ESTIMATING PRODUCTIVITY DYNAMICS DURING INSTITUTIONAL CHANGE: AN APPLICATION TO CHINESE STATE OWNED ENTERPRISES 1980-1994

PETER MCGOLDRICK[*] AND PATRICK PAUL WALSH[**]

[*] DEPARTMENT OF ECONOMICS, UNIVERSITY COLLEGE DUBLIN

[**]DEPARTMENT OF ECONOMICS, TRINITY COLLEGE, DUBLIN

ABSTRACT

We estimate the productivity dynamics of 680 industrial Chinese State-Owned Enterprises (SOEs) between 1980 and 1994. During this time managerial autonomy over factor markets was introduced. The timing of autonomy varied across SOEs and take-up was an endogenous process: high-productivity SOEs where more likely to take managerial control. We allow for this by adapting an algorithm developed in Olley & Pakes (1996) in order to generate estimates of productivity dynamics that deal with both simultaneity and endogenous selection biases. Apart from offering a methodology to estimate productivity dynamics during endogenous institutional change, we demonstrate that SOEs in China obtained productivity gains from managerial autonomy over factor markets in the years before privatisation.

KEYWORDS: Endogenous Selection to Institutional Change, Simultaneity, Production Functions, Productivity Dynamics, Chinese Industrial State-Owned Enterprises.

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I. INTRODUCTION

The focus of this paper is to outline a methodology that estimates the parameters of a production function but allows for the level and changes in the unobservable to be affected by discrete endogenous enterprise-level institutional change, among other factors. This is achieved by adapting an algorithm developed in Olley and Pakes (1996) and applying it to a balanced panel of 680 SOE's the industrial sector of the Chinese economy with annual observations for the period 1980 to 1994, which was gathered by the Chinese Academy of Social Science, with the aid of the universities of Oxford and California[1]. The motivation for choosing an adapted version of the Olley & Pakes (1996) algorithm is to allow for productivity to be dynamic, while controlling for simultaneity and a particular type of selection bias. Rather than allowing for a selection bias due to entry and exit of companies, as in Olley & Pakes (1996), our selection bias results from an entry rule into a reform that creates unbalanced panels of SOE's in reformed and unreformed states, a discrete choice, whose adoption dates are enterprise specific and depend on the productivity type of the enterprise, among other factors.

The Olley & Pakes (1996) approach postulates a structural model of the unobservable, which suggests that a selection rule and investment dynamics of enterprises, given the observable state variables, should allow one to control effectively for the omitted unobservable (productivity) using a non-parametric techniques. This allows one to get consistent estimates of the β's on labour and

[1] Groves et al. (1994), (1995) and Li, (1997) have used the same data covering the period 1980-89 and Li and Wu (2002) extend the data for 1990-1994. These papers also use a production function approach to evaluate the reform process but there are three key issues not addressed by them that are the focus of this paper. First, they correct for simultaneity bias by using a naïve within group estimator, which assumes productivity to be time invariant. Secondly, they do not allow for selection bias coming from an endogenous reform process, i.e. they assume the tendency to reform is assumed to be a random process and not linked to productivity considerations. Finally, our analysis incorporates a reform overlooked by other studies. These reforms are equivalent to the final separation of control from ownership, since they give enterprise managers autonomy in decisions regarding hiring and firing of labour, the buying and selling of capital assets, investment decisions, and the ability to buy (intermediates) and sell (final or intermediates goods) on international markets. These reforms were largely taken up as a package by enterprise managers but at different points of time during the late 1980s and early 1990s. Initial or preparatory reforms during the 1980s, such as increased output autonomy, payment of wage bonuses, and devolution of general control from the centre to the region, and the use, in part, of market prices, are not considered here, as several studies have failed to link productivity gains to these. While the early reforms where necessary for the implementation of further reform researchers have not been able to link productivity to initial reforms in a significant way, see Li and Wu (2002) and Groves et al. (1994). Indeed, Coady and Wang (2000) provide evidence that rent sharing was driving the allocation of bonuses in Chinese SOEs with little efficiency gain.

capital, amongst other observables. A consistent productivity index for each enterprise can then be backed out as a residual in the production function.

Even though Olley & Pakes (1996) motivate their structural (theoretical model) of the unobservable with Ericson and Pakes (1995), which assumes the existence of Markov perfect Nash equilibrium over-time, the econometric technique is operational when investment sequences and adoption of reform are weakly rational, driven in some part by observable and unobservable state variables[2]. In other words the technique does not require investment dynamics and adoption of reform in Chinese State Owned Enterprises to be optimal but they have to be weakly related to economic factors such as enterprise level productivity**.** We argue that this is the case. It is noteworthy, that during the sample period enterprises were signed up to the "contract responsibility system". The contract had profit and tax targets to be paid to the government and, failing this, managers would forgo a bond posted prior to the contract. In return, managers and workers would be paid agreed bonuses. They also had the right to divert retained profits to a welfare and investment fund. Even though incentive problems were not solved, clearly planners would target investment at enterprises where profit and taxes were channelled back to Government. Investment dynamics and adoption of reform should be driven in some part by the unobservable productivity type and hence we can use Olley & Pakes (1996), selection rules and investment dynamics of enterprises to control for the omitted unobservable (productivity) using semi-parametric techniques in our estimation of production functions. Having consistent estimates of the β's on observables we hope to back out consistent productivity dynamics for each enterprise.

What is interesting about our set-up is that managerial autonomy over factor markets are introduced at different times to different enterprises, which all remain under state ownership**.** Thus, we make a contribution to the ownership-versus-control debate, which attempts to tackle the question as to whether significant performance gains through competitive pressures are possible by operational reform only, or whether private ownership is essential for this. Our results indicate that enterprises that embrace managerial autonomy over factor markets under State Ownership exhibit

[2] Another approach would be to use a "system" GMM estimator, such as Blundell, Bond and Windmeijer (2000). The simultaneity bias is addressed by modelling the unobservable as a dynamic error component model and they use linear and non-linear moment restrictions on the error structure for identification. This parametric structure is not theoretically well motivated and the extension of this approach to also address the problem of an "endogenous" reform dummy is not straight forward.

higher productivity compared to enterprises in the initial stages of reform, controlling for simultaneity and selection biases. Most western studies that have failed to find efficiency gains from privatisation argue that State Owned Companies tend to operate with competitive pressures in factor and product markets pre-privatisation, and hence the contributions of privatisation are hard to isolate, see Walsh and Whelan (2001) for an overview. This paper presents us with nice piece of evidence that supports this view.

In our example a clear relationship between the adoption of managerial control of factor markets and improvements in SOE productivity over-time can be documented but only when we allow for the unobservable to be affected by endogenous enterprise-level institutional change in the estimation of the parameters of the production function. Naïve OLS, GLS estimators and even an Olley & Pakes (1996) algorithm that allows for productivity to be dynamic and controls for only simultaneity biases, treating reform as a state or exogenous variable, do not give us clear-cut results.

The methodology to allow for selection biases resulting from enterprise level reform sequences in the estimation of productivity, can easily be applied to other areas of economic interest, such as evaluating productivity across groups defined by exporting versus non-exporting status, state versus private ownership and domestic versus foreign outsourcing of intermediate inputs[3].

The remainder of the paper is structured as follows. Section II provides the reader with the background of enterprise reform in China. Then the behavioural model of Olley and Pakes (1996) and the estimation procedure are outlined, as is its adaptation to our particular problem, in section III. Our results and conclusions are set out in sections IV and V, respectively.

[3] See Jan De Loecker (2004) addresses the link between productivity and exporting versus non-exporting status. Amiti and Konings (2005) focus on status of imports in terms of final versus intermediate goods. Another literature that is relevant considers the effect of imported versus indigenous input status on productivity, Feenstra et al. (1992) and Kasahara and Rodrigue (2004). The tendency here is to estimate TFP, without controlling for endogenous selection to a status, and in a second step TFP is linked to a particular status. Clearly, it is better to allow for endogenous selection in the estimation of TFP in the first place. Otherwise, the TFP backed out results from a badly specified production function and could have spurious relationships with other variables.

II Reform of Chinese State-Owned Enterprises

Reform in China was initiated in 1978, and the process refers to institutional changes that move the economy from planned to a market economy. The crucial difference is reflected in prices, which are set by the planner in the former, and set in the market in the latter case. Prices under planning are often set such that inputs are cheap and final goods are expensive, especially industrial goods. Thus, profits from the industrial sector are the main source of government revenue, rather than taxes as in market economies. Hence, the allocation of goods in the economy is not achieved by demand and supply creating a price that reflects the value/scarcity of a product. Rather, the planner must process a wealth of information and then use this information in order to gear the economy toward arriving at some set of desirable goals, defined by quotas. Information and incentive problems lead to stockpiling and loss of economic prowess. Over time this system has had to reform due to these inefficiencies and stagnation. (Naughton, 1995).

Since the act of planning is so complex, partial reform within planning may not improve efficiency significantly, but may lead to distortions, which adversely affect efficiency and the commitment to further reform, see Dewatripont & Roland (1995). However, a big bang approach, that removes all aspects of planning without the institutions of a market economy in place, could result in a period of disorganisation, which could in turn result in an initial massive fall in output as witnessed in the former Soviet Union; see (Repkine and Walsh, 1999) and (Konings and Walsh, 1999).

In 1978 the Chinese tentatively sought for a way to avoid this problem, where the 'government's role often has been to permit change rather than to initiate it' (McMillan, 1994). The planned economy was upheld, while firms bought and sold goods in the market, at market prices, if they were in excess of quotas regulations. While initial reforms in industry were deemed unsuccessful, with some retrenchment by 1983, there was a strong push for reforms again after 1983 (Naughton, 1995). Thus, we witness the birth of the *Dual-Track* system, which allows both planned and market prices to coexist for goods produced to quotas and excess goods respectively.

> "Beginning in 1978 […], China reformed its industrial sector. Enterprises that had been largely controlled by the state were given some market or market-like

> incentives. […] State owned enterprises were allowed to keep some fraction of their profits, where before all profits had to be remitted to the state. Enterprises began to sell some of their outputs and buy some of their inputs in free markets, rather than selling and procuring everything at state-controlled prices" (Groves et al., 1994; see also Byrd 1991, Naughton 1995, Qian, 1999).

In 1978 SOE's accounted for 78 percent of industrial output, 19 percent of total employment (Kennedy & Marquis, 1988). The degree of state produced output sold at market prices rose steadily, and averaged 38 percent of state-owned enterprises' output by 1989, and, in particular cases, even amounted to all output. By the same time on average 56 percent of inputs to state production was procured at market prices. (McMillan, 1994)

By the latter half of the 1980s nearly all SOEs in our sample had completed this type of reform, thus having obtained the right to determine output value, pay bonuses, retain excess profits, and produce and sell at market prices. Also, the level of control was devolved from the state, or provincial level to the municipal level. We view these reforms as initial steps toward creating a market economy environment. The effect of these reforms by themselves is overviewed in Li and Wu (2002), who conclude that their effect was indeed limited. Groves et al. (1994) take a more benevolent view of initial reforms, but their results fail to establish a strong link from the reform process to productivity enhancement.

Thus, the main function of initial reforms appears to be the creation of institutions necessary for the second stage of reforms to be successful. A standstill at the level of initial reform was counterproductive, as some agents made use of the status quo in this halfway house by trading between the co-existing parts of the economy. This reportedly led to a rise in social tension in the late 1980s (See Laffont & Qian, 1999; Dewatripont & Roland, 1995; Fang, 1994).

It is at this point that the authorities began to appreciate the necessity to advance further reforms, but still they lacked a clear goal or path, which is summed up in the slogan *crossing the river by touching stones*. '[U]ncertainty over its vision of the future and aversion to risk help explain China's initial groping reform strategy. …and success has sustained the continuity of a gradual evolutionary approach to reform.' (Jefferson & Singh, 1999) It was appreciated that the growth in the private sector could not be matched by the state-sector. One can say with respect to this

phenomenon that, rather than destroying the old institutions and starting from scratch, China let its new economy grow around what already existed, i.e. was '*[g]rowing out of the Plan*'. (Naughton, 1995).

Further reforms were initiated. Figure I and Figure II show how reforms evolved over time in our sample of enterprises. While the reform process began in the late 1980s only from the late 1980s onwards do we see autonomy over hiring and firing of factors which permeates most of the sample by the early 1990s. Even though we see only the aggregate outcomes, careful analysis of the data shows that an enterprise's endeavour in one of these areas in terms of autonomy over factor markets tended to be followed by further reform in another aspect of factor markets. Hence managerial autonomy over factor inputs reforms were not taken up gradually: enterprises tended to select to the full package or not at all.

Regarding the causality of reforms, which is an important part of our analysis, we find support for our view that it runs from enterprise performance to reform and vice-versa.

> "Virtually all of the literature on the enterprise reform examines the impact of reform on performance. Causality also operated strongly in the other direction. […] Indeed, the industrial innovation ladder predicts that causality should run from enterprise to reform" (Jefferson & Singh, 1999).

The dataset provides information on various types of reform undertaken by enterprises by year. The strong heterogeneity across enterprises, regions, industries and time, does not support a view of top-down initiated reforms. Naughton (1995) supports our view when he states that the ex-post apparent consistency of the reform process came about only because reforms were introduced in a heterogeneous/experimental fashion, where failures were disguised in the mass or by retrenchment. The information gathered in these initial, localised experiments were then reapplied to most SOEs in the mid-1980s, thus reducing the cost of implementation due to trial and error (McMillan and Naughton, 1992; Qian, 1999). It was not then a grand vision and divine leadership that has produced seemingly successful reform in Chinese SOEs, as one might be led to believe, but rather, the process was initiated from pressure at the grassroots level.

With respect to SOEs, prior to 1992 they were not privatised. Over the coming years there was a marked increase in levels of privatisation. Small SOEs were privatised at the county level and layoffs emerged at the city-level. This form of holding on to large enterprises was promoted by the slogan "*grasping the large and letting go of the small*". Small- and medium-sized enterprises made up 95 percent of SOEs in 1993, and in many provinces about half of these were privatised by 1996. At this stage some ten million workers had been laid off from SOEs, and a further 11.5 million in 1997. This appears typical of China's initially slow pace of reform, which then accelerates. Large-scale layoffs were never a feature in modern China prior to this. This analysis does not evaluate the benefit of privatisation after 1994. However, it does attempt to estimate the impact of competitive pressure coming from factor market liberalisation on productivity at the enterprise level under state ownership. Li (2003) using data from 1998 models the selection of enterprises to private ownership and finds the same decentralised nature of the reform process. The enterprises that faced the most competitive pressure and hardest budget constraints where the first to select to privatization.

III THE BEHAVIOURAL MODEL AND ESTIMATION PROCEDURE

As outlined above, the aim of this paper is to generate dynamic enterprise-level productivity estimates. A necessary condition for this analysis is the computation of consistent estimates of production function parameters. Since the productivity variable is not measured directly in our data, the possibility that selection to reform, as well as choice of factors of production, should depend on productivity type leads to two complications when attempting to estimate the parameters of a production function. The first complication appears if productivity levels observed by managers determine input levels. Thus, we face the classic simultaneity problem analysed by Marshak and Andrews (1944). The second complication arises out of the fact that some enterprises select to reform, while others do not.

The problems associated with entry and exit of companies is widely discussed in western literatures. Here we have a balanced panel of enterprises, but unbalanced panels of reformed and unreformed enterprises, since not all enterprises engage in reform, and those that do, select at different points in time. If the decision to induce reform is related to their productivity level, then our unbalanced panels of reformed

and unreformed enterprises result in part due to an endogenous selection process based on unobserved productivity. This would create selection bias in the production function estimates and lead to inconsistent estimates of production function parameters

Enterprises across different industries are assumed to produce homogeneous products with Cobb-Douglas technology. The log-linear production function to be estimated is given by

$$y_{it} = \beta_0 + \beta_a a_{it} + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \eta_{it} \quad (1)$$

Thus, the log of enterprise *i's* value added at time *t*, y_{it}, is modelled as a function of the log of that enterprise's state variables at t, namely age, a_{it}, capital, k_{it}, and the choice variable labour, l_{it}. The error structure is comprised of a stochastic component, η_{it}, with zero expected value, and a component that represents unobserved productivity differences, ω_{it}. Both ω_{it} and η_{it} are unobserved, but ω_{it} is a state variable, and thus affects firm's choice variables. On the other hand η_{it} has zero expected value given current information, and hence does not affect decisions.

Simultaneity means OLS estimates should provide biased estimates for inputs if ω_{it} is serially correlated, and the bias should be higher for more readily adjusted inputs. On the other hand, selection to the reform process has a negative bias on the capital coefficient. Enterprises with a higher capital stock have higher profits, ceteris paribus, and hence can select to reform with lower realisations of ω_{it} The entry to the reform process may be decreasing in *k*, producing a negative bias in the estimate of the capital coefficient.

Whether we treat reform as an exogenous or endogenous, the manager freely chooses labour and real investment levels. Given that a profit motive could be argued to exist more when the manager has control we allow the elasticity of value added with respect to labour to vary when mangers have autonomy over factors, compared to when they do not. In addition, the non-parametric relationship between investment and the observable and unobservable state variables is not specified ex-ante and can be allowed to differ across enterprises in unreformed and reformed states. Real investment, together with enterprise-level depreciation, δ_t, determines next period's capital stock. The accumulation equations for capital and age are given by $k_{t+1} = (1 - \delta_t)k_t + i_t$ and $a_{t+1} = a_t + 1$.

Two-Step Procedure: We assume that investment sequences, i_{it}, chase performance to some degree and are short-run decisions that are mainly determined by state variables such as the observable stock of physical assets, k_{it}, age of the enterprise, a_{it}, the unobservable productivity type of the company, $\omega_{it.}$, and the state of reform, r_{it} (1 or zero). Assume that $i_{it} = h_{it}(\omega_{it}, a_{it,}, r_{it}, k_{it})$ and more importantly can be inverted and differentiated, $\omega_{it} = h_{it}(i_{it}, , a_{it}, r_{it}, k_{it})$, generating the following regression:

(2) $$y_{it} = \beta_l l_{it} + \varphi_{it}(i_{it}, a_{it}, r_{it}, k_{it}) + \eta_{it}$$

where $\varphi_{it}(\bullet) = \beta_0 + \beta_a a_{it} + \beta_k k_{it} + \beta_r r_{it} + h_i(\bullet)$ and is proxied with a third-order polynomial in $i_{it,}$, a_{it}, r_{it} and k_{it}. We can allow for the possibility that the elasticity with respect to labour may change when the enterprise has autonomy over factors $r_{it} =1$. An interaction of labour with this reform dummy can control for this effect. The first term on the R.H.S. would be expanded to $\beta_l l_{it} + \beta_{lr} l_{it} * r_{it}$.

Since, one is unable to distinguish the effect of age, capital and reform on the investment and selection decision from that on output, we estimate our β_a, β_k and β_r using a non-linear least square estimator:

(3) $$y_{it+1} - \beta_l l_{it+1} = c + \beta_a a_{it+1} + \beta_k k_{it+1} + \beta_r r_{it+1} + \sum_{j=o}^{3} \beta_j \hat{h}_{it}^{j} + e_{it+1}$$

We proxy the fifth term on the R.H.S. of the equation with a third order polynomial in estimates of h_{it}, where the estimate of $h_{it}(\bullet) = \varphi_{it}(\bullet) - \beta_0 - \beta_a a_{it} - \beta_k k_{it} - \beta_r r_{it}$. We assume that ω_{it} follows a markov process allowing use to a one period lag in the non-linear structure for ω_{it}. In addition if we allowed for the possibility that the elasticity with respect to labour may change when the enterprise acquires the right to hire and fire labour in step 1, then the estimated coefficient on the interaction term times labour when the reform dummy equals 1 must be subtracted from the L.H.S of the above equation. We also include time and industry dummies in our regressions. The above may be re-written to allow for intercept shifts for each year and sub-industries.

Three-Step Procedure: The estimation of the return to labour in the production function above can be extended to control for selection bias, the probability (ρ_{it}) of

being in a reformed state ($r_{it} = 1$) is modelled given the firm's productivity type and other set of characteristics, X_{it} :

$$(4) \qquad Pr\{ r_{it} = 1 | \omega_{it}, a_{it}, k_{it}, X_{it}\} = \rho_{it}(i_t, a_{it}, k_{it}, X_{it})$$

To estimate unbiased estimates of β_l, partially linear equation is a semi-parametric regression model allowing for both selection and simultaneity bias, one can proxy for $\varphi_{it}(\bullet_t)$ with a third order polynomial in i_{it} , a_{it}, k_{it} and ρ_{it} . This can be run on sub-samples of enterprise in reformed and unreformed states to allow all for the possibility that the elasticity with respect to labour may chance when the enterprise has autonomy over factors, $r_{it} = 1$, and in addition the parameters of the third order polynomial in i_{it} , a_{it}, k_{it} and ρ_{it} can be different.

In step 3, to distinguish the effect of capital and age on the investment and selection decision from that on output, we estimate our β_a and β_k using a non-linear least square estimator:

$$(5) \qquad y_{it+1} - \beta_l l_{it+1} = c + \beta_a a_{it+1} + \beta_k k_{it+1} + \sum_{j=o}^{3-m} \sum_{m=0}^{3} \beta_{mj} \hat{h}_{it}^{j} \hat{\rho}_{it}^{m} + e_{it+1}$$

We proxy the fourth term on the R.H.S. of the equation with a third order polynomial in estimates of h_{it} and ρ_{it} (reform probability), where the estimate of $h_{it}(\omega_{it}, k_{it}) = \varphi_{it}(i_{it}, k_{it}) - \beta_0 - \beta_a a_{it} - \beta_k k_{it}$. We assume that ω_{it} follows a markov process allowing use lag one period in the non-linear structure for ω_{it}. Again this can be estimated in sub-samples of enterprises in reformed and unreformed states to allow for different β's in reformed and unreformed samples. We also include time and industry dummies in our regressions. The above may be re-written to allow for intercept shifts for each year and sub-industries.

IV RESULTS

In this section the results of the regressions are reported. The summary statistics of the data are outlined in Table 1 and detail of data construction is outlined in Appendix I. Enterprises with control over factors, are older, bigger in terms of employment, capital and value added, and investment is larger.

To begin with, the reform status of an enterprise is treated as exogenous, or randomly assigned. In this context OLS and GLS within estimators are contrasted with the Olley-Pakes 2-step estimator in Table 2. The standard errors of the Olley-Pakes coefficients are bootstrapped and clustered by 2-digit industry codes. Comparing GLS estimates and the Olley-Pakes 2-step, see that the co-efficient on labour is higher than the Olley-Pakes first-step estimates. Also, the GLS estimates for the co-efficient on capital are significantly lower than the Olley-Pakes second stage estimates. The reform dummy estimated in the second step and its interaction with labour is significant and positive in Olley-Pakes two-step estimates as in the OLS regression but are negative when we use the within group estimator. We report aggregated productivity measures for each year aggregating over reformed and unreformed enterprises using our 2-step Olley-Pakes consistent estimates, where productivity is measured as $TFP_{it} = exp(y_{it} - \beta_l l_{it} - \beta_a a_{it} - \beta_k k_{it})$. Productivity in table 4 is a weighted average of enterprise productivity, weighted by real value added, suggest that the Olley-Pakes 2-step productivity estimate is to some degree larger for the set of reformed versus the unreformed enterprises after 1984. In Figures III the distribution of our estimates of productivity across reformed and non-reformed enterprises are compared, by graphing the log distributions computed from using a simple OLS model, GLS and 2-step Olley and Pakes procedure. The imposed distribution allows us to easily compare productivity distributions across graphs. Differences in productivity distributions across reformers and non-reformers are not that pronounced across the reformed and non-reformed population.

We next allow for the reform status of an enterprise to be endogenous to its productivity type in our 3-step procedure. After estimating the labour coefficient for both sub-samples, one progresses by estimating coefficients for age and capital, allowing semi-parametrically for simultaneity and selection bias in the unobservable productivity. By splitting the sample according to reform status, technology is implicitly allowed to vary across the sub-samples, as it the investment decision and its relation to state variables. The standard errors of the Olley-Pakes coefficients are bootstrapped and clustered by 2-digit industry codes.

In Table 5 we note that the coefficient on labour drops and capital increases significantly relative to the GLS estimator. In the unreformed sub-sample the return to observable factors is higher, but what about the evolution of the unobservable? In

Table 6 and 7 we again report unit and output weighted average aggregate TFP estimates. It seems clear that productivity for the reformers, allowing for an endogenous split of the data, is on average higher for the reformed enterprises vis-à-vis the unreformed enterprises. Finally, in Figure IV the distribution of our estimates of productivity across reformed and non-reformed enterprises are compared, by graphing the log distributions computed from using the 3-step Olley and Pakes procedure. The imposed distribution allows us to easily compare productivity distributions across graphs. While the 3-step Olley and Pakes procedure produces lower productivity estimates, on average, across reformers and non-reformers, the difference between the reformed and non-reformed population is much more pronounced. This highlights the importance of allowing for selection to reform biases when one is estimating productivity dynamics during institutional change. The adapted 3-step Olley and Pakes procedure allows us to do this with relative ease.

V CONCLUSION

Using a unique balanced panel of 680 State-Owned Enterprises in the industrial sector of China during 1980 to 1994 we outline a methodology to estimate productivity dynamics allowing for the level and changes in the unobservable to be affected by discrete endogenous enterprise-level institutional change, among other factors.

Consistent production function estimates were found using an adapted algorithm, initially outlined in Olley and Pakes (1996), which allows one to control for simultaneity and (our innovation) endogenous selection to reform biases. This gave us dynamic productivity estimates that allows for consistent comparisons across groups and time. The conclusion of this analysis is that enterprises that exhibited better performance were more likely to take control over factor inputs and such competitive pressures induced further productivity improvements under state ownership.

TABLES

Table 1 Summary Statistics for the Whole Sample, and Reformed & Non-Reformed Sub-Samples

Sub-Sample Variable	Whole Sample		Non-Reformed		Reformed	
Age	Obs	10185	Obs	7287	Obs	2898
	Mean	27.04	Mean	24.93	Mean	32.32
	Std. Dev.	13.59	Std. Dev.	13.12	Std. Dev.	13.31
Value Added	Obs	9355	Obs	6650	Obs	2705
	Mean	1899.6	Mean	1659.9	Mean	2488.924
	Std. Dev.	3975.7	Std. Dev.	3777.5	Std. Dev.	4370.535
Labour	Obs	10025	Obs	7133	Obs	2892
	Mean	1719.5	Mean	1682.2	Mean	1811.5
	Std. Dev.	2705.5	Std. Dev.	2662.5	Std. Dev.	1992.9
Capital	Obs	9269	Obs	6618	Obs	2651
	Mean	2056.8	Mean	1813.473	Mean	2664.1
	Std. Dev.	4634.5	Std. Dev.	4100.22	Std. Dev.	5711.6
Investment	Obs	9344	Obs.	7062	Obs	2282
	Mean	316.0	Mean	09.82	Mean	335.09
	Std. Dev.	444.0	Std. Dev.	2573.0	Std. Dev.	1992.9
Reform Dummy	Obs	10185	Obs	7287	Obs	2898
	Mean	0.28	Mean	0	Mean	1
	Std. Dev.	0.45	Std. Dev.	0	Std. Dev.	0

Notes : This table provides the summary statistics for the entire sample of, and sub-samples of non-reformed and reformed, enterprises of variables central to the analysis. All variables are in 10,000 Yuan, apart from Age (Years), Labour (average number of workers), and reform dummy equal to one when an enterprise has control over either the hiring and firing of labour, investment, the buying and selling of assets and the right to buy and sell intermediates on international markets, zero otherwise. Statistics reported are: the number of observations (Obs.) considered, and their mean score (Mean) and standard deviation (Std. Dev.) on that variable.

Table 2 Alternative Estimates of Production Function Parameters Assuming Random Selection into an Exogenous State of Reform

Variable \ Estimator	(1) OLS	(2) GLS	(3) Two-Step Olley-Pakes
Labour	0.55*	0.84*	0.51*
	(0.02)	(0.04)	(0.02)
Labour * Reform Dummy	0.06*	-0.04*	0.11*
	(.03)	(0.02)	(0.03)
Capital	0.36*	0.19*	0.34*
	(0.01)	(0.02)	(0.02)
Age	0.25*	0.32*	0.16*
	(0.02)	(0.05)	(0.03)
Reform Dummy	0.06*	-0.09*	0.12*
	(0.03)	(.02)	(0.03)
Time Trend	Yes	Yes	Yes
Fifth Order Polynomial Expansio n in *h*	-	-	Yes $\chi 2$ (5) = 4,680
Observations	8,330	8,330	6,026
R-sq	0.56	0.55	0.95

Notes: The dependent variable in regressions (1) and (2) is the log of value added. In column (3), for the labour coefficients has log(Value Added) was the dependent variable in step 1 of Olley and Pakes (Labour, Labour interaction with Reform and the polynomial in Age, Capital, Reform and Investment). In column (3), capital and age coefficients, the dependent variable is log(Value Added) – b_1*log(Labour) – b_2*log(Labour)*log(Reform) Figures in brackets are standard errors. The Olley-Pakes 2-step standard errors are bootstrapped with 1000 replications, clustered by industry.

Table 3 Unit-Weighted Average TFP from the 2-Step Procedure

	Unreformed Sample	Reformed Sample
Year	Mean TFP	Mean TFP
81	1.22	-
82	1.32	-
83	1.69	1.64
84	1.58	1.14
85	1.76	2.01
86	1.87	2.22
87	1.94	2.07
88	2.35	2.56
89	2.18	2.35
90	2.22	2.66
91	1.89	2.47
92	1.72	2.59
93	2.06	2.71

Note: This table reports the unit-weighted average total factor productivity estimate generated by the 2-Step Olley-Pakes algorithm, by year, for reformed and un-reformed sub-samples.

Table 4 Output-Weighted Average TFP from the 2-Step Procedure

	Unreformed Sample	Reformed Sample
Year	TFP*($y_i/\Sigma y$)	TFP*($y_i/\Sigma y$)
81	1.43	-
82	1.52	-
83	2.05	1.80
84	1.81	1.22
85	2.01	2.28
86	2.13	2.55
87	2.20	2.29
88	2.72	2.84
89	2.49	2.64
90	2.57	3.03
91	2.15	2.85
92	2.03	2.98
93	2.47	3.20

Note: This table reports the output-weighted average total factor productivity estimate generated by the 2-Step Olley-Pakes algorithm, by year, for reformed and un-reformed sub-samples.

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Table 5 OP 3-Step Productivity Estimates with Endogenous ReformSelection

Variable \ Sample	(4) Reformed Sample	(5) Non-Reformed Sample
Labour	0.44* (0.05)	0.52* (0.02)
Capital	0.38* (0.04)	0.47* (0.03)
Age	0.22* (0.08)	0.33* (0.07)
Time Dummies	Yes	Yes
Third Order Polynomial Expansion in P & h	Yes $\chi 2$ (15) = 1,783	Yes $\chi 2$ (15) = 3,415
Observations	1,083	4,543
R-sq	0.96	0.93

Notes: The regression for the labour coefficients has log(Value Added) was the dependent variable. (Labour, Labour interaction with Reform and the polynomial in Age, Capital, Investment and the probability of been a reformer). For capital and age coefficients, the dependent variable is log(Value Added) – b_1*log(Labour). Figures in brackets are standard errors. Olley-Pakes 3-step standard errors in brackets, bootstrapped with 1000 replications clustered by industry.

Table 6 Unit-Weighted Average TFP Estimates from 3-Step OP

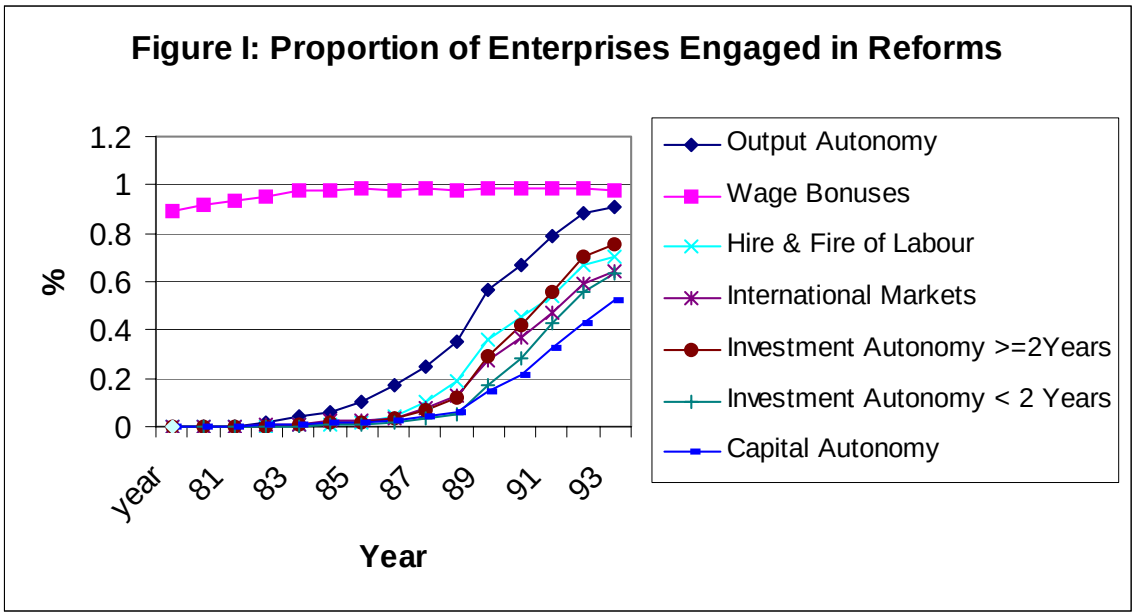
	Unreformed Sample	Reformed Sample
Year	Mean TFP	Mean TFP
81	0.32	-
82	0.34	-
83	0.41	2.31
84	0.39	1.2
85	0.42	1.7
86	0.44	2.71
87	0.44	2.48
88	0.52	2.62
89	0.48	2.65
90	0.48	2.73
91	0.40	2.66
92	0.35	2.78
93	0.42	2.71

Note: This table reports the unit-weighted average total factor productivity estimate generated by the 3-Step Olley-Pakes algorithm, by year, for reformed and un-reformed sub-samples.

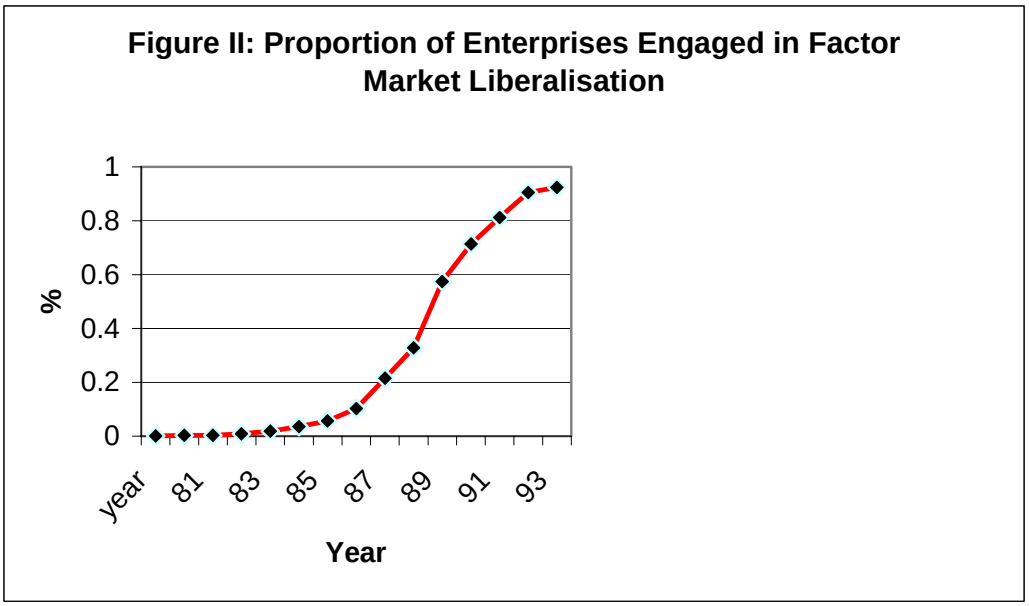
Table 7 Output-Weighted Average TFP Estimates from 3-Step OP

	Unreformed Sample	Reformed Sample
Year	TFP*($y_i/\Sigma y$)	TFP*($y_i/\Sigma y$)
81	0.35	-
82	0.37	-
83	0.47	2.5
84	0.42	1.21
85	0.46	1.84
86	0.47	2.99
87	0.47	2.65
88	0.57	2.81
89	0.51	2.82
90	0.52	2.96
91	0.34	2.97
92	0.43	3.09
93	0.39	3.01

Note: This table reports the output-weighted average total factor productivity estimate generated by the 3-Step Olley-Pakes algorithm, by year, for reformed and un-reformed sub-samples.

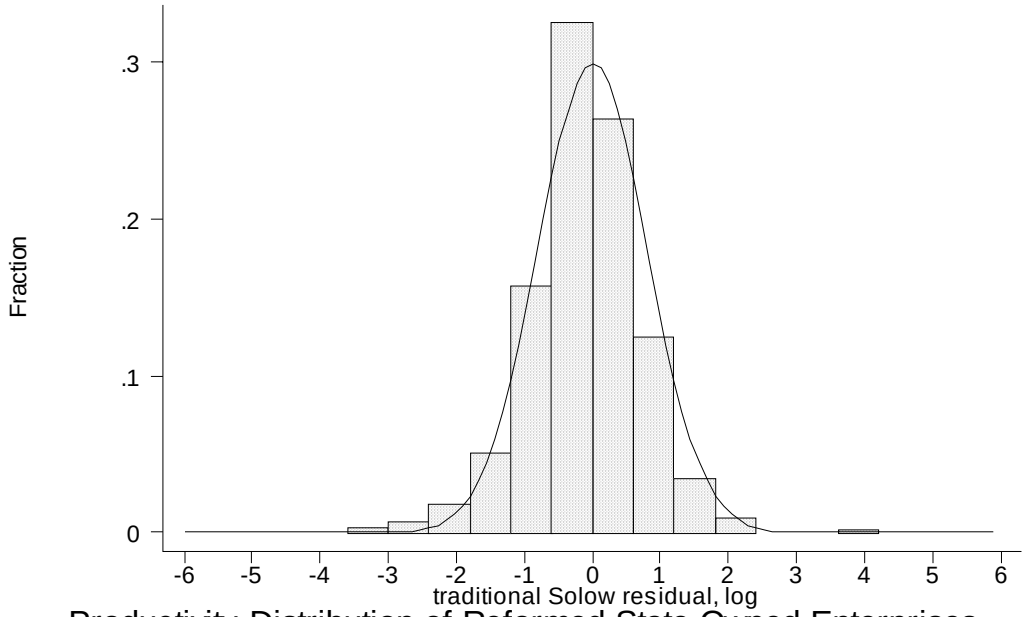


This figure sums up the percentage of enterprises that gained certain types of autonomy [Autonomy in setting output, payment of wage bonuses, hiring and firing of labour, long-run investment (>=2 years), short-run investment (<2 years), importing raw materials on International Markets, and buying and selling of Capital Assets over the 1980-1994 period.

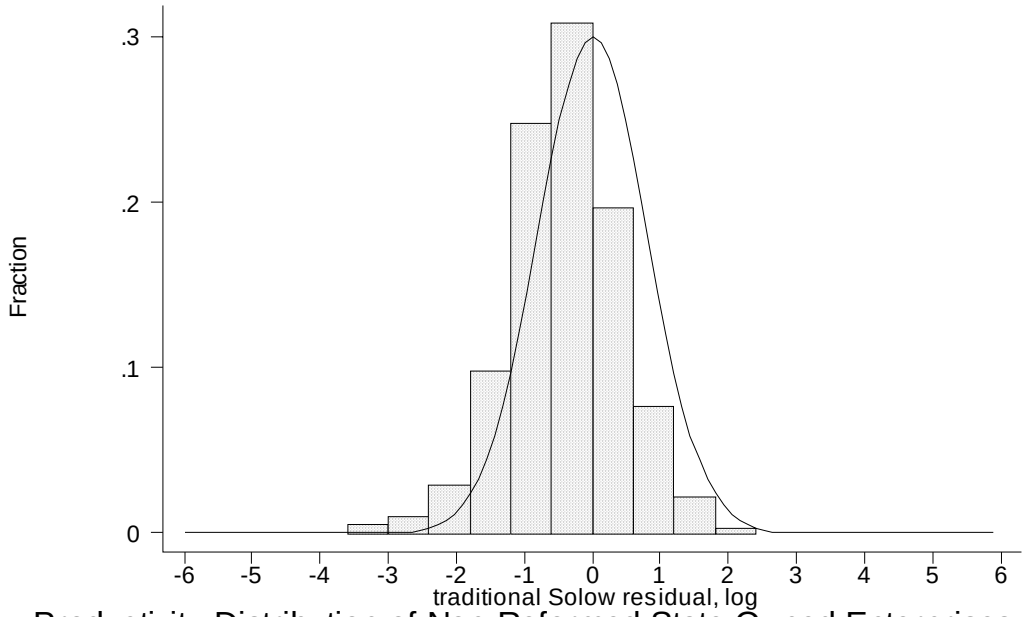


This figure sums up the percentage of enterprises that gained autonomy over factor markets reflecting a dummy equal to one when an enterprise has control over either, the hiring and firing of labour, investment, the buying and selling of assets and the right to buy and sell intermediates on international markets, zero otherwise over the 1980-1994 period.

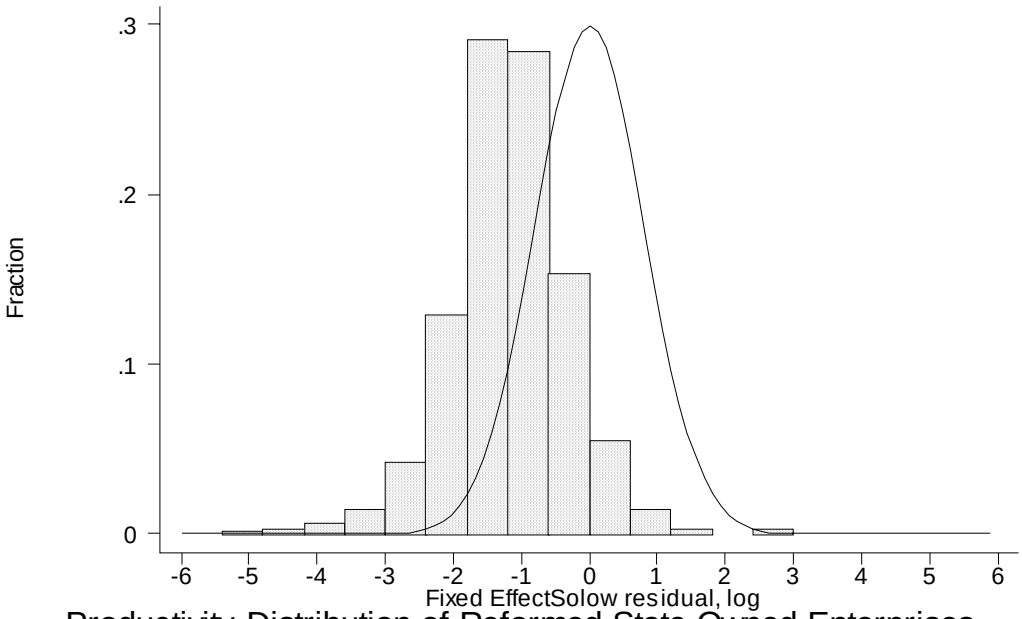
Figure III: Reformed versus Unreformed State-Owned Enterprises' Productivity Estimate Distributions (Estimated from OLS, GLS, and OP 2-Step Procedures, respectively)



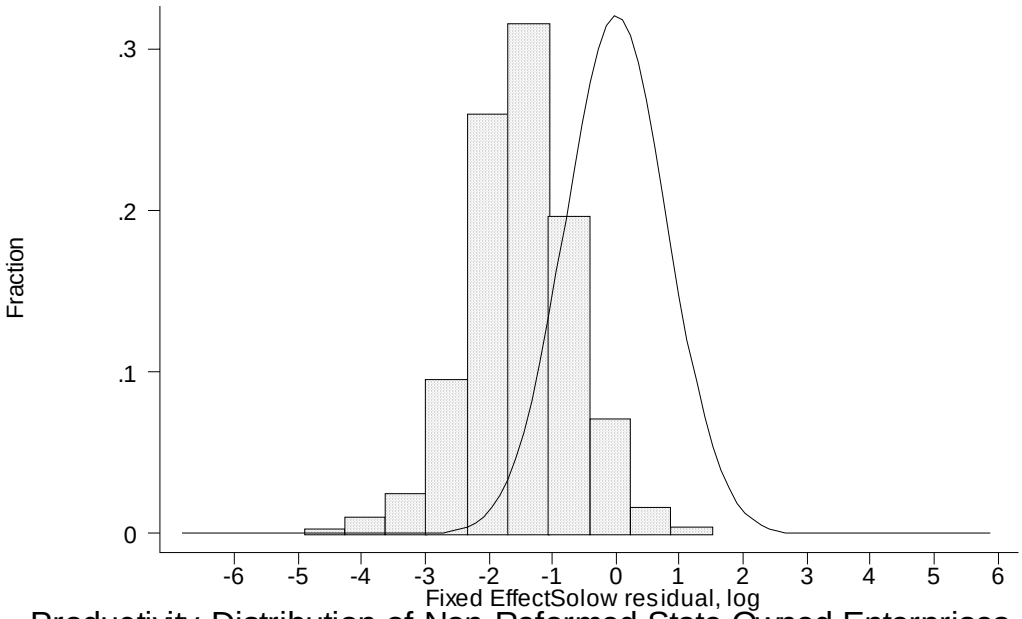
Productivity Distribution of Reformed State Owned Enterprises



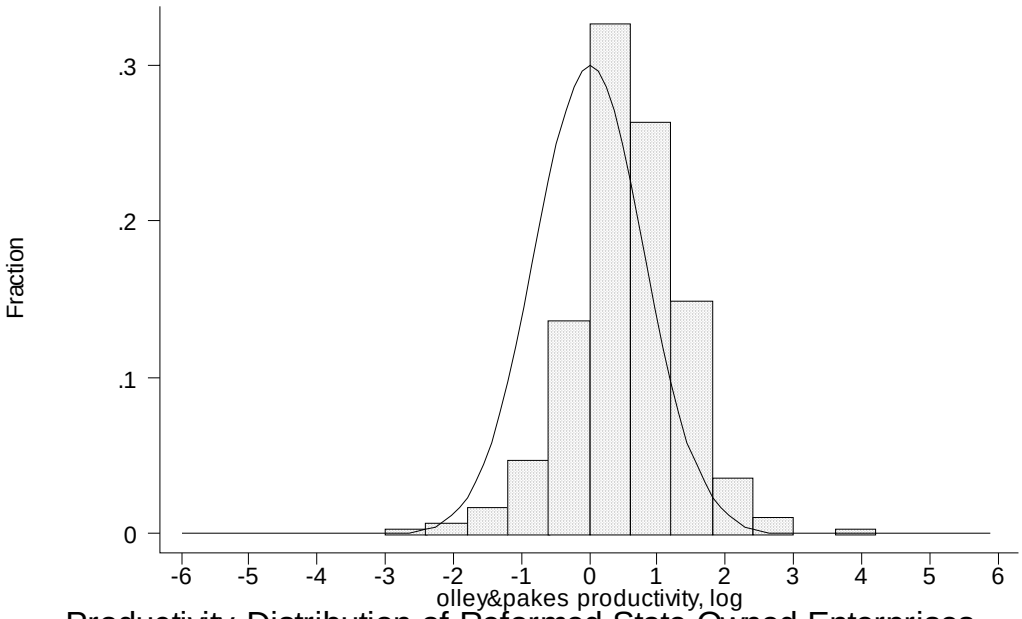
Productivity Distribution of Non-Reformed State Owned Enterprises



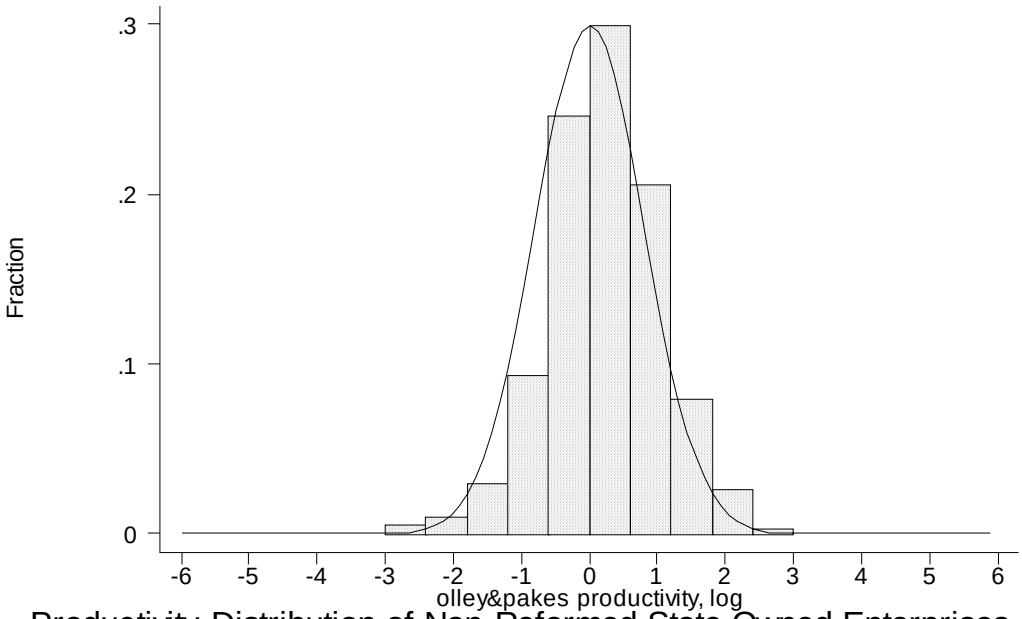
Productivity Distribution of Reformed State Owned Enterprises



Productivity Distribution of Non-Reformed State Owned Enterprises



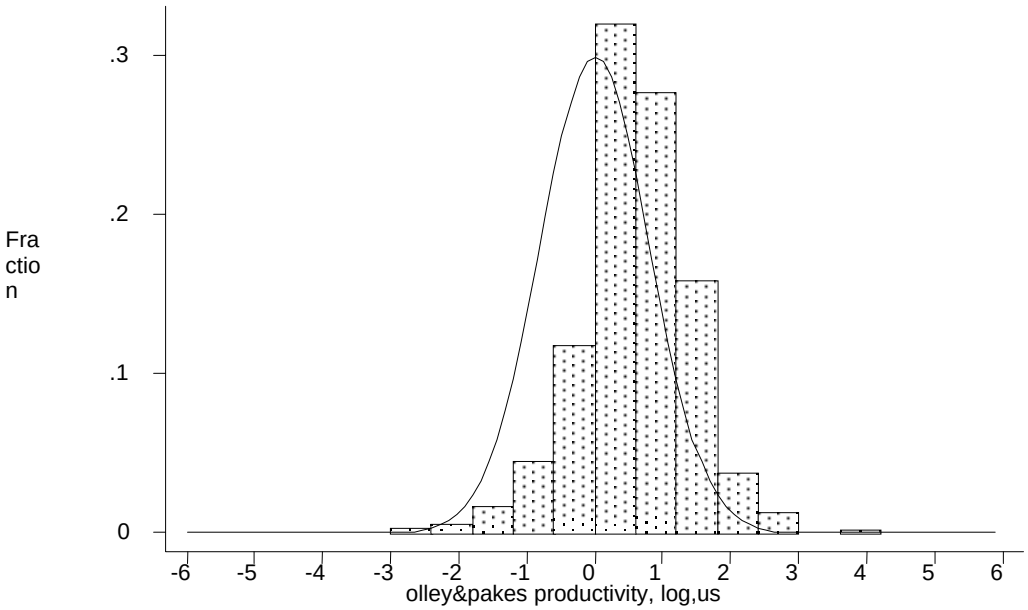
Productivity Distribution of Reformed State Owned Enterprises



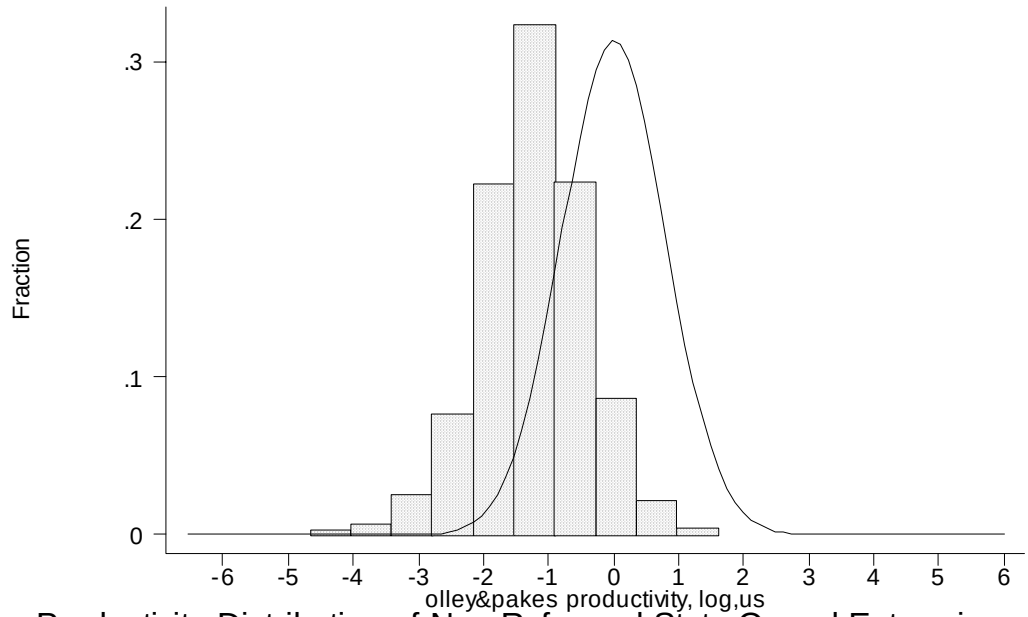
Productivity Distribution of Non-Reformed State Owned Enterprises

Note: This figure plots the distribution of the log of productivity estimates, generated by OLS, GLS fixed effects, and using the Olley-Pakes 2-Step procedure for reformed and non-reformed sub-samples. The 'Normal' curve is simply superimposed and centred on zero for illustrative purposes.

Figure IV: Reformed versus Unreformed State-Owned Enterprises' Productivity Distribution Estimates from the OP 3-Step Procedure.



Productivity Distribution of Reformed State Owned Enterprises



Productivity Distribution of Non-Reformed State Owned Enterprises

Note: This figure plots the distribution of the log of productivity estimates, generated by using the Olley-Pakes 3-Step procedure for reformed and non-reformed sub-samples. The 'Normal' curve is simply superimposed and centred on zero for illustrative purposes.

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APPENDIX I: THE DATA

In what follows we will describe our data. We will proceed by first describing general features of the raw data and how we have used them to generate the actual dataset we use in our analysis. The data are compiled from SOE surveys conducted by the Institute of Economics, Chinese Academy of Social Science (CASS), in consultation with a dozen economists from Michigan and Oxford Universities, as well as from the University of California, San Diego. These surveys are unique in detail and quality.

In total we have four individual sets of data, which can be subdivided into two different types of data. The first type is contained in two sets and contains quantitative information on individual enterprises, which is supplied annually by each enterprise's accountant. These data have been recorded over two time periods. The first dataset ranges from 1980 to 1989, and the second ranges from 1990 to 1994. The earlier dataset contains 769 enterprises, while the latter dataset contains a subset of the enterprises represented in the first, namely 681 enterprises.

The second type of data is qualitative in nature, since it deals with the institutional environment of the firm, and also comprises two sets. The data represent the answers of each enterprise's manager to a questionnaire in 1990 and 1995. Thus, the institutional questionnaires append the final year of the quantitative questionnaires, and hence they each contain information on exactly those enterprises that were present in the respective antecedent quantitative datasets.

Since some the questions posed have not remained identical, it is important that we give a detailed account of how we constructed the variables in our dataset from these. We proceed by describing the features of the quantitative questionnaires first, followed by a description of the institutional ones.

The 1980-1989 quantitative questionnaire contains 321 questions which are subdivided into twelve categories, labelled *Output*, *Production Expenses*, *Wages*, *Labour and Personnel*, *Operations*, *Investment*, *Capital Accounts*, *Profit Accounts*, *Profit Retention and Enterprise Funds*, *Supplementary Materials*, *Costs of Main Products*, and *Other*.

The 1990-1994 accounts questionnaire contains 166 questions, which are subdivided into eight categories, *Output*, *Input*, *Wages*, *Financial Condition*, *Assets*, *Liability and Equity*, *Investment*, and *Utilisation of Capacity*.

The two institutional questionnaires are very similar. The 1990 one contains seventy questions in five categories, the 1995 one has eighty-four questions subdivided into six sections. Both have sections entitled *Enterprise Characteristics*, *Contract and Management Appointment*, *Relations Between Enterprise and Its Supervisors*, *Internal Incentive Stem*, and *Management Characteristics*. The 1995 questionnaire has an extra section with the title *Property Rights and asset Structure*, although many of the questions were already present in the 1990 questionnaire. Of these two we only need to make use of the 1995 questionnaire.

The remainder of this appendix deals with the quantitative questionnaires, and with how we created the variables from these, which now form our data series from 1980 through 1994. We will subdivide this section into various categories, depending on the type of variable we are dealing with.

TABLE A1: FIRM CHARACTERISTICS

Variable \ Dataset	Symbol	1980-1989	1990-1994
ENTERPRISE IDENTIFIER	id	Unique Identifier for each firm {1 - 769}	
Location	*loc*	Three digit number, first indicates province and last the district	
Industry	*ind*	Number from 0 – 40, indicating the industry the firm belongs to	
Operation Year	*Op_y*	Year from which an enterprise commenced operation	

Table A1 describes some of the unchanging firm characteristics. Each of the 681 firms has its own unique identifier in form of a firm identification number, ranging from 1 to 769. An enterprise's location is given by a three digit number, where the first number identifies the province a company resides in, and the last identifies the district in that province; the middle digit is a separator and is always zero. The industry affiliation of an enterprise is indicated by its industry code, which is a

number between one and forty. The year of operation is given by a two-digit number, which indicates the year in the twentieth century that a firm commenced its operation.

Table A2 is concerned with the creation of our Real Value Added Variable, which has been constructed from variables in the raw data and some deflators. We have enterprise's value of output in present prices as well as in the prices of the base year for each dataset, namely 1980 and 1990. In order to get a consistent series spanning 1980-1994 we decided to make use of the 1980-1989 real value of output series, and then applied a deflator, with 1980 as base year, to the present value of output 1990-1994 series. The deflator supplied was by Changqi Wu. In addition, we have information on the value of raw materials consumed. By making use of the prices of the primary inputs and the quantities they were used in, we have constructed a firm-level material input deflator. Thus, we can create a variable that gives us the value of raw materials consumed at 1980 prices. When we subtract this real raw materials variable from real output value, we gain a variable that measures the value added for each enterprise in each year.

TABLE A2: REAL VALUE ADDED

Variable \ Dataset	Symbol	1980-1989	1990-1994
Nominal Output	*Yn*	Current Price Value of Output in 10,000 Yuan	Total Value of Gross Output of Enterprise (present Value) in 10,000 Yuan
Base Year Output	*Yr*	Actual Value of Output (1980 Fixed Prices) in 10000 Yuan	Total Value of Gross Output of Enterprise (based on 1990 value) in 10,000 Yuan
Output Deflator	*ydef*	Nominal Divided by Real	Output Deflator in 1980 Prices (Li & Wu, 2002)
OUTPUT	***YR = YN/YDEF***	Actual Value of Output (1980 Fixed Prices) in 10,000 Yuan	Nominal Output divided by 1980 prices Deflator in 10,000 Yuan
Materials	*mn*	Total Raw Material Consumption in 10,000 Yuan	Total Raw Material Consumption 10,000 Yuan
Material Deflator	**mdef**	Firm level raw material price index as calculated by Changqi, replaced by industry level deflator if missing. 1980 Base Year.	
REAL MATERIALS	***M= MN/MDEF***	Materials Divided by the 1980 Prices Material Deflator	
Real Value Added	***y = yr - m***	Real Output minus Real Materials	

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Table A3, the labour variable simply measures the number of employees the enterprise employed at year-end.

Table A3: Labour

Variable \ Dataset	Symbol	1980-1989	1990-1994
LABOUR	*l*	Workers at Year End	Total Number of Employees

Table A4 contains information on how we created our Real Capital Stock and Real Investment variables. The 1980 level of the real capital stock is given by the net capital asset position of each enterprise. For every following year we create a new Real Capital Stock value, which is given by the previous year's real capital stock, adjusted for firm level depreciation, to which we add Real Investment, which is investment in 1980 prices. Each of these constituent variables will be discussed in turn. Investment is deflated by a machinery output price index, with 1980 as base year, which yields Real Investment. Investment itself is given, where available, by productive fixed investment for the years 1980-1989. Where it is not available, which includes the years following 1989, we use the year on year change in productive capital. Productive Capital, in turn, is given by the cumulative value, that is adding up receipts of purchases, of industrial production related fixed assets for all years. We get firm level depreciation rates by dividing depreciation by the capital stock. For the years 1980 to1989 depreciation is defined as the year on year change in cumulative depreciation. For the years 1990 to 1994 we use depreciation of fixed assets for the year. The Capital Stock is the cumulative value of fixed assets.

Table A4: Investment and Capital Stock Variables

Variable \ Dataset	Symbol	1980-1989	1990-1994
Net Capital	*netk*	Net Value of Fixed Capital, end of 1980	N/a
Capital	**kn**	Fixed assets, at Purchase Price, year end	Original Price of Fixed Assets
Productive Capital	*kprodn*	Industrial Production Fixed Capital Part of Capital	Original Price of Industrial Production Fixed Capital Part of Capital
Depreciation	*deprn*	Net change in cumulative nominal depreciation, year on year in 10,000 Yuan	Depreciation of fixed assets of the year in 10,000 Yuan
Machinery Price Index	*mpi*	Machinery Output price Index	
Real Capital	*kr = kn/mpi*	Capital divided by 1980 based machinery output price index	
Real Depreciation	*depr = deprn/mpi*	Depreciation divided by 1980 based machinery output price index	
Depreciation Rate	$\delta = depr/kr$	Depreciation divided by Capital	
Investment	*in*	Productive Fixed Investment	
Real Investment	***i = in/mpi***	Investment deflated by 1980 based machinery output price index	
Real Capital Stock	***k***	1980	1981-1994
		$k_{80} = netk_{80}$	$k_{t+1} = k_t(1-\delta_t)+ i_t$

TABLE A5: REFORM VARIABLES

Variable \ Dataset	Symbol	1995 Questionaire
Output Autonomy	*Output*	Year from which had autonomy over output, its value, and daily regular decisions
Hiring and Firing Autonomy	Hire and Fire	Year from which had autonomy over employing and dismissing workers
Import and Export Autonomy	Trade	Year from which had autonomy over exporting products and importing materials
Short-run Investment Autonomy	Investment_min2	Year from which had autonomy over investment with a recovery period within two years
Long-run Investment Autonomy	Investment_max2	Year from which had autonomy over investment with a recovery period above two years
Autonomy over Buying and Selling Assets	Buy and Sell Assets	Year from which had autonomy over the purchase and sale of assets
Reform Dummy	Reform Dummy	Dummy equal to one when an enterprise has control over either hiring and firing of labour, investment, the buying and selling of assets and the right to buy and sell intermediates on international markets, zero otherwise over the 1980-1994 period.

When a manger gets autonomy over one factor investment there is a push to be able to have autonomy over all. Hence we have a dummy equal to one when an enterprise has control over any factor.