibly exogenous increase in privatization expectations generated by a quasi-natural experiment in China — that is, the split share structure reform that commenced in 2005. We adopt a DiD approach to examine the effect of privatization prospects on innovation. The DiD approach has two key advantages. First, the DiD methodology rules out omitted time trends that are correlated with privatization and innovation in both SOEs (the treatment group) and non-SOEs (the control group). Second, the DiD approach controls for constant unobserved differences between the treatment and the control groups that may bias our estimation.

We start with a univariate DiD analysis in a sample of SOEs and propensity score matched non-SOEs in Section 5.1. We then perform the DiD tests in a multivariate regression framework in Section 5.2. In Sections 5.3 and 5.4, we perform dynamic analysis and placebo tests to support our baseline results. In Section 5.5, we conduct robustness checks using future global citations as an alternative proxy for patent quality.

[14] We follow this procedure to identify SOEs because the state ownership information provided by the CSMAR database is not very reliable. There are misclassifications or missing values of state and non-state ownership in the CSMAR database.

[15] We use the 25% threshold to ensure that the government has a significant influence on the listed firms. Our main findings do not change if we set the threshold for defining SOEs to be 20%, 30%, or 50%.

[16] Bates et al. (2009) show that U.S. firms hold more cash than long-term debt after 2004. It appears that Chinese firms exhibit a similar pattern in our sample.

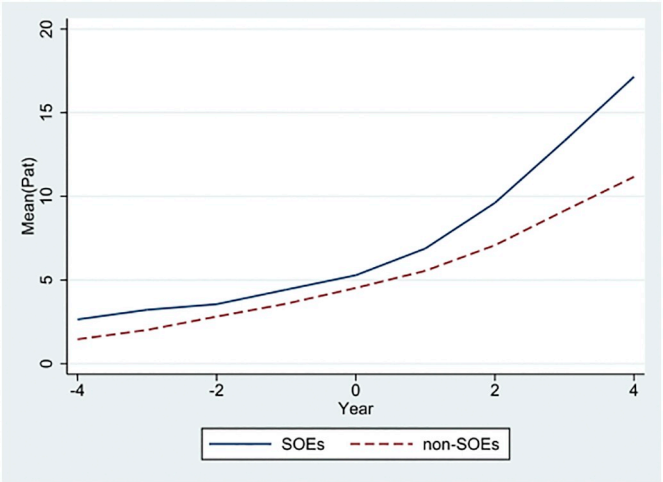

Fig. 1. Patent dynamics around the share reform.
This figure shows the mean difference in innovation captured by the average number of patents for SOE and non-SOE firms from four years before privatization to four years after privatization. Year 0 is the year in which the firm completes its split share structural reform. Panel A shows the difference in invention and utility model patents (*Pat*) and Panel B shows the difference in invention patents (*InvPat*).

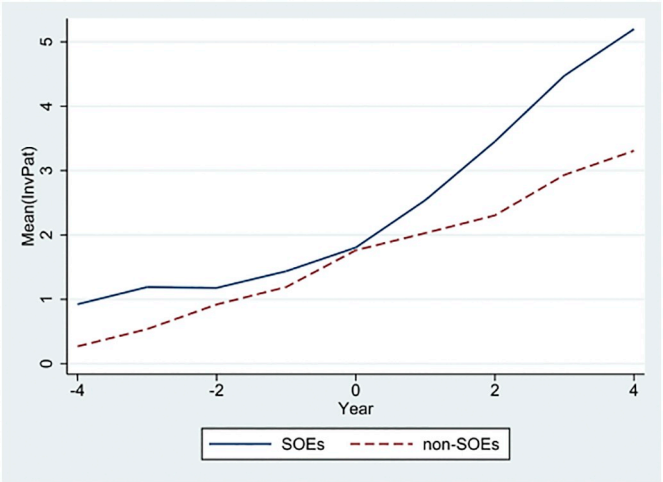

Fig. 1. (*continued*)

5.1. Univariate DiD analysis

For each SOE, we select a matched non-SOE using a propensity score matching algorithm. When applying the propensity score matching procedure, we first estimate a probit model based on all sample firms with non-missing matching variables in the year prior to the share reform.

In the probit model, the dependent variable is an SOE dummy that equals one for SOEs and zero otherwise. We include a vector of firm characteristics in the probit regression, including firm size, net leverage, ROA, sales growth, firm age, asset tangibility, and patent growth. We define patent growth as the average annual change in *Pat* over three years prior to the share reform. We include this variable to ensure the satisfaction of the parallel trend assumption of the DiD approach.[17] All other variables are measured at the fiscal year end before the share reform. In addition, we include industry and year dummies in the probit model.

We report the probit model results in Column (1) of Table 2 Panel A (labeled "Pre-Match"). The estimation results suggest that the specification captures a significant amount of variation in the choice variable, as indicated by a pseudo-R^2 of 10.1% and a *p*-value

[17] As Lemmon and Roberts (2010) point out, the parallel trend assumption does not require the level of outcome variables (innovation variables in our setting) to be identical across the treatment and control firms or across the two regimes, because these distinctions are differenced out in the estimation. Instead, this assumption requires similar trends in the innovation variables during the pre-reform regime for both the treatment and control groups.

Table 2
Univariate DiD test results.

Panel A: Propensity score regession and diagnostic regression

Dep. Var.	Pre-Match	Post-Match
	(1)	(2)
Leverage	0.098	−0.014
	(0.739)	(−0.091)
Tangibility	0.340	0.016
	(1.270)	(0.053)
Profitability	−0.523	0.170
	(−0.953)	(0.291)
SalesGrowth	0.078	0.051
	(1.097)	(0.669)
Log(Age)	0.030	−0.058
	(0.356)	(−0.631)
Log(Sales)	0.282***	0.031
	(8.344)	(0.761)
Patent Growth	−0.017**	−0.003
	(−2.126)	(−0.413)
Constant	−5.766***	−0.454
	(−7.526)	(−0.504)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	1178	827
Pseudo R-square	0.101	0.013
P-value of χ^2	< 0.001	0.656

Panel B: Balance tests.

	Treatment	Control	Diff.	*t*-test	P-value
Leverage	−0.180	−0.157	−0.023	−1.090	0.277
Tangibility	0.288	0.290	−0.002	−0.160	0.873
Profitability	0.011	0.008	0.003	0.560	0.578
SalesGrowth	0.193	0.158	0.035	0.860	0.388
Log(Age)	1.972	2.007	−0.035	−0.940	0.346
Log(Sales)	20.200	20.090	0.110	1.320	0.188
Patent Growth	0.792	0.789	0.003	0.010	0.995

Panel C: Univariate DiD tests

	Treatment (After-Before)	Control (After-Before)	DiD	Observations
	(1)	(2)	(3)	(4)
Ln(Pat)	0.884***	0.696***	0.188**	418
	(14.498)	(11.316)	(2.171)	
Ln(InvPat)	0.701***	0.498***	0.203***	418
	(13.612)	(9.722)	(2.803)	

This table reports the diagnostics and results of the DiD tests on the effect of privatization on innovation. Sample selection begins with all firms with non-missing matching variables and non-missing innovation outcome variables in the year prior to the share reform. We match firms using a one-to-one nearest neighbor propensity score matching, without replacement, on a set of observable firm characteristics. Panel A reports parameter estimates from the probit model used in estimating the propensity scores for the treatment and control groups. The dependent variable in the probit model is the SOE dummy. The "Pre-Match" column contains the parameter estimates of the probit model estimated using the sample prior to matching. These estimates are then used to generate the propensity scores for matching SOE and non-SOE firms. The "Post-Match" column contains the parameter estimates of the probit model estimated using the subsample of matched treatment-control pairs after matching. Definitions of all other variables are listed in Panel B of Table 1. The models in both columns of Panel A are estimated with industry and year fixed effects. Coefficient estimates are reported and t-statistics are displayed in parentheses below. Panel B reports the balance test results for the pairs of treatment and control firms after matching. Panel C reports the DiD test results and their corresponding t-statistics in parentheses below. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

from the χ^2 test of the overall model fitness well below 0.001. We then perform a nearest-neighbor propensity score matching procedure, using the predicted probabilities (propensity scores) obtained from the estimation in Column (1). Specifically, we match each SOE firm (labeled "Treatment") to a non-SOE firm (labeled "Control") with the closest propensity score. We end up with 418 one-to-one pairs of matched firms (836 observations).

Because the validity of the DiD estimate depends critically on the satisfaction of the parallel trend assumption, we undertake three diagnostic tests to check whether this assumption holds. First, as we discussed before, Fig. 1 shows that the number of patents trends closely in parallel for both SOEs and non-SOEs in the four years leading up to the share reform. This observation suggests that the parallel trend assumption of the DiD test is not violated.

Second, we re-estimate the probit model using the matched sample and report the estimation results in Column (2) of Table 2 Panel A (labeled "Post-Match"). None of the independent variables is statistically significant. In particular, the insignificant coefficient for pre-reform patent growth suggests that the treatment and control firms exhibit a similar growth rate in innovation outcomes before the share reform. In addition, the pseudo-R^2 drops dramatically from 10.1% prior to the matching to 1.3% after the matching, and the χ^2 test for the overall model fitness suggests that we cannot reject the null hypothesis that all of the coefficient estimates of independent variables in Column (2) are zero (i.e., the *p*-value is 0.656).

Finally, we report the univariate comparisons in firm characteristics between the treatment and control firms and their corresponding *t*-statistics in the year before the share reform in Table 2 Panel B. None of the observed differences between the treatment and control firms' pre-reform characteristics is statistically significant. In particular, the univariate comparison for the pre-reform patent growth is statistically insignificant and economically small, suggesting the satisfaction of the parallel trend assumption.

Overall, the diagnostic test results show that the propensity score matching process has removed meaningful observable differences in pre-reform characteristics between the treatment and control groups and that the parallel trend assumption is not violated. As a result, the matching procedure increases the likelihood that the observed difference in innovation output changes between SOEs and non-SOEs is caused by the share reform.

Table 2 Panel C reports the univariate DiD test results. We calculate the DiD estimator for *Ln(Pat)* by first subtracting the total number of invention and utility model patents that a firm generates during the four-year period preceding the share reform from that during the four-year period after the share reform for each treatment or control firm. Columns (1) and (2) present the average differences for, respectively, the treatment group and the control group. Column (3) reports the DiD estimation of *Ln(Pat)*, which is the difference between Columns (1) and (2). The DiD estimate for *Ln(InvPat)* is calculated in a similar way and is reported in the second row of Panel C.

The results reported in Panel C Columns (1) and (2) show that both the treatment and control firms experience improvements in innovation output after the share reform. More importantly, the DiD estimates of the innovation output variables reported in Column (3) are all positive and statistically significant at the 5% or 1% level. This finding suggests that the post-reform increase in innovation output is larger for the treatment group than for the control group. The economic effect is sizable. The DiD estimate for *Ln(InvPat)* is 0.203, suggesting that, in comparison with the average change in *Ln(InvPat)* in our matched sample (0.5995), the treatment firms experience an approximate 33.8% larger increase in invention patent counts than matched control firms over a nine-year period surrounding the share reform.[18] The magnitude of the DiD estimate for *Ln(Pat)* is also economically sizable.

The evidence from the univariate DiD tests suggests that SOEs experience a larger post-reform increase in innovation output than non-SOEs. Thus, the privatization expectation generated by the share reform appears to have a positive effect on innovation output.

5.2. Multivariate DiD analysis

In this subsection, we perform the DiD test in a multivariate regression framework. Specifically, we estimate the model in Eq. (1) in the full sample.

$$y_{i,t+4} = \alpha_i + \beta SOE_i \times Post_{i,t} + \gamma' Z_{i,t} + \delta_t + \varphi_i + \varepsilon_{i,t} \quad (1)$$

where i indexes firm and t indexes year. The dependent variable $y_{i,t}$ represents either *Ln(Pat)* or *Ln(InvPat)* measured at year $t + 4$.[19] SOE_i is a dummy variable that takes the value of one for SOEs and zero for non-SOEs. $Post_{i,t}$ is a dummy variable that equals one for firm-year observations after a firm completes the share reform and zero otherwise. $Z_{i,t}$ is a vector of control variables that may affect a firm's innovation output and is defined in Table 1 Panel B. We include year fixed effects, δ_t, to account for time-specific shocks to a firm's innovation output and firm fixed effects, φ_i, to absorb any time-invariant unobservable firm characteristics that may bias the results. We cluster standard errors by firm in all regressions.

The coefficient estimate of $SOE_i \times Post_{i,t}$ is the DiD estimate that captures the causal effect of privatization prospects on innovation. If the share reform leads SOEs to achieve a larger increase in innovation output than non-SOEs, this coefficient should be positive and statistically significant. Note that we include only the interaction term $SOE_i \times Post_{i,t}$ in the regressions, but not the two dummy variables alone because these two variables are absorbed by firm and year fixed effects, respectively.

Table 3 presents the results from estimating Eq. (1). In Column (1), the dependent variable is the innovation quantity variable, *Ln(Pat)*. Consistent with the results from our univariate analysis, the coefficient estimate of the interaction term is positive and significant at the 1% level. The economic effect of the share reform on firm innovation output is sizable. The magnitude of the DiD coefficient estimate in Column (1) suggests that, in comparison with the innovation output prior to the share reform, SOEs exhibit a

[18] In Table 2 Panel C, the changes in *Ln(InvPat)* are 0.701 and 0.498, respectively, for the control and treatment groups. Thus, the average change in *Ln(InvPat)* for the combined propensity score matched sample is 0.5995 = (0.701 + 0.498)/2.

[19] We choose to use a four-year-ahead innovation output variable as the dependent variable because it generally takes time for innovation processes to generate observable outputs due to the fact that innovation represents a long-term investment in intangible assets. Our main results, however, do not change if we use the patent output variables two or three years ahead as the dependent variables.

Table 3
The effect of privatization on innovation: DiD regressions.

Dep. Var.	$Ln(Pat)_{t+4}$	$Ln(InvPat)_{t+4}$
	(1)	(2)
SOE × Post	0.134***	0.115***
	(2.880)	(3.272)
Leverage	0.007	0.001
	(0.104)	(0.017)
Tangibility	−0.066	−0.077
	(−0.626)	(−1.061)
Profitability	0.182	0.124
	(1.615)	(1.593)
SalesGrowth	−0.008	−0.010
	(−0.570)	(−1.089)
Log(Age)	0.274***	0.119*
	(3.093)	(1.832)
Log(Sales)	0.082***	0.052***
	(3.860)	(3.727)
Constant	−1.088**	−0.721**
	(−2.352)	(−2.327)
Year FE	Yes	Yes
Firm FE	Yes	Yes
Observations	8965	8965
R-squared	0.788	0.745

This table reports the results of the DiD regressions designed for testing the effect of privatization on innovation. Variable definitions are reported in Panel B of Table 1. All regressions include firm and year fixed effects. The t-statistics reported in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

13.4% larger increase in innovation output than non-SOEs four years after the share reform. The regression in Column (2) takes the innovation quality measure, *Ln(InvPat)*, as the dependent variable. The coefficient estimate of the interaction term is positive and significant at the 1% level. The magnitude of the coefficient suggests that, in comparison with patent quality prior to the share reform, SOEs exhibit an 11.5% larger increase in innovation quality than non-SOEs four years after the share reform. Because the DiD estimates are significantly positive in both columns, the evidence suggests that SOEs experience substantially larger improvement in both patent quantity and patent quality than non-SOEs surrounding the share reform.

Taken together, the evidence from the univariate and multivariate DiD tests suggests that SOEs experience greater improvement in innovation output than non-SOEs after the share reform. The evidence is consistent with the conjecture that the expectation of further privatization generated by the share reform has a positive effect on innovation output.

5.3. Dynamics of innovation output surrounding the share reform

In this subsection, we examine the dynamics of innovation output surrounding the share reform to address the potential reverse causality concern. As discussed earlier, although the share reform represents a plausibly exogenous shock to privatization expectations, it is still possible that our results are driven by reverse causality. That is, changes in innovation productivity may trigger the share reform. For example, the government may choose to launch the share reform in response to improved innovative productivity. Another concern is that there could be pre-existing trends in innovation output between SOEs and non-SOEs that are not captured by our visual check of Fig. 1. If so, these pre-existing trends could drive our results even in the absence of the share reform.

To address the reverse causality concern, we examine the dynamics of innovation output surrounding the share reform in the spirit of Bertrand and Mullainathan (2003). Specifically, we estimate the following model:

$$y_{i,t} = \alpha_i + \beta_1 SOE_i \times Before^{-1}_{i,t} + \beta_2 SOE_i \times Current^{0}_{i,t} + \beta_3 SOE_i \times After^{1}_{i,t} + \beta_4 SOE_i \times After^{2}_{i,t} + \beta_5 SOE_i \times After^{3}_{i,t} + \beta_6 SOE_i \times After^{4+}_{i,t} + \tau_1 Before^{-1}_{i,t} + \tau_2 Current^{0}_{i,t} + \tau_3 After^{1}_{i,t} + \tau_4 After^{2}_{i,t} + \tau_5 After^{3}_{i,t} + \tau_6 After^{4+}_{i,t} + \gamma' Z_{i,t} + \delta_t + \varphi_i + \varepsilon_{i,t}, \quad (2)$$

where *Before-1 i,t* is a dummy variable that equals one if the observation is one year before a firm completes the share reform and zero otherwise. *Current0 i,t* is a dummy variable that equals one if the observation is in the share reform completion year and zero otherwise. Similarly, *After1 i,t*, *After2 i,t*, and *After3 i,t* are dummy variables that equal one if the observation is the first, second, and third year after a firm completes the share reform and zero otherwise, respectively. *After4+ i,t* is a dummy variable that takes the value of one for all years starting from the fourth year after the share reform and zero otherwise. All other variables have the same definitions as in Eq. (1). If there is a pre-existing trend in the innovation output of SOEs and non-SOEs, we should observe statistically significant coefficient estimates of β_1 and β_2.

Table 4
Privatization and innovation: dynamics.

Dep. Var.	$Ln(Pat)_t$	$Ln(InvPat)_t$
	(1)	(2)
$SOE \times Before^{-1}$	0.028	0.026
	(0.645)	(0.797)
$SOE \times Current^{0}$	0.046	0.028
	(0.897)	(0.756)
$SOE \times After^{1}$	0.091	0.057
	(1.597)	(1.320)
$SOE \times After^{2}$	0.138**	0.103**
	(2.247)	(2.207)
$SOE \times After^{3}$	0.110	0.109**
	(1.577)	(2.068)
$SOE \times After^{4+}$	0.167**	0.149***
	(2.276)	(2.752)
$Before^{-1}$	−0.040	−0.021
	(−0.879)	(−0.557)
$Current^{0}$	−0.057	−0.014
	(−0.845)	(−0.256)
$After^{1}$	−0.025	0.016
	(−0.285)	(0.224)
$After^{2}$	0.051	0.049
	(0.481)	(0.546)
$After^{3}$	0.179	0.152
	(1.377)	(1.380)
$After^{4+}$	0.274*	0.224*
	(1.770)	(1.676)
Leverage	−0.064	−0.033
	(−1.144)	(−0.847)
Tangibility	0.130	0.098
	(1.362)	(1.505)
Profitability	−0.038	−0.054
	(−0.396)	(−0.786)
SalesGrowth	−0.049***	−0.025***
	(−4.566)	(−3.470)
Log(Age)	0.248***	0.153***
	(3.437)	(2.776)
Log(Sales)	0.169***	0.101***
	(7.753)	(6.995)
Constant	−3.297***	−2.185***
	(−6.959)	(−6.819)
Year FE	Yes	Yes
Firm FE	Yes	Yes
Observations	13,977	13,977
R-squared	0.712	0.660

This table reports the results of the dynamic DiD regressions designed for examining innovation output surrounding the privatization year. $Before^{-1}$ is a dummy variable equal to one if it is one year before a firm completes the share reform. $After^{t}$ ($t \in \{1, 2, 3, 4^{+}\}$) is a dummy variable equal to one if it is t year after a firm completes the reform. $Current^{0}$ is a dummy variable for the share reform completion year. All regressions are estimated with firm and year fixed effects. The t-statistics in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

We report the results estimating Eq. (2) in Table 4.[20] The coefficient estimates on β_1 and β_2 are both statistically insignificant and economically negligible, suggesting that SOEs and non-SOEs do not exhibit significantly different trends in innovation output before the share reform.[21] In contrast, we find that the coefficient estimates on β_4, and β_6 are positive and significant in both columns. In Column (2), β_5 is also significantly positive. The estimation results suggest that SOEs start to exhibit a higher level of innovation output than non-SOEs two years after the share reform.

Besides addressing the reverse causality concern, the dynamic test results allow us to rule out an alternative explanation of our main results, which argues that the contracting environment for SOEs changed after the share reform. In the new contracting

[20] Because the regressions in Table 3 require information about innovation outcomes four years ahead, the last three years of observations are not used in regressions in Table 3. Thus, there are more observations in Table 4 than in Table 3.

[21] In unreported analysis, we confirm that our results do not change if we include $SOE_i \times Before_{i,t}{}^{-2}$ as an additional control variable. *Before-2 i,t* is a dummy variable that takes the value of one if the observation is two years before a firm completes the share reform and zero otherwise.

Table 5
Placebo tests.

Variable	Mean	P5	P25	Median	P75	P95	S.D.	N
Model (1) of Table 3								
Coefficient of *SOE*×*Post*	0.024	−0.042	−0.003	0.024	0.051	0.091	0.040	5000
T-stat for *SOE*×*Post*	0.520	−0.887	−0.059	0.516	1.087	1.963	0.860	5000
Model (2) of Table 3								
Coefficient of *SOE*×*Post*	0.038	−0.011	0.018	0.038	0.058	0.085	0.030	5000
T-stat for *SOE*×*Post*	1.056	−0.311	0.493	1.062	1.623	2.397	0.831	5000

This table reports the placebo test results for the multivariate DiD analysis. The results are obtained from randomization tests based on a sample from 5000 simulations. For each simulation, we draw a random sample of 801 "SOEs" from the pool of actual SOE and non-SOE sample firms, and then treat the remaining firms as "non-SOEs". We then perform the DiD tests as in Table 3 on this simulated sample. We repeat the simulation process 5000 times and summarize the distributions of the coefficients and corresponding t-statistics for the main variable of interest, *SOE*×*Post*. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

environment, SOEs enjoy less protection from the government than before and rely more on legal protection for intellectual properties. Thus, they may choose to file more patent applications even if they experience no real improvement in innovation productivity. If this alternative explanation is true, we should observe an immediate increase in patent applications for SOEs after the reform. Yet, our estimation results suggest that the increase begins two years after the reform, which is consistent with the notion that it takes time to observe innovation output improvement because innovation represents a long-term investment in intangible assets.

5.4. Placebo tests

This subsection addresses the concern that our DiD results could have been driven by chance instead of by the expectation of further privatization. Hence, we conduct a placebo test by running simulations that artificially assign SOE or non-SOE status to our sample firms. Specifically, in each simulation, we randomly draw 801 "SOEs" from the pool of all firms (SOEs and non-SOEs) in the pre-reform sample. We then treat the remaining 488 firms as "non-SOEs." We perform the DiD analysis, as specified in Eq. (1), on this simulated sample and then repeat the simulation process 5000 times.

In Table 5, we summarize the distributions of the simulated DiD estimates (i.e., the coefficient estimates of *SOE*×*Post*) by reporting the mean, 5th percentile, 25th percentile, median, 75th percentile, 95th percentile, and standard deviation. We also report the distribution of the corresponding *t*-statistics. Although the mean and median of simulated DiD estimates are positive, they are much smaller in magnitude than those reported in Table 3. In addition, the corresponding *t*-statistics are small and statistically insignificant. Hence, we cannot reject the null hypothesis that the DiD estimates obtained from this placebo test are zero. This finding suggests that our main results are unlikely to be driven by chance.

5.5. Patent quality

So far, we have used the number of invention patents (*InvPat*) as a measure of patent quality. To further address the concern that SOEs may switch to the strategy of producing a larger number of patents at the expense of quality, we examine the effect of the share reform using future citations as a measure of patent quality. Following Fang et al. (2017), we obtain citation data from the Patent Sight GmbH database.

We report the estimation results in Table 6. In Column (1), we regress *TotCites* on the same set of explanatory variables as in Table 3. *TotCites* is defined as the logarithm of one plus the number of future citations received by the invention patents applied by a sample firm in a year that are eventually granted. When we count future citations, we take into consideration the citations received by the patents across multiple patent offices around the world. The coefficient estimate on *SOE*×*Post* is positive and significant at the 5% level, suggesting that the quality of SOEs' aggregate innovation output increases relative to the quality of non-SOEs' after the share reform. The dependent variable in Column (2) is *AvgCites*, which is defined as the logarithm of one plus the average number of future citations received by the invention patents applied by a sample firm in a year that are eventually granted. This variable captures the average quality of a firm's patents. The DiD estimator is statistically insignificant in Column (2). These findings suggest that the innovation quality of SOEs is at least as good as that of non-SOEs and that SOEs do not appear to increase innovation quantity by sacrificing the quality of patents.

A potential concern about the above results is that our data do not allow us to adjust for the truncation problem of patent citations. Citation counts are inherently truncated, since patents continue to receive citations over a long period, but we observe at best the citations received up to the last year of the available data. Hall and Adam (2002) state that, for their sample of US patents, "50% of citations are made to patents at least 10 years older than the citing patent, 25% to patents 20 years older or more, and 5% of citations refer to patents that are at least 50 years older than the citing one." Because our paper uses fairly recent patents, the truncation problem could be a serious concern. To address the citation truncation problem, we need a long time series of data. Chinese patent and citation data, however, are sparsely available before 2000, making the time series too short for truncation adjustment. To check the robustness of our results, we construct four alternative measures of patent quality and undertake a series of additional tests. We find qualitatively similar results and confirm our findings. We report the results in the Internet Appendix.

Table 6
The effect of privatization on patent quality: DiD regressions.

Dep. Var.	$TotCites_{t+4}$	$AvgCites_{t+4}$
	(1)	(2)
SOE × Post	0.129**	0.037
	(2.571)	(1.369)
Leverage	0.009	−0.013
	(0.126)	(−0.297)
Tangibility	−0.092	−0.049
	(−0.842)	(−0.762)
Profitability	0.161	0.061
	(1.374)	(0.868)
SalesGrowth	−0.024*	−0.010
	(−1.908)	(−1.489)
Log(Age)	0.132	0.049
	(1.405)	(0.964)
Log(Sales)	0.068***	0.018**
	(3.621)	(2.160)
Constant	−0.810*	0.005
	(−1.916)	(0.025)
Year FE	Yes	Yes
Firm FE	Yes	Yes
Observations	8965	8965
R-squared	0.717	0.563

This table reports the results of the DiD regressions designed for testing the effect of privatization on patent quality. Variable definitions are reported in Panel B of Table 1. All regressions include firm and year fixed effects. The t-statistics reported in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

6. Plausible underlying mechanisms

So far, our empirical results suggest that there is a causal link between privatization prospects and firm innovation. In this section, we explore plausible underlying economic mechanisms through which the expectation of further privatization enhances firm innovation. We hypothesize that privatization encourages corporate innovation through two possible underlying mechanisms: better interest alignment between government agents and other shareholders and improved stock price informativeness.

6.1. Interest alignments

The first plausible mechanism that allows privatization to promote innovation is better interest alignment between government agents and minority shareholders. SOEs are arguably owned by all people in China, but are controlled by government agents (i.e., controlling shareholders and SOE executives). According to Shleifer (1998), the primary concern about state ownership is that government agents may use their control rights to engage in rent seeking and politically motivated resource allocation activities. For example, government agents could ask SOEs to boost local employment or to engage in projects that are strategically important for the government even if these activities are not in the best interest of minority shareholders. They could even directly exploit minority shareholders through various tunneling activities (Jiang et al., 2010; Jian and Wong, 2010).

The split share structure exacerbates the conflict of interest between government agents and minority shareholders. Because state-owned shares are non-tradable, government agents operating SOEs are evaluated based on the book value of firm assets, revenues, and short-term profits. Thus, they have limited incentives to invest in long-term, value-enhancing projects, such as innovation, that can boost the firms' stock prices and market value. After the share reform, state-owned shares become market priced and legally transferable. Government agents will be evaluated based on the market value, rather than book value, of state-owned shares. Moreover, to generate more proceeds from expected future sales of state-owned shares, government agents will have more incentives to boost stock prices. As a result, they will be more willing to invest in risky long-term projects that could enhance firm value and stock price, such as innovation projects.

If the interest alignment between government agents and minority shareholders is an underlying economic mechanism, the positive effect of the privatization expectation on innovation should be more pronounced for firms with more serious conflicts of interest between the two groups before the share reform. Following Liao et al. (2014), we use related-party transactions as a proxy for potential conflicts of interest between corporate insiders and outside investors. Through related-party transactions, firm resources can be transferred between listed firms and affiliated entities. The existing literature suggests that related-party transactions are one of the most widely used rent-seeking methods in China (e.g., Cheung et al., 2006; Liao et al., 2014) and represent serious conflicts of interest between corporate insiders and outside investors. Thus, we use the volume of related-party transactions to capture the conflict of interest faced by firms. We define *RelatedTrans* as the transaction amount with related parties scaled by lagged total assets. We obtain information on related-party transactions from the CSMAR database.

Table 7
Mechanisms – conflicts of interest.

Panel A: Subsamples analysis

	$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$	
Partition Var.	*Low*	*High*	*Low*	*High*
PreRelatedTrans	(1)	(2)	(3)	(4)
SOE × Post	0.057	0.244***	0.055	0.167***
	(0.840)	(3.213)	(1.061)	(2.963)
Leverage	−0.001	−0.023	−0.029	0.040
	(−0.006)	(−0.239)	(−0.409)	(0.562)
Tangibility	0.009	−0.023	−0.006	−0.079
	(0.057)	(−0.154)	(−0.059)	(−0.790)
Profitability	0.222	0.211*	0.134	0.119
	(0.819)	(1.723)	(0.685)	(1.501)
SalesGrowth	0.005	−0.008	0.004	−0.011
	(0.156)	(−0.485)	(0.181)	(−1.003)
Log(Age)	0.088	0.356**	0.046	0.118
	(0.608)	(2.189)	(0.407)	(1.121)
Log(Sales)	0.132***	0.058**	0.099***	0.034**
	(2.704)	(2.500)	(3.225)	(2.311)
Constant	−2.185**	−1.290**	−1.716***	−0.652*
	(−2.226)	(−2.388)	(−2.738)	(−1.919)
Year FE	Yes	Yes	Yes	Yes
Firms FE	Yes	Yes	Yes	Yes
Observations	3990	4021	3990	4021
R-squared	0.788	0.749	0.754	0.680
H_0: $\beta_{SOE*Post}{}^{High} = \beta_{SOE*Post}{}^{Low}$				
χ^2 Test	8.019***		4.683**	
P-Value	0.005		0.030	

Panel B: The effect of privatization on *RelatedTrans*.

Dep. Var.	*RelatedTrans*
	(1)
SOE × Post	−0.013*
	(−1.913)
Leverage	0.006
	(0.856)
Tangibility	−0.018
	(−0.834)
Profitability	−0.101***
	(−3.878)
SalesGrowth	0.027***
	(7.669)
Log(Age)	0.039***
	(3.407)
Log(Sales)	−0.019***
	(−4.841)
Constant	0.320***
	(4.124)
Year FE	Yes
Firms FE	Yes
Observations	12,060
R-squared	0.426

This table reports the results from our cross-sectional tests based on the degree of interest conflicts. The multivariate DiD models in Panel A are estimated on median partitioned subsamples, using the innovation outcome variables as the dependent variables. The Wald test reported at the bottom of Panel A tests the equivalence of the coefficients for *SOE × Post* between the high and low groups. The partition variable *PreRelatedTrans* is the average *RelatedTrans* calculated using the most recently available four years of data before the reform, *RelatedTrans* is defined as the total value of the related-party transactions scaled by lagged total assets, measured at the end of 2004. The DiD models in Panel B are estimated on the whole sample, using *RelatedTrans* as the dependent variable. Variable definitions can be found in Panel B of Table 1. All regressions are estimated with firm and year fixed effects. The t-statistics reported in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

We partition our sample into two subsamples based on whether a firm's *PreRelatedTrans* is above or below the sample median. The *PreRelatedTrans* variable is defined as the average *RelatedTrans* calculated using the most recently available four years of data before the reform. In the presence of incentive misalignments, more related-party transactions will be conducted on terms unfavorable to outside investors. Therefore, firms with above-median related-party transactions are considered to have a higher pre-reform exposure to conflicts of interest between corporate insiders and outside investors. These firms should benefit more from improved incentive alignments resulting from the share reform. To test this conjecture, we perform the DiD test in Eq. (1) separately for each of the two subsamples.

Table 7 Panel A presents the regression results. Columns (1) and (2) report the results with *Ln(Pat)* as the dependent variable. Columns (3) and (4) report the results with *Ln(InvPat)* as the dependent variable. The DiD estimates (i.e., the coefficient estimates of *SOE*×*Post*) are positive and significant at the 1% level in Columns (2) and (4), in which firms with more serious pre-reform conflicts of interest are examined. However, in Columns (1) and (3) in which firms with fewer pre-reform related-party transactions are examined, the DiD estimates have negligible magnitudes and are statistically insignificant. For example, the coefficient estimate of *SOE*×*Post* is 0.057 (*t*-statistic = 0.840) in Column (1), but 0.244 (*t*-statistic = 3.213) in Column (2). The magnitude of the coefficient is about four times larger for firms with above-median *PreRelatedTrans* than for those with below-median *PreRelatedTrans*. We test the equivalence of the DiD estimates between the high and low *PreRelatedTrans* groups using a Wald test and report the test statistics at the bottom of the table. Both test statistics are significant at the 1% or 5% level. Hence, we are able to reject the null hypothesis that the DiD estimates are the same across these two groups of firms. The evidence in Table 7 Panel A suggests that the effect of privatization expectations on innovation is more pronounced for firms with more related-party transactions and hence more severe conflicts of interest before the share reform.

The validity of this mechanism relies on the premise that the conflict of interest between government agents and minority shareholders of SOEs is indeed mitigated after the share reform. We next examine this premise in the DiD framework and report the results in Table 7 Panel B. We estimate Eq. (1) after replacing the dependent variable with *RelatedTrans*. The coefficient estimate of *SOE*×*Post* is negative and significant, suggesting that SOEs experience a larger reduction in related-party transactions than non-SOEs surrounding the share reform. The evidence is consistent with the view that the privatization expectation helps to align the interests of government agents in charge of SOEs with the interests of minority shareholders of SOEs. Taken together, the evidence in Table 7 suggests that this better interest alignment is a plausible underlying economic mechanism through which privatization prospects triggered by the share reform promote firm innovation.

6.2. Stock price informativeness

The second possible mechanism through which privatization spurs firm innovation is improved stock price informativeness. The privatization expectation generated by the share reform alters government agents' incentives, motivating them to engage in less politically motivated resource allocations and run SOEs more like profit-maximizing entities. This should make fundamental analysis more valuable when determining the investment worthiness of SOEs than before. As a result, more market participants should be willing to spend time and resources on collecting and analyzing information about SOEs.

Financial markets can aggregate the information gathered by many investors who, though individually less informed, are collectively more informed than firm managers (Grossman, 1976; Subrahmanyam and Titman, 1999). The resulting improvement in stock price informativeness could enhance firm innovation for two reasons. First, as Gupta (2005) points out, various stakeholders can use the information contained in stock prices to monitor managers more effectively. Better monitoring could lead to more efficient corporate decisions on investments, especially investments in long-term, risky projects, such as innovation. Second, more informative stock prices allow firm managers to acquire new information and insights. These pieces of information could be very relevant and valuable to their innovation decisions.[22] Thus, improved stock price informativeness is likely an underlying economic mechanism through which privatization prospects promote firm innovation.

To explore this mechanism, we perform the DiD tests on subsamples of firms with different levels of stock price informativeness before the share reform. If our conjecture is supported, the positive effect of the share reform on innovation should be more pronounced for firms that could benefit more from better price informativeness — i.e., firms with less informative stock prices before the share reform. Following Gul et al. (2010), we use the stock price non-synchronicity measure as a proxy for stock price informativeness. We define *Info* as the logit transformation of ($1\text{-}R^2$), where R^2 is obtained by estimating the regression model in Eq. (3) using daily stock return in each year.

$$Ret_{i,t} = \alpha_i + \beta_1 MktRet_t + \beta_2 MktRet_{t-1} + \beta_3 IndRet_t + \beta_4 IndRet_{t-1} + \varepsilon_{i,t} \quad (3)$$

In Eq. (3), $Ret_{i,t}$ is daily stock returns for firm i in day t, $MktRet_t$ is value-weighted Chinese market returns, and $IndRet_t$ is value-weighted industry returns at day t. Following Gul et al. (2010), we require at least 200 trading days of return data when estimating *Info*. Previous research argues that *Info* captures the amount of firm-specific information reflected in its stock price (e.g., Ferreira and Laux, 2007; Chen et al., 2007; Gul et al., 2010). The rationale is that if a firm's stock price contains more firm-specific information, then the market model explains a smaller proportion of stock price fluctuation, leading to a lower R^2 (i.e., higher *Info*).

We partition the sample based on whether a firm's *PreInfo* is above or below the sample median. *PreInfo* is the average *Info*

[22] Consistent with this view, Chen et al. (2007) and Luo (2005) find that managers acquire and incorporate private information contained in stock prices when making investment decisions.

Table 8
Mechanisms – stock price informativeness.

Panel A: Subsample analysis

Dep. Var.	$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$	
Partition Var.	*Low*	*High*	*Low*	*High*
PreInfo	(1)	(2)	(3)	(4)
SOE × Post	0.206***	0.050	0.184***	0.019
	(2.867)	(0.666)	(3.256)	(0.338)
Leverage	−0.024	0.013	0.039	−0.025
	(−0.261)	(0.118)	(0.521)	(−0.347)
Tangibility	0.085	−0.052	−0.087	0.006
	(0.467)	(−0.343)	(−0.646)	(0.063)
Profitability	0.168	0.224*	0.056	0.118
	(0.466)	(1.672)	(0.211)	(1.322)
SalesGrowth	0.024	−0.019	0.020	−0.020*
	(0.657)	(−1.052)	(0.779)	(−1.894)
Log(Age)	0.139	0.223	0.053	0.078
	(0.977)	(1.303)	(0.471)	(0.683)
Log(Sales)	0.178***	0.083***	0.097**	0.070***
	(2.882)	(2.686)	(2.348)	(3.764)
Constant	−3.264***	−1.512**	−1.726**	−1.269***
	(−2.661)	(−2.199)	(−2.060)	(−3.023)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	3842	3902	3842	3902
R-squared	0.788	0.751	0.753	0.695
H_0: $\beta_{SOE*Post}^{High} = \beta_{SOE*Post}^{Low}$				
χ^2 Test	5.180**		9.395***	
P-Value	0.023		0.002	

Panel B: The effect of privatization on stock price informativeness.

Dep. Var.	*Info*
	(1)
SOE × Post	0.065**
	(2.114)
Leverage	0.146***
	(4.128)
Tangibility	−0.017
	(−0.232)
Profitability	0.005
	(0.047)
SalesGrowth	0.086***
	(8.674)
Log(Age)	0.266***
	(3.784)
Log(Sales)	−0.113***
	(−9.007)
Constant	2.765***
	(10.640)
Firm FE	Yes
Year FE	Yes
Observations	11,112
R-squared	0.580

This table reports the results from our cross-sectional tests based on stock price informativeness. The multivariate DiD models in Panel A are estimated on median partitioned subsamples, using the innovation outcome variables as the dependent variables. The partition variable *PreInfo* is the average *Info* calculated using the most recently available four years of data before the reform, where *Info* is defined as the logit transformation of $1\text{-}R^2$ where R^2 is estimated by Eq. (3), measured at the end of 2004. The Wald test reported at the bottom of Panel A tests the equivalence of the coefficients for *SOE × Post* between the high and low groups. Variable definitions used in the analysis can be found in Panel B of Table 1. The DiD models in Panel B are estimated on the whole sample, using *Info* as the dependent variable. All regressions are estimated with firm and year fixed effects. The t-statistics reported in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

calculated using the most recently available four years of data before the reform. Then we estimate the model in Eq. (1) separately for each subsample and report the estimation results in Table 8 Panel A. As in Table 7, we report the results for firms with below-median *PreInfo* in Columns (1) and (3) and those for firms with above-median *PreInfo* in Columns (2) and (4).

The coefficient estimates of the DiD variable, $SOE \times Post$, are statistically significant for the subsample of firms with low pre-reform stock price informativeness, but not for the subsample with high pre-reform stock price informativeness. The magnitudes of the DiD estimates are also over four times greater for firms with low pre-reform stock price informativeness than for firms with high stock price informativeness. We conduct a Wald test to test the equivalence of the DiD estimates between the two regressions. The *p*-values of the tests are significant at the 1% or 5% level, suggesting that the positive effect of privatization prospects on firm innovation is more pronounced for firms with low pre-reform stock price informativeness.

The above analysis is based on the premise that the share reform improves the stock price informativeness of SOEs more than that of non-SOEs. To determine whether the premise is accurate, we examine the change in stock price informativeness surrounding the share reform in a DiD framework and report the results in Panel B of Table 8. We estimate Eq. (1) using *Info* as the dependent variable. The DiD estimate is positive and significant at the 5% level, suggesting that SOEs experience a larger improvement in stock price informativeness than their non-SOE peers after the share reform. Taken together, the evidence reported in this subsection supports the view that improved stock price informativeness is a plausible underlying mechanism through which privatization prospects triggered by the share reform promote firm innovation.

7. Privatization expectation, local institutions, and innovation output

In this section, we examine how local institutions affect the post-reform innovation performance of SOEs. We divide all provinces in China into two groups by their marketization index value as of 2004. Constructed by the National Economic Research Institute (NERI), the provincial level marketization index is widely used in the existing literature to capture a province's progress toward a market economy (Lin et al., 2016; Wang et al., 2008; Fan et al., 2011). A higher index value indicates that the province is more market-oriented. The marketization index comprises several component sub-indexes, among which there is a sub-index for local IPR protection and a sub-index for government-market relation. The IPR protection sub-index and the government-relation sub-index are highly correlated with the overall marketization index. Thus, firms in high-marketization provinces tend to enjoy better local IPR protection and face less government intervention than those in low-marketization provinces.

Local institutions can affect the post-reform innovation performance of SOEs through either an IPR protection effect or an interest alignment effect. On one hand, Fang et al. (2017) argue that ex-post expropriation, as a result of poor IPR protection, discourages corporate investment in innovation. Following their logic, the positive effect of the share reform should be more pronounced in high-marketization provinces. On the other hand, because firms in low-marketization provinces are subject to more government intervention, they tend to be more seriously affected by the conflict of interests between government agents and private shareholders. These firms therefore can potentially benefit more from the share reform due to better interest alignment resulting from the share reform. This means that the positive effect of the share reform should be more pronounced in low-marketization provinces.

To test these two effects, we estimate our baseline model separately for the high- and low-marketization groups and report the estimation results in Table 9 Panel A. For the low-marketization group reported in Columns (1) and (3), the DiD estimates are positive and significant at the 1% level. In Columns (2) and (4) in which we report the results for firms in high-marketization provinces; however, the DiD estimates are statistically indistinguishable from zero. Consider the results in Columns (3) and (4), for example. The coefficient estimates of $SOE \times Post$ suggest that, in provinces with low marketization, SOEs experience a 19.7% larger increase in invention patents than non-SOEs four years after the share reform. In provinces with high marketization, however, the difference between SOEs and non-SOEs is much smaller and statistically insignificant. The results in Table 9 Panel A are more consistent with the interest alignment effect than with the IPR protection effect.

Next, we divide the sample firms by the *government-market relation sub-index*, which measures the relation between the government and market in a province. Firms in provinces with lower *government-market relation sub-index* values are subject to more government intervention and hence are more adversely affected by the conflict of interest between government agents and private shareholders. We estimate our baseline model separately for each group and report the estimation results in Panel B. Consistent with the results in Panel A, the DiD estimates are positive and significant for firms in provinces with weaker institutions, but statistically insignificant in provinces with stronger institutions.

The results in Panels A and B support the view that better interest alignment is a channel through which privatization enhances innovation, but are inconsistent with Fang et al. (2017). To compare our findings with theirs, we divide our sample firms into two groups by the *IPR protection sub-index* and estimate our baseline model separately for each group and report the results in Panel B. Once again, we find that firms in provinces with weaker institutions (i.e., provinces with poorer IPR protection) before the share reform experience a greater increase in innovation output after the share reform. The evidence suggests that the interest alignment effect outweighs the IPR protection effect for the listed firms in our sample.

There are a few plausible explanations for the discrepancy between our findings and those of Fang et al. (2017). As we discussed earlier, Chinese law states that patent right infringement cases shall be “under the jurisdiction of the court of the place where the infringing act is committed or of the place of domicile of the defendant.” Thus, local IPR protection plays a more important role in preventing local companies from infringing the patent rights of other companies than in protecting the patent rights of local companies from being infringed. It is not surprising, therefore, that the IPR protection effect is outweighed by the interest alignment effect. Moreover, we examine a very different sample of firms. Our sample consists of firms listed on the Shanghai and Shengzhen stock exchanges. On average, their assets are more than 90 times larger than those examined by Fang et al. (2017). Because of the

Table 9
The impact of local marketization.

Panel A: Analysis partitioned by *marketization*

	$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$	
Partition Var.	*Low*	*High*	*Low*	*High*
Marketization Index	(1)	(2)	(3)	(4)
SOE × Post	0.236***	0.038	0.197***	0.041
	(3.506)	(0.585)	(3.952)	(0.815)
Leverage	−0.031	0.042	−0.026	0.026
	(−0.321)	(0.479)	(−0.347)	(0.400)
Tangibility	−0.265*	0.124	−0.245**	0.086
	(−1.871)	(0.763)	(−2.448)	(0.761)
Profitability	0.299**	−0.022	0.132	0.076
	(2.029)	(−0.121)	(1.296)	(0.631)
SalesGrowth	−0.032	0.012	−0.019	−0.005
	(−1.598)	(0.603)	(−1.528)	(−0.384)
Log(Age)	0.244*	0.278**	0.034	0.164*
	(1.891)	(2.278)	(0.369)	(1.732)
Log(Sales)	0.076***	0.098***	0.047***	0.064***
	(2.856)	(3.033)	(2.696)	(3.180)
Constant	−0.952	−1.357*	−0.440	−1.051**
	(−1.619)	(−1.929)	(−1.138)	(−2.289)
Year FE	Yes	Yes	Yes	Yes
Firms FE	Yes	Yes	Yes	Yes
Observations	4539	4426	4539	4426
R-squared	0.741	0.820	0.666	0.790
H_0: $\beta_{SOE*Post}{}^{High} = \beta_{SOE*Post}{}^{Low}$				
χ^2 Test	10.768***		10.809***	
P-Value	0.001		0.001	

Panel B: Analysis partitioned by *government-market relation subindex* and *IPR subindex*

	$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$		$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$	
Partition Var.	*Government-market Relation Subindex*				*IPR Subindex*			
	Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SOE × Post	0.232***	0.025	0.194***	0.028	0.230***	0.048	0.188***	0.052
	(3.532)	(0.382)	(3.947)	(0.567)	(3.276)	(0.795)	(3.640)	(1.071)
Leverage	0.035	−0.025	0.016	−0.017	0.087	−0.038	0.059	−0.026
	(0.369)	(−0.296)	(0.216)	(−0.267)	(0.807)	(−0.482)	(0.745)	(−0.441)
Tangibility	−0.269*	0.151	−0.308***	0.193*	−0.350**	0.145	−0.318***	0.118
	(−1.888)	(0.939)	(−3.093)	(1.750)	(−2.237)	(0.997)	(−2.909)	(1.176)
Profitability	0.248*	0.058	0.110	0.117	0.341**	−0.032	0.147	0.073
	(1.758)	(0.306)	(1.100)	(0.954)	(2.267)	(−0.189)	(1.427)	(0.632)
SalesGrowth	−0.027	0.005	−0.021	−0.005	−0.026	0.003	−0.017	−0.009
	(−1.185)	(0.314)	(−1.496)	(−0.444)	(−1.171)	(0.170)	(−1.232)	(−0.719)
Log(Age)	0.161	0.324***	0.010	0.170*	0.246*	0.233**	0.055	0.134
	(1.256)	(2.637)	(0.116)	(1.727)	(1.859)	(1.969)	(0.598)	(1.397)
Log(Sales)	0.082***	0.083***	0.050***	0.057***	0.070**	0.105***	0.046**	0.063***
	(2.987)	(2.786)	(2.872)	(2.958)	(2.485)	(4.127)	(2.565)	(3.488)
Constant	−1.312**	−1.468**	−0.729**	−1.021**	−1.131**	−1.814***	−0.678*	−1.104***
	(−2.374)	(−2.352)	(−2.067)	(−2.435)	(−2.007)	(−3.323)	(−1.877)	(−2.777)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4805	4160	4805	4160	4490	4475	4490	4475
R-squared	0.755	0.819	0.692	0.788	0.746	0.823	0.678	0.789

(*continued on next page*)

Table 9 (*continued*)

Panel B: Analysis partitioned by *government-market relation subindex* and *IPR subindex*

	$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$		$Ln(Pat)_{t+4}$		$Ln(InvPat)_{t+4}$	
Partition Var.	*Government-market Relation Subindex*				*IPR Subindex*			
	Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
H0: $\beta_{SOE*Post}^{High} = \beta_{SOE*Post}^{Low}$								
χ^2 Test	11.824***		12.189***		9.026***		8.135***	
P-Value	0.001		0.000		0.003		0.004	

This table reports the results from our cross-sectional tests based on local marketization. DiD models in the table are estimated on subsamples partitioned by the marketization level of headquarters provinces in Panel A. In Panel B, the models are estimated on subsamples partitioned by, respectively, the *government-market relation subindex* and the *IPR protection subindex*. The marketization index measures a province's progress toward a market economy. The *government-market relation subindex* measures the relation between the government and the market. The *IPR protection subindex* measures the local protection for intellectual property rights. The Wald tests reported at the bottom of the panels test the equivalence of the coefficients for $SOE \times Post$ between the high and low groups. Variable definitions can be found in Panel B of Table 1. All regressions are estimated with firm and year fixed effects. The t-statistics reported in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

large size and important role played by our sample firms in the Chinese economy, they are able to establish political ties and other informal relationships with different local authorities, which could help protect them from ex post expropriation of their investment in innovation. As a result, these large listed SOEs do not rely on formal institutions to protect their intellectual properties. Our findings suggest that different sectors of the Chinese economy may rely on different mechanisms for growth.

8. Conclusion

In this paper, we examine how the expectation of further partial privatization affects corporate innovation. To address endogeneity concerns, we explore plausibly exogenous variation in privatization expectations generated by China's split share structure reform commenced in 2005. Using a DiD approach, we show that the prospect of further partial privatization has a positive effect on innovation. Additional tests suggest that our findings are not driven by chance or by pre-existing trends in innovation output before the share reform. We further show that better alignment of the interests of government agents with those of private shareholders and improved stock price informativeness are two plausible underlying economic mechanisms through which privatization prospects enhance firm innovation. Our paper sheds new light on the real effects of partial privatization and has important policy implications for policymakers who aim to promote technological innovation.

Panel A: Differences in the number of invention and utility model patents around the share reform.

Panel B: Differences in the number of invention patents around the share reform.

Appendix A. Procedure for matching patents to firms

We obtain patent data from the State Intellectual Property Office of China (SIPO) and financial information about Chinese listed firms from the China Stock Market & Accounting Research (CSMAR) Database. Our patent dataset includes 1,303,603 invention patents and 3,440,497 utility model patents filed (and eventually granted) between January 2000 and September 2014. For each patent, information is available on application ID, application date, publication date, granting ID, granting Date, application entity name, inventor, IPC, address, patent name and patent type. When we link patent data to financial information, we consider the patent applications filed by both listed firms and their subsidiaries. Information about subsidiaries is obtained from the WIND Financial Database. We match applicant entity names in the patent dataset to firm and subsidiary names, using the procedure described below.

First, we standardize both firm (subsidiary) names and application entity names.

Second, we generate all possible pairs of standardized firm (subsidiary) names and standardized application entity names. For each pair, we calculate a fuzzy matching score using the SAS COMPGED procedure.

Third, we organize two groups of researchers and research assistants to manually check all pairs with fuzzy matching scores below 150. In determining whether a firm (subsidiary) is indeed a match to an application entity, we also consider such information as address and industry. When necessary, we search for information about the entities on the Internet. Both research groups go over the entire sample. Afterward, three researchers compare the matching results from the two groups. In a small number of cases, the two groups disagree. The three researchers settle the disagreements by vote.

Fourth, three researchers randomly pick 1500 firm-year combinations and manually search for the patent applications filed by each firm in each year on the SIPO website. The search results are compared with the results of our matching procedure.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcorpfin.2020.101661.

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