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The Dynamics of Investment: State vs. Non-state Plants in China*

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Abstract

This paper studies the dynamics of investment in physical capital of private and public manufacturing plants in China. I map the types of plant to its adjustment cost in investment, and link the type of plants to their efficiency. First, using a balanced panel of Chinese manufacturing plants from 1998 to 2007, I document the stylized facts in plant's investment behavior: (i) for both public and private plants, the distributions of investment rates are skewed to the right, and there are considerable mass around zero; (ii) compared to private firms, public firms have a lower investment rate, lower frequency of large positive investment, and less volatile in investment rate; (iii) there is an increase in investment rate when a public plant becomes private, and a drop in investment rate when a private plant becomes public. Second, I present a dynamic model of investment, which maps the types of plants to their adjustment cost. The parameters in adjustment cost for both public and private plants are then simultaneously estimated via Simulated Method of Moments (SMM) procedure. The paper shows that public plants have higher quadratic and fixed costs, compared to private plants. Third, based on those estimated parameters, I explore the impact of difference in cost on aggregate economy, by extending the model into general equilibrium setting. The model predicts that privatization of all plants in the economy will lead to 0.04%-0.32% increase in aggregate output, and 0.06%-0.07% decrease in aggregate output if all plants are state.

JEL classification: E22 L33 O43 P23

Keywords: Investment dynamics, Capital accumulation, China, Firm-level data, State and non-state, Adjustment cost, SMM

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1 Motivation

This paper investigates the adjustment costs for state and non-state manufacturing plants in China, and explores the impact of privatization of state sector, using Chinese firm-level data from year 1998 to 2007. I map the types of firm (state vs. non-state) to the cost of investment in physical capital, the parameters in the adjustment cost are recovered by matching certain moments of investment rates that are directly observed from the firm-level data. Based on these parameters recovered, I explore the impact of converting firm's type on aggregate economy in a DSGE model. Two novel features make this study unique. First, investment has taken a relatively high share in GDP in Chinese economy, compared to other developed countries. Figure 1 shows gross capital formation to GDP ratio of China, along with United States, EU, East Asian, and the world level from 1978 to 2011. Gross domestic investment over the entire period averaged a fairly steady 39% of GDP in China, while the corresponding average ratio is 19% in US. economy. To have a better understanding about the movement of aggregate investment, I focus on the investment behavior at the micro-level, and recover the structural parameters in the cost of investment, which play a key role in understanding the dynamics of capital stock. Second, a salient feature in China's industrial sector is that the co-existence of state and non-state firms[1], and the dramatic change in enterprise ownership structure during the last two decades. This raises some interesting questions for policy makers: has the privatization in the state sector increased firm's productivity and efficiency? How does the policy of privatization affect firm's investment decision and thus its overall efficiency? I answer these questions by capturing the institutional difference in investment behavior between state and non-state firms, and establish a channel that links a firm's type to its efficiency, and finally investigate the impact of privatization in China's state sector.

In this paper, I document the stylized facts regarding investment behavior of state and non-state firms. The facts can be summarized as: (1) for both state and non-state plants, the distributions of their investment rates are skewed to the right, considerable mass around zero; (2) compared to non-state firms, state firms have a lower investment rate, fewer positive spikes and less volatile in investment rate; (3) a increase in investment rate when a state plant becomes non-state and a drop in investment rate when a non-state plant becomes state. Based on these facts, I propose a dynamic optimization problem regarding firm's investment decision, with a rich set of adjustment costs. In the model, I map the type of firms to the adjustment cost, which links to firms' efficiency essentially. The parameters in the adjustment cost are estimated via simulated method of moments (SMM). The idea is to use key moments of investment rate and productivity at the plant level to infer the structure parameters in the dynamic optimization problem. The state plants have a relatively higher quadratic cost and fixed cost, compared to non-state plants. Last, I explore the impact of privatization on the aggregate economy in a general equilibrium model, based on the parameters estimated directly from the plant-level data.

[1] As discussed in section 2, the classification of state and non-state plants is determined by the share holdings rather than registration type.

This paper fits into a broader context of the reform of state sector in China since 1978. Prior to the economic reform, the state firms in China dominated the economy, accounting for over 95% of total industrial output[2]. Till 1980, China's industrial sector consisted almost exclusively of state and collective-owned enterprises. China's state-sector reforms started in 1978 till present, aiming at increasing the efficiency of firms and promoting economic growth. The first phase, from 1978 to 1984, concentrated in increasing managerial autonomy in order to motivate the state-owned enterprises (SOE) to pursue profit and growth. The second phase, from 1985 to 1993, focused on separating company ownership and management by introducing a "contract responsibility" system. Managers signed a contract with the relevant government agencies and become the legal representative of the SOE, consequently being held responsible for the company's profit and losses. The third phase, starting from 1993 and continuing to the present, emphasized transforming SOEs into modern corporations. The main elements of reform during this period included policies "reinforcing the large SOEs while releasing the small ones (zhuada fangxiao)". The authority mandated the conversion of all but the largest 300 or so of the nation's industrial SOEs, as well as changing the State's position towards shareholders under mixed ownership (state and non-state ownership). During this period, privatization took place on a large scale, notably among small SOEs. This process of conversion has been extensive even among the largest and most successful collective-owned enterprises.

The paper proceeds as follows. Section 2 describes the micro-level data of Chinese industrial firms and summarizes the stylized facts regarding firm's investment behavior and the change of ownerships. In Section 3, I propose a dynamic optimization problem regarding firm's investment decision, taking into consideration of converting firm's ownership type. The parameters in the cost functions are estimated in Section 4, as well as model's evaluations. The partial analysis is extended to the general equilibrium setting in Section 5. Conclusions are drawn in Section 6.

2 Data and Facts

2.1 Data set

The plant-level data I used are from the Annual Surveys of Industrial Production on China's Above Scale Industrial Enterprises (Above Scale) from year 1998 to year 2007. These surveys are censuses of all non-state firms with more than 5 million Yuan (about $\$700,000$) in revenue, plus all state-owned enterprises. The annual surveys are conducted by Chinese government's National Bureau of Statistics (NBS).

Although the data set contains rich information, some samples are noisy and thereby misleading. I clean the data set and omit outliers by using the following criteria. First, observations whose key

[2]Reported by Chinese government media internet: news.Xihuannet.com at 2004.07.08

financial variables (such as total assets, net value of fixed assets, sales, and gross value of industrial output) are missing were dropped. Secondly, the number of employees hired from a firm had to be no less than 10 people. Third, observations whose profile variables have unreasonable values (i.e., the region code should be 6 digits, the ownership code should be 3 digits, and the industrial code should be 4 digits) are dropped. Further, I delete observations according to the basic rules of Generally Accepted Accounting Principles if any of the following are true: (1) liquid assets are higher than total assets; (2) total fixed assets are larger than total assets; (3) the net value of fixed assets is larger than total assets; (4) the firm's identification number is missing; (5) the firm has an invalid established time, e.g., the opening year is greater than current reporting year. Last, since this paper focus on plant's capital stock, I delete the observations whose Net Value of Fixed Assets (NVFA) is not positive.

The final sample I used is a balanced panel from Above Scale consisting of approximately 73,000 enterprises that were continuously in operation between 1998 and 2007. Although there is likely a selection biased induced by choosing a balanced panel, it enables me to focus on firm's investment decision, and avoid modeling the exit and/or entry decisions. I calculate the real investment rate, I/K, for each plant[3], and the features of investment rate are presented in the subsequent session. Further, I compare the investment rate of balanced panel to the unbalanced panel, the average investment rates in two samples do not differ significantly. The standard deviation of investment rate in unbalanced sample is larger than that in balanced sample. This is expected, since exit and entry create dramatic change in investment rate, thus larger variation in investment rate in unbalanced panel.

The observations in the data set are firms; however the model I specify is based on plants. So I drop those firms who have more than one plant[4]. In order to eliminate the cases of merge and acquisition, I simply constrain the plants' investment rates be between -1 and $+1$, excluding the suddenly dramatic changes in investment rates. Also by doing this, all observations' investment rate is within 5 standard deviations from its mean.

Regarding the classification of state or non-state plants, the Above Scale data set has two variables defining whether the plant is state or not. The first variable is "ownership types", representing state-owned, collective, domestic private, joint venture and foreign (including Hong Kong, Macao and Taiwan) private firms. State-owned means that the firm is owned by all the people in the country, while collective means the firm is owned by part of the people in the country. According to Chinese constitution, both state-owned and collective firms are classified as public. A firm is termed as a joint venture if part of its shares is owned by foreign investors or companies, no matter how large the fraction is. Ownership type is the type that the firm is registered at the Administration of Business and Commerce, as well as the Administration of Taxation. It provides little information on who, among the shareholders, has the decision right. For instance, the decision maker of a joint venture could be state shareholders or

[3]The construction of investment variables are described in Appendix A.

[4]The multi-plant firms account about 15% of all observation. Brandt, Biesebroeck and Zhang (2009) note that about 95% of the firms own a single plant

non-state private shareholders.

The second variable is the “status of share-controlling”. It has six categories, which are: state-controlled, collectively controlled, domestically privately controlled, privately controlled by Hong Kong, Macao and Taiwan, foreign privately controlled, and others. “Control” means holding over 50% of total shares, or being pivotal in decision making if not holding over 50% of total share. By this standard, a joint venture is public if it is stated controlled or collectively controlled, even if it is not registered as state-owned or collective firms, according to the ownership type criterion. For example, Volkswagen, Ford, and Honda in mainland China are all state-owned joint ventures, though they are registered as foreign private firms. There are also a large fraction of enterprises that are registered as collective but are controlled by domestic private shareholders.

In this paper, I classify state- and non-state controlled firms by their “status of share-controlling”. State plants are those that are state-controlled or collectively controlled, they could be state-owned enterprises, foreign or joint-ventures. Non-state plants are the plants are privately owned, not state or collectively controlled. Strictly speaking, collectively controlled firms are not state-controlled, they share more resemblance with state-controlled firms (i.e., formal or informal connections to central, municipal or local authorities, state-owned banks, etc.) other than those non-state private firms, and they both belong to public firms. This classification is consistent with Cooper, Gong & Yan (2012) and Poncet, Steingress & Vandenbussche (2010). In the balanced sample, there are 70,965 plants in total. Among those, according to the state non-state classification, 18,465 plants are state, the rest 52,500 plants are non-state or private. State plants account for 26.02%, non-state plants account for 73.98%. In the rest of the paper, I use state and public plants interchangeably, private and non-state plants interchangeably.

2.2 Facts

Table 1 summarizes several key financial variables, valued-added, gross value of industrial output, capital (net value of fixed assets) and employment (number of worked employed), by enterprises type from 1998 to 2007. Except employment, all nominal variables are deflated. Specifically, valued-added and gross value of industrial output are deflated by output price level at provincial level; capital is deflated by fixed asset price level at provincial level. Public plants are on average in large scale, compared to private plants. Public plants have higher valued added and output, hire more worker and capital goods. Public plants are also considerably more capital intensive on average. In terms of average output per worker, public plants are more productive than their private counterparts on average. In terms of average revenue or output per capital, private plants have higher output capital ratio. These statements mirror that high capital intensity of state and collective plants. Relative high capital intensity in state and collective plant might be due to their easy access to formal financial institution. Private plants, small, and medium enterprises have significantly less access to formal financial institutions than state enterprise and large firms. The ease access to external loans leads to low lending rates which contributed to excessive investment and high capital intensity.

Figure 2 plot the histogram of investment rates by firm's type. Apparently, in both distributions, there are considerable mass around zero. The distributions are skewed to the right and the standard tests for non-normality yield strong evidence to skewness and kurtosis. Further, to see whether the two distributions are different, Kolmogorov-Smirnov test rejects the null hypothesis that two distributions are identical.

Table 2 presents the summary statistics of investment rates for both state and private plants. The first seven rows report the fractions in investment rates distribution. For state plants, there are about 13% of (plant, year) observations exhibit investment rates around zero, 9.26% inaction rate for private plants. Inaction investment is defined as the plant's investment rate is less than 1% in absolute value. In the following analysis, I use the term spike referring the episodes of investment rates in excess of 20%. There are 20.21% of observations whose investment rates are greater than 20% for state plants, and the negative spikes accounts for only 4.03%. Regarding private plants, fraction of positive spikes is 27.28%, while negative spikes accounts for only 3.53%. For both state and private plants, most of investment rates lie between 0 and 10%. State plants have lower average investment rates and smaller variance, compared to private plants. Further, to see whether private plants have a higher average investment rate, I regress the investment rate on a dummy variable, State, controlling year, firm's location and their industries. The regression result is reported in Table 3. In both OLS and Fixed Effect, the coefficient in front of State dummy is significantly negative.

Table 2 also reports two correlations. The first correlation is auto correlation of investment rate, which is positive. The second is cross correlation of investment rates to profitability shock, which are measured at the plant level. The measurement of the profitability shocks are discussed in 4.2. The correlation between investment rates and fundamentals are surprisingly low, although it is positive.

The standard errors of those moments are reported in parentheses. The small standard errors are mainly due to the relatively large sample size. Such precision should not be understood as there is little dispersion among plants. For all the variables listed in Table 2, the dispersions are substantial. For example, the standard deviation of investment rate for state plants is 21.70%, and 27.73% for private plants. This implies the heterogeneity of the plants, which is supposed to be taken account into the estimation of profitability shocks. The bottom line is that I estimate the mean and other moments of micro-investment very precisely, due to the relatively large sample size.

The stylized facts described above are similar to U.S. manufacturing data. Domes & Dunnes (1998) and Cooper & Haltiwanger (2006) document the stylized facts in investment using U.S. manufacturing plants data from 1972 to 1988. The distribution of investment rate is not normal, asymetric, and skewed to the right; inaction rate is 8%, 18.6% observations have investment rate is greater than 20%, while there is only 1.8% observations whose investment rate is less than -20%.

The distribution of state and private plants is changing over the years, which is reported in Table 4.

The fraction of state plants decreased over the sample years, except a relatively large in crease from 2005 to 2006. One possible explanation is that the authority was in fears of losing state-owned assets to the non-state sector after China's accession to WTO. This led to the establishment of the State-owned Assets Supervision and Administration Commission (SASAC). In 2006, SASAC declared that the state had "absolute control" over seven key industries, which are: armaments, power generation and distribution, oil and petrochemicals, telecommunications, coal, aerospace, and air freight industries. Also, the state would play a large supervisory role in the "underpinning" industries, which are equipment manufacturing, automobiles, electronic communications, architecture, steel, non-ferrous metals, chemicals, surveying and design. The SOE reform was fundamentally reversed after the eruption of the global financial crisis in 2008.

Figure 3 plot the investment rate for plants that switching from state to private plants. Likewise, Figure 4 reports the investment rate for plants that change from private to state plants. In both figures, vertical axis is plant's investment rate, horizontal axis is time period, 0 means the time at which switch ownerships happen, 1 means one period after the switching, -1 means one period before the switching happens. Green square dots are average of investment rates, two blue lines are 95% confidence intervals regarding the average investment rate.

Figure 3 shows that state plants increase their investment rates when they become private plants. Private plant's investment rates exhibit a drop when they become state-controlled, as showed in Figure 4.The switching, changing from state to private, or private to state, does not happen only once for a certain plant in the balanced sample. About 16.49% observations stay as private plant from 1998 to 2007, 54.45% plants stay as private during the sample period. 14.14% observations experience one time switch, the rest of 14% plants switched multiple times. The number of switching in the sample is tabulated in Table 5.

3 Dynamic Optimization Problem

This section presents dynamic problem regarding investment decision at plant level. The generic dynamic problem is

$$V(A,S,K) = \max_{I} \left\{ \Gamma(A,S,K,I) + \beta E[V(A',S',K')|A,S] \right\} \tag{3.1}$$

$$s.t.\ K' = (1-\delta)K + I \tag{3.2}$$

for all (A,S,K). It takes one period for investment to become productive.The function $V(A,S,K)$ is the value function of a plant continuing in operation. The state vector contains three elements: A is the stochastic profitability shock facing the plant, S represents the type of the plant, $S=1$ means the plant is state controlled, $S = 0$ represents private plant.K is the current capital stock. The control variable is I, the amount of investment the plant chooses.

The function $\Gamma(A, S, K, I)$ represents the current payoff to the plant. Embedded in this function are the adjustment costs as well as objective function. Ultimately, the difference between state-controlled and private plants are captured by this function.

The generic model in (1) can be specified as:

$$\Gamma(A, S, K, I) = \Pi(A, K) - C(S, K, I) \tag{3.3}$$

where $\Pi(A, K)$ is the plant's (reduced-form) profit function, which depends only on capital stock K , and the profitability shock A. It has the form:

$$\Pi(A, K) = AK^{\theta} \tag{3.4}$$

The parameter θ captures the curvature of production function and the elasticity of demand. Other factors that are used in production, like labor, raw material and energy, are assumed not to entail any adjustment cost. And they are optimally chosen given the current state (A, S, K). The cost of changing capital stock is given by $C(S, K, I)$. Follow Cooper & Haltiwanger (2006), a general cost of adjustment function would be

$$C(S, K, I) = \frac{\gamma(S)}{2} * (\frac{I}{K})^2 * K + F(S) * K + I \tag{3.5}$$

if there is a positive investment $I > 0$, i.e.,$K' > (1 - \delta)K$. Price of purchasing capital good is normalized to be 1 through the whole analysis. Similarly,

$$C(S, K, I) = \frac{\gamma(S)}{2} * (\frac{I}{K})^2 * K + F(S) * K + p_s(S) * I \tag{3.6}$$

$$s.t.\ p_s(S) < p_b \tag{3.7}$$

if there is a dis-investment $I < 0$, i.e.,$K' < (1 - \delta)K$. p_s is the price of selling used, undepreciated capital goods. The assumption $p_s < p_b$ means that plants are not able to sell used capital goods at the original buying price. Last, if $K' = (1 - \delta)K$, there are no investment, then $C(S, K, I) \equiv 0$.

One feature of the model is that the parameters in adjustment cost depend on the type of the plant, because from the plant level data, I observe the fact that investment behavior are different between state plants and private one, and simultaneously there are considerable events that plants switched between state and private. It is reasonable to assume that state-controlled and private plants have different adjustment cost, the three parameters γ, F, P_s are functions of type of the plant. In the following estimation procedure, the cost parameters for both state and private plants are estimated simultaneously. Although the cost parameters depend on the type of the plant, the profitability shock A is assumed to be orthogonal to the type of the plant S. A major reason for this orthogonal assumption between two shocks is that the profitability shock is estimated from the plant-level data. Orthogonal assumption allows me to separate the calibrations of the profitability shock and the transition of plant's type.

There are three forms of adjustment cost. The first is a quadratic adjustment cost, parameterized by $\gamma(S)$. Two types of non-convex costs are considered[5]. One, parameterized by $F(S)$ is the traditional fixed cost, which is independent of investment I. A second, parameterized by $p_s(S)$, created a gap between buying price and selling price. This reflects the irreversibility of investment, and the frictions in the market for used capital as well as specific aspects of capital equipment that may make them imperfectly suitable for uses at other production sites.

The optimization generates choices along a couple of dimensions. First there are the discrete choices of purchase capital good, sales of capital good, or inaction. The latter is an important option given the plant-level observations of no investment. Second, there is the continuous choice of investment. If the current capital stock exceeds certain threshold, additional non-convex adjustment costs would apply.

4 Quantitative Analysis

Before I recover the parameters in the adjustment cost, I need to determine the values of discount rate and depreciation rate, the process of profitability shock and transition shock. They are either calibrated or estimated from the plant-level data.

4.1 Calibration

The real annual interest rate is set to be 5%, which implies the plant's discount rate $\beta = 0.95$. Depreciation rate of capital $\delta = 10\%$, which is backed out from the plant-level data (Please see Appendix A). The transition probability between state and private is:

$$\pi(S'|S) = \begin{pmatrix} P_{11} & P_{10} \\ P_{01} & P_{00} \end{pmatrix} = \begin{pmatrix} 0.57 & 0.43 \\ 0.15 & 0.85 \end{pmatrix} \tag{4.1}$$

This transition probability matrix is consistent with the following two facts: average duration of a plant staying state is about 2.34 years; fraction of state plants in the balanced sample is about 26%.

[5]There is another type of non-convex adjustment cost, opportunity cost, which is a loss of profit flow equal to $(1 - \lambda)$. In this paper, I do not consider this opportunity cost. The reasons are: the decision rules in the opportunity cost case share the same features as they are in the case of fixed cost; in the case of opportunity case, the profitability shock and cost parameters must be estimated jointly, which is computationally expensive.

4.2 Profitability Shock

Using the plant level data on output and capital stock, I estimate the stochastic process of profitability shock A and θ in the reduced-form profit function. Specifically, I assume that profits of plant i at year t are given by:

$$\Pi_{it} = A_{it}K_{it}^{\theta} \tag{4.2}$$

regardless of the level of investment activity. Suppose $a_{it} = ln(A_{it})$ that has the following structure:

$$a_{it} = b_t + \epsilon_{it}$$

where b_t is a common shock faced by all the plants at year t, and ϵ_{it} is a plant-level idiosyncratic shock, $\alpha_i$is plant's unobservable individual fixed effect. Assume ϵ_{it} follows an AR(1) process: $\epsilon_{it} = \rho_\epsilon \epsilon_{it-1} + \eta_{it}$, where$\eta_{it} \sim iid(0, \sigma_\eta^2)$. Taking logs of the reduced form profit function and quasi-differencing yields:

$$\pi_{it} = \rho_\epsilon \pi_{it-1} + \theta k_{it} - \rho_\epsilon \theta k_{it-1} + b_t - \rho_\epsilon b_{t-1} + \eta_{it} \tag{4.3}$$

I estimate this equation via non-linear least squares method, using a complete set of year dummies to capture the aggregate shock and individual dummies to control the heterogeneity among the plants. Modeling the idiosyncratic shock as an AR(1) process intends to keep the state space relatively parsimonious for the numerical analysis at later stage (Detailed discussions are in Appendix B).

The results give us an estimate of θ and an estimate of the process for the idiosyncratic components of the profitability shocks. From the plant-level data, θ is estimated at 0.32 (0.007) and ρ_ϵ is estimated at 0.49. Having estimated θ I recover a_{it} from the reduced form profit function and decompose it into aggregate and idiosyncratic components. This latter step amounts to measuring the aggregate shock b_t as the mean of a_{it} in each year and the idiosyncratic shock ϵ_{it} as the deviation of a_{it} from the year-specific mean. Using this decomposition, b_t is approximated by an AR(1) process:

$$b_t - 6.29 = 0.98(b_{t-1} - 6.29) + v_t,\ v_t \sim iid(0, 0.02^2) \tag{4.4}$$

The estimation of profitability shock is summarized in Table 6.

4.3 SMM Estimation

The remaining parameters in the adjustment cost are estimated via Simulated Method of Moments (SMM). The approach revolves around finding the vector of structural parameters, denoted Θ, to minimize the weighted difference between simulated and actual data moments. That is to solve the following minimization problem:

$$\mathcal{L}(\Theta) = \underset{\Theta}{min}[\Psi^d - \Psi^s(\Theta)]W[\Psi^d - \Psi^s(\Theta)]' \tag{4.5}$$

In this expression, Ψ^d are the data moments for state and private plants, $\Psi^s(\Theta)$ are the simulated counterparts. The moments to match are the ones listed in Table 2, two serial correlations, the first and second moments of investment rates and distribution of investment rates for state and private plants. So there are 20 moments in total. W is the optimal weighting matrix, which is the inverse of variance-covariance matrix of actual data moments.

The simulated moments are obtained by solving the dynamic programming problem from Equation (3.1) to (3.7) for a given value of Θ. The resulting decision rules are used to simulate a panel data set. The simulated moments are calculated from that data set.

Due to the fact that the data have a relatively short time horizon, only 10 years, it is difficult to construct the variance-covariance matrix by actual data moments. Therefore, I apply 2-stage SMM procedure. In the first stage, I use identity matrix as the weighting matrix, and then get a set of estimator $\hat{\Theta}_0$ by minimization Equation (4.5); next I simulate the corresponding moments with relatively long time horizon, and calculate $\hat{W}_0$ the variance-covariance matrix by the simulated moments. In the second stage, using$\hat{W}_0$ from the first stage, I solve the minimization problem again, then get a set of estimator $\hat{\Theta}$, which is the final estimation and reported.

The parameters to be estimated by SMM are $\Theta \equiv (\gamma^s, \gamma^p; F^s, F^p; P^s_s, P^p_s)$. The first two parameters are the quadratic cost for state and private plants, respectively. The fourth and fifth are the fixed cost, and the last two are the price of re-selling capital goods. Superscript s represents the parameters for state plants; superscript p corresponds to private plants. The moments were selected because they are informative about these underlying parameters. The reasons are explained in Cooper & Halitwanger (2006), Thomas & Khan (2008), and Khan & Thomas (2007). The primary purpose of introducing adjustment cost is to reduce the distance between model-generated and actual data. In an investment model without adjustment cost, the investment rate will be excessively responsive to profitability shock. Including adjustment cost attempts to increase the fitness of mode. However, different types of adjustment cost have different impact on investment rates. Roughly speaking, quadratic cost will make investment smooth, less volatile, and generate small investment rates; the serial correlation of investment rate is expected to be positive, and correlation between investment rates to profitability shock is expected to be relatively large. Incorporating fixed cost, investment rate will become very volatile, and investment rates are concentrated at zero and two tails. The reason is that under fixed adjustment cost, the decision rule follows typical (S, s) policy: the plant will not invest till its capital stock falls below certain critical value. So it is expected that lots of inaction punctuated by large bursts in investment rate. And the auto correlation of investment rates is expected to be negative, correlation between investment rate and profitability shock is expected to be low. Last, the gap between buying and selling capital good will create inaction in investment, and plants are cautious in investment decision: when facing a high profitability shock, the plant would investment, but the amount of investment would be less compared to the case of no irreversibility; when facing a negative shock, the plant would hold its capital stock, instead of selling them, to avoid the loss inducing by the lower selling price. Irreversibility will create inaction in investment, and the average investment rates will be lower. The lower the selling price, the lower the average investment rates, the higher fraction of inaction and it is more likely that serial correlation of investment rates to be positive.

4.4 Estimation Results

This section provides results from SMM estimation. I do not attempt to estimate and identify all six parameters in Θ simultaneously. Instead, I consider three specifications separately. Specification 1 is quadratic cost only; Specification 2 is fixed cost only, and Specification 3 is irreversibility only. The estimation results are reported in Table 7. Numbers in parentheses are standard errors. The second last column report the value of objective function $\mathcal{L}(\widehat{W})$, using $\widehat{W}$ as the weighting matrix, the last column is the value of objective function $\mathcal{L}(I)$, using the identity matrix as weighting matrix.

The first two columns report the estimated quadratic cost for state and private plants, respectively. Both quadratic costs are significantly positive, and state plants have higher quadratic cost than private ones. I put the two estimated quadratic cost parameters back to the model, simulated the model and generated the corresponding moments. The simulated moments are presented in Table 8. First, only including quadratic cost, the model has difficulty generating the negative spikes, and the inaction rates are lower for both state and private plants. But the model is able to generate the distributions that investment rates ranging from -20% to 20%. Second, the quadratic model is not able to reproduce the second moments of investment rates. This is expected because quadratic cost alone will make investment very smooth, thus reduce the variance of investment rate. Third, this model fails to reproduce the feature of two correlations. The model predicts the serial correlation to be negative, and the correlation between investment rate and profitability shock is too high. With quadratic cost alone, in order to generate positive serial correlations, the quadratic costs are expected to be very large. However, large quadratic cost will reduce the fraction of two tails, and make the variation of investment rate very small. Further, I plot the changes in investment for the switching plants, in Figure 5 and Figure 6. In both figures, the left graph is what we observe from the data, the right one is what the model generates. In the model with quadratic cost only, it generates a jump in investment when a state plant becomes private, and a drop in investment when a private plant becomes state, both jump and drop are not significant though.

The third and fourth columns in Table 7 show the estimated fixed cost for state and private plants, respectively. In this specification, the state plants bear a significantly positive fixed cost, while the fixed cost for private plants is basically zero. To evaluate the fixed cost model, I put the two estimated fixed cost back to the model, and the simulated moments from model are reported in Table 9. First, introducing fixed cost is able to generate both positive and negative spikes, but it is not able to generate the fractions of investment rates falling into -20% to 0. And this model fails to generate inaction in private plants, since the estimated fixed cost is zero. Second, incorporating fixed cost, investment rates are expected to become volatile. So in this fixed cost model, both variances of investment rates for state and private plants are higher, than the quadratic cost model. But it over-estimates the variance for state plants. Third, this fixed cost model is not able to reproduce the two correlations. With fixed cost alone, it is very hard to generate positive serial correlation of investment rates, since fixed cost model will generate the pattern of investment rates like this: considerable inaction punctuated with large bursts. Further, I plot the changes in investment for the switching plants, in Figure 7 and Figure 8. In both figures, the left graph is what we observe from the data, the right one is what the model generates. In the model with fixed cost only, it generates a small jump in investment when a state plant becomes private, while no change in investment when a private plant becomes state.

The last two columns in Table 7 present the estimated price of reselling capital good. The both prices are significantly lower than 1, however in this case, the price of state plants is significantly higher than that of private plants. This might be due to the reason that most state plants are capital intensive, their capital good embodied more advanced technology, while most private plants are labor intensive, and their capital good might be as advanced as that in state plants. To see how the model fit the data, I generate the corresponding moments based on the two estimated prices. The simulated moments are reported in Table 10. First, the irreversibility model is able to reproduce the distribution of investment rates, but it over estimates inaction rates for both state and private plants. Second, the model predicts a higher average investment rate in state plants than private plants; this contradicts the fact that private plants have a higher average investment rate. Third, the irreversibility model fails to reproduce the two correlations. With irreversibility, the price of selling capital good has to be very low, in order to generate positive serial correlation. However, lower selling price will reduce the fraction of two spikes, and introduce too much inaction. Further, I plot the changes in investment for the switching plants, in Figure 9 and Figure 10. In both figures, the left graph is what we observe from the data, the right one is what the model generates. In the model with irreversibility only, it generates a small drop in investment when a state plant becomes private, while no change in investment when a private plant becomes state, since the reselling price is higher for state plants compared to private ones.

For all three models, their values of $\mathcal{L}(I)$ are smaller than 0.223, which is the value of $\mathcal{L}(I)$ when there is no adjustment cost. This indicates that adding adjustment cost makes the model fit the observed data better. Further, in all three models, the values of objective function using optimal weighting matrix are large, this is because the numbers in optimal weighting matrix are large, lots of elements are in magnitude of 10^6. The reason is that all moments are small in magnitude, so their variations are very small, this lead to large elements in the optimal weighting matrix. If comparing $\mathcal{L}(\widehat{W})$, the irreversibility model has the best fit, then the fixed cost model, and the quadratic cost model is the worst. However, if we look at the $\mathcal{L}(I)$, the quadratic model has the best fit, not the irreversibility model. Because I use 2-stage SMM, the optimal weighting matrices $\widehat{W}$ are different in the three models. The quadratic model can hardly generate the negative spikes, which lead a large weight on the moment of negative spikes, which gives a large $\mathcal{L}(\widehat{W})$.

In Table 11, I report the fraction of average adjustment cost paid by each type of plants to their average revenue, based on the parameters estimated in three models. As expected, the larger value of γ or F translate into larger fraction of adjustment cost paid, and the lower reselling price P_s translates to a larger fraction of adjustment cost paid.

There are studies that estimate capital adjustment cost using U.S. manufacturing data. Hall (2004) estimates the quadratic adjustment cost through Euler equation, using manufacturing industrial level data from 1949 to 2000. In all 56 industries, the capital adjustment costs are all small (most of the estimators are in magnitude of 0.1 or 0.01), not significantly different from zero. My estimations of quadratic cost and irreversibility are in the same magnitude as in in Cooper & Haltiwanger (2006), the fixed costs in my estimation — 0.000375 for state plants and 0 for non-state plants — are much smaller than theirs, which is 0.0695 or 0.039. The large difference in fixed cost estimation is likely due to different values of input in model: the profitability shock and curvature of the reduced-form profit function. On the other hand, Cooper, Gong & Yan (2012) estimate adjustment cost in labor using Chinese manufacturing plant data from 2005 to 2007. Their estimated firing, hiring costs, and quadratic costs are also small in magnitude.

In sum, the above estimation results show that state plants have higher quadratic and fixed cost, while the private plants have a lower price of selling capital good. Higher quadratic cost and higher fixed cost can generate an increase in investment when a state plant becomes private and a decrease in investment when a private plant becomes state-controlled.

5 General Equilibrium Effects

In this section, I extend the model to general equilibrium setting. And I run two policy experiments: what happens to aggregate output, consumption, capital and investment if all firms are state-controlled, or if all firms are privatized. Suppose in an economy, there is only one input, K capital, which is owned by household. Household lend K to firm, which produce a single output through the production function $Y_t = A_t * K_t^{\theta}$. Household owns the firm, and make investment decision. The general equilibrium mode is described by the following dynamic problem:

$$\max_{\{C_t, I_t\}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(C_t) \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t ln(C_t) \right\} \tag{5.1}$$

$$C_t + I_t + \frac{\gamma(S_t)}{2} * (\frac{I_t}{K_t})^2 * K_t = A_t * K_t^{\theta} \tag{5.2}$$

A_t and S_t follow the stochastic process described in section 4. Again, $\beta = 0.95$, $\delta = 10\%$, and $\theta = 0.32$. I plug the quadratic cost that estimated in Section 4 into the above general equilibrium model. The only difference from the previous model presented in Section 4 is here the objective function is household utility, instead of firm's profit. In this section, Here, I do not consider the irreversibility model, because it predicts a higher average investment rate in state plants, which contradicts the fact from the data.

Based on the two quadratic cost that I estimate in Section 4, $\gamma = [0.108, 0.082]$, I simulate 3 economies and compare their stationary equilibrium. The inputs of 3 economies are described in Table 12. Everything else is the same, except the fraction of state and private plants, thus the quadratic cost. One economy is full of state plants, which have a relatively higher quadratic cost; the second economy has the same distribution of state and private plants as in the data; all plants are private in the third economy. The stationary equilibriums of 3 economies are reported in Table 13. The baseline for comparison is the economy with a mixed of state and private plants, in term of the average and volatility of aggregate output, consumption, capital stock and investment. As expected, if all plants are privately owned, the economy has the highest aggregate output, consumption, capital stock and investment level.

Incorporate the fixed cost in the general equilibrium, I have the following dynamic problem:

$$\max_{\{C_t, I_t\}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(C_t) \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t ln(C_t) \right\} \tag{5.3}$$

$$C_t + I_t + C(S_t, K_t, I_t) = A_t * K_t^{\theta} \tag{5.4}$$

$$C(S_t, K_t, I_t) = \begin{cases} F(S_t) * K_t & I_t \neq 0 \\ 0 & I_t = 0 \end{cases} \tag{5.5}$$

Based on the two fixed cost that I estimate in Section 4, $F = [0.000375, 0]$, I simulate 3 economies and compare their stationary equilibrium. The inputs of 3 economies are described in Table 14. Everything else is the same, except the fraction of state and private plants and the fixed cost. One economy is full of state plants, which have a relatively higher quadratic cost; the second economy has the same distribution of state and private plants as in the data; all plants are private in the third economy. The stationary equilibrium of 3 economies are reported in Table 15. Again, the baseline for comparison is the economy with a mixed of state and private plants, in term of the average and volatility of aggregate output, consumption, capital stock and investment. As expected, if all plants are privately owned, the economy has the highest aggregate output, consumption, capital stock and investment level.

The effect in general equilibrium is not significant, the main reasons are: the difference in adjustment cost between state and private plants is small in magnitude; general equilibrium usually squeezes out the difference.

6 Conclusion

In this paper, I characterize the adjustment costs in physical capital for public and private manufacturing plants in China, using a balanced panel of Chinese manufacturing plants from 1998 to 2007. I map the types of plant to its adjustment cost in investment, and link the type of plants to their efficiency. I document the stylized facts in plant's investment behavior: (i) for both public and private plants, the distributions of investment rates are skewed to the right, and there are considerable mass around zero; (ii) compared to private firms, public firms have a lower investment rate, lower frequency of large positive investment, and less volatile in investment rate; (iii) there is an increase in investment rate when a public plant becomes private, and a drop in investment rate when a private plant becomes public. Then I present a dynamic model of investment, which maps the types of plants to their adjustment cost. The parameters in adjustment cost for both public and private plants are then simultaneously estimated via Simulated Method of Moments (SMM) procedure. The paper shows that public plants have higher quadratic and fixed costs, compared to private plants. Last, based on those estimated parameters, I explore the impact of difference in cost on aggregate economy, by extending the model into general equilibrium setting. The model predicts that privatization of all plants in the economy will lead to 0.04%-0.32% increase in aggregate output, and 0.06%-0.07% decrease in aggregate output if all plants are state.

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7 Tables

Table 1: Characteristics of Plants, 1998-2007 Balanced Panel

Variables	All	State	Non-state
Value Added	26,418	36,961	22,611
	(135,224)	(213,140)	(91,812)
Gross Output	99,736	118,425	93,162
	(471,472)	(648,138)	(390,588)
Employment	391	462	367
	(670)	(685)	(662)
Capital Stock	40,043	74,695	27,855
	(261,981)	(465,456)	(126,521)
Cap/Emp	168.28	360.79	100.49
	(8181.29)	(16,022)	(297.71)
VA/Emp	93.50	141.12	76.28
	(3,250)	(6,297)	(198.24)
VA/Cap	1.48	1.02	1.64
	(2.74)	(2.39)	(2.84)
Opt/Emp	322.88	368.87	306.68
	(5,169)	(10,060)	(701.61)
Opt/Cap	5.787	3.62	6.55
	(9.81)	(8.74)	(10.04)
No. Obs	70,965	18,465	52,500

Notes: numbers in parenthesis are standard deviations.All monetary terms, i.e., Value added, gross output, capital stock, are in 1,000 RMB Yuan. Value added and gross output are deflated by annual output price deflator at provincial level, capital stock is deflated by annual price deflators in fixed investment at provincial level. Specifically, Cap/Emp is the ratio of capital stock to employment, VA/Emp is the ratio of value added to employment, VA/Cap is the ratio of value added to capital stock, Opt/Emp is the ratio of output to employment, Opt/Cap is the ratio of output to capital stock.

Table 2: Summary Statistics of Investment Rates

	State	Non-state
Fraction of $i_{it} < -20\%$	4.03%	3.53%
	(0.06%)	(0.03%)
Fraction of $i_{it} \in (-20\%, -10\%)$	3.77%	3.09%
	(0.06%)	(0.03%)
Fraction of $i_{it} \in (-10\%, 0)$	11.67%	9.69%
	(0.10%)	(0.05%)
Fraction of $i_{it} = 0$	13.01%	9.26%
	(0.13%)	(0.06%)
Fraction of $i_{it} \in (0, 10\%)$	32.44%	30.14%
	(0.15%)	(0.09%)
Fraction of $i_{it} \in (10\%, 20\%)$	14.86%	17.00%
	(0.11%)	(0.07%)
Fraction of $i_{it} > 20\%$	20.21%	27.28%
	(0.15%)	(0.09%)
$E(i_{it})$	8.96%	13.74%
	(0.17%)	(0.11%)
$E(i_{it}^2)$	0.055	0.074
	(0.001)	(0.001)
$corr(i_{it}, i_{it-1})$	0.148	
	(0.005)	
$cov(i_{it}, a_{it})/var(a_{it})$	0.043	
	(0.002)	

Notes: numbers in parenthesis are standard errors. i_{it} is the plant-level investment rate, $E(i_{it})$ is the first moment of investment rate, $E(i_{it}^2)$ is the second moment of investment rate. $corr(i_{it}, i_{it-1})$ represents the first-order auto-correlation of investment rate, $cov(i_{it}, a_{it})/var(a_{it})$ is the cross-correlation between investment rate i_{it} and profitability shock a_{it}, which is estimated directly from the plant-level data.

Table 3: Regression result

Dep: Investment Rate	OLS	FE
State	-0.046***	-0.014***
	(0.002)	(0.004)
Year	Yes	Yes
Region	Yes	Yes
3-digit industry	Yes	Yes
Observations	70,965	70,965
R-sq	0.027	0.006

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Notes: first column reports the coefficients via OLS, second column reports the coefficients via Fixed Effect, controlling plant's individual fixed effect.State is a dummy variable for state plants.

Table 4: Distribution of state-private by years

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
State	30.13%	27.93%	26.39%	25.62%	24.40%	23.09%	21.93%	21.33%	33.35%
Non-state	69.87%	72.07%	73.61%	74.38%	75.60%	76.91%	78.07%	78.67%	66.65 %

Notes: in each column, I report the relative frequency of state and non-state plants.

Table 5: Number of switchings

	State	Non-state	1	2	3	4	5	6	7	8	Total
Frequency	11,700	38,637	10,035	1,962	1,827	1,134	1,287	1,710	1,170	1,503	70,965
Percent	16.49%	54.45%	14.14%	2.76%	2.57%	1.60 %	1.81%	2.41%	1.65%	2.12%	100%

Notes: the first row reports the number of plants in the balanced sample, the second row report the percentage of plants compared to the balanced sample.

Table 6: Parameterization of Profitability Shock

parameters	θ	ρ_ϵ	σ_η	ρ_b	μ_b	σ_v
	0.32	0.49	0.37	0.98	6.29	0.02

Notes: this table means that the reduced-profit function is: $\pi_{it} = (b_t + \varepsilon_{it}) * k_{it}^{0.32}$, where $b_t - 6.29 = 0.98 * (b_{t-1} - 6.29) + v_t$, $vt \sim iid(0, 0.02^2)$, and $\varepsilon_{it} = 0.49 * \varepsilon_{i-1} + \eta_{it}$, $\eta_{it} \sim iid(0, 0.37^2)$.

Table 7: Estimated Parameters

	γ^s	γ^n	F^s	F^n	P^s	P^n	$\mathcal{L}(\widehat{W})$	$\mathcal{L}(I)$
γ only	0.108	0.082	0	0	1	1	19714	0.080
	$(0.12e-03)$	$(0.08e-03)$						
F only	0	0	0.000375	0	1	1	19206	0.301
			$(2.08e-07)$	$(2.90e-07)$				
$p_s$only	0	0	0	0	0.99	0.985	5755	0.170
					$(2.70e-05)$	$(1.12e-05)$		

Notes: numbers in parenthesis are standard errors. Superscript s represents state or public plants and superscript n represents non-state plants. $\mathcal{L}(\widehat{W})$ is the value of objective function defined in Equation (4.5), using the optimal weighting matrix; $\mathcal{L}(I)$ is the value of objective function defined in Equation (4.5), using an identity matrix.

Table 8: Simulated Moments —γ only

	State								
	N20	N1020	N010	Inaction	P010	P1020	P20	$E(i_{it})$	$E(i_{it}^2)$
Data	4.03%	3.77%	11.67%	13.01%	32.44%	14.86%	20.21%	8.96%	0.055
Model	0.07%	3.35%	9.96%	6.30%	34.48%	26.98%	18.87%	10.22%	0.022
s.e.	(0%)	(0%)	(0.01%)	(0.04%)	(0.05%)	(0.01%)	(0%)	(0%)	(0)
	Non-state								
	N20	N1020	N010	Inaction	P010	P1020	P20	$E(i_{it})$	$E(i_{it}^2)$
Data	3.53%	3.09%	9.69%	9.26%	30.14%	17.00%	27.28%	13.74%	0.074
Model	0.16%	3.51%	9.80%	7.00%	30.53%	24.36%	24.65%	10.80%	0.025
s.e.	(0%)	(0.01%)	(0.01%)	(0.10%)	(0.09%)	(0.06%)	(0%)	(0%)	(0)

	$corr(i_{it}, i_{it-1})$	$cov(i_{it}, a_{it})/var(a_{it})$
Data	0.148	0.043
Model	-0.0006	0.188
s.e.	(0.0001)	(0)

Notes: the first panel reports moments of investment rates regarding state plants, the second panel corresponds to moments of investment rates for non-state plants, and the third column presents two serial correlations for both state and non-state plants. In the above three panels, the number in the first row is data moments, the number in the second row is the moment simulated by the model, and number in parenthesis is standard error of the simulated moment. N20 is the fraction of $i_{it} < -20\%$, N1020 is the fraction of $i_{it} \in (-20\%, -10\%)$, N010 is the fraction of $i_{it} \in (-10\%, -1\%)$, inaction is the fraction of $i_{it} \in (-1\%, 1\%)$, P010 is the fraction of $i_{it} \in (0, 10\%)$, P1020 is the fraction of $i_{it} \in (10\%, 20\%)$, P20 is the fraction of $i_{it} > 20\%$. $E(i_{it})$ is the first moment of investment rate i_{it}, $E(i_{it}^2)$ is the second moment of investment rate i_{it}. $corr(i_{it}, i_{it-1})$ represents the first-order auto-correlation of investment rate, $cov(i_{it}, a_{it})/var(a_{it})$ is the cross-correlation between investment rate i_{it} and profitability shock a_{it}.

Table 9: Simulated Moments —F only

	State								
	N20	N1020	N010	Inaction	P010	P1020	P20	$E(i_{it})$	$E(i_{it}^2)$
Data	4.03%	3.77%	11.67%	13.01%	32.44%	14.86%	20.21%	8.96%	0.055
Model	5.36%	14.53%	5.57%	11.51%	20.41%	13.74%	28.88%	13.02%	0.086
s.e.	(0%)	(0%)	(0%)	(0.07%)	(0.17%)	(0.09%)	(0.02%)	(0%)	(0)
	Non-state								
	N20	N1020	N010	Inaction	P010	P1020	P20	$E(i_{it})$	$E(i_{it}^2)$
Data	3.53%	3.09%	9.69%	9.26%	30.14%	17.00%	27.28%	13.74%	0.074
Model	5.07%	20.42%	0.63%	0.01%	30.00%	17.14%	26.74%	13.09%	0.083
s.e.	(0%)	(0%)	(0%)	(0%)	(0.08%)	(0.08%)	(0.01%)	(0%)	(0)

	$corr(i_{it}, i_{it-1})$	$cov(i_{it}, a_{it})/var(a_{it})$
Data	0.148	0.043
Model	-0.282	0.333
s.e.	(0)	(0)

Notes: the first panel reports moments of investment rates regarding state plants, the second panel corresponds to moments of investment rates for non-state plants, and the third column presents two serial correlations for both state and non-state plants. In the above three panels, the number in the first row is data moments, the number in the second row is the moment simulated by the model, and number in parenthesis is standard error of the simulated moment. N20 is the fraction of $i_{it} < -20\%$, N1020 is the fraction of $i_{it} \in (-20\%, -10\%)$, N010 is the fraction of $i_{it} \in (-10\%, -1\%)$, inaction is the fraction of $i_{it} \in (-1\%, 1\%)$, P010 is the fraction of $i_{it} \in (0, 10\%)$, P1020 is the fraction of $i_{it} \in (10\%, 20\%)$, P20 is the fraction of $i_{it} > 20\%$. $E(i_{it})$ is the first moment of investment rate i_{it}, $E(i_{it}^2)$ is the second moment of investment rate i_{it}. $corr(i_{it}, i_{it-1})$ represents the first-order auto-correlation of investment rate, $cov(i_{it}, a_{it})/var(a_{it})$ is the cross-correlation between investment rate i_{it} and profitability shock a_{it}.

Table 10: Simulated Moments —P_s only

	State								
	N20	N1020	N010	Inaction	P010	P1020	P20	$E(i_{it})$	$E(i_{it}^2)$
Data	4.03%	3.77%	11.67%	13.01%	32.44%	14.86%	20.21%	8.96%	0.055
Model	5.36%	2.89%	10.41%	17.77%	24.59%	12.69%	26.28%	11.41%	0.054
s.e.	(0.03%)	(0.02%)	(0.03%)	(0.11%)	(0.15%)	(0.10%)	(0%)	(0%)	(0.0001)
	Non-state								
	N20	N1020	N010	Inaction	P010	P1020	P20	$E(i_{it})$	$E(i_{it}^2)$
Data	3.53%	3.09%	9.69%	9.26%	30.14%	17.00%	27.28%	13.74%	0.074
Model	2.94%	5.39%	4.90%	24.30%	24.48%	11.79%	26.20%	11.79%	0.050
s.e.	(0%)	(0%)	(0%)	(0.02%)	(0.08%)	(0.07%)	(0%)	(0%)	(0)

	$corr(i_{it}, i_{it-1})$	$cov(i_{it}, a_{it})/var(a_{it})$
Data	0.148	0.043
Model	-0.140	0.272
s.e.	(0.0001)	(0.0001)

Notes: the first panel reports moments of investment rates regarding state plants, the second panel corresponds to moments of investment rates for non-state plants, and the third column presents two serial correlations for both state and non-state plants. In the above three panels, the number in the first row is data moments, the number in the second row is the moment simulated by the model, and number in parenthesis is standard error of the simulated moment. N20 is the fraction of $i_{it} < -20\%$, N1020 is the fraction of $i_{it} \in (-20\%, -10\%)$, N010 is the fraction of $i_{it} \in (-10\%, -1\%)$, inaction is the fraction of $i_{it} \in (-1\%, 1\%)$, P010 is the fraction of $i_{it} \in (0, 10\%)$, P1020 is the fraction of $i_{it} \in (10\%, 20\%)$, P20 is the fraction of $i_{it} > 20\%$. $E(i_{it})$ is the first moment of investment rate i_{it}, $E(i_{it}^2)$ is the second moment of investment rate i_{it}. $corr(i_{it}, i_{it-1})$ represents the first-order auto-correlation of investment rate, $cov(i_{it}, a_{it})/var(a_{it})$ is the cross-correlation between investment rate i_{it} and profitability shock a_{it}.

Table 11: Adjustment Costs Paid as a Fraction of Revenue

	γ only	F only	P_s only
State Plants	$0.228e-02$	$9.901e-07$	0.206
Non-state Plants	$0.206e-02$	0	0.216

Notes: this table reports the average adjustment cost paid and type of plant as a fraction of revenue, in three models, quadratic cost γ only, fixed cost F only and irreversibility P_s only, respectively.

Table 12: Inputs in 3 economies — γ only

Input	All State	State & Non-state	All Non-state
γ^s	0.108	0.108	0
γ^n	0	0.082	0.082
S	$S = 1$	$S = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$	$S = 0$
$\pi(S'\|S)$	$\begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$	$\begin{pmatrix} 0.57 & 0.43 \\ 0.15 & 0.85 \end{pmatrix}$	$\begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$

Notes: this table shows the different inputs of the DSGE model described by Equation (6.1)-(6.2). The first column labeled "All State" shows the inputs corresponding to the case that all plants are state plants, the second column labeled "State & Non-state" corresponds to the case of mixture of state and non-state plants, which is consistent with the data, and the third column labeled "All Non-state" corresponds to the case that all plants are private ones. The values of quadratic costγ^s and γ^n are estimated in Section 4.

Table 13: Comparison of stationary equilibrium in 3 economies— γ only

	All State	All Non-state
$E(Yt)/\overline{Y}_{S\&N} - 1$	-0.07%	0.04%
$Var(Yt)/\sigma^2_Y - 1$	-0.25%	0.11%
$E(Ct)/\overline{C}_{S\&N} - 1$	-0.16%	0.08%
$Var(Ct)/\sigma^2_C - 1$	-0.40%	0.15%
$E(Kt)/\overline{K}_{S\&N} - 1$	-0.22%	0.13%
$Var(Kt)/\sigma^2_K - 1$	-1.02%	0.36%
$E(It)/\overline{I}_{S\&N} - 1$	-0.22%	0.08%
$Var(It)/\sigma^2_I - 1$	-1.53%	0.57%

Notes: this table compares the stationary equilibrium to the baseline economy: a mixture of state and private plants. The first column labeled "All State" reports the comparison between the case that all plants are state to the baseline economy. The second column labeled "All Non-state" reports the comparison between the case that all plants are private to the baseline economy. In both columns, I compare average and variation of aggregate output Y, aggregate consumption C, aggregate capital stock K and aggregate investment I. $E(\cdot)$ corresponds to the average of a variable, $Var(\cdot)$ corresponds to the variation of a variable, subscript $S\&N$ means the variables in the baseline economy.

Table 14: Inputs in 3 economies — F only

Input	All State	State & Non-state	All Non-state
F^s	0.000375	0.000375	0
F^n	0	0	0
S	$S = 1$	$S = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$	$S = 0$
$\pi(S'\|S)$	$\begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$	$\begin{pmatrix} 0.57 & 0.43 \\ 0.15 & 0.85 \end{pmatrix}$	$\begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$

Notes: this table shows the different inputs of the DSGE model described by Equation (6.3)-(6.5). The first column labeled "All State" shows the inputs corresponding to the case that all plants are state plants, the second column labeled "State & Non-state" corresponds to the case of mixture of state and non-state plants, which is consistent with the data, and the third column labeled "All Non-state" corresponds to the case that all plants are private ones. The values of fixed cost F^s and F^n are estimated in Section 4.

Table 15: Comparison of stationary equilibrium in 3 economies— F only

	All State	All Non-state
$E(Yt)/\overline{Y}_{S\&N} - 1$	-0.06%	0.32%
$Var(Yt)/\sigma_Y^2 - 1$	-0.12%	0.63%
$E(Ct)/\overline{C}_{S\&N} - 1$	-0.10%	0.12%
$Var(Ct)/\sigma_C^2 - 1$	-0.04%	-0.24%
$E(Kt)/\overline{K}_{S\&N} - 1$	-0.21%	1.13%
$Var(Kt)/\sigma_K^2 - 1$	-0.49%	2.10%
$E(It)/\overline{I}_{S\&N} - 1$	-0.21%	1.14%
$Var(It)/\sigma_I^2 - 1$	-0.15%	1.20%

Notes: this table compares the stationary equilibrium to the baseline economy: a mixture of state and private plants. The first column labeled "All State" reports the comparison between the case that all plants are state to the baseline economy. The second column labeled "All Non-state" reports the comparison between the case that all plants are non-state to the baseline economy. In both columns, I compare average and variation of aggregate output Y, aggregate consumption C, aggregate capital stock K and aggregate investment I. $E(\cdot)$ corresponds to the average of a variable, $Var(\cdot)$ corresponds to the variation of a variable, subscript $S\&N$ means the variables in the baseline economy.

8 Figures

Figure 1: Gross Capital Formation to GDP Ratio

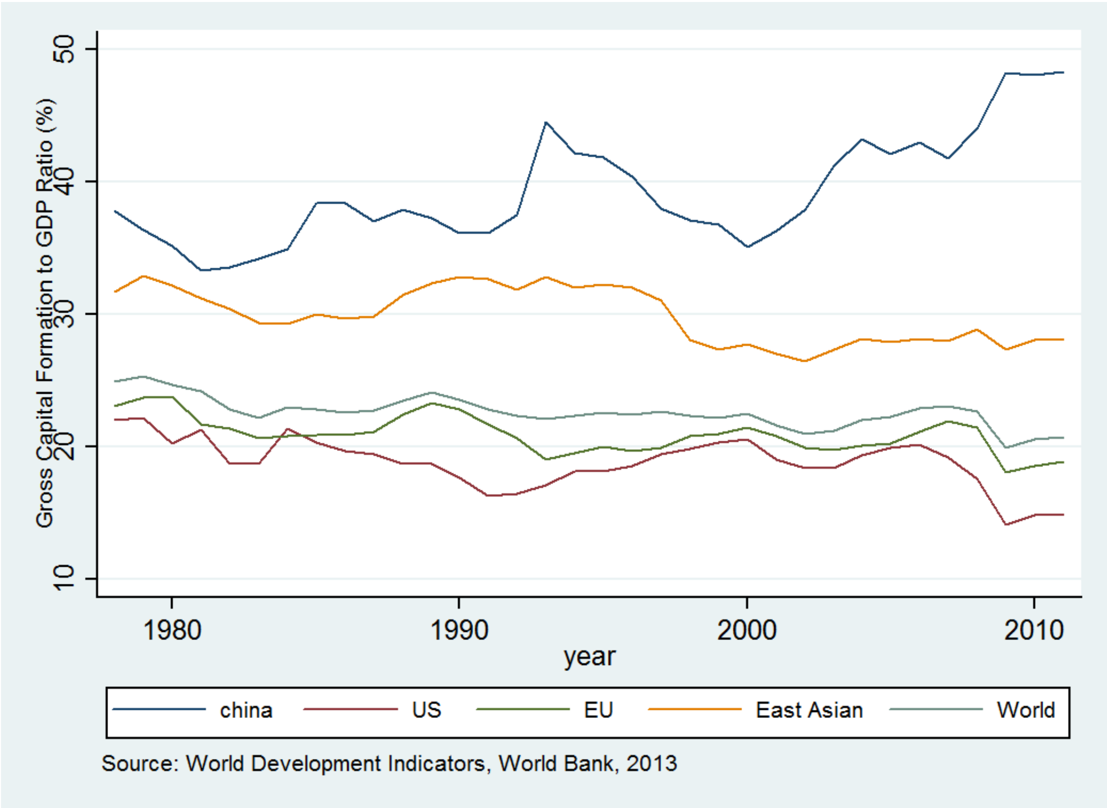
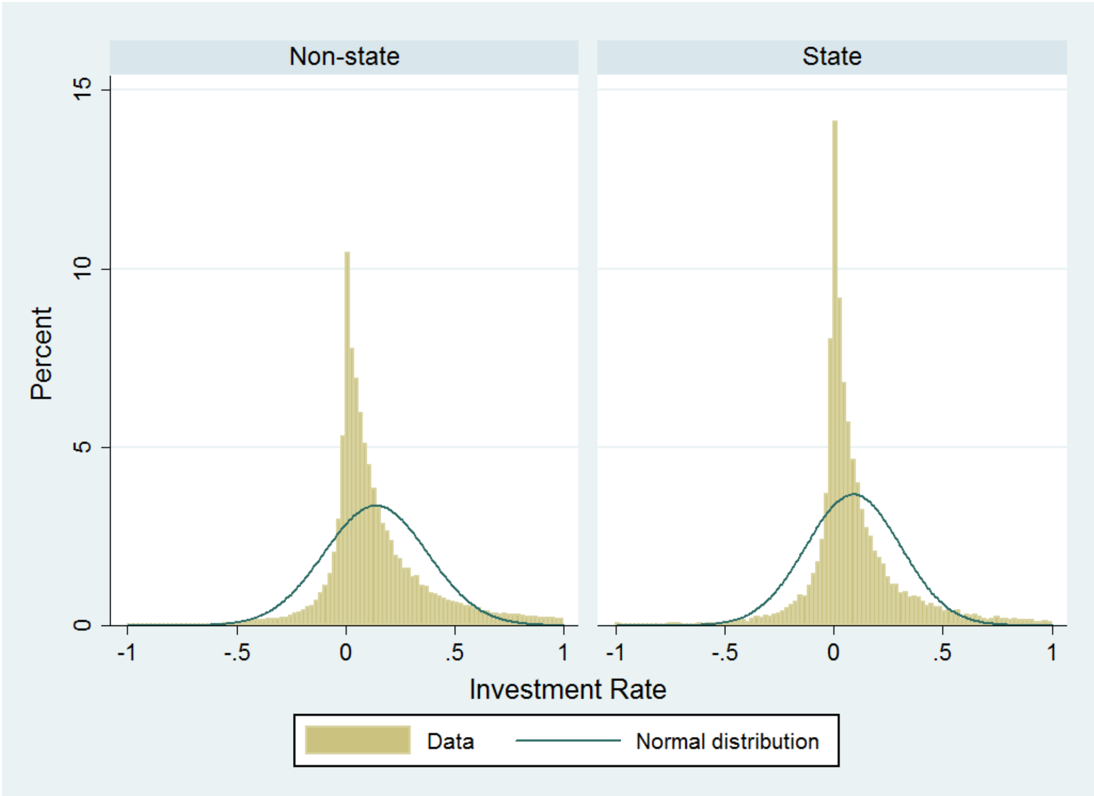
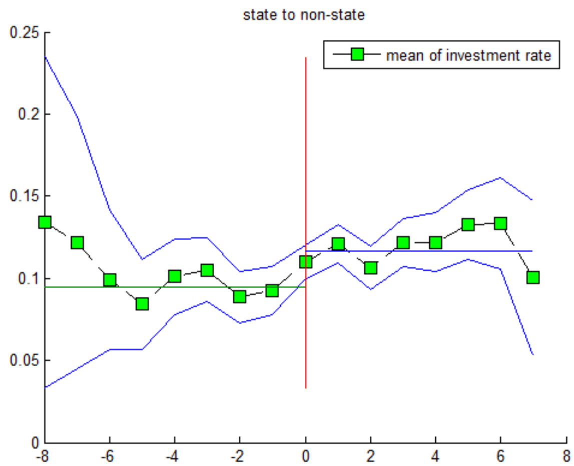


Figure 2: Distribution of Investment Rates



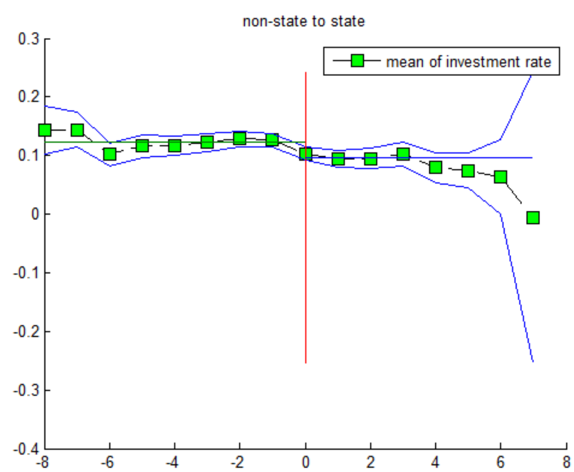
Notes: the left panel is the distribution of investment rate for non-state plants, and the right panel is the distribution of investment rate for state plants, from the balanced panel of Above Scale Enterprises Data set, 1998 - 2007. The blue curve in each panel is a density function of a normal distribution.

Figure 3: State to Private: Investment Rate



Notes: the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the state plant switching to non-state plant, and negative numbers represents number of periods before the state plant switching to non-state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate.

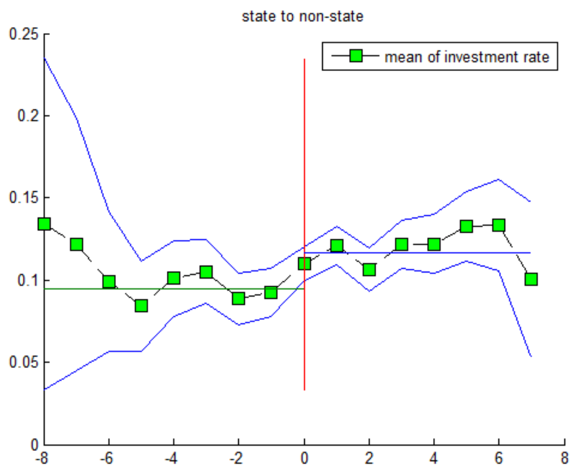
Figure 4: Private to State: Investment Rate



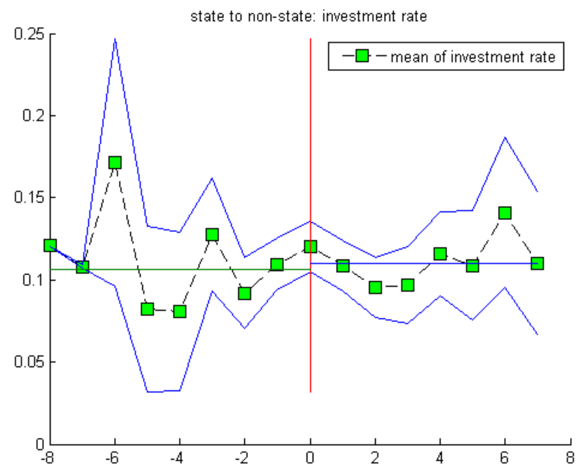
Notes: the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the non-state plants switching to state plants, and negative numbers represents number of periods before the non-state plants switching to state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate.

Figure 5: Comparison—γ only

(a) Data



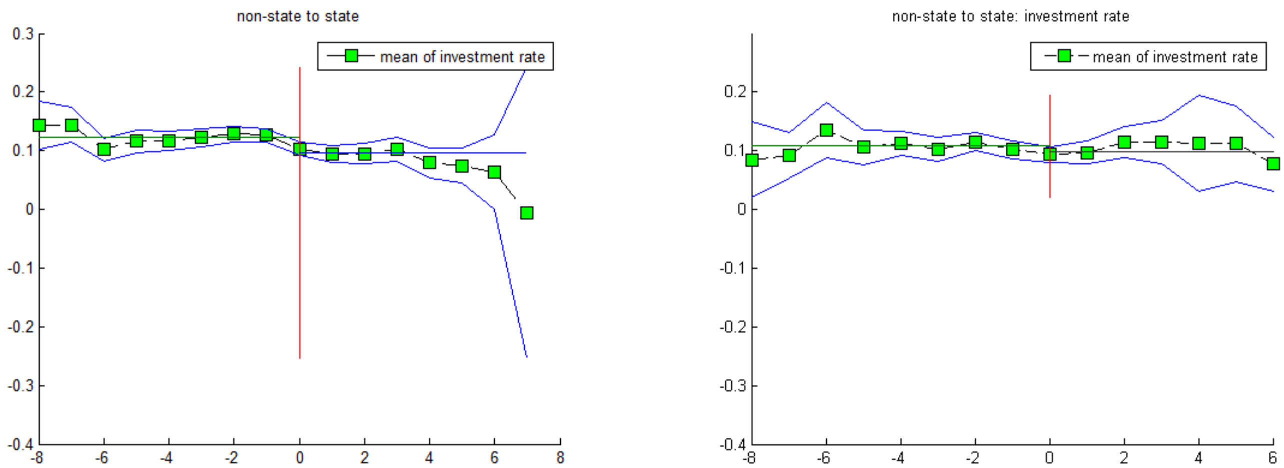
(b) Model —γ only



Notes: in both figures, the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the state plants switching to non-state plants, and negative numbers represents number of periods before the state plants switching to non-state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate. Figure (a) shows the switching pattern from data, figure (b) shows the switching pattern from the model with quadratic cost γ only.

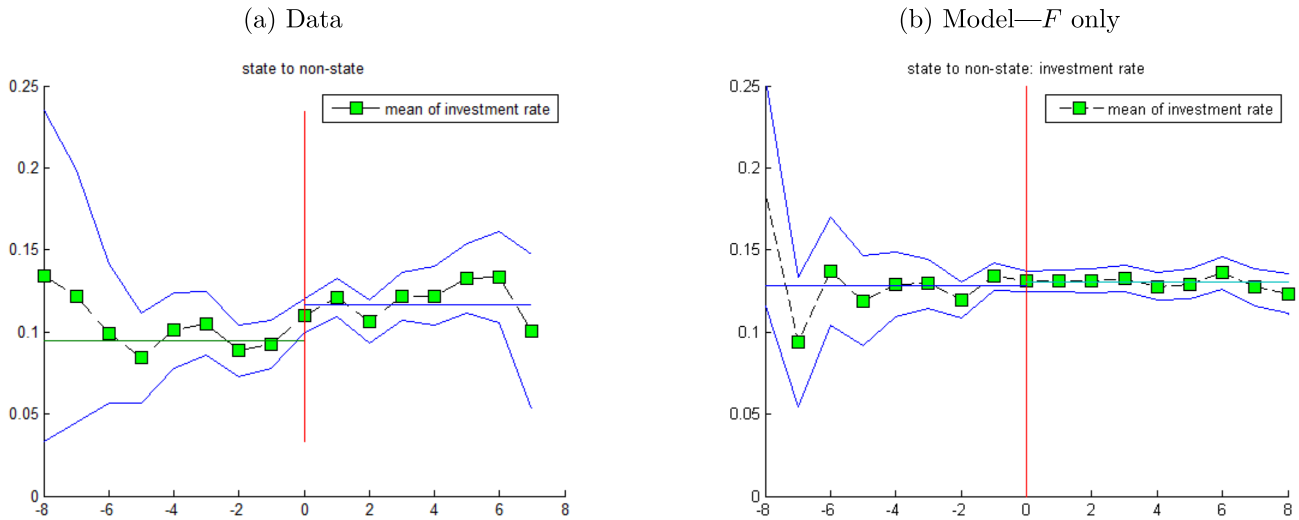
Figure 6: Comparison—γ only

(a) Data (b) Model —γ only



Notes: in both figures, the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the non-state plants switching to state plants, and negative numbers represents number of periods before the non-state plants switching to state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate. Figure (a) shows the switching pattern from data, figure (b) shows the switching pattern from the model with quadratic cost γ only.

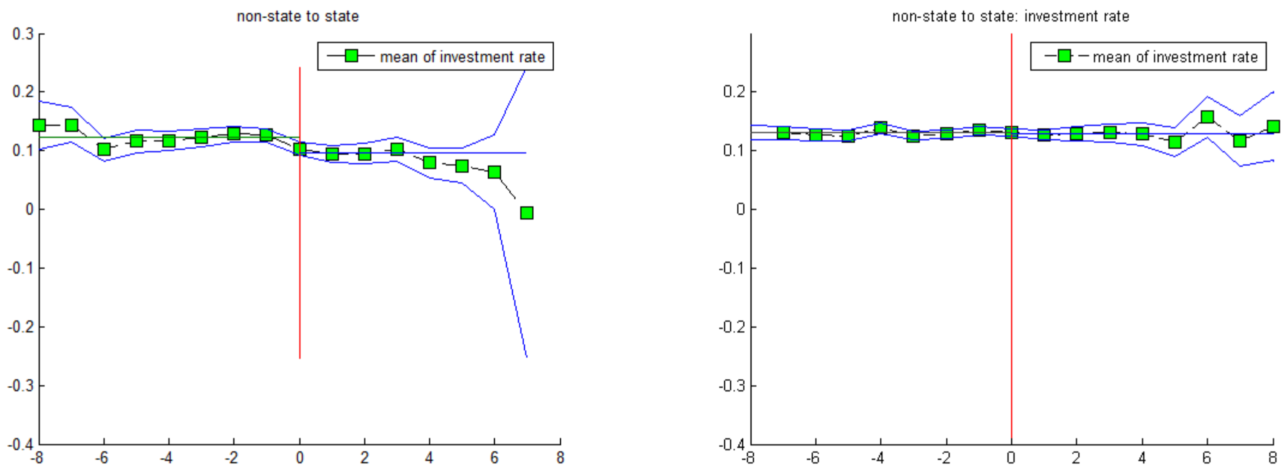
Figure 7: Comparison—F only



Notes: in both figures, the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the state plants switching to non-state plants, and negative numbers represents number of periods before the state plants switching to non-state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate. Figure (a) shows the switching pattern from data, figure (b) shows the switching pattern from the model with fixed cost F only.

Figure 8: Comparison—F only

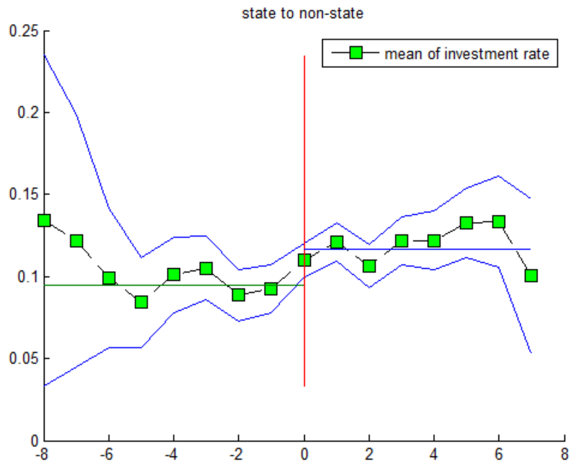
(a) Data (b) Model—F only



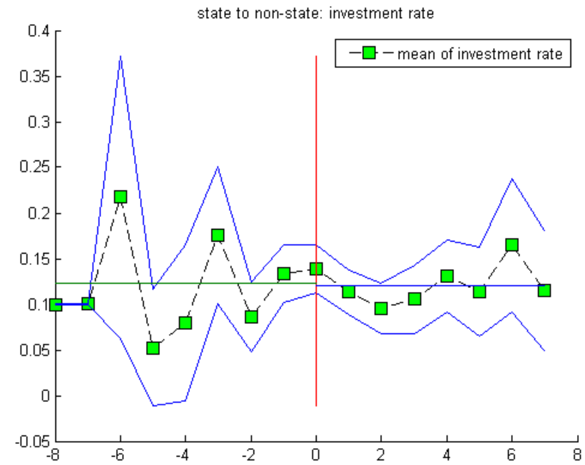
Notes: in both figures, the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the non-state plants switching to state plants, and negative numbers represents number of periods before the non-state plants switching to state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate. Figure (a) shows the switching pattern from data, figure (b) shows the switching pattern from the model with fixed cost F only.

Figure 9: Comparison—P_s only

(a) Data



(b) Model—P_s only

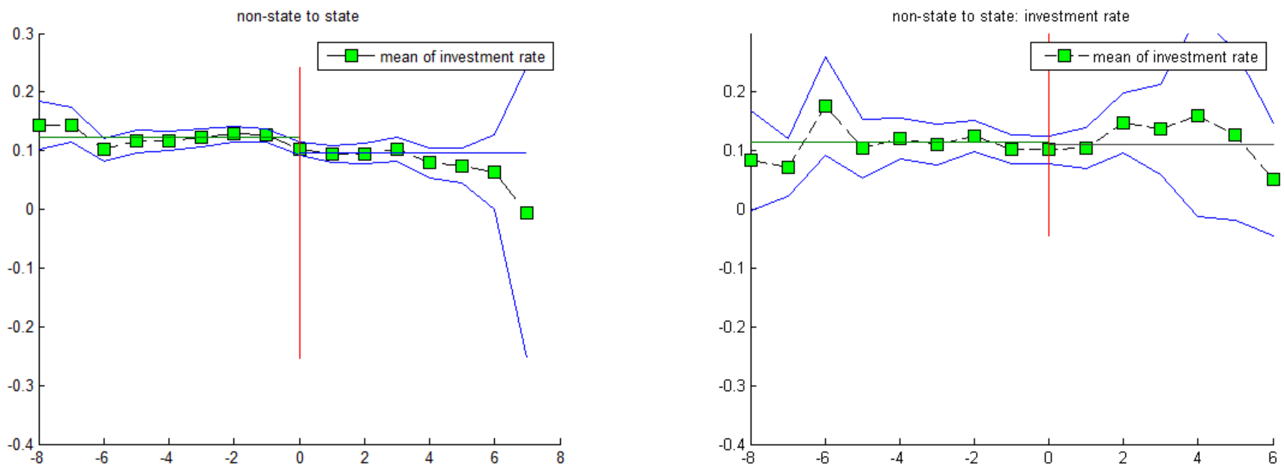


Notes: in both figures, the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the state plants switching to non-state plants, and negative numbers represents number of periods before the state plants switching to non-state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate. Figure (a) shows the switching pattern from data, figure (b) shows the switching pattern from the model with irreversibility P_s only.

Figure 10: Comparison—P_s only

(a) Data

(b) Model—P_s only



Notes: in both figures, the vertical axis is investment rate, horizontal axis represent time. Positive number on horizontal axis means number of periods after the non-state plants switching to state plants, and negative numbers represents number of periods before the non-state plants switching to state plants. Green squares represents the average investment rate, and two blue lines are 95% confidence interval of average investment rate. Figure (a) shows the switching pattern from data, figure (b) shows the switching pattern from the model with irreversibility P_s only.

Appendix

A: Data and variables

In the Above Scale data set, there are 4 variables relevant to fixed assets, they are: original value of fixed assets (OVFA), current depreciation (CURDEP), cumulative depreciation (CUMDEP), and net value of fixed assets (NVFA). Given the above available variables, I construct the investment at plant level using perpetual inventory method. Assume the evolution of capital stock follows

$$K_{t+1} = (1 - \delta)K_t + I_t \tag{.1}$$

Backwards substitution gives

$$I_t = NVFA_{t+1} - NVFA_t + CUMDEPR_{t+1} - CUMDEPR_t \tag{.2}$$

In principle, the difference of cumulative depreciation in two consecutive years should be equal to the current depreciation, and it is supposed to be greater than zero, i.e., $CUMDEPR_{t+1} - CUMDEPR_t = CurrentDepreciation_{t+1} > 0$. However, in the Above Scale data set, there are about 15% observations have negative $CUMDEPR_{t+1} - CUMDEPR_t$. This might be due to the fact that firms adjust their cumulative depreciation, when they dispose or retire certain capital goods, or merge and/or acquire assets from other firms. Compared with current depreciation, the variable cumulative depreciation may involve more measure errors or mus-reporting issues. Since all observations have positive current depreciation, I construct investment variable by: $I_t = NVFA_{t+1} - NVFA_t + CURDEPR_{t+1}$.

After the calculation of investment at plant level, I use equation (19) to calculate plant depreciation rate δ. In the sample, the average of depreciation rate is 10.69%, standard error is 0.02%. Therefore, I set depreciation rate at 10% through whole analysis. Previous papers on growth accounting in China, like Woo (1998), Yong (2000) and Wang & Yao (2001), etc used depreciation rate ranging from5% - 6%. The reasons are: those growth literature use data before year 2000, my sample is from 1998 to 2007; those authors used aggregate data to back out capital stock and depreciation rate, I use plant-level data to calculate the depreciation rate directly. 10% annual depreciation rate is a reasonable value of most calibration exercise, see Song etc (2008).

B: Estimation of profitability shock

This section discusses the measurement of key variables and estimation of the static reduced-form profit function in Section 4.2.

Assume that a plant uses two inputs, K capital and L labor to produce a single final good Y. The production function is Cobb-Douglas form: $Y = \widehat{A}K^{\alpha}L^{\psi}$, where $\widehat{A}$ represents productivity shock, α and ψ are share of capital K and labor L respectively. The market structure of final good Y monopolistic competition, and the demand function facing by a plant is $P = Y^{-\eta}$, where η is the inverse of demand elasticity. Given its current capital stock K, a plant chooses the amount of labor L to maximize its profit. Let wage be w. Hence, the statici profit-maximization problem can be described as:

$$\max_{L} \pi = PY - wL = (\widehat{A}K^{\alpha}L^{\psi})^{1-\eta} - wL \tag{.3}$$

The optimal choice of labor$L$ is: $L^* = (\frac{w}{\psi(1-\eta)})^{\frac{1}{\psi(1-\eta)-1}} \widehat{A}^{\frac{\eta-1}{\psi(1-\eta)-1}} K^{\frac{\alpha(\eta-1)}{\psi(1-\eta)-1}}$. Plug the optimal choice of labor L^* back the profit function, I get the reduced-form profit $\pi = AK^{\theta}$, where $\theta = \frac{\alpha(\eta-1)}{\psi(1-\eta)-1}$, and $A = (2-\psi(1-\eta)) * (\frac{w}{\psi(1-\eta)-1})^{\frac{\psi(\eta-1)}{\psi(1-\eta)-1}} * \widehat{A}^{\frac{\eta-1}{\psi(1-\eta)-1}}$. The profitability shock A incoporates the shock to productivity $\widehat{A}$, the shock to demand η, and variation in factor prices of variable inputs, in this case, wage w.

In the estimation of the reduced-form profit function, revenue $P * Y$ is approximated by the variable "GVIO" (Gross Value of Industrial Output). $w * L$ corresponds to the sum of variable "Total Wage Payable" and variable "Total Welfare Payment". Hence profit is construed by GVIO-(Total Wage Payable+Total Welfare Payment), then it is deflated by annual output price at provincial level.

Suppose $a_{it} = ln(A_{it})$ that has the following structure:

$$a_{it} = b_t + \epsilon_{it} + \alpha_i$$

where b_t is a common shock faced by all the plants at year t, and ϵ_{it} is a plant-level idiosyncratic shock, $\alpha_i$is plant's unobservable individual fixed effect. Assume ϵ_{it} follows an AR(1) process: $\epsilon_{it} = \rho_{\epsilon}\epsilon_{it-1} + \eta_{it}$, where$\eta_{it} \sim iid(0, \sigma_{\eta}^2)$. Taking logs of both sides of (18), we have:

$$\pi_{it} = b_t + \epsilon_{it} + \alpha_i + \theta k_{it} \tag{.4}$$

First, to get rid of the individual fixed effect, I use de-mean method:

$$\frac{\sum_t \pi_{it}}{T} = \frac{\sum_t b_t}{T} + \frac{\sum_t \epsilon_{it}}{T} + \alpha_i + \theta \frac{\sum_t k_{it}}{T} \tag{.5}$$

$$\pi_{it} - \frac{\sum_t \pi_{it}}{T} = (b_t - \frac{\sum_t b_t}{T}) + (\epsilon_{it} - \frac{\sum_t \epsilon_{it}}{T}) + \theta(k_{it} - \frac{\sum_t k_{it}}{T}) \tag{.6}$$

Let's assume $\mu_b = \frac{\sum_t b_t}{T}$, $\frac{\sum_t \epsilon_{it}}{T} = 0$ (if $\frac{\sum_t \epsilon_{it}}{T}$ is not equal to zero, it can be incorporated into constant term in the final estimation equation). Let $\frac{\sum_t \pi_{it}}{T} =$, $\frac{\sum_t k_{it}}{T} = \overline{k_i}$. Quasi-differencing (4) yields:

$$\pi_{it} - \overline{\pi_i} = \rho_\epsilon(\pi_{it-1} - \overline{\pi_i}) + \theta(k_{it} - \overline{k_i}) - \rho_\epsilon\theta(k_{it-1} - \overline{k_i}) + (b_t - \rho_\epsilon b_{t-1}) + (\rho_\epsilon\mu_b - \mu_b) + \eta_{it} \quad (.7)$$

where $\overline{\pi_i} = \frac{\sum_t \pi_{it}}{T}$, $\overline{k_i} = \frac{\sum_t k_{it}}{T}$, b_t is year dummy.

I estimate this equation (22 via non-linear least squares method, using a complete set of year dummies b_t to capture the aggregate shock. From the plant-level data, the estimation results are in Table 17.

$R^2 = 0.365$. The non-linear least square estimation results are robust, regardless of the initial values that are chosen. Having estimated θ , I recover a_{it} from the reduced form profit function (4) and decompose it into aggregate and idiosyncratic components. This latter step amounts to measuring the aggregate shock b_t as the mean of a_{it} in each year and the idiosyncratic shock ϵ_{it} as the deviation of a_{it} from the year-specific mean. Using this decomposition, b_t is approximated by an AR(1) process:

$$b_t - 6.29 = 0.98(b_{t-1} - 6.29) + v_t,\ v_t \sim iid(0, 0.02^2) \quad (.8)$$

To sum up, in what follows, I use the following key estimates from the plant-level data in estimation of adjustment costs as reported in Table 16.

Table 16: Profit Function Estimation

parameters	θ	ρ_ϵ	σ^2_η
	0.32	0.49	0.14
s.e.	(0.007)	(0.003)	

Note: numbers in the parentheses are standard errors.

C: Numerical methods

In this appendix, I describe how I use numerical techniques to solve the dynamic optimization problem and implement SMM procedure.

C.1 Model Solution

The dynamic problem for the plant's investment decision can be re-expressed by the following equations:

$$V(A,S,K) = \max\left\{V^n(A,S,K), V^b(A,S,K), V^s(A,S,K)\right\} \quad (.9)$$

where superscript n represents no investment, superscript b corresponds to buying capital goods, and superscript s corresponds to selling capital goods. Specifically, they are:

$$V^n(A,S,K) = AK^\theta + \beta E[V(A', S', (1-\delta)K)|A,S] \quad (.10)$$

$$V^b(A,S,K) = \max_{K'>(1-\delta)K}\{AK^\theta - (K'-(1-\delta)K) - \frac{\gamma(S)}{2}(\frac{K'-(1-\delta)K}{K})^2K - F(S)K + \beta E[V(A^{'},S^{'},K^{'})|A,S]\} \quad (.11)$$

$$V^s(A,S,K) = \max_{K'<(1-\delta)K}\{AK^\theta - P_s(S)(K'-(1-\delta)K) - \frac{\gamma(S)}{2}(\frac{K'-(1-\delta)K}{K})^2K - F(S)K + \beta E[V(A^{'},S^{'},K^{'})|A,S]\} \quad (.12)$$

First, the profitability shock A_{it} is estimated directly from data, which is described in Appendix B. Then the aggregate shock b_t and the idiosyncratic shock ε_{it}, which both follow AR(1) processes, are discretized into 2 and 3 states, respectively. I follow the method described in Adda & Cooper (2003). Second, I descretize the capital grid over 40 uneven points, which covers by the steady-state value, and more points when capital stock is low and fewer points when capital stock is large. Hence, with two states for the type of plants$S$, there are $2*3*2*40 = 480$ points in the state space of the above dynamic problem.

I take two steps to solve the unknown value functions in the case of no investment, buying and selling capital goods, $V^n(A,S,K), V^b(A,S,K)$ and $V^s(A,S,K)$. First, I approximate the value functions by linear interpolations. (Due to the fixed cost or irreversibility in the model, the value function is continuous but not differentiable. Although it might not be efficient, linear interpolations are shape-preserving and derivative free.) Second, I find the optimal value of capital stock in next period via golden section search method, then update the value function till the difference in value function between two consecutive iterations is small. Specifically, value function iterations stop till the change of decision rule is less than 10^{-4} or the change of value functions is less than 10^{-2} in two consecutive iterations.

C.2 SMM Procedure

Given the policy function I found via solving the dynamic problem, I simulate a balanced panel with time periods $T = 400$, and $S = 300$ plants in every period. Simulated moments are then calculated from this simulated data set.

In the procedure of recovering the parameters in the adjustment cost, I apply 2-stage SMM procedure. In the first stage, I use identity matrix as the weighting matrix, then get a set of estimator $\hat{\Theta}_0$ by minimization Equation (4.5); next I simulate the corresponding moments with relatively long time horizon (Specifically, the simulated panel has 450 time periods and 300 plants. As the process is ergodic, after dropping the first 50 period, the simulated moments are determined by the total observations), and calculate $\hat{W}_0$ the variance-covariance matrix based on the simulated data. Considering the serial correlation of moments, I use Newey-West estimator to construct $\hat{W}_0$. In the second stage, I solve the minimization problem Equation (4.5) again, then get a set of estimator $\hat{\Theta}$, using $\hat{W}_0$ from the first stage. Standard errors of the estimators and simulated moments are calculated based on the optimal weighting matrix $\hat{W}_0$. The estimator and standard errors reported in the paper are from the second-stage result.

I use Nelder-Mead algorithm to solve the minimization problem in Equation (4.5). Although it is slow and unreliable, Nelder-Mead algorithm is simple and derivative free. Due to the fact that the objective function in equation (12) does not have an analytical form, and might not differentiable, Nelder-Mead algorithm might be better than other algorithm, like quasi-Newton methods. To overcome the unreliability in Nelder-Mead algorithm, I solve the minimization problem in Equation (4.5) ten times, in each time it starts with a different randomly-assigned initial values. I choose the solutions that have the smallest value of the objective function. Moreover, I plot the the objective function over a rectangle of the optimal solution, and the objective function is basically convex and reaches the local minimum at the optimal solution.