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**Innovation output and state ownership:
Empirical evidence from China's listed firms**

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Abstract

China has experienced a surge in innovation output in which state-owned enterprises (SOE) play an essential role. Using panel data of Chinese listed firms, this paper examines the influence of the state ownership on innovation output at the firm level. Controlling for size, we analyse the effects of central and local government control on the number of firms' patent applications in different time periods. Doing so, standard assumptions on state ownership's inhibiting character are confirmed. However, we then qualify these finding by running separate models for different regions and sectors find that the impact of state-control on innovation performance depends on a number of conditions. More precisely, state control of firms has a negative impact on innovation output in particular in China's Northeast region and in mid-tech sectors whereas under other circumstances it does either not matter or can even exert a positive influence.

1 Introduction

In many countries, state-owned enterprises (SOEs) are the main providers of public services such as energy, infrastructure and transport, which indicates that SOEs have an influence on everyday life of citizens and the economy. In some other countries, especially transition economies such as China, SOEs have played or are playing an important role in the market, so that their performance, not least with a view to innovation, is of great importance to broad segments of the population and to many other parts of the economy (OECD 2015). In these countries, it is essential to ensure that the governance of SOEs is implemented effectively.

During China's economic transition, the role of SOEs has been changing with the reform of the economic system. Nonetheless, the reform of SOEs remains one of the most important issues in China's transition to a market economy. Improving SOE performance is crucial for social stability and sustained growth in China (Bai et al. 2006; Lin et al. 1998).

In 1980s, most SOEs were assigned a compulsory plan for input, output and employment. Until the end of that decade, some SOEs had additional capacity available for production of above-plan and were allowed to exchange a small amount of goods in the market. The surpluses of government-controlled firms made up the main source of government revenue. Due to the distorted price system in the centrally-planned economy, SOEs became extremely profitable, even when they were not very efficient, and they served as a "cash cow" for the government and for the economy (Naughton 2007). At that time, SOEs were seen as the pillar and the core of the whole economy.

An effort to restructure the SOEs began in 1990s. Followed by the adoption of the new Company Law in 1994 which provided a uniform legal framework for ownership reform, the government gave more freedom and autonomy to its SOEs step by step. From the mid-1990s, Chinese government began to allow SOEs to go bankrupt or be sold to private buyers and companies if they had lost their competitiveness. In this period it restructured not only the enterprises, but also the sectors dominated by SOEs, such as textile and coal industry, in which, as a consequence a large number of SOEs exited from market. SOE restructuring meant converting vaguely defined state ownership into more explicit, legally defined ownership categories, sometimes involving "privatization" (Naughton 2007), a term that was frequently used by scholars, but avoided by the Chinese government.

In 2003, a new organization, the State-owned Assets Supervision and Administration Commission (SASAC) was formed through the consolidation of various other industry-specific ministries to take over the control of large SOEs. SASAC is responsible for managing and restructuring the remaining SOEs, including approving exchanges of stock or assets and appointing top managers, assessing and supervising firm performance, exercising ownership rights of the central government, as well as drafting legislation related to SOEs.

Up to today, SOE reform is considered a central challenge in China's transition process. Motivations for reform are found not only in economic but also in political considerations, such as the ambition to give a greater role to market forces in domestic demand through enhanced enterprise autonomy, and central government policies to promote large businesses with a view to the nation's strategic integration with the world economy (Nolan and Wang 1999). The creation of modern, flexible, and efficient corporations is the crucial prerequisite to moving to a higher level of market economy and a more productive firm sector that is able to face international competition (Naughton 2007). Although past SOE reforms have already brought some achievements in terms of average firm performance, detrimental effects of state ownership remain an issue in many areas. Despite reforms, it is still widely believed that China's SOEs tend to have lower performance than private or foreign enterprises in the market (Qian 1996; Zheng et al. 2003). At the same time, their role in the market is artificially enhanced by preferential policies and unfair competition supported by both central and local governments (Sheng and Zhao 2012). Against this background, it is the aim of this paper to analyse the innovation performance of Chinese enterprises in light of the influence of state ownership.

So far, most academic literature suggests that SOEs' economic performance is lower than that of private companies (Shirley 1999; Shleifer 1998). In the field of innovation economics there is similar evidence that SOEs operate less innovatively (Jefferson 2006; Zhang et al. 2003). That notwithstanding PwC's CEO Pulse survey suggests that even many top managers of private firms believe that state ownership has advantages in infrastructure related and can help to ascertain stability within and across supply chains in times of crisis (PwC 2015). With a specific view on China, anecdotal evidence suggests that some SOEs have achieved great success in applied research and innovation, e.g. in nuclear energy, the defence sector and electricity networks but also in less obvious areas like telecommunications. This apparent discrepancy between mainstream academic research and Chinese reality makes it necessary to investigate the performance of SOEs on a broader basis and in more detail.

As many previous theoretical and empirical studies do not take the specificity of SOEs into consideration (Bozec et al. 2002), this study focuses on the relation between innovative activities and state ownership in listed firms in China, controlling for provincial and sectoral differences. Overall, the paper aims to establish under which framework conditions state ownership will inhibit innovative activities in firms and under which others it may – contrary to general expectations – be beneficial.

The remainder of this paper is organized as follows: Section 2 provides the conceptual framework and hypotheses. Section 3 presents the dataset and empirical method. Section 4 reports the results. Section 5 discusses them in light of the initial conceptual considerations and Section 6 concludes.

2 Conceptual Background and Hypotheses

By definition, SOEs are characterized by state ownership and/or dominant state influence on corporate governance. Depending on the specific country's legal system, public ownership rights of state can be exercised under various frameworks and through different legal structures. According to OECD (2015), the state can exercise control in different ways, from an excessive "intervenor" to an "absentee owner", with the third option of "informed and active ownership" the preferable one. At both the micro and the macro level, the challenge is to ensure that SOEs operate transparently in an accountable manner, with a high degree of professionalism and effectiveness. Despite these acknowledged differences, however, the prevailing academic paradigm suggests that state ownership is in a generic manner harmful, favours undue interference and remains inferior to robust regulation (Megginson and Netter 2001).

Generally, state interference in enterprise governance will result in market failures due to SOE governance systems' inability to properly attribute property rights and risk (Shirley 1999). At the same time, state interference can enable firms to mobilize capital and resources at lower cost and unduly increase their propensity to spend and invest. Hence, a company operating under an unclear property rights regime will perform less efficiently and less profitably than private enterprises. (Alchian and Demsetz 1972; Barzel 1989; Boardman and Vining 1989; 1989; Demsetz 1988-1989; Grossman and Hart 1986; Naughton 1994; Weitzman and Xu 1994).

Against this background, a system of well-defined private property rights is seen as a basic precondition to the proper functioning of a market economy and the foundation of enterprise governance. In firms with governance systems based on private property rights, owners have the rights and incentives to monitor inputs, manage and assign worker to various tasks to increase the profit of firms and benefit from it. At the same time, they bear the risk of mistakes (Demsetz 1974; Weitzman and Xu 1994).. If no such property rights exist or a state-owned mode of governance does not hold managers accountable for their performance, firms will tend to fall short of their economic and innovative potential (Shirley 1999; Vickers and Yarrow 1988).

Another argument can be developed based on principle-agent theory, pointing out that in case of information problems principals will face difficulties to hold agents accountable for achieving agreed targets (Laffont and Tirole 1985). This theory views the firm as a nexus of contracts between principal (owners) and agent (managers) (Peng et al. 2016). Routinely, agents tend to have better information than principals in a way that maximizes their own utility instead of principal's interest. In SOEs the state employs managers as agents to make decisions in the interest of the firms and – ultimately – in the public interest. However, self-interested managers will often pursue own agendas not directly related to a high level of firm performance (Peng et al. 2016). Unless there are proper corporate governance mechanisms, such rent seeking behaviour is difficult to prevent in both private and public firms. Compared with e.g. related issues in shareholding corporations, however, conflicts of interest between principals and agents tend to be more fundamental in SOEs (Jensen and Meckling 1976). Firms that are managed by bureaucrats, will not only have to deal with personal opportunism, but also with the fact that bureaucratic systems reward budget maximization and associated career benefits rather than efficiency (Buchanan et al. 1980). Hence, the deviation of the agent's interests from the defined objective is higher and the (equally bureaucratic) principle's ability to manage that situation lower than in e.g. shareholding corporations.

Consequently, many previous studies find that private firms perform better than SOEs and that privatization is the best way to improve the performance of SOEs (Bai et al.

2006; Djankov and Murrell 2002; Jefferson and Su 2006; Megginson and Netter 2001). In Norway, where SOEs play an important role, it is found that private companies perform significantly better than SOEs with regard to return on assets and costs relative to sales revenue by referring market structure (Goldeng et al. 2008). In China it is also commonly argued that SOEs are less efficient than private enterprises. The leaders of Chinese SOEs act as both managers and government officials and tend to give priority to their political career, requiring that they ascertain the security of state assets or social stability or duly perform assigned administrative tasks, while the firm could be more profitable if it operated uninhibited in the market (Li and Xia 2008). Furthermore, institutional arrangements, include weak incentive mechanisms and government interference in corporate decision making are also viewed as a reason of SOEs' poor performance (Park et al. 2006).

With regard to measurements of firm performance, the OECD (2016) lists several performance evaluation indicators for SOEs, for instance return on investment, value added and labour productivity. In this context, it is notable that the frequently used measurement for innovation output, the number of new products, is also seen as an important indicator measuring SOEs' performance by the OECD, underlining that innovation is an essential activity for SOEs, and a relevant part of their activities.

Although many results thus suggest that private firms are more efficient than public ones, the evidence remains inconclusive, because these studies have the common limitation that they compare firms which do not have the same goals (Bozec et al. 2002). State ownership results in problems in defining the targets of the firm (Megginson and Netter 2001). As outlined above, most of the established arguments in favour of private firms are derived more or less directly from property rights or principal-agent theory, leading on to the argument that managers of SOEs have weaker incentives for profit-maximizing behaviour (Goldeng et al. 2008; Megginson and Netter 2001; Shleifer 1998). As mentioned above, however, many SOEs either operate in public sectors where profit maximization is a less prominent objective to start with. Taking into account that this paper's aim is to analyse innovative performance, moreover, it seems relevant that successful investment in innovation is in objective to which action guided by short-term profit maximization has often been found harmful rather than conducive.

Since the underlying motivations could thus influence the relative performance of state-owned firms, it is meaningful to compare the performance between SOEs and private enterprises with similar financial goals. Bozec et al. (2002) utilize the data of the large Canadian SOEs, some of which maximize their profit as business target, and find that effectively managed SOEs can reach similar levels of economic performance like their private counterparts, measured by return on sales, return on assets and assets turn-

over, when they are given the same profitability goal as privately-owned companies. According to this study, state ownership has a negative effect on performance only if the SOE has to pursue additional, unrelated goals. Moreover, privatization per se is not always an effective solution to improve the performance of firms. Omran (2004) matches privatized firms with SOEs in similar pre-privatization situations and finds that private firms do not present significant improvement in their performance changes quantified by earnings, sales and income.

Besides abovementioned clarifying objectives and motives, there are also two important areas that well-performing SOEs concentrate on and are also considered as successful experience from private enterprises: 1) focusing scarce resources on few fields with highest financial impact instead of embarking on a broad agenda that could fail for lack of resources; 2) redefining the company image and recruitment system to attract more talented people, for instance bring compensation packages closer to private-sector standards, or even the multinationals (Budiman et al. 2009). Therefore, the remedy for the performance problem of SOEs might not only be transformation of enterprises' ownership, like privatization, but identification of enterprises' objectives and goals and optimization of the cultural norm and behaviour required to meet these objectives and goals (Vernon-Wortzel and Wortzel 1989).

Thus, with regard to China, it becomes unsurprising that there are few Chinese SOEs that have been completely privatized, in the sense that the state gives up all of its shares. Usually, the central or local government retain still a substantial portion of their ownership, although the firms' governance mechanism has been reformed. In real life situation, the SOE reform in China is even not viewed as a privatization, but restructuring, or sometimes "corporatization", namely restructuring the internal corporate governance and decreasing state shares while preserving state ownership. It is found that this type of reform, corporatization without privatization, is an effective way of improving the SOEs' performance of return on assets, sales and output (Aivazian et al. 2005). Moreover, the relationship between state ownership and firm performance is believed to be an inverted U-shape. Although too frequent state interference has a negative influence, partial state ownership could increase SOE performance (Sun et al. 2002). Hence, the coexistence of SOEs and private firms is by some considered a good arrangement for China, which helps maintain social stability and fulfil social outcomes (Bai et al. 2006). With a perspective on future, however, further changes in the economic governance framework may be needed to put China on a track to reach the ambitious official targets of becoming an innovative nation by 2020, an international leader in innovation by 2030, and a world powerhouse of innovation by 2050 (State Council 2016). In this process, the role of SOE may once more have to be reconsidered in an informed manner.

In general, there are a lot of empirical studies on the role and performance of SOEs based on evidence from industrial countries with developed market economy systems, but their results will not necessarily apply under other conditions. Typically, theory tends to consider the standard case in which SOEs and private firms compete on equal terms without specific institutional and political preference – which then results in a better performance of private forms.

In reality, however, the performance of SOEs and the extent to which principal-agent issues resulting from state ownership will occur is strongly associated with the political and institutional environment they operate under. In countries that follow a comprehensive strategy of reforms to improve SOE performance while at the same time still displaying an institutional environment and market conditions that discourage innovation in private enterprises, the situation may be reversed – with SOE becoming more productive than private firms. At the same time, privatization and corporatization are associated with politically costly reforms (Shirley 1999) so that they may remain incomplete under circumstances in which both SOEs and private firms are inhibited by diffuse policies and an unclear institutional framework.

In an economy under transition like China, therefore, different institutional and political framework conditions in regions and sectors suggest that entirely or at least substantially different relations of performance may result, depending on the specific framework conditions.

So far, some studies have been conducted a panel of China's 22,000 large- and medium-size enterprises' data, which collectively account for one third of the nation's total industrial output. Across ownership types considerable variation was found with respect to measures of innovation performance, including new product output and patents (Acs et al. 2002; Acs and Audretsch 1988; Jefferson et al. 2003; Kraft 1989). As mentioned above, China's SOEs have been deeply reformed by the government in the last years. In the abovementioned studies, patterns of asset ownership were found associated with performance. SOEs with the highest concentrations of state assets perform at the low end, whereas those with low concentrations of state-owned assets perform at the high end (Jefferson et al. 2003). The distribution of R&D resources shows different images in different ownership types. R&D performers are more concentrated among SOEs and shareholding companies and less concentrated among foreign and overseas enterprises. But the R&D resources of SOEs are not transferred from input to output efficiently. Although there is a high growth rate of technical efficiency for SOEs (Zhang et al. 2003), state-owned enterprises exhibit the lowest efficiency in knowledge production (Jefferson 2006). Within the non-state sector, foreign firms have higher R&D

and productive efficiency, followed by firms from Hong Kong, Macau and Taiwan, joint stock enterprises and collective-owned enterprises (Zhang et al. 2003).

Since the rapid increase of patent applications and grants in China during the last decade, the question which types of companies contribute most strongly to this trend has been repeatedly analysed. It seems that all non-state enterprises but jointly-owned groups have a higher propensity to patent than SOEs (Hu & Jefferson, 2009). The image among listed firms is a similar one. Privately owned enterprises not only obtain higher returns from own R&D than majority and minority SOEs, they are also able to increase their leading position (Boeing et al. 2016).

Except ownership, the involvement of the Chinese Communist Party (CCP) in companies has been analysed as an indicator of the state influence in Chinese firms. Using survey data of private small and medium-sized enterprises (SME) in the electronics industry of the Pearl River Delta in China, Liefner et al. (2016) examine the influence of firms' formal ties with the CCP on their patenting behaviour. Different from previous studies which argued that SMEs were less susceptible to central government influence than other Chinese firms, they find that the state has a notable influence on the patenting behaviour not only of larger state-owned corporations, but also of those smaller firms.

In summary, **Hypothesis 1** can be formulated as: In principle, i.e. on national average, state ownership has negative influences on the innovation output of firms.

However, as stated before, state-owned firms might occasionally outperform private ones, at least with regard to quantitative performance measures in their role as executors of Keynesian public investment in times of crises. In late 2008, the central government of China launched a controversial stimulus package of 4 trillion yuan (equivalent to 586 billion dollar) as an attempt to minimize the impact of the financial crisis. In the following two years, the Chinese economy recovered from the recession gradually, not least due to this stimulus plan. At the same time, however, it has caused a surge in Chinese debt among local governments (Huang and Bosler 2014). The stimulus package was invested in key areas such as rural infrastructure and transportation, which were dominated by SOEs. The stimulus is traced to state control over its banking system and corporate sector (Deng et al. 2011). Since then, the SOEs obtained credit from state-owned banks much more easily. The average leverage ratio of state-owned manufacturing firms increased steadily and SOEs promptly expanded their fixed assets investment due to new loans. During the recession period, SOEs expanded their credit borrowing, investment and production capacity, which generated a prompt recovery of aggregate demand. It is found that the effectiveness of China's stimulus packages is

derived from the contribution of the SOEs (Wen and Wu 2014). It remains remarkable that one of the measurements in the policy package is a new political initiative towards "indigenous innovation", which means that the government invested a large amount of capital in R&D, in order to improve the S&T development.

In summary, **Hypothesis 2** can be formulated as: (nominal) deviations from the rule outlined in Hypothesis 1 are likely to emerge as a result of SOEs role in the stimulus package that changed the political and institutional 'rules of the game'. Positive deviations in SOE performance will result from a recovery policy that emphasized the need to increase independent innovation capabilities in national high-tech industries.

Furthermore, most of the enterprises that are nominally "state-owned" are not actually controlled by the central government. Central SOEs are defined as SOEs that controlled by ministries of central government like SASAC (which manages around 100 central SOEs), Ministry of Finance and China Banking Regulatory Commission. After China embraced the development of small-scale enterprises in mid-1990s, when the central government decided only to keep control of large SOEs and to release more autonomy to small-sized SOEs, it was impossible for the central government to exercise effective oversight of assets of all types of SOEs (Naughton 2007). In 2004 and 2005 local SASACs were set up at the provincial and municipal level. The authority to manage local SOEs was delegated to local governments, in particular local SASACs. The local government obtained the power to take part into decision-making and management of local SOEs and exerted influence on financing and accessing to production materials. Due to fiscal reforms local government officials have more incentives to pursue economic development (Oi 1992). Local SOEs were seen as the core of local economy, so that they could obtain more financial and political supports from governments than private counterparts.

The supports that come from central and local governments to central and local SOEs are not the same. Local SOEs focus more on local market, while central SOEs possess more sources to enter new markets around China. However, most of the existing researches ignore the effects of the administrative level of enterprises and do not differentiate central and local SOEs.

So as **Hypothesis 3** we suggest that, due to the different amount of resources, competences and political power available to them central and local SOEs will perform differently with respect to innovation. Central SOEs are still deeply influenced by assignments from the national authorities and are responsible for the fulfilment of political targets of central government. They control more resources with a view to R&D capital than local SOEs and enjoy preferential market access. A large number of national stra-

tegic technology projects are implemented in central SOEs. For that reason, we suggest that central SOEs are more innovative than local ones.

Another factor that should be taken into account is geographic location. In China economic development, innovation performance as well as political and institutional framework conditions vary from province to province – more strongly than in many other countries. With regard to the area, population and economic volume, most Chinese provinces are as large as a country. Since the reform in the late 1970s, especially since the 1990s, the central government has given provincial (and some local) governments substantial leeway in the design of economic policy. Today, most of them can decide rather autonomously about their support policy, public expenditure and, to some extent, institutional framework conditions (Gu and Lundvall 2006). As development pathway, business culture, cultural habits as well as progress in economic transformation differ strongly among different provinces (Kou 2015; Liu and White 2001), it is reasonable to assume that the role and performance of SOEs would differ accordingly. In the coastal regions, for example, provinces develop dynamically and have established relative market-oriented institutions since the reforms. Amounts of SOEs have been reformed or privatized in late 1990s. In contrast, the regions in Western and Central China still keep lagging behind (Kroll 2010). Despite the new trends, these traditional innovation centres still belong to the most innovative regions of China (Kroll and Frietsch 2014; Tagscherer et al. 2012).

Moreover, the overall pattern of developed and less developed regions is changing in recent years. Technologically advanced industries are moving further inland while more and more regional innovation systems are developing outside the classic "islands of innovation", like Beijing, Shanghai and Guangdong (Kroll and Liefner 2008; Kroll and Schiller 2010).

For these reasons, it is reasonable to analyse to what extent these general trends with regard to the regional distribution of development as well as science and innovation influence the local role of SOEs in the respective innovation systems.

Hence, we suggest as **Hypothesis 4**, that due to the disparity of development levels and innovative capacity between provinces and larger statistical regions¹, state ownership may play a distinct role in different environments. In innovative regions, such as China's Eastern provinces, firms including SOEs obtain stronger and more strategically

¹ East: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan; Northeast: Liaoning, Jilin, Heilongjiang; Central: Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan; West: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

coordinated support to participate in innovative activities while, at the same time, their internal governance mechanisms have been more profoundly reformed and create less principle-agent problems. Hence, they will likely be more innovative or at least lag behind less than those in Central or Northeastern China.

Finally, the institutional and political environment and thus the role and performance of SOE is determined not only by their regional, but also by their sectoral position. SOEs dominate not only strategic industries such as natural resource, aerospace and arms industry, but also infrastructure industry. Depending on the concrete sector in which they are active, not only the intensity of private competition will differ, but also the amount of resources, competences, and preferential treatment by policy makers that SOEs can draw upon to survive in this competition.

In the catching-up regions in the middle and west, innovation activities are dominated by mature industrial sectors, which have been transferred out of leading provinces. An argument for this phenomenon is that political interference demands a contribution of these provinces to the so-called "indigenous innovation" (Kroll 2015), more precisely, to innovate through indigenous S&T and resources instead of purchasing foreign technologies and know-how. Jefferson et al. (2003) use a panel data of China's 22,000 large- and medium-size enterprises for 1994–1999 and investigate patent applications in different sectors. They find a high concentration of patenting activity within China's manufacturing sector, and among the patent applicants, the petroleum and gas industry leads by a wide margin.

As **Hypothesis 5**, we suggest that the firms in different sectors have different innovation performance. In the sectors in which the government intervenes less, market-oriented factors play a more important role and thus SOEs are more likely to hinder the increase of innovation output.

3 Data and methods

To obtain the companies assessment of innovation activities, this paper establishes a data set of the Chinese firms listed at the two stock exchanges of Shanghai and Shenzhen throughout the time period 2003 – 2014. Information on companies is obtained from the database China Stock Market & Accounting Research (CSMAR) of GTA which is a provider of China financial market data, China industries and economic data, and the economic and financial database of Peking University China Center for Economic Research (CCER). The provincial data is collected from National Bureau of Statistics of China.

As previously stated, due to complex ownership policy and structure and interference of state, SOEs are often less transparent and insulated from the legal framework applicable to other companies such as competition laws and government subsidy², which increases the difficulty of evaluating the economic performance of SOEs, since SOEs rarely aim at the maximization of profit (Rainey 2009; Ramanadham 1991), but specific non-commercial goals and social outcomes. In order to avoid this bias, this paper uses the data of listed firms. The reason is that in order to be a listed firm, a SOE must be restructured into a stock company through selling shares to other companies, legal entities or its own employees firstly. Then, the SOE sells part of shares (usually 1/3) to the general public investors. Thereafter, shares of the SOE are split into three parts: state, legal-entity, and tradable shares. Regardless of share type, each share enjoys the same cash flow and voting right (Wang 2005). Firms that are publicly traded must concentrate on the interest of stakeholders, for instance profitability and firm value. Xu and Wang (1997) find that value of listed firms in China has no relation with state ownership. Even at an early stage of the country's institutional transformation, this confirmed that state ownership is not in principle an obstacle to pursuing commercial goals successfully. When public firms set themselves the target to generate profits, their performance can be comparable to that of the private counterparts (Bozec et al. 2002), and thus, these SOEs also obtain similar circumstances and motivations to participate in innovation activities like privately owned companies. The second advantage of focusing on listed firms is that due to the legal structure of stock exchanges, listed firms must provide a high degree of transparency, including disclosure of information (OECD 2015), which makes their financial data more reliable than that of non-listed SOEs.

The patent information of CSMAR is a relatively new dataset which was published in 2015. There are still few studies applying this data to investigate the innovative performance of Chinese firms. The dataset of CSMAR includes all industries from agriculture, industry to service sectors. Because innovation activities, precisely, patenting activities, are of limited importance in some industries such as financial and the retail sector (Boeing et al. 2016), the observations from the agricultural and service sectors are excluded. The few firms that did not release the number of patents in their financial report are also eliminated. The full estimation sample is based on information for 1,625 firms including 10,203 observations. With regard to data quality, the dataset of Chinese listed firms including CSMAR data has been found representative and of high quality in a number of studies (Fisman and Wang 2010; Gul et al. 2010; Kato and Long 2006; Sun and Tong 2003), not least because the information efficiency of China's leading

² See PwC report "State-Owned Enterprises Catalysts for public value creation?" for more details.

stock markets has increased substantially since the late 1990s (Boeing 2016; Long et al. 1999).

The dependent and independent variables are summarized in Table 1. The descriptive information on all variables is presented in Table 2. As indicator of innovation output we use the number of invention patents. In China there are three categories of patents: invention, utility model and design patents. According to Article 22 of the Chinese Patent Law, an invention patent should possess prominent substantive features and indicate remarkable advancements. Invention patents are granted after a substantive and strict examination, while the other two are in a strict sense only registered, rather than examined and granted (Lei et al. 2012b; Prud'homme 2017). Compared with the other two patent types, invention patents are judged by higher standards, closest to those typically required by USPTO or EPO and, in the literature, therefore often used as an indicator for the independent intellectual property (Lei et al. 2012a; Li 2012). Hence, the dependent variable used in this paper reflects exclusively invention patents.

To measure state ownership, three independent dummy variables are introduced: STATE (NAT) for SOE controlled by central government, STATE (PRV) for SOE controlled by provincial governments and STATE (MUN) for SOE controlled by municipal governments.

As is well-known, firm size is an important general predictor of innovative capacity (Acs and Audretsch 1987; Scherer 1965; Schumpeter 1942). To take into account these generic effects of firm size, and to thus compensate the use of absolute numbers in the dependent variable, the annual revenue of the firm is introduced as a further main independent variable. Further general control variables are the GDP per capita in the respective province, which measures the influence of macroeconomic environment, the interaction term of dummy variable of SOE and the number of employees, which presents to what extent the size of SOE influences innovative activities. Additionally, the model controls for Chinese firms surge in patenting by means of time *dummies* for each year covered by the regression.

In summary, the regression model can be written as the following equation:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon$$

where y is the number of patent applications, x_1 stands for the revenue of firms, x_2 is the vector for SOE factors, x_3 is the vector for control variables.

Table 1: Definition of variables

Variable name	Definition
L_PATENT	log of number of invention patent
L_REVENUE	log of revenue
STATE (NAT)	dummy for SOE controlled by central government
STATE (PRV)	dummy for SOE controlled by provincial government
STATE (MUN)	dummy for SOE controlled by municipal government
L_GDP_PC	log of relevant province's GDP per capita
SOE_SIZE	interaction between SOE and log of number of employee

Table 2: Descriptive statistics:

Variable	Obs	Mean	Std. Dev.	Min	Max
L_PATENT	10,203	1.31	1.40	0	9.62
L_REVENUE	10,203	21.17	1.43	11.60	28.69
STATE (NAT)	10,203	0.17	0.37	0	1
STATE (PRV)	10,203	0.11	0.31	0	1
STATE (MUN)	10,203	0.16	0.37	0	1
L_GDP_PC	10,203	10.61	0.60	8.22	11.56
SOE_SIZE	10,203	3.54	4.13	0	13.22

4 Empirical Results

Table 3 summarizes the results of the main fixed effects regression models.

With a view to Hypothesis 1, the analysis finds that for all listed companies, state ownership controlled by central authorities and provincial governments has significant negative effects on the number of patent applications even if the significance of the latter is somewhat lower. Effects of municipal government ownership, to the contrary, remain insignificant (although in principle also negative).

Moreover, all other independent and control variables behave in line with expectations. Revenue is associated positively with patent output for all types of firm ownership. Large companies contribute more to innovation. If the revenue of a firm increases by 1%, the number of patent applications rises by around 0.13%. In particular, this effect is

found in the 2011-14 period, while it is not significant for the 2003-10 period. Likewise, the negative association of average per capita income in the host province ad patent behaviour seems counterintuitive only at first. Overall, however, it is not that surprising, at least for the 2003-10 period. At that time, many of the most extensively patenting firms were located in Guangdong. Among the leading group of regions, however, Guangdong displays a comparatively low GDP per capita, due to internal disparities. Furthermore, large SOE appeared more productive in terms of patent applications on top of the general size effect from 2003-10 while this additional effect was reversed during the 2011-14 period. Apparently, many large SOEs have in some respect either become less effective in absolute terms or, with more private firms catching up, less exclusively benefit from size effects than before. Finally, the year specific dummies appropriately capture the nationwide uptake in industrial patenting in China during the 2003-14 period of observation.

With a view to Hypothesis 2, the analysis finds that all of the three types of public control have significantly negative impacts on innovation output between 2003 and 2010 while for the 2011-14 period, the effects for all three of them turn significantly positive. The stimulus policy of Chinese government was implemented since the end of 2008 and lasted until 2010. Acknowledging that a certain time lag should be taken into account because, in itself, the adjustment of a firm's R&D portfolio might take time and, more importantly, its full effect only emerges with delay (Boeing 2015) Thus, hypotheses 2 can be considered confirmed.

In contrast, Hypothesis 3 can surprisingly not be confirmed. SOEs controlled by central government do not produce more innovative output than local SOEs. To the contrary, central government control over an enterprise decreases its number of patent applications more strongly than provincial or municipal ownership. Between 2011 and 2014, when effects are positive, the positive coefficient of the dummy for central government control is lower and less significant than that of those for provincial and municipal ownership.

Concerning Hypothesis 4, Table 4 confirms that the role of state ownership for innovative output varies between different regions. Interestingly, no effects of state-ownership can be found in either the most or the least developed areas of the country (Eastern and Western region). In Northeast and Central China, to the contrary, all types of state ownership have negative effects on firms' tendency to apply for patents. In the Northeast, affected by structural change in old industries, the coefficients are extraordinarily high and above average for provincial and municipal ownership. In this area, much of the currently state-owned industrial infrastructure was established as part of large, soviet-style combines in the 1950s and 1960s and at a later stage severely disrupted by the market reforms. Nonetheless, large SOEs perform notably better than smaller ones

in that region, although industrial patenting in the Northeast does not in general depend on firm size. This situation is reversed on the developed East coast where the general effect is notable and highly significant but the one for SOE can not be detected.

As for hypothesis 5, Table 5 illustrates the effect of state-ownership on SOEs innovation output in different sectors. In low-tech industries, state ownership does not exert a negative effect on patenting behaviour. In the "textile and apparel" sector, all types of state ownership lead to a significantly higher number of patent applications. In the "paper and print" sector, these effects may not be significant, but they are still detectable as a tendency. In these sectors, firm size does not influence innovation significantly. In line with that, the additional effect of being a large SOE is significantly or as a tendency negative. The geographical distribution of highly patenting firms, in contrast, seems to differ, with more leading textile firms located in wealthier provinces while the opposite is true for the paper sector. Quite different, in contrast, is the picture for machinery and IT, representing mid-tech and high-tech sectors. In those, general size effects are notable and all types of state ownership is, in principle, negatively associated with firm level patent output. Their association with provinces with high GDP per capita levels (Beijing, Shanghai, etc.) is as a tendency high, yet insignificant. Despite these commonalities, the effects for genuinely technology-related industries like the IT sector, differ notably from that for mid-tech sectors in that the effects of central government ownership are not *significantly* negative and that there are positive additional effects of SOE size.

Table 3: Basic model with year differences (fixed effects model)

	(1) all	(2) 2003-2010	(3) 2011-2014
L_REVENUE	0.132*** (0.037)	0.075 (0.049)	0.066*** (0.026)
STATE (NAT)	-0.874** (0.416)	-1.289** (0.563)	0.601* (0.352)
STATE (PRV)	-0.717* (0.426)	-1.189** (0.566)	0.698** (0.356)
STATE (MUN)	-0.628 (0.411)	-1.102* (0.563)	0.712** (0.352)
L_GDP_PC	-0.429* (0.232)	-0.876*** (0.294)	0.240 (0.371)
SOE_SIZE	0.102** (0.051)	0.143** (0.069)	-0.081* (0.045)
yr2004	0.209*** (0.057)	0.317*** (0.065)	
yr2005	0.452*** (0.093)	0.630*** (0.111)	
yr2006	0.664*** (0.124)	0.920*** (0.151)	
yr2007	0.830*** (0.164)	1.201*** (0.203)	
yr2008	1.074*** (0.198)	1.537*** (0.246)	
yr2009	1.396*** (0.215)	1.906*** (0.268)	
yr2010	1.669*** (0.251)	2.312*** (0.314)	
yr2011	2.061*** (0.286)		
yr2012	2.452*** (0.306)		0.344*** (0.034)
yr2013	2.773*** (0.327)		0.619*** (0.067)
yr2014	3.028*** (0.343)		0.837*** (0.093)
_cons	1.105 (2.382)	6.750** (2.938)	-2.781 (3.985)
N	10203	4386	5817
r2	0.598	0.433	0.511
r2_a	0.597	0.431	0.511

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 4: Separate models for different regions (fixed effects model)

	(1) East	(2) Northeast	(3) Central	(4) West
L_REVENUE	0.188*** (0.050)	0.151 (0.162)	0.039 (0.110)	-0.005 (0.085)
STATE (NAT)	-0.585 (0.524)	-5.747* (3.034)	-1.970** (0.787)	-0.145 (1.230)
STATE (PRV)	-0.386 (0.537)	-8.743** (3.843)	-1.897** (0.833)	-0.013 (1.288)
STATE (MUN)	-0.380 (0.514)	-6.437** (2.844)	-1.609** (0.810)	-0.119 (1.213)
L_GDP_PC	0.157 (0.345)	-0.640 (1.905)	-0.158 (0.954)	0.215 (0.758)
SOE_SIZE	0.075 (0.062)	0.920** (0.419)	0.222** (0.100)	0.030 (0.152)
yr2004	0.138* (0.079)	0.154 (0.278)	0.181 (0.195)	-0.050 (0.190)
yr2005	0.318** (0.133)	0.350 (0.579)	0.354 (0.333)	0.071 (0.283)
yr2006	0.456** (0.178)	0.343 (0.845)	0.559 (0.466)	0.181 (0.395)
yr2007	0.542** (0.228)	0.484 (1.189)	0.689 (0.648)	0.208 (0.559)
yr2008	0.760*** (0.271)	0.579 (1.547)	0.744 (0.824)	0.325 (0.695)
yr2009	1.034*** (0.295)	0.854 (1.750)	1.142 (0.925)	0.546 (0.751)
yr2010	1.215*** (0.341)	1.234 (2.100)	1.346 (1.117)	0.718 (0.896)
yr2011	1.524*** (0.386)	1.833 (2.459)	1.671 (1.293)	0.970 (1.055)
yr2012	1.867*** (0.411)	2.278 (2.661)	2.033 (1.391)	1.302 (1.147)
yr2013	2.131*** (0.440)	2.655 (2.803)	2.338 (1.477)	1.550 (1.232)
yr2014	2.339*** (0.465)	2.857 (2.897)	2.595* (1.549)	1.764 (1.297)
_cons	-5.827 (3.579)	2.325 (17.904)	0.393 (8.309)	-1.883 (7.389)
N	6729	407	1722	1345
r2	0.627	0.629	0.580	0.511
r2_a	0.626	0.612	0.575	0.505

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 5: Separate models for different industries (fixed effects model)

	(1) textile	(2) paper	(3) machinery	(4) IT
L_REVENUE	0.039 (0.175)	-0.092 (0.276)	0.226*** (0.071)	0.376 (0.273)
STATE (NAT)	1.688 (1.067)	2.259 (2.321)	-2.003*** (0.752)	-3.869 (2.775)
STATE (PRV)	3.057** (1.243)	1.777 (2.266)	-2.055** (0.796)	-4.494* (2.693)
STATE (MUN)	2.896** (1.166)	2.057 (2.141)	-1.432* (0.752)	-4.659* (2.728)
L_GDP_PC	2.230** (1.010)	-3.550** (1.564)	0.101 (0.587)	0.852 (1.266)
SOE_SIZE	-0.314** (0.139)	-0.253 (0.279)	0.089 (0.100)	0.645* (0.353)
yr2005	0.653 (1.015)	-5.915*** (1.741)	-2.078*** (0.697)	-1.367 (1.259)
yr2006	0.397 (0.840)	-4.951*** (1.581)	-2.021*** (0.609)	-1.503 (1.119)
yr2007	0.122 (0.711)	-4.240*** (1.272)	-1.952*** (0.500)	-1.562* (0.868)
yr2008	0.074 (0.613)	-3.506*** (1.004)	-1.770*** (0.416)	-1.450** (0.661)
yr2009	0.111 (0.555)	-3.150*** (0.894)	-1.489*** (0.355)	-1.048* (0.567)
yr2010	-0.154 (0.430)	-2.168*** (0.606)	-1.250*** (0.256)	-1.043** (0.439)
yr2011	-0.198 (0.279)	-1.382*** (0.375)	-0.933*** (0.161)	-0.815*** (0.282)
yr2012	-0.086 (0.188)	-0.907*** (0.251)	-0.518*** (0.107)	-0.445** (0.198)
yr2013	-0.069 (0.089)	-0.395*** (0.119)	-0.215*** (0.051)	-0.204** (0.097)
_cons	-24.232** (10.316)	42.432** (17.499)	-3.090 (6.627)	-15.169 (13.731)
N	286	227	1414	370
r2	0.620	0.602	0.636	0.683
r2_a	0.599	0.574	0.632	0.669

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

dummies for years 2004 and 2014 excluded during estimation for technical reasons

5 Summary and Discussion

Evidently, most of our findings have been found to be in line with our general assumptions while one of the assumptions could be proved to be wrong. With a view to this paper's hypotheses, the following findings can be reported:

Firstly, there is indeed a notable influence of state ownership on the innovation performance of China's listed firms. In general terms, this underlines the mainstream assumption that state ownership inhibits innovative activities. Equally in line with previous literature, however, this finding needs to be qualified along several dimensions when more dimensions such as time, disparity of regional development and technological orientation of industries are taken into account.

Secondly, as developed in the conceptual section, the effect of state control on innovative output varies over time, depending on the evolution of a country's economic and institutional system. In line with this, this study suggests that time should be taken into consideration as a proxy for overall framework conditions before any general statements on the role of state ownership are derived. Possibly due to the effects of the fiscal recovery package or other policies aiming to boost indigenous innovation, SOEs in fact generated more innovation output than other firms during the years following the financial crisis.

Thirdly, the administrative hierarchy of SOEs in China's bureaucracy system influences patenting behaviour even though in a different manner than intuition might suggest. Differing from our assumption, national SOEs do not per se become more productive in terms of output despite their prominent role in central government policy and the wealth of resources bestowed upon them. A reason might be that, in line with initial conceptual arguments, some local SOEs not only obtain more effective and targeted direct support from their provincial or municipal government, but, one the micro level, deploy more effective governance models and pursue more clearly defined strategies – profiting especially in those provinces where a market-oriented system is already best established and management skills more broadly available. However, this paper's results equally suggest that some exceptions from this rule might apply in particular sectors, most notably in the low-tech area, but possibly also in the government-driven IT sector, where central control has no significantly negative effects and larger SOE churn out more patents than others.

Fourthly, China's provinces can be divided into four main groups based on geographic locations and development level. Among them, the Northeastern and Central provinces remain most strongly characterised by planned economy mechanisms. In these areas, the governance and management models of many traditional SOEs have hardly been

reformed. Consequently, the negative impact of state ownership is found to be particularly severe in Northeast and Central China in a close to paradigmatic manner. In China's Eastern provinces, in contrast, there is no traceably negative effect of state control on patenting behaviour. One possible explanation for these findings is that better SOE governance can be assumed in economically and institutionally more developed provinces.

Finally, the association of negative effects of state ownership and certain industries remains partially in line with conceptual considerations, partially surprising. While it appears logical that it is somewhat more pronounced in the market oriented machinery industry than in the government-driven, research-based IT sector, its positive role in low-tech sectors appears surprising and merits further investigation. Possibly, it could be due to the fact that many, strictly price and profit-maximisation oriented firms in these sectors do not innovate at all and all firms that are in any way active in the area of innovation remain associated with the state.

6 Conclusions

In summary, this paper has explored the effects of state ownership of listed firms on patent applications. In line with earlier studies, it confirmed that in the most general terms, state ownership can be considered as an obstacle to innovation.

Beyond confirming the well-known general assumptions that state-ownership and SOE management models can hinder innovative activities, the analyses developed in this paper revealed several relevant qualifications – using data for the concrete case of China but providing a basis for generalisation. Firstly, the effects of state ownership on innovation vary dynamically over time, visibly correlating with changes in political and institutional framework conditions. Secondly, stronger economic and political support for some SOE does not per se position them more favourably in comparison to others, while, thirdly, positioning them in more developed regional innovation ecosystems might well have that effect, even with respect to private enterprises. With respect to sectoral orientation, finally, this study underlined the already established finding that mainstream assumptions on the role of state ownership for innovation may apply less in government-driven high-tech industries. Surprisingly, however, this difference was less clear than expected, but instead, larger in low-tech sectors where it remains less easy to explain.

Consequently, the most important contribution of this study is to have conceptually developed and empirically confirmed that the role of state ownership for innovative performance needs to be analysed in its specific economic, institutional and political con-

text, rather than on a generic level. That said, some specific findings will require further inquiry in subsequent studies to be fully understood and the precise nature of those policies and circumstances that have put SOEs ahead of private enterprises under specific circumstances remains to be uncovered.

Similar research questions than those addressed in this paper could be addressed with a view to the effects a concrete innovation promotion strategies implemented by the Chinese government bringing later studies closer to the establishment of causal relations. Another further research avenue could be to explain innovation output by more detailed information on corporate governance and internal management mechanisms of specific SOEs that influences the level of principal-agent conflicts in their governance and the decision processes relevant for R&D and innovative activity. Finally, it would be worthwhile to expand the reach of the dataset to non-listed companies and additional industries.

Politically, the results underline that SOE reform remains a matter of urgency in particular in China's Northeast and should arguably concentrate on reducing political, administrative and agency costs through effective and modern corporate governance. SOEs managers should be given clear objectives and goals and operate under clear frameworks of accountability. In addition, our findings suggest that the provision of more resources to central government-level SOEs as "innovation drivers" will probably not in a general manner create much added value for the national innovation system outside very specific areas. In that light, the identified lead of SOEs under specific framework conditions should be interpreted with care. Even in the case of the research-driven IT sector, it remains, as a tendency, negative. In summary, the relative nature of all analyses presented in this paper needs to be consciously considered before drawing simplistic conclusions – not least, as the most recent changes may not yet empirically be covered.

While this study's findings suggest that a smart reform of the SOE sector can bring concrete benefits it may at the same time simply highlight a remaining lack of attention for the needs of requirements of private enterprises – even in China's more developed regions. That attention, however, will certainly be needed if China is to become an international leader in innovation by 2030.

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