How State Ownership Affects Corporate R&D: An Inverted-U-Shaped Relationship

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Abstract

The existing literature provides mixed evidence about the effect of state ownership on corporate research and development (R&D). As this paper hypothesizes, state ownership has a positive institutional effect on the investment environment for R&D and a negative institutional effect on firm operations for innovation. With evidence from China, we confirm that state-owned shares have an inverted-U-shaped causal effect on corporate R&D and that having the state as a minority shareholder is optimal for corporate R&D. We further document that, when a firm's R&D investment at least equals reinvestment of its profit, the threshold for state-owned shares is larger than it would be otherwise. Therefore, we justify the contradictory institutional effects of state ownership with an inverted-U-shaped relationship, thereby enhancing understanding of institutions and state ownership for corporate finance.

JEL classification: O32, P31, P20.

Keywords: China, corporate R&D, state ownership.

1 Introduction

A classic question in economics concerns the scope of government. Mainstream economics asserts that state ownership reduces incentives for research and development (R&D) (Hart et al., 1997; Jia et al., 2019)[1] and even R&D efficiency (e.g., Aghion et al., 2013; He et al., 2019). However, as a new branch of economic doctrine for the twenty-first century, innovation economics develops Schumpeterian (Schumpeter, 1934, 1942) theory and then presents a different picture of it; it reminds us that state ownership creates monopoly power for firms (Shleifer, 1998) and then breeds R&D for competitiveness (Hall and Rosenberg, 2011). Increasing evidence from emerging economies and transitional countries has recently shown that state-owned enterprises (SOEs) have comparative advantages in R&D (e.g., Choi et al., 2011, 2012; Howell, 2017). Motivated by the government-scope puzzle, this paper explores how state ownership affects corporate R&D.

The effect of state ownership on corporate R&D also has essential importance in the corporate finance theory. In principle, state ownership shapes a firm's incentives (Chen et al., 2006) and constraints (Luo et al. 2017; Huang et al., 2017). On the one hand, we must understand the effect of state ownership on corporate R&D because state ownership inherently determines whether a firm invests in R&D for long-term growth (Li, 2011; Mao and Zhang, 2018). On the other hand, the effect of state ownership is much more complicated in R&D investment than in other types of corporate investment (Bardhan, 2016). Specifically, state ownership tends to soften a firm's financing constraints (Cull et al., 2015) but harden investment constraints (Huang et al., 2017; Wang et al. 2017). Given that corporate R&D is highly sensitive to financial risks (Berk et al., 2004; Li, 2011), the effect of state ownership on R&D investment is a critical test for corporate finance.

[1]As Hart et al. (1997) concludes, state ownership has weak incentives for engaging in both quality improvement and cost reduction, although it can avoid excessive incentives for cost reduction. Simply speaking, the effect of state ownership on corporate R&D is linearly qualified and specifically negative.

The existing literature lacks a deep understanding of the institutional effect on corporate R&D, as it focuses on either the positive institutional effect of state ownership on access to economic, human, and natural resources (Cai et al., 2011; Huang, 2010; Jiang and Kim, 2015) or the negative institutional effect of government intervention (Hart et al., 1997) that reduces R&D investment (e.g., Ayyagari et al., 2011). As a novelty, we distinguish these contradictory institutional effects and then formally hypothesize an inverted-U-shaped relationship between state-owned shares (hereafter, state shares) and corporate R&D (see Figure 1). To support our view, we further argue that R&D investment that equals or exceeds reinvested profit tend to impose financial constraints on the firm (see Cull and Xu, 2005) and then weaken the promotional effect of state ownership on corporate R&D. Thus, we also hypothesize a threshold of state ownership for R&D intensity when a firm's R&D investment at least equals its profit reinvestment that is larger than it would be otherwise (see Figure 2).

[Insert Figures 1-2 about here]

This paper collects evidence from China because the source of endogeneity bias in China's institutional background is not difficult to identify. State ownership in China is the historical product of political intervention (Wang and Chen, 2006), so a firm's state shares are historically (and politically) determined (see Section 2). Thus, we can use cross-sectional data, i.e., the 2005 World Bank Investor Climate Survey, to avoid reverse causality.[2] Moreover, given the politically sensitivity of state shares, the information on state shares should be precise, and so the corresponding measurement is credible.

As explained above, this study focuses on the endogeneity bias due to omitted variables. This paper adopts some strategies to determine whether the relationship of interest is causal.[3]

[2] The data are labeled 2005 because the survey was undertaken in 2005, but they were investigating information in 2004. Hence, our data are actually in 2004.

[3] As Chang (2011) points out, most of the institutional literature overlooks the endogeneity issue. There are some exceptions, but they do not focus on state shares (e.g., Acemoglu et al., 2001; Fu and Jian, 2018).

First, we conduct the test suggested by Altonji et al. (2005) to calculate how much greater the influence of omitted variables needs to be, relative to controlled factors, to completely explain away the relationship of interest. As a result, the endogeneity bias is unlikely to offset the true effect of competition.

To formally address the endogeneity bias, we conduct instrumental variable (IV) esitmation. Unfortunately, it is impractical to seek an IV that affects corporate R&D only through *firm-level* state ownership.[4] As an additional novelty, we adopt the heteroskedasticity-IV method developed by Lewbel (2012) to address the endogeneity (see Section 4). Lewbel (2012) suggests defining an IV with the residuals of the first-stage regression multiplied by an exogenous variable, for which this paper uses the population of a city in 1978.[5] Specifically, our generated IV reflects the heteroskedasticity of state shares resulting from the historical population in 1978. Thus, it is relevant to state shares by definition. At the same time, the heteroskedasticity measured by the generated IV captures the idiosyncratic information on state shares, so it would not be correlated with the pattern of corporate R&D and then satisfy exclusion restriction. After empirically confirming the validity of our IV, we use IV estimates to identify a significant inverted-U-shaped effect of state shares on corporate R&D.

Additionally, we conduct the nonlinearity test developed by Lind and Mehlum (2010) to confirm that the relationship of interest under ordinary least squares (OLS) or IV estimates is inverted-U-shaped. All this evidence together confirms an inverted-U-shaped causal effect of state shares on corporate R&D. In particular, our estimates reveal that minority state ownership is optimal for corporate R&D.

After identifying the causal effect of state shares, we exploit the scale effect of corporate

[4] In theory, we may use an city-level IV that determines firm-level state ownership, but it is less rigorous of the IV to satisfy the exclusion restriction assumption.

[5] We use the population in 1978 to generate an IV, rather directly using it as an IV because it can have direct effects on corporate R&D in 2004, thereby violating the exclusion restriction.

R&D to explain the inverted-U-shaped relationship. We conduct sample-splitting estimations to confirm that the threshold of state ownership for R&D intensity is larger when a firm's R&D investment at least equals its profit reinvestment than it would be otherwise. .

This contribution of the paper is its new finding, i.e., an inverted-U-shaped relationship, which enhances understanding of state ownership. More generally, this paper sheds new light on corporate finance. The mainstream literature on institutions and finance agrees that the quality of economic institutions, such as private investor/creditor protection (La Porta et al., 1997, 2008) and private property protection (Acemoglu et al., 2001, 2005), promotes financial development. However, later scholars believe that we lack a deep understanding of institutions (Chang, 2011). They hold that institutional effects depend on antecedents and background (e.g., Chang, 1998, 2005; Peng et al., 2008), and this paper shows that institutional effects need to be decomposed. Specifically, we distinguish the institutional effect on access to resources from that on the utilization efficiency of resources,[6] thereby explicating the effect of state-owned institutions for corporate R&D. Ultimately, we demonstrate that the scope of government should be designed quantitatively, rather than qualitatively.

This paper also has general implications for the competitive strategies of firms. As this paper shows, the optimal ratio of state shares is less than 0.5, so the state had better not be the largest shareholder. As we reveal, if the state is only a minority shareholder in firm operations, it can give a firm better institutional advantage in access resource. At the same time, as the state is not the largest shareholder, the government intervention issue can be constrained. Moreover, this paper offers insight for reducing the inefficiency at R&D (see Antonelli, 2011; Hall and Rosenberg, 2011). Specifically, given that state shares are given exogenously in the short run, this paper suggests that we can still constrain shirking behavior or value diversion when investing in R&D by introducing incentive designs such as private

[6] Thus, it explains why the traditional literature (e.g., Shleifer, 1998; Ramaswamy, 2001) criticizes state ownership for inefficiency, but much recent literature (e.g., Kim and Jiang, 2015) finds that firms with state shares have advantages in government-controlled sectors or emerging markets.

institutional ownership (Aghion et al., 2013) or incentive payment mechanisms (Lin et al., 2010b).

This paper is structured as follows. Section 2 generates our hypotheses about the effect of state ownership on corporate R&D. Section 3 introduces our data and variables, whereas Section 4 describes our identification strategy. We report our main results to confirm the inverted-U-shaped hypothesis in Section 5. Then, we explore the scale effect of corporate R&D to confirm our explanation on the inverted-U-shaped relationship in Section 6. Section 7 concludes.

2 Hypotheses

The following briefly reviews the institutional background and setting and then develops hypotheses for later empirics.

2.1 Institutional Background and Setting

The People's Republic of China launched its socialist transformation in 1953, and all private and foreign-owned property was nationalized in 1956. To help spark economic development, the Chinese government began to allow some private economic activity in 1978 and launched economic reforms in the 1980s and 1990s. As a result, some SOEs were either privatized or came under collective ownership (held by villages or communities). At the same time, some industries gradually accepted foreign investment. At the same time, some firms remained state owned even after the reforms, due to political decisions (Wang and Chen, 2006).

The Chinese government maintains a role in the economy, thus, any change, regardless of its magnitude, in state-owned shares is thus politically sensitive, and this sensitivity maintained the stability of state shares, at least for the cross-sectional data in 2004. So, the government can intervene in the micro-economy as a shareholder based on its political considerations (Bennedsen, 2000; Hart et al., 1997) and achieve its macro strategies through its control over firms with state shares (Ferguson and Voth, 2008; Shleifer, 1998). Under this institutional setting, we explore the theoretical effects of state ownership on corporate R&D as follows.

2.2 Conceptual Framework

As the property rights theory of the firm (Holmstrom, 1999) points out, a firm gains control of assets via ownership. Considering that state ownership has different characteristics from private ownership, it affects the firm's investment strategy: Because R&D products have externality and uncertainty, and they produce economic profit only in the future (e.g., Berk et al., 2004), corporate R&D is vulnerable to institutional risks, inefficiency, and financial constraints, respectively. State ownership pragmatically weakens risks/constraints, while it breeds government intervention thereby weakening R&D efficiency (Hart et al., 1997).

We assume that a firm's return on R&D investment ($R\&D_i$) hinges on its resources (R_i) and resource utilization (U_i).[7] In particular, a firm's resource utilization is determined not only by its economic efficiency but also the quality of economic institutions that ensure the firm to exclusively capture the return on R&D investment.

Moreover, both resources and resource utilization are affected by state ownership. In theory, state ownership represents a formal tie with the government; a higher ratio of state shares represents a closer connection with the government. Its institutional effect can be decomposed. On the one hand, state ownership provides a firm with a favorable institutional environment. Specifically, it gives a firm comparative advantages to better obtain government-controlled resources, such as capital and environmental resources (Huang, 2010; Jiang and Kim, 2015); thus, $\frac{\partial R}{\partial S} > 0$, where S is state shares. It also gives firms higher-

[7] Given that a firm produce goods or service by accessing and using resources/factors, the efficiency of a firm is determined by its accessed resources and the utilization of resources.

quality economic institutions; specifically, a firm with state shares obtains better protection from government expropriation (Du et al., 2015); without losing generality, it can access government support for loans and/or other preferential policies (Li et al., 2008; ; Wu et al., 2012). It also tends to obtain higher contract enforcement (Du et al., 2014), and favorable regulatory treatment (Agrawal and Knoeber 2001).[8] At the same time, economic institutions are important conditions for corporate R&D (e.g., Fu and Jian, 2018; Lin et al., 2010a). Thus, state ownership helps a firm to better capture its R&D products through the resource utilization due to economic institutions (U^{EI}): $\frac{\partial U^{EI}}{\partial S} > 0$. Therefore, the institutional effect of state ownership on the investment environment can be reflected as $\frac{\partial R}{\partial S}$ and $\frac{\partial U^{EI}}{\partial S}$, $\frac{\partial R}{\partial S} > 0$, and $\frac{\partial U^{EI}}{\partial S} > 0$.

On the other hand, a firm with state shares is exposed per se to government intervention. According to Hart et al. (1997), when the government is (one of) owner(s), it has decision-making rights on R&D investment. Considering that the government seeks welfare and political benefits (Shleifer 1998), state ownership tends to distort a firm's resource utilization and then weakens the firm's R&D efficiency (Hart et al. 1997). In other words, state ownership constrains a firm's resource utilization due to economic efficiency (U^{EE}), $\frac{\partial U^{EE}}{\partial S} < 0$. Therefore, the institutional effect of state shares on firm operations can be defined as $\frac{\partial U^{EE}}{\partial S}$, and we expect it to be negative, $\frac{\partial U^{EE}}{\partial S} < 0$.

Given these contradictory institutional effects, we use the following to explain how state ownership affects corporate R&D.

$$R\&D_i = aS_i^R + b_1 S_i^{EI} + b_2 S_i^{EE} + Z'\Gamma + e_i, a > 0, b_1 > 0, b_2 < 0 \quad (1)$$

where S_i^R is state shares that affect corporate R&D through the resource channel (R), S_i^{EI} refers to the effect of state shares through the economic institutional channel (for resource

[8]Traditionally speaking, the quality of economic institutions has two dimensions: protection from government expropriation and contract enforcement (North, 1990). Recently, the literature emphasizes a third dimension, market freedom (Chang, 2011).

utilization), and S_i^{EE} represents the effect through the firm's economic efficiency channel (for resource utilization). Z is the set of controls that affect R&D. As mentioned before, a firm's return on R&D investment ($R\&D_i$) hinges on its resources (R_i) and resource utilization (U_i). At the same time, we have qualified that $\frac{\partial R}{\partial S} > 0$, $\frac{\partial U^{EI}}{\partial S} > 0$ and $\frac{\partial U^{EE}}{\partial S} < 0$; thus, we expect that a and b_1 are positive, and b_2 is negative.

Given that a and b_1 are expected to be positive, we merge S_i^R with S_i^{EI} into S_i^{IE} for later empirics because both resources (R) and economic institutions (EI) depend on the investment/institutional environment (IE). Thus, we reduce Equation (1) as follows.

$$R\&D_i = aS_i^{IE} + b_2 S_i^{EE} + Z'\Gamma + e_i, a > 0, b_2 < 0 \tag{2}$$

where S_i^{IE}=(S_i^R, S_i^{EI}). As Equation (2) reveals, state ownership promotes corporate R&D through the institutional environment, i.e., $a > 0$, whereas it impedes R&D investment through economic efficiency, i.e., $b_2 < 0$. Theoretically speaking, as Equation (2) demonstrates, state ownership has contradictory effects on corporate R&D. In comparison with the direct identification of the positive institutional effect (S_i^{IE}) and the negative one (S_i^{EE}), it is more econometrically rigorous and feasible to examine them by regress corporate R&D on state ownership according to a quadratic equation:

$$R\&D_i = \alpha_1 S_i + \alpha_2 S_i^2 + Z'\Gamma + e_i, \alpha_1 > 0, \alpha_2 < 0 \tag{3}$$

where S_i^2 is the square of S_i. In particular, we hypothesize an inverted-U-shaped relationship between state shares and corporate R&D instead of a U-shaped one.

In the same definition way, we use $R\&D_i^{IE}$ to reflect corporate R&D determined by IE (institutional environment) and $R\&D_i^{EE}$ to indicate the one determined by EE (economic efficiency), respectively. Because either IE or EE is affected by state shares, S, there are $R\&D_i^{IE}(S_i)$ and $R\&D_i^{EE}(S_i)$; $R\&D_i = R\&D_i^{IE}(S_i) + R\&D_i^{EE}(S_i)$. Recall that $a > 0$ and $b_2 < 0$ in Equation (2), so there are $\frac{\partial R\&D_i^{IE}(S_i)}{\partial S} > 0$ and $\frac{\partial R\&D_i^{EE}(S_i)}{\partial S} < 0$. Moreover, because the resources and the quality of economic institutions are limited, $\frac{\partial^2 R\&D_i^{IE}(S_i)}{\partial S^2} \leq 0$. By contrast, a larger ratio of state shares induces more government intervention, which intensifies the incentive distortion, so $\frac{\partial^2 R\&D_i^{EE}(S_i)}{\partial S^2} \geq 0$. These first-order or second-order partial derivatives imply that $R\&D_i^{IE}(S_i)$ and $R\&D_i^{EE}(S_i)$ are continuous and differentiable (see the lines of $R\&D^{IE}$ and $R\&D^{EE}$ in Figure 1, respectively). Without losing generality, we assume that $R\&D_i^{EE}(0) \gg R\&D_i^{IE}(0)$ and $R\&D_i^{IE}(1) \gg R\&D_i^{EE}(1)$. Thus, $R\&D_i^{IE}(\varepsilon) + R\&D_i^{EE}(\varepsilon) > R\&D_i^{IE}(0) + R\&D_i^{EE}(0)$; $R\&D_i^{IE}(1-\varepsilon) + R\&D_i^{EE}(1-\varepsilon) > R\&D_i^{IE}(1) + R\&D_i^{EE}(1)$. Therefore, $\max R\&D_i = R\&D_i^{IE}(S_i^*) + R\&D_i^{EE}(S_i^*)$, where $0 < S_i^* < 1$ and $\frac{\partial R\&D_i^{IE}(S_i^*)}{\partial S} + \frac{\partial R\&D_i^{EE}(S_i^*)}{\partial S} = 0$. Easily speaking, there is an interior solution for the potential maximized R&D investment so that the relationship between corporate R&D and state shares (i.e., $R\&D(S)$ in Figure 1) takes an inverted-U shape.

We also hypothesize optimal state ownership, whose value should be less than 0.5. In theory, when the state holds more than half the ownership, the firm is legally registered as an SOE, and then it must have a largest power to decide the firm's investment. Thus, efficiency at $S = \bar{S}$ will be reduced, where $\bar{S}$ is the largest share of ownership and $\bar{S} \leq 0.5$. By contrast, the investment environment for the firm will not be dramatically improved when $S \to \bar{S}$. Thus, $R\&D(\bar{S} - \varepsilon) > R\&D(\bar{S})$. Optimal state ownership has a ratio of less than 0.5.[9] At the same time, only when the state is a minority shareholder whose smallest share is 0.05 (Denis, 2001), the government has rights and real control in corporate investment. Accordingly, the optimal state shares for R&D investment should be larger than 0.05 and less than 0.5. We summarize this analysis as follows:

Hypothesis 1: The effect of state shares on corporate R&D takes an inverted-U shape; minority state ownership (i.e., state shares reach at least 0.05 but are less than 0.5) is optimal for corporate R&D.

[9]In mathematics, we only need to assume the $R\&D(S_i)$ is a differentiable function of S_i, which is satisifed as mentioned before.

To justify our theory, we exploit the scale effect of corporate R&D to explain the inverted-U-shaped relationship. When a firm's R&D investment equals or exceeds its reinvested profit (see $R\&D_1$ in Figure 2), the firm needs to obtain external finance for its investments.[10] Given the financial underdevelopment in China (Allen et al., 2005; Ayyagari et al., 2010) and the high cost of external finance (e.g., Leary and Roberts, 2005), an R&D investment whose scale equals or exceeds profit reinvestment exposes financial constraints on the firm. Thus, the promotion effect of state shares on R&D due to resources is weakened; namely, $R\&D_1^{IE} < R\&D_2^{IE}$ in Figure 2. Correspondingly, the optimal point of the inverted-U-shaped relationship for firms whose R&D investment equals or exceeds profit reinvestment is larger than it would be otherwise (i.e., $S_1^* > S_2^*$ in Figure 2).

Hypothesis 2: The threshold in the inverted-U-shaped relationship will be larger when a firm's R&D investment equals or exceeds its profit reinvestment than it would be otherwise.

Equations (1)-(3) are used for theoretical analyses, and the formal empirical specifications are described in Sections 4-5.

3 Data and variables

3.1 Data

Our data come from the Investment Climate Survey in China undertaken by the World Bank in 2005, which provides cross-sectional information in 2004. As mentioned above, the survey follows a stratified random sampling methodology, thereby avoiding self-selection bias.

The survey includes 12,400 firms located across 120 cities in 30 provinces in China. Only Tibet is excluded, which is appropriate because it has a clearly different institutional

[10] Firms may have internal financial capital, but "Chinese firms must rely heavily on retained earnings to finance investments" (Song et al., 2011: 208). Moreover, internal financial capital is usually retained as a buffer against unexpected needs, instead of (R&D) investment.

background from the other provinces in the survey. At the same time, the survey samples all (precisely, 30) manufacturing industries (at two-digit SIC codes) in China. The sample firms are also representative of the country in firm size, comprising small, medium-size, and large companies. Therefore, the survey has considerable firm variance geographically, industrially, and in size. The data have been used by many scholars of China's economy (e.g., Cai et al., 2011; Cull et al., 2015).

The survey we use offers information on state shares and corporate R&D in 2004, but it is still relevant to China's present reality. It is a common sense that the Chinese government intervenes in the operation of economic system (Song et al., 2011). Specifically, local governments control resources (Huang, 2010) and implement legal or regulatory rules (Yan et al., 2016; van Rooij et al., 2016). As the Chinese government emphasizes, state ownership is the micro-foundation of socialist market system; so state-owned shares maintain strictly controlled by the government. Thus, the survey data providing information in 2004 help investigate the state ownership for the current situation. To say the least, considering that this paper explores the theoretical effect of state ownership, as long as the background reflected by the data is as expected, the data are valuable. We present the descriptive statistics and the correlation matrix for the main variables in Tables 1-2, respectively.

[Insert Tables 1-2 about here]

3.2 Variables

Corporate R&D: We capture corporate R&D by R&D intensity or R&D decisions. R&D intensity is measured by the natural log of [1 plus R&D investment per employee in 2004], whereas R&D decisions equal 1 if the surveyed firm invests R&D in 2004. Both R&D variables are standard measures in the existing literature (e.g., Lin et al. 2010b). In particular, to explore the effect of state ownership with the focus of corporate finance, our measurement is generalized to reflect R&D intensity rather than only R&D efficiency or R&D output.

Specifically, we measure R&D intensity with R&D per employee. In fact, we can also measure it by the ratio of R&D investment relative to sales and the results are robust to generate the same findings. Because sales are relatively unstable in the short run, we incline to use the former measure rather than the latter measurement.

State shares: The survey provides information on the percentage of state shares in a firm's ownership, so we can calculate the ratio of state-owned shares. State shares indicate that the central/local government is a shareholder of the firm (Huang et al. 2017). As mentioned earlier, state ownership is the historical product of political intervention in China's economy during the 1980s and 1990s (Wang and Chen 2006), so state shares can avoid reverse causality from corporate R&D. Moreover, any changes in state shares are politically sensitive for the Chinese government (Wang and Chen 2006), so the information on state shares should be accurate. Thus, our measures of state ownership should not present concern about measurement noise.

Control variables: We control for firm characteristics and market properties. At the firm level, we first control for firm age because an older firm has a weaker response to the external environment (e.g., Argyres and Silverman, 2004). Second, we control for firm size because it can determine R&D investment (Cohen and Klepper, 1996; Scherer, 1992). To reduce the endogeneity issue, we use the natural logarithm of the number of employees in 2003 to measure firm size.[11] According to the definition, if firm size is linearly related to R&D intensity, one can infer that the correlation is negative; otherwise, the correlation becomes uncertain. In particular, we do not assume the linear relationship, and specifically expect firm size to be positively related to corporate R&D because big firms have the required resources for R&D (Schumpeter, 1942).[12]

[11] A few variables, including the number of employees, cover the period 2002-2004, so we can measure firm size in 2003.

[12] In other words, firm size captures not only the scale effect but also ability and other relevant characteristics. It is common to control for firm size in empirical microeconomics. More specifically, according to

Third, we control for foreign-owned shares for two reasons. For one thing, they differ from private, state, and collective shares, all of which are from domestic investors; foreign shares represent a different category of share. For another, they have an important effect on corporate R&D because foreign investment may introduce foreign techniques (Antras, 2005) and reduce the R&D incentive.[13]

Fourth, we control for whether a sample firm is part of a corporate group because such firms have an advantage in conducting R&D (e.g., Zhao 2006). Fifth, we control for an export dummy because export firms have a larger investment incentive (Wang and You 2012; Dong et al. 2016).

At the market level, we first control for the strictness of the regulatory regime (i.e., regulatory stringency). Specifically, we measure regulatory stringency with the natural logarithm of [1 plus the official number of regulatory certificates]. Because regulatory certificates include licenses and registrations, regulatory stringency in our data reflects entry regulations (Djankov et al., 2002; World Bank, 2006). Second, because R&D investments have returns in future periods (Berk et al. 2004), we also control for the severity of policy instability. Specifically, the survey asks about the extent to which access to finance affects the surveyed firm's operations and growth on a scale from 0 to 4: (0) not at all, (1) a little, (2) somewhat, (3) a lot, and (4) very much (all, whole).

We do not control for endogenous variables, such as firm liquidity or profit; otherwise, there will be the bad-control issue (see Angrist and Pischke 2008). Specifically, it will enlarge the impact of the potential endogeneity bias, which IV estimation cannot address. Moreover, we use a relatively stable measure for exogeneity. Recall that the survey involves data only

Schumpeter (1934 and 1942), firm size is one of the most important firm characteristics for innovation.

[13] As explained above, we control for foreign shares based on economic reasoning. In fact, our later estimates show that foreign shares are significantly related to corporate R&D. At the same time, controlling for foreign shares does not lead to collinearity. For one thing, China has privately owned and collectively owned shares as well as state and foreign shares. For another, the variable for foreign shares has a variance inflation factor whose values in all later estimations are less than 5.

in 2004 across firms, so the control variables should be relatively exogenous when it is stable over time. That is why we include an export dummy instead of export sales.

4 Identification strategy

Identifying the causal effect of state ownership on corporate R&D requires an empirical strategy to address the potential endogeneity of state shares. The endogeneity problem arises because the unobserved or uncontrolled variables may affect both state shares and corporate R&D. Because state shares are a political and historical product of Chinese government intervention in the 1980s and 1990s, the possible instruments in this context include political and historical government intervention. However, these potential instruments tend to affect a firm's investment in multiple channels, thereby violating exclusion restriction. We adopt the generated-IV estimations that can deal with the endogeneity bias due to omitted variables or measurement errors. Specifically, we follow the heteroskedasticity-IV method suggested by Lewbel (2012).

First, the endogenous variable needs to be regressed to obtain the residuals e_i, which are consistent estimates of the reduced form error e_i.

$$S_i = \gamma_0 + \gamma_1 Z_i + \gamma_2 z_i + u_j + v_k + e_{1,i} \tag{4}$$

$$S_i^2 = \gamma_0' + \gamma_3 Z_i + \gamma_4 z_i + u_j + v_k + e_{2,i} \tag{5}$$

where i, j, and k represent the firm, city, and industry, respectively. S is state shares; S^2 is the square of S. Z is the set of control variables; z is Z, a subvector of Z or other exogenous variable(s) for the dependent variable. u_j and v_k represent the fixed effects of city and industry, respectively. In particular, z is the population of a city in 1978. The Chinese government introduced economic reforms in 1978, so the 1978 population reflects initial embeddedness for later economic development. More specifically, it reflects the historical background of innovation, so it can unilaterally affect corporate R&D in 2004.

After these regressions according to Equations (4)-(5), we can obtain the residuals $e_{1,i}$ and $e_{2,i}$. When the bias due to omitted variables is not severe (Emran and Shilpi, 2012; Lewbel, 2012), which we confirm in Section 5.2, e_i can capture heteroskedasticity. Thus, we can generate heteroskedasticity-IVs for S and S^2, respectively.

$$IV_{1,i} = (z_i - \overline{z}_i)\widehat{e}_{1,i} \tag{6}$$

$$IV_{2,i} = (z_i - \overline{z}_i)\widehat{e}_{2,i} \tag{7}$$

where $\overline{z}_i$ is the average value of z. Because z, i.e., the population in 1978, tends to violate the exclusion restriction, it is not a suitable IV for estimations. Specifically, it captures the political power of a city in 1978 and other characteristics relevant to population size. Political power in 1978 promotes privatization initiated in the 1980s and then affects the state shares of the sample firms in 2004. By contrast, the other characteristics affect firm R&D investments in 2004 by channels other than state shares. Thus, the population in 1978 theoretically violates the exclusion restriction. However, the 1978 population is exogenous for corporate R&D in 2004, so we can use it to generate a heteroskedasticity-IV. To better capture heteroskedasticity, it is suggested to use the original size of the population, rather than the log or the relative size of the population.[14]

As Lewbel (2012) points out, the exogenous variable helps generate a heteroskedasticity-IV to address the endogeneity issue. On the one hand, the generated IV is relevant to our variable of interest according to the definition (see Equations (6)-(7)). Theoretically speaking, it reflects the heteroskedasticity of state shares resulting from the historical population in 1978, so it is related to state shares in 2004. On the other hand, the heteroskedasticity reflected by the generated IV in this paper is more likely to be idiosyncratic, rather than

[14]Specifically, Lewbel (2012)'s method has a requirement, $cov(Z, e_i^2) \neq 0$. Namely, the error terms of the first-stage regression must have heteroskedasticity with respect to Z.

due to the common determinants of state shares (square). In other words, it is unlikely that these residual common exogenous determinants drive the pattern of state shares (Emran and Shilpi, 2012). We test the validity of our generated IV in Section 5.

5 State Shares and Corporate R&D Investments

This section provides evidence for an inverted-U-shaped causal relationship between state shares and corporate R&D. First, we examine the correlation relationship between state shares and R&D intensity/decision. The correlation can be biased by omitted variables, so we assess that potential bias and then find that it is insignificant. To formally address the endogeneity bias due to omitted variables, we generate a heteroskedasticity-IV and use IV estimations to confirm the predicted effect of state shares. Finally, we identify that the non-linearity between state shares and corporate R&D takes an inverted-U-shape. Ultimately, this section confirms H1.

5.1 Baseline estimates

We examine the relationship between state shares and corporate R&D based on the following equation.

$$R\&D_i = \alpha_0 + \alpha_1 S_i + \alpha_2 S_i^2 + \alpha_3 Z_i + u_j + v_k + e_i \tag{8}$$

where R&D refers to R&D intensity or R&D decisions. As a benchmark, we first run the linear regression (without S^2) before the noon-linear one (i.e., Equation (8)). To show the robustness of our baseline estimates, we further estimates Equation (8) using clustering standard errors at the city level.[15] Because maximum likelihood estimation cannot identify

[15] If controlling for robust standard errors in this research, we can obtain highly similar results and then the same findings.

the particular (U or inverted-U) shape of S^2, we use the OLS method (instead of Tobit and Probit methods) for the R&D intensity/decision.[16]

[Insert Table 3 about here]

As Table 3 shows, the coefficients of state shares are positive and highly significant across estimations, whereas those of the square of state shares are significantly negative. Specifically, the coefficient of state shares for R&D intensity equals 1.107 and that of the square of state shares equals -1.253;[17] thus, the threshold for R&D intensity equals 0.442, which is less than 0.5. Similarly, the threshold of state shares for R&D decisions is 0.338, which is also less than 0.5. These findings support H1. As a visual illustration, we draw a fitted line (Figure 3) that shows a clear inverted-U shaped relationship between state shares and corporate R&D intensity. Moreover, the threshold is at 0.442. As such, the fitted line confirms H1.

[Insert Figure 3 about here]

Moreover, firm age and foreign shares are negatively and significantly related to corporate R&D, whereas other variables are positively and significantly associated with corporate R&D. All control variables obtain the expected signs except policy instability, which is positively related to R&D intensity/decision. However, it is also understandable because firms have R&D incentives to maintain market power when the investment environment is poor (Gu, 2015).

[16] In fact, if we use the Tobit or Probit method, we obtain the same finding.

[17] Considering that there is more than 40% of the sample with zero R&D, we conduct regression of R&D intensity with only positive observations; as a result, the coefficient of state shares is 0.999 and the one of [state shares]^2 is -1.093, both of which are highly significant. This reveals the same finding as the full sample does. Thus, our results are robust to the concern due to a large size of zero R&D.

5.2 The test of potential bias from omitted variables

Our data is cross-sectional, so we cannot add firm-fixed effects. The estimates may be still biased by omitted variables. We here test the potential bias due to omitted variables, as Altonji et al. (2005) suggest. Theoretically speaking, selection on observables can be used to assess the potential bias from omitted variables. Thus, Altonji et al. (2005) develop a strategy to gauge the strength of the likely bias arising from omitted variables.

Although we have regressions with a full set of control variables (see Equation (8)), we conduct the following regression:

$$R\&D_i = \beta_0 + \beta_1 S_i + \beta_2 S_i^2 + \beta_3 size_i + u_j + v_k + e_i \tag{9}$$

This regression has only a restricted set of control variables (i.e., firm size and city- and industry-fixed effects). Then, we can use the coefficients of state shares in Equations (8) and (9) to calculate the ratio, $\alpha_1/(\beta_1 - \alpha_1)$, to test the bias from omitted variables. In words of Nunn and Wantchekon (2011: 3238), the higher the ratio is, "the less the estimate is affected by selection on observables, and the stronger selection on unobservables [i.e., omitted variables] needs to be (relative to observables) to explain away the entire effect." Similarly, we can use the coefficients of the square of state shares in Equations (8)-(9) to calculate the ratio, $\alpha 2/(\beta_2 - \alpha_2)$, to assess its bias.

As a result, the ratio to measure the variable-omitting bias on state share is 4.813 while that for the coefficient of the square of state shares is 5.309.[18] Thus, if we attribute the entire OLS estimate to selection effects, selection on omitted variables would have to be at least four times greater than selection on observables. Simply speaking, the omitted variable should have explanation power at least four times greater than our independent variables.

[18] With a restricted set of controls, the coefficient of state share is 1.337 and that of [state share]^2 is -1.489; with a full set of controls, the coefficient of state share is 1.107 and that of [state share]^2 is -1.253. Thus, we can obtain the ratios as mentioned.

This is unpractical, not to mention that the omitted variables can have contradictory effects between each other. Therefore, the bias due to omitted variables should not be big enough to offset the true effect of coefficients.

5.3 IV estimates

With the generated heteroskedasticity-IVs, we can conduct the IV estimations:

$$R\&D_i = \alpha_0 + \alpha_1 \widehat{S}_i + \alpha_2 \widehat{S}_i^2 + \alpha_3 Z_i + u_j + v_k + e_{1,i} \tag{10}$$

$$S_i = \theta_0 + \theta_1 IV_{1,i} + \theta_2 Z_i + u_j + v_k + e_{2,i} \tag{11}$$

$$S_i^2 = \vartheta_0 + \vartheta_1 IV_{2,i} + \vartheta_2 Z_i + u_j + v_k + e_{3,i} \tag{12}$$

where $\widehat{S}$ and $\widehat{S}^2$ are the fitted value of state shares obtained from the regression based on Equations (11)-(12). We report only IV estimates with clustered standard errors in Table 4.

Table 4 shows not only the validity of our IVs but also the supporting evidence of H1. First, the generated IVs are significantly related to the variables of interest (see Columns 1-2), respectively. F statistics are larger than 10, which indicates that our IVs are jointly significant with control variables to explain the variables of interest.

Second, we examine whether our IVs have direct effects on R&D intensity/decision. As Columns 3-4 show, after the variables of interests are controlled for, our IVs are no longer significantly related to dependent variables. Thus, the generated IVs should satisfy the exclusion restriction, as Lewbel (2012) suggests.

Finally, as Columns 5-6 show, state shares and the square of state shares are negatively and positively related to R&D intensity/decisions at the 1% significance level, respectively. All our control variables have the same signs and significance as before. Hence, the predicted effects of state ownership on corporate R&D in the inverted-U-shaped relationship are confirmed and are robust to the potential endogeneity bias.

[Insert Table 4 about here]

5.4 The Test for an Inverted-U Shape

As Lind and Mehlum (2010) show, the traditionally used criterion for determining a U-shaped/inverted-U-shaped curve in an empirical relationship relies on the significance of the quadratic term, but it may be too weak. The confidence interval for the potential extremum point may be too close to the lower/upper bound of the data range, so the curvature is insufficient to distinguish it from a monotonic relationship. It is more appropriate to test an inverted-U-shaped relationship with a joint test of significance of the combined null and alternative hypotheses in our research:

$$\alpha_1 + 2\alpha_2(S_i^e)_L \leq 0 \text{ and/or } \alpha_1 + 2\alpha_2(S_i^e)_H \geq 0 \tag{13}$$

$$\alpha_1 + 2\alpha_2(S_i^e)_L > 0 \text{ and/or } \alpha_1 + 2\alpha_2(S_i^e)_H < 0 \tag{14}$$

where $(S_i^e)_L$ and $(S_i^e)_H$ are suitably chosen lower and upper bounds of S (state shares), respectively. In particular, $\alpha_1 + 2\alpha_2(S_i^e)_L$ shows the first-order derivative of R&D intensity/decisions for the lower bound of S, whereas $\alpha_1 + 2\alpha_2(S_i^e)_H$ calculate the first-order derivative for the upper bound. To conduct this test, we follow the test designed by Lin and Mehlum (2010). The results are summarized in Table 5.

[Insert Table 5 about here]

As Table 5 shows, either baseline estimates or IV estimates report a positive and highly significant slope at the lower bound of state shares and a negative and highly significant slope at the upper bound. This indicates that the relationship of interest behind by our baseline or IV estimates has an inverted-U shape. Formally, the statistics of the test for an inverted-U shape are at least 3.50; thus, we can reject the null hypothesis in Equation (13) at the 1% significance level. This provides us with robust evidence of an inverted-U-shaped relationship between state shares and corporate R&D.

6 The Mechanism: A Scale Effect of R&D Investment

H2 suggests that the relationship between state ownership and corporate R&D has a large threshold for firms with large-scale corporate R&D investment; as such, we conduct sample-splitting estimations. Because of endogeneity concerns, we conduct estimations as follows.

$$R\&D_i = \eta_0 + \eta_1 \widehat{S}_i + \eta_2 \widehat{S}_i^2 + \eta_3 Z_i + u_j + v_k + e_i, i \in \{i | RDE_i \geq PR_i\} \tag{15}$$

$$R\&D_i = \delta_0 + \delta_1 \widehat{S}_i + \delta_2 \widehat{S}_i^2 + \delta_3 Z_i + u_j + v_k + e_i, i \in \{i | RDE_i < PR_i\} \tag{16}$$

where RDE is a firm's R&D expenditure, and PR is profit reinvestment. Thus, Equation (15) refers to IV estimates for the large-scale subsample that consists of firms whose R&D investments reach or exceed reinvestment of their profits, whereas Equation (16) is for the small-scale subsample. According to H2, $-\eta_1/(2\eta_2) > -\delta_1/(2\delta_2) > 0$. We report the results in Table 6.

[Insert Table 6 about here]

As Table 6 shows, when a firm's R&D investment equals the reinvestment of its profits, the threshold for R&D intensity[19] is 0.454. On the contrary, the threshold is 0.418 when R&D investment is less than reinvestment of profits. Thus, the threshold is higher for the large-scale subsample than for the small-scale subsample.

Moreover, the coefficients of state shares and the square of state shares are more significant for firms with large-scale R&D investment than for firms with small-scale R&D

[19] R&D decision is not used because it must be 1 when the firm's R&D investment equals reinvestment of its profits (in our data).

investment. Specifically, both coefficients for the former type of firm are significant at the 1% level, but for latter type of firm, the coefficient of state shares is significant at the 15% level and the coefficient of the square of state shares is significant at the 10% level. That is why the inverted-U-shaped test reports a highly significant statistic (4.81) for the former subsample but a moderately significant statistic (1.53) for the latter subsample. Thus, it is reasonable to believe that the former subsample has a larger threshold. H2 is supported by our evidence.

7 Conclusions and Policy Implications

State ownership is a formal tie between a firm and the government. Because of this tie, the effect of state shares is complicated. As a novelty, we distinguish the institutional effect of state shares on the institutional/investment environment from the institutional effect of state shares on firm operations. In theory, the former effect is positive, and the latter is negative. Using evidence from China, we document a significant inverted-U-shaped effect of state shares on corporate R&D. As an additional novelty, this paper clarifies the source of endogeneity bias and addresses the bias to estimate the effect of interest. To further justify our inverted-U-shape hypothesis, we document that the threshold of the inverted-U-shaped relationship is larger when a firm's R&D investment equals or exceeds the reinvestment of its profit than it would be otherwise. Ultimately, this paper contributes by revealing how state shares affect corporate R&D.

The existing literature provides mixed evidence about the effect of state shares on corporate R&D. This paper is not only consistent with these two contrasting views on the effect of state shares but also enhances understanding of state ownership as a socioeconomic institution with an inverted-U-shaped hypothesis.

This paper offers applications for competitive strategies of firms in most developing countries. Given that state ownership is exogenous and thus cannot be changed in the short run, this paper suggests that firms with state shares can use deliberate designs to weaken the negative institutional effect of state shares on corporate R&D. For example, SOEs can use private institutional ownership to reduce the negative effect of state shares on R&D. Firms with state shares should incentivize their general managers with performance-based compensation to constrain them from shirking behavior or value diversion when investing in R&D.

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Tables

Table 1: Descriptive statistics of the main variables

	Variable	No.	Mean	Std. Dev.	Min	Max
1	R&D intensity	12,340	0.813	1.250	0	7.865
2	R&D decision	12,340	0.568	0.495	0	1
3	State ownership shares	12,340	0.135	0.316	0	1
5	Firm age	12,340	12.720	13.619	2.000	139.000
6	Firm size	12,340	5.553	1.491	0	11.700
7	Foreign shares	12,340	0.146	0.317	0	1
8	Group-affiliation dummy	12,340	0.377	0.485	0	1
9	Export dummy	12,340	0.307	0.461	0	1
10	Regulatory stringency	12,340	1.608	0.720	0	5.553
11	Policy instability †	12,340	0.930	1.058	0	4

† The variable measures the severity of the issue at five optional levels, i.e., from 0 (none), 1 (low), 2 (moderate), 3 (high) and 4 (very high, all, whole).

Table 2: correlation of the main variables

	Variable	1	2	3	5	6	7	8	9	10	11
1	R&D intensity	1									
2	R&D decision	0.567	1								
3	State ownership shares	0.044	0.048	1							
5	Firm age	0.055	0.083	0.400	1						
6	Firm size	0.248	0.304	0.233	0.308	1					
7	Foreign shares	0.044	-0.052	-0.147	-0.137	0.117	1				
8	Group-affiliation dummy	0.204	0.189	-0.030	0.022	0.361	0.345	1			
9	Export dummy	0.196	0.116	0.157	0.062	0.290	0.177	0.130	1		
10	Regulatory stringency	0.063	0.049	-0.020	-0.001	0.110	0.103	0.102	0.053	1	
11	Policy instability	0.105	0.086	0.110	0.110	0.169	0.023	0.058	0.119	0.070	1

Table 3: Baseline estimates (OLS)

Dependent var.	R&D intensity			R&D decision		
Model	Linear	Non-linear		Linear	Non-linear	
State shares	-0.075**	1.107***	1.107***	-0.055***	0.256***	0.256***
	(0.036)	(0.181)	(0.202)	(0.015)	(0.074)	(0.073)
$[\text{state shares}]^2$		-1.253***	-1.253***		-0.330***	-0.330***
		(0.188)	(0.208)		(0.077)	(0.077)
Threshold#		0.442			0.388	
Firm age	-0.003***	-0.003***	-0.003**	-0.001***	-0.001**	-0.001**
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Firm size	0.132***	0.129***	0.129***	0.087***	0.086***	0.086***
	(0.008)	(0.008)	(0.013)	(0.003)	(0.003)	(0.004)
Foreign shares	-0.364***	-0.370***	-0.370***	-0.231***	-0.233***	-0.233***
	(0.039)	(0.039)	(0.063)	(0.016)	(0.016)	(0.022)
Group-affiliation dummy	0.165***	0.154***	0.154***	0.021**	0.018*	0.018*
	(0.024)	(0.024)	(0.034)	(0.010)	(0.010)	(0.011)
Export dummy	0.303***	0.295***	0.295***	0.123***	0.121***	0.121***
	(0.024)	(0.024)	(0.029)	(0.010)	(0.010)	(0.011)
Regulatory stringency	0.067***	0.066***	0.066***	0.021***	0.021***	0.021***
	(0.014)	(0.014)	(0.022)	(0.006)	(0.006)	(0.007)
Policy instability	0.056***	0.054***	0.054***	0.016***	0.015***	0.015***
	(0.010)	(0.010)	(0.011)	(0.004)	(0.004)	(0.004)
Constant	-0.351***	-0.344***	-0.344***	-0.006	-0.004	-0.004
	(0.121)	(0.121)	(0.075)	(0.049)	(0.049)	(0.026)
City	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE##	No	No	Yes	No	No	Yes
R^2	0.20	0.250	0.250	0.20	0.202	0.202
N	12,340					

Threshold means the optimal point of state shares for corporate R&D; in statistics, it equals $-\alpha_1/2\alpha_2$, where α_1 is the coefficient of state shares and α_2 is the coefficient of state shares. ## Standard errors are clustered at the city level. * p<0.1; ** p<0.05; *** p<0.01.

Table 4: IV estimates (Hypothesis 1)

	Test for IV validity				second-stage estimates	
	first-stage estimates		Exogeneity test			
Dependent var.	State share	[state share]^2	R&D intensity	R&D decision	R&D intensity	R&D decision
Method	Tobit		Tobit	Probit	Lewbel (2012)	
IV for state shares	0.084***		-0.164	-0.255		
	(0.001)		(0.129)	(0.168)		
IV for [state shares]^2		0.065***	0.189	0.280		
		(0.001)	(0.136)	(0.184)		
State share			1.616***	0.989***	1.351***	0.327***
			(0.287)	(0.252)	(0.222)	(0.079)
[state share]^2			-1.918***	-1.232***	-1.462***	-0.403***
			(0.301)	(0.265)	(0.228)	(0.084)
Firm age	0.018***	0.018***	-0.005***	-0.002*	-0.003**	-0.001**
	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)
Firm size	0.177***	0.161***	0.284***	0.266***	0.126***	0.086***
	(0.000)	(0.000)	(0.018)	(0.013)	(0.013)	(0.004)
Foreign shares	-0.524***	-0.528***	-0.764***	-0.731***	-0.366***	-0.233***
	(0.005)	(0.004)	(0.107)	(0.065)	(0.062)	(0.022)
Group-affiliation dummy	-0.073***	-0.083***	0.496***	0.390***	0.294***	0.121***
	(0.002)	(0.002)	(0.045)	(0.034)	(0.029)	(0.011)
Export dummy	0.369***	0.333***	0.194***	0.061*	0.149***	0.017
	(0.002)	(0.002)	(0.050)	(0.034)	(0.033)	(0.011)
Regulatory stringency	-0.039***	-0.038***	0.110***	0.063***	0.067***	0.021***
	(0.001)	(0.001)	(0.032)	(0.021)	(0.022)	(0.007)
Policy instability	0.045***	0.040***	0.086***	0.049***	0.054***	0.015***
	(0.001)	(0.001)	(0.018)	(0.013)	(0.011)	(0.004)
Constant	-5.876***	-5.352***	-2.344***	-1.470*	-0.843***	0.065
	(0.002)	(0.002)	(0.728)	(0.784)	(0.314)	(0.286)
City	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
F statistics	26.55	90.58				
N			12,340			

Standard errors are clustered at the city level. * *p*<0.1; ** *p*<0.05; *** *p*<0.01.

Table 5: Test for inverted-U-shaped relationship

Estimates	Baseline estimates		IV estimates	
Method	OLS		Lewbel (2012)	
Dependent var.	R&D intensity	R&D decision	R&D intensity	R&D decision
Slope at lower bound	1.107***	0.256***	1.350***	0.327***
Slope at upper bound	-1.400***	-0.403***	-1.572***	-0.478***
Test for inverted-U shape	5.47***	3.50***	6.08***	4.13***
Controls	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	12,340			

Standard errors are clustered at the city level. * *p*<0.1; ** *p*<0.05; *** *p*<0.01.

Table 6: Sample-splitting estimates (Hypothesis 2)

R&D>=profit reinvestment	State shares	1.040***	(0.216)
	[state shares]^2	-1.145***	(0.215)
	Threshold	0.454	
	Inverted-U-shape test	4.81***	
	N	10,053	
R&D<profit reinvestment	State shares	0.583[a]	(0.381)
	[state shares]^2	-0.699*	(0.405)
	Threshold	0.418	
	Inverted-U-shape test	1.53*	
	N	2,287	

Despite controls, city and industry are controlled for. * p<0.1; ** p<0.05; *** p<0.01; in particular, a = 0.126. Standard errors are clustered at the city level.

Figures

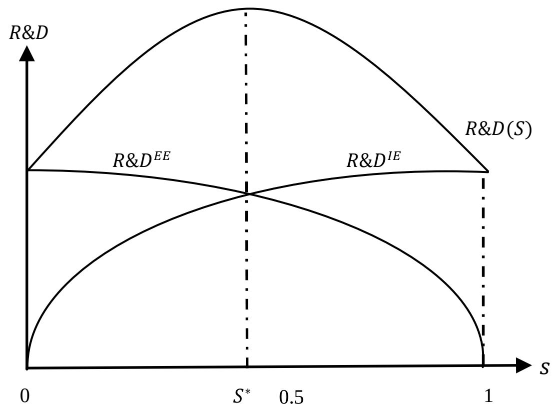

Figure 1: Inverted-U shaped relationship

Notes: $R\&D^{EE}$ refers to R&D determined by state shares (S) through economic efficiency; $R\&D^{IE}$ refers to the one through institutional environment; S^* is the optimal point.

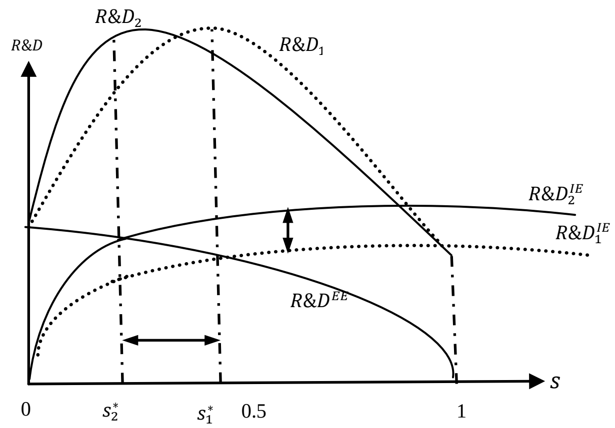

Figure 2: comparison

Notes: Subscript 1 for firms whose R&D≥profit reinvestment; Subscript 2 for firms whose R&D<profit reinvestment. See others in Figure 1.

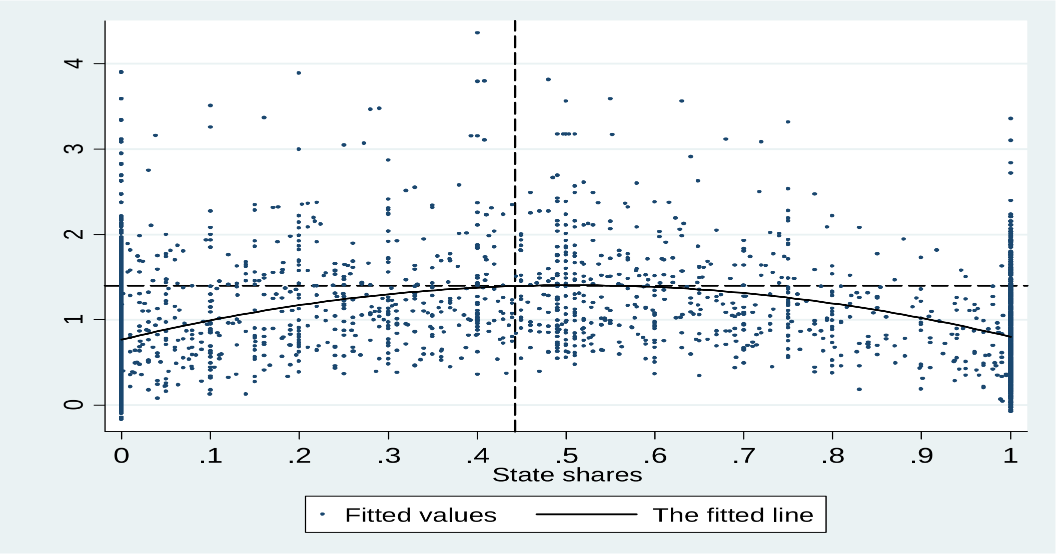

Figure 3: the fitted line