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Innovation in China: Ownership, efficiency, and current innovation policy

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INTRODUCTION

Over the past 40 years, China's economy has experienced tremendous growth. Between 1980 and 2015, gross domestic product (GDP) grew by 8.7 percent each year on average and real per capita income increased by 1,759 percent cumulatively, from $714 in 1980 to $13,277 in 2015 (Wei et al. 2017). Recently, however, GDP growth has started to moderate. Annual growth has hovered around 6 to 7 percent since 2014 and many expect it to slow further (Wei et al. 2017). Part of this slowdown is structural: China has completed its transition from a primarily agricultural to mostly industrial economy and it has caught up technologically to the rest of the industrialized world (Naughton and Tsai 2015). Favourable demographic conditions, such as its large population of working age individuals and low dependency ratio, are changing and low labour costs have started to rise (Cheng et al. 2019). Furthermore, productivity gains from market reforms and reducing resource misallocation are smaller after four decades of economic reform (Wei et al. 2017). As a result, future sustainable economic growth must come from growth in total factor productivity.

A large component of productivity growth comes from innovation and technological improvement through the creation of new products and new designs. China's leadership recognizes this and has launched a number of industrial policies aimed at increasing "indigenous innovation." For example, *Made in China 2025*, launched in 2015, aims to transform China from a "low value-added manufacturing giant" into a "high value-added manufacturing power" (Cheng et al. 2019). More recently, in Xi Jinping's 2017 report to the 19th Party Congress, Xi asserted that during the next stage of China's development, between 2020 and 2035, China must become a "global leader in innovation" (Xi 2017).

Over the past decade, the size and importance of the state sector has also increased (Naughton and Tsai 2015). Since 2003, the position and role of the state sector has stabilized and following the 2008 global financial crisis, state-owned enterprises have grown in size and importance. In addition, Xi has continually emphasized the role of state-owned enterprises as drivers of growth, innovation, and productivity in China's economy (Naughton and Tsai 2015). Historically, however, a large body of research finds that state-owned enterprises are less efficient than privately-owned enterprises due to corporate governance issues and political interference (Naughton 2018; Brandt et al. 2012; Li et al. 2014).

In light of this information, I investigate two aspects of innovation and industrial policy in China. First, are state-owned enterprises less innovative than privately-owned enterprises? While state firms generally perform worse that private firms in terms of productivity and profitability, this does not necessarily imply that they are less innovative. Second, is China's current innovation policy effective? More specifically, how are state subsidies for research and development (R&D) being allocated to firms, do public subsidies crowd out a firm's own R&D investments, and do these subsidies actually promote innovation output and productivity? If R&D subsidies are allocated based on factors other than innovative capacity, this misallocation may limit the effectiveness of China's innovation policy.

Overall, I find that within China's current institutional environment, minority state ownership is optimal for innovation production. Minority state ownership allows a firm to obtain crucial resources for the production of innovation, such as loans and government subsidies, but does not interfere substantially in the firm's business operations. In addition, while state ownership and a firm's historical innovation are factors in R&D subsidy allocation, political connections and level of corruption among government officials are more important

determinants. This indicates some inefficiency in the allocation of government R&D subsidies, which reduces their effectiveness in promoting innovation. I also find that while government subsidies do crowd a firm's own R&D investment that same year, in subsequent years, their effect on investment is neutral. Interestingly, this immediate crowding out does not occur in minority state-owned firms, reinforcing the previous conclusion that minority state ownership is optimal for innovation production. Finally, while R&D subsidies promote innovation output across all levels of ownership, this does not immediately translate to productivity increases. Instead, R&D efficiency, which tends to be higher in private firms, seems to be the more salient channel through which productivity rises, and therefore, private firms see the greatest productivity gains from R&D and innovation.

OWNERSHIP AND INNOVATION

Two approaches: Agency theory and institutional theory

The conventional view in economics says that state ownership is incompatible with efficiency due to conflicts between owners and managers (Zhou et al. 2017; Teng and Yi 2017). Under this view, state ownership suffers from the principal-agent problem, which arises when the desires and goals of the owner (the principal) are not aligned with those of manager (the agent) due to separation of ownership and control (Teng and Yi 2017). Therefore, close monitoring is required to ensure managers are working for the interests of the owners rather than their own. State-owned enterprises are more likely to suffer from this problem since there is no contractual or monitoring mechanism to ensure that the objectives of the politicians and bureaucrats managing state firms are aligned with those of the citizens (Zhou et al. 2017).

State firms rarely face the close scrutiny that private firms face from shareholders on a regular basis. Without effective monitoring, politicians are more likely to use state-owned enterprises to maximize their own interests, secure political favours, and achieve political or social goals, thus interfering in state firms' regular business operations. In addition, government-appointed managers may misuse R&D funds, leading to inefficiency in generating innovation output (Zhou et al. 2017). Under this view, state ownership reduces a firm's innovative capacity and therefore, state-owned enterprises are less efficient than private firms at producing innovation output from R&D input.

A different approach to economic growth argues that firm behaviour is determined by its surrounding institutions (Acemoglu et al. 2005). Of these institutions, the government is one of the most important, as it can strongly influence business through national strategic planning, banking regulations, protection of certain industries, and enforcement of intellectual property rights (Zhou et al. 2017). Furthermore, the government plays a key role in allocating resources, such as land and subsidies. Therefore, as government-owned organizations, state firms often enjoy privileges granted by the government, in the form of preferential regulatory treatment, access to low-interest loans, and government subsidies, all of which enable state firms to invest more heavily into R&D (Zhou et al. 2017). Currently, the Chinese government sees innovation as a national priority and consequently Chinese state-owned enterprises are under significant pressure to invest in R&D and innovation development. As a result, the institutional view suggests that state firms are more innovative than private firms.

Zhou et al. (2017) suggest that that the institutional and agency views pertain to different facets of state ownership. The institutional view highlights the advantage of state ownership in resource allocation. State-owned enterprises have greater access to resources, which translates to

more inputs into the R&D process. On the other hand, agency theory highlights utilization of resources: The principal-agent problem caused by state ownership leads to misuse of R&D resources. As a result, state ownership could help a firm obtain more resources for R&D investment but also decrease the firm's ability to convert R&D input into innovation output. Therefore, the degree of state ownership, from minority to majority, may make either the institutional or agency argument more salient.

A third approach: Market failure

A different argument for why state ownership favours innovation deals with the public goods nature of knowledge. Knowledge is non-rival, non-excludable, and an additional user can enjoy new knowledge at zero marginal cost (Arrow 1962). In addition, R&D and the production of new knowledge has externalities: New technology at one firm may be used at other firms to increase productivity overall, and therefore, private returns to R&D investment are lower than social returns (Arrow 1962). Consequently, private firms might underinvest in R&D (Arrow 1962). This argument is often used to justify the use of government R&D subsidies to correct private sector underinvestment in R&D. Another common method of promoting private investment in R&D is through protection of intellectual property rights. Indeed, Lin et al. (2010) find that stronger property rights protection and contract enforcement are associated with higher corporate R&D investment in China while Fang et al. (2017) find that following the privatization of state firms, innovation increased the most in Chinese cities with stronger intellectual property rights. However, despite significant strides made in intellectual property law over the last three decades, China's intellectual property rights regime is weaker than that of most advanced economies, in part because rule of law is weak and subject to political manipulation (Li and Alon 2019). Consequently, private firms will still underinvest in R&D.

Furthermore, R&D is risky in nature, and private firms may not be willing to take on R&D projects which have uncertain potential for ground-breaking innovation. State firms, however, may not be profit maximizing and are therefore less sensitive to variation in profits. This, combined with a longer-term outlook, may make state firms more conducive for R&D and innovation (Belloc 2014). Finally, R&D is a collaborative process and may be less likely to occur in private firms, which tend to focus on individual sectors. State ownership in multiple firms, however, may be conducive for fostering inter-firm relations and allow for connections between seemingly disparate lines of research (Belloc 2014; Tonurist and Karo 2016). For these reasons, state ownership may increase a firm's R&D investment and innovation output.

How are ownership, R&D and innovation measured?

Before discussing some findings of recent papers, a brief discussion of how ownership, R&D input and innovation output are measured in practice is beneficial. Most researchers use one of two measures of ownership. First is the percentage of shares held by the state or by private or foreign entities as a continuous variable. Second is a categorical measure of ownership. Sometimes, this is assigned based on a firm's legal registration as a private or state-owned firm. Often, it is assigned by the researcher based on whether or not the state holds majority shares in a firm. If yes, then the firm is generally considered to be state-owned. If not, then it may be considered a foreign-invested firm or a private firm, depending on what percentage of shares are foreign held. For example, Wei et al. (2017) consider firms that have less than 50 percent state ownership but more than 10 percent foreign ownership to be foreign-invested firms and less than 10 percent foreign ownership to be private firms. Some papers will further distinguish between minority and majority state ownership. Minority ownership refers to a 1 percent to 49 percent government stake while majority ownership refers to government

ownership of 50 percent or greater of shares. In this case, private ownership refers to 0 percent state ownership.

A common measure of R&D input is R&D intensity, which is calculated by dividing R&D expenditures by total sales. Meanwhile, innovation output is often measured by the volume of new patents registered. While not all innovation activity leads to patents, nor do all patents registered represent innovation performance, patent data provide the most detailed and systematically compiled data on innovation in China (Choi et al. 2011). There are three types of Chinese patents: Invention, utility, and design. Of these three categories, invention patents are the most technically intensive and are generally what researchers use as their measure of patents.

Some researchers, such as Wei et al. (2017), also measure innovation output by the citation count of patents rather than the number of patents granted. Since a patent applicant is required to cite previously patented ideas, patent citations track knowledge building across people, firms, and regions (Almeida et al. 2002). China's State Intellectual Property Office does not disclose patent citations, so this is typically done using US patents received by Chinese firms or by the researcher's own estimates of Chinese patent citations (Wei et al. 2017; Boeing 2016). Another alternative measure of innovation, relevant for industrial R&D, is the share of total sales that come from sales of new products.[1] Since a large portion of industrial R&D is channeled into new product development, the share of new product sales is a measure of innovation that is immediately commercialized.

Evidence on ownership and innovation

The literature studying the effect of state ownership on innovation tends to generate mixed results. Teng & Yi (2017), using data from the National Bureau of Statistics between 2005

[1] Calculated as new product sales divided by total product sales.

and 2007, find that state ownership increases both R&D intensity and new product sales compared to private ownership. Even when controlling for R&D intensity, they find that state ownership increases a firm's innovation output. However, this relationship is only statistically significant for firms owned by the central government and not for firms affiliated with local governments. Choi et al. (2011) also find that state ownership increases the number of patents a firm receives in subsequent years using data on firms trading publicly on the Shanghai and Shenzhen Stock Exchanges between 2001 and 2004. These findings suggest that some amount of central state ownership is important for innovation performance in China's institutional environment.

In contrast, Lin et al. (2010), using a 2003 World Bank dataset of 2,400 Chinese, find that state-owned enterprises are less likely to invest in R&D in the first place. Compared with state firms, private firms are 7 percent more likely to conduct R&D projects. They also find that firms with government-approved or appointed chief executive officers (CEO) are 6 percent less likely to invest in R&D projects. Furthermore, Wei et al. (2017) find that state-owned enterprises are less efficient at generating innovation output compared to private and foreign-invested firms. Between 2005 and 2007, for every 10 million RMB invested into R&D, domestic private firms and foreign-invested firms generated 6.5 and 7.6 patents, respectively. State firms, however, produced 2.2 patents with the same R&D investment. This measure of R&D efficiency suggests that state firms are less efficient at converting R&D input into innovation output than private firms.

Zhou et al. (2017) find evidence to support both arguments. Using data from 2001 to 2007 from the Annual Census of Chinese Industrial Enterprises, conducted by National Bureau of Statistics, they find an inverted U-shaped relationship between state ownership and

innovation. State ownership up to a certain level increases innovation output but above this level, state ownership has a negative effect on innovation output. This holds when using both new product sales and number of patents as the measure of innovation output. With new product sales, they find that the effect of state ownership is positive up to 29.18 percent ownership; beyond this point, the effect is negative. With patents, the turning point occurs at 28.89 percent. These findings suggest that within China's current institutional environment, a minority state ownership of around 29 percent is optimal for a firm's production of innovation. At low levels, state ownership can help the firm gain access to crucial resources, such as bank credit and government subsidies, but does not interfere in the conversion of R&D input into innovation output. However, at higher levels, state ownership starts to interfere in this process, suggesting that majority state ownership leads to lower R&D efficiency.

This finding has two main implications for current industrial policy. First, majority state-owned firms may not be the drivers of China's technological advancement or productivity growth. Instead, the Chinese government should consider reducing their stake in state-owned enterprises in order to improve these firms' R&D efficiency. Second, if Chinese institutional factors, such as financial markets and intellectual property rights, strengthen, the advantages of minority state ownership will no longer be as important. Within China's current institutional setting, state-owned enterprises enjoy preferential regulatory treatment, easier access to bank loans, and government subsidies, all of which can increase R&D investment and thus, innovation output. If state and private firms were on a level playing field, however, with similar access to loans and government subsidies, the institutional advantages of state ownership would be less salient. Consequently, the R&D efficiency gains from private ownership could outweigh the advantages of state ownership.

CHINA'S CURRENT INNOVATION POLICY

As discussed earlier, market failures in the production of knowledge can lead to underinvestment in R&D by private firms (Arrow 1962). Consequently, governments often correct for this using tax credits and direct subsidies. According to the OECD, all major industrialized nations subsidize R&D and China is no exception (Fang et al. 2018; Wei et al. 2017). Given China's preferential treatment of state firms, its history of government interference in business, and the importance of innovation to future economic growth, I investigate three aspects of Chinese R&D subsidies:

1. To what extent does ownership play a role in the allocation of R&D subsidies;
2. Do government R&D subsidies crowd out a firm's own R&D investment; and
3. Do government R&D subsidies lead to more innovation output and higher productivity?

Allocation of R&D subsidies

R&D investment is a crucial input into the R&D and innovation process and in China, about 60 percent of industrial R&D investment comes in the form of government R&D subsidies to firms (Boeing 2016). Therefore, the extent to which these subsidies promote innovation output depends in large part on whether these subsidies are allocated efficiently. If government officials allocate R&D subsidies based on merit and innovative capacity, then subsidies should be positively related to subsequent innovation output. However, if subsidies are politically driven by state ownership or corruption, then they would have little effect on innovation (Fang et al. 2018).

Boeing (2016) finds that minority state ownership is associated with a greater chance of receiving a R&D subsidy, compared to private or majority state ownership. In addition, R&D subsidy allocation is highly persistent: prior subsidies are important determinants of future subsidies. Interestingly, prior patent citations increase the probability that a firm receives an

R&D subsidy, while the level of patent stock is negatively associated and statistically insignificant. This suggests that patent quality, and not quantity, is important for determining future R&D subsidy allocation. Boeing's findings that past innovation output and minority state ownership are strong determinants of future R&D subsidies are consistent with Zhou et al.'s (2017) finding that minority state ownership is optimal for producing innovation.

Cheng et al. (2019) initially find that a majority state-owned enterprise is more likely to receive an R&D subsidy than a private enterprise. After controlling for firm attributes, such as number of employees, firm age, and R&D intensity, and CEO characteristics, such as CEO's years of schooling, CEO's work experience, and whether the CEO has an MBA, the effect of state ownership becomes substantially smaller and loses statistical significance. They find, however, that a politically connected firm is far more likely to receive a subsidy than a firm that is not politically connected.[2] Even when controlling for state ownership and firm and CEO characteristics, a politically connected firm is 9 percentage points more likely to receive an R&D subsidy, on average, than a non-politically connected firm. This suggests that political connection, rather than state ownership, is an important factor for receiving R&D subsidies.

A natural follow-up question is: Are state firms more likely to be politically connected? In the sample of firms studied by Cheng et al. (2019), 35.1 percent of state-owned enterprises and 22.4 percent of non-state firms are politically connected, by their definition of political connection.[3] This sample average excludes a number of other factors, such as firm size and age, and is not necessarily representative of the population of Chinese firms. Despite this caveat, state

[2] A firm is politically connected if the CEO or owner of the firm is a member of the People's Congress or the People's Political Consultative Conference, the legislative and democratic supervision branches of government.
[3] Author's calculations: See appendix for details.

firms are more likely to have government-appointed CEOs than non-state firms and therefore, to be politically connected.

Fang et al. (2018) find that the anticorruption campaign which began in 2012, and the subsequent departure of local officials responsible for innovation programs, strengthened the relationship between a firm's historical R&D efficiency and the subsidies it receives. To measure corruption, they use a firm's "Entertainment and Travel Costs" disclosed in financial statements, which are often used to expense gifts to officials. Prior to the anticorruption campaign, they found that both corruption and a firm's R&D efficiency influence subsidy allocation equally. A one standard deviation increase in either variable results in a roughly 10 percent increase in subsidies as a percentage of revenue. After the anticorruption campaign and the departure of local officials, however, the influence of a firm's R&D efficiency increases while the effect of corruption falls.

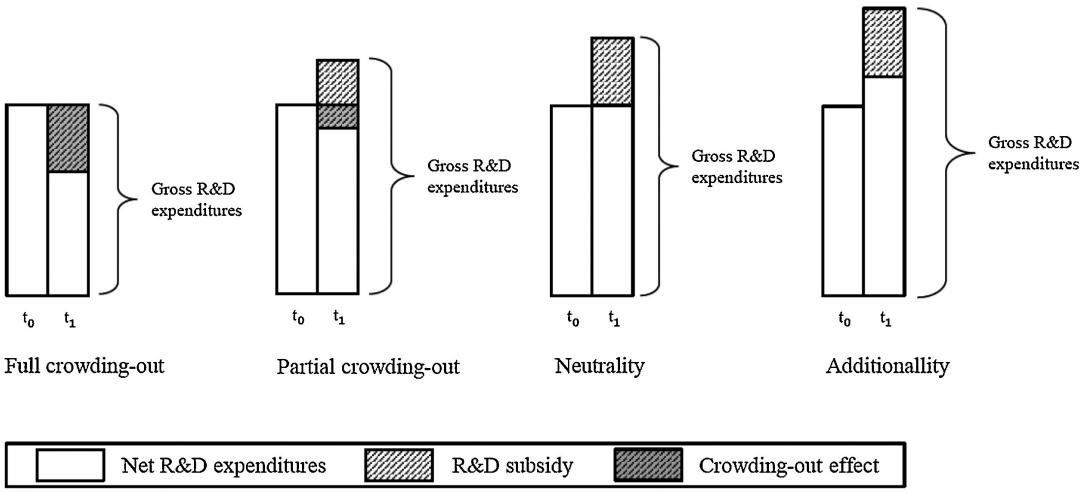
These results suggest that political connections and level of corruption in China are better determinants of R&D allocation than state ownership. Since R&D subsidies are being allocated based on factors other historical innovative capacity, their allocation is inefficient, regardless of whether it is due to ownership or corruption. This calls into question the effectiveness of China's innovation policy; phasing out preferential policies to create a fair business environment will likely increase China's innovation output in the future.

Crowding-out of R&D investment

Another concern about government R&D subsidies is that they might crowd out a firm's own R&D investment. In this case, R&D subsidies would fail to substantially increase total R&D investment and innovation output. Full or partial crowding-out occurs when the firm reduces its own investment in response to receiving a subsidy. With the presence of partial crowding out,

total R&D investment still increases. Neutrality occurs when an R&D subsidy does not affect the firm's investment whereas additionality occurs when a subsidy actually increases the firm's own investment. Figure 1 illustrates these concepts.

Figure 1: Crowding-out effect of R&D subsidies on a firm's own R&D investment.



Source: Boeing (2016): "The allocation and effectiveness of China's R&D subsidies – Evidence from listed firms."

To avoid crowding-out, many R&D programs require that firms match public funds with equal private funds; however, in practice, a firm may readjust its R&D investments in other projects, making the substitution of private for public investment difficult to prevent (Boeing 2016). In China, Boeing (2016) finds that government R&D subsidies partially or fully crowd out the firm's own R&D investment that same year. However, these subsidies have no effect on private investment in subsequent years, suggesting neutrality in the longer term. Therefore, it appears as though firms use public funds to immediately reduce their R&D expenses, but do not change their R&D portfolio, thus maintaining their level of investment in later years (Boeing 2016).

Boeing (2016) repeats this analysis, splitting up his sample into high-tech and low-tech firms. For the low-tech firms, he finds evidence of immediate crowding out, but fails to find

similar evidence for high-tech firms. He concludes that high-tech firms exhibit neutrality, which is likely due to the fact that high-tech firms depend heavily on R&D to remain competitive.

Finally, he splits up his sample into private, minority state-owned, and majority state-owned firms and finds evidence of crowding-out in both private and majority state-owned firms. In contrast, minority state-owned firms exhibit neutrality, reinforcing previous findings which suggest that minority-state ownership is optimal for R&D and innovation.

Do R&D subsidies increase innovation output and productivity?

The ultimate goal of government R&D subsidies is to increase innovation output and consequently, productivity. Therefore, the success of China's innovation program depends on whether it has succeeded at increasing Chinese firms' innovative capacity and productivity.

Cheng et al. (2019) find that R&D subsidies increase the probability that a firm receives a patent by about 28 percent, even after controlling for state ownership and political connection. However, subsidies increase total number of patents the firm receives by only 0.46 percent, suggesting that subsidies encourage incremental improvements in technology but not highly innovative discoveries (Cheng et al. 2019). In addition, they find that firms that receive subsidies are about 18 percent more likely to introduce new products. In general, however, they do not find that innovation subsidies translate to increases in productivity, profits, or market share, even in state firms. Political connections, on the other hand, tend to increase labour productivity, market share, and profits, supporting their finding that political connections are more important than ownership for business in China.

Fang et al. (2018) find that innovation subsidies are positively associated with future patents in general, and that this effect strengthened after the anticorruption campaign in 2012. After the campaign, a one standard deviation increase in subsidies as a percentage of sales is

associated with a 54 percent increase in US patenting rates. This indicates that better allocative efficiency due to less government corruption strengthened the effect of R&D subsidies on subsequent innovation. Guo et al. (2016) also find that innovation subsidies help generate innovation output: the new patent growth rate in small to medium subsidy-backed firms is 13.2 percent higher than in firms that do not receive subsidies. However, neither Fang et al. (2018) nor Guo et al. (2016) extend their studies to increases in productivity.

Howell (2017) finds that while R&D subsidies lead to more new product sales in high-tech industries, the effect of R&D subsidies on productivity is negative and statistically significant for all levels of technology. Consequently, he concludes that the increase in innovation output does not translate to higher productivity. Zhang et al. (2003) find that state firms exhibit higher R&D intensity but lower R&D efficiency than non-state firms, similar to results by Zhou et al. (2017) and Wei et al. (2017). Zhang et al. (2003) also argue that R&D efficiency is a better determinant of overall productivity than R&D intensity and that state firms' lower R&D efficiency leads to lower productivity overall. Boeing et al. (2016) finds similar results showing that private firms achieve greater increases in productivity from increases in R&D investment and number of patents than minority or majority state-owned enterprises.

Overall, China's R&D subsidies increase innovation output in most firms and the effect is stronger when subsidies are allocated based on innovative capacity rather than ownership or political connection. However, R&D subsidies do not necessarily lead to higher productivity, and in some cases, actually reduce productivity. This may be because R&D subsidies tend to support incremental improvements in technology that do not result in large productivity gains. In addition, misallocation of R&D subsidies may lead to lower R&D efficiency overall, which is a better determinant of productivity growth than R&D intensity. Finally, R&D is a long-term

process and most studies focus on at most six years of data. Consequently, a study covering a longer period of time may find different results.

CONCLUSION

China's future economic growth relies on growth in total factor proudctivity. A large component of productivity growth depends on innovation and technological change. Under China's current institutional setting, minority state ownership is optimal for innovation: Minority state ownership allows a firm to gain crucial inputs to R&D, such as bank loans, but does not strongly reduce the firm's R&D efficiency. With regard to China's innovation policy, a number of studies find evidence of inefficiency due to the influence of political connections and corruption on subsidy allocation. As a result, while R&D subsidies promote innovation output, these do not necessarily translate to gains in productivity. Moving forward, in order to increase the effectiveness of its innovation policies, China should phase out its preferential policies and ensure that subsidies are allocated based on innovative capacity. This will ensure that the most R&D efficient firms receive innovation subsidies. Strengthening institutional factors, such as financial markets and intellectual property rights, can further incentivise all firms to invest more in R&D and innovation. With fairer policies and stronger institutions, the advantages of state ownership throughout the R&D process may be less salient; in this case, the private sector, which is more R&D efficient, will likely be the driver of Chinese innovation and economic growth.

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APPENDIX

Table 1: Political connections and ownership in Cheng et al.'s (2019) sample of firms

	Without Political Connections		With Political Connections		Total	
	No.	Row %	No.	Row %	No.	Row %
Non-SOEs	771	77.6	223	22.4	994	100
SOEs	50	64.9	27	35.1	77	100

Source: Cheng et al. (2019): "Do innovation subsidies make Chinese firms more innovative? evidence from the china employer employee survey."

Calculations:

$$\begin{aligned}\text{share of state firms that are politically connected} &= \frac{\text{number of state firms that are politically connected}}{\text{total number of state firms}} \\ &= 22/77 \\ &= 35.1\%\end{aligned}$$

$$\begin{aligned}\text{share of non-state firms that are politically connected} &= \frac{\text{number of non-state firms that are politically connected}}{\text{total number of non-state firms}} \\ &= 223/994 \\ &= 22.4\%\end{aligned}$$