5. Productive performance of Chinese state-owned enterprises in the early 1990s: a stochastic production frontier and Malmquist productivity index analysis

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INTRODUCTION

Low efficiency and the absence of incentives were two serious problems in pre-reform Chinese state-owned enterprises (SOEs). Targeting these problems, the Chinese government initiated industrial reforms in 1979. During the first 10-year reform period, the reform measures mainly focused on increasing the SOEs' autonomy, on profit sharing between the governments and enterprises, and on implementing various forms of the 'responsibility system'. The first two years of the 1990s did not see much change, but following Deng Xiaoping's trip to south China, a new round of industrial reforms began in 1992. Compared with previous reforms, the new round of reforms emphasized the transformation of SOEs' managerial mechanisms and ownership structures. During this period, various contract systems were implemented by most SOEs. New managerial mechanisms and ownership structures were also introduced and experimented with. In addition to the existing manager-responsibility and contract system, corporate shareholding, leasing, selling and so on were also experimented with as possible solutions to the problems facing SOEs.

Using an enterprise survey data set covering the years 1990–94, this chapter attempts to determine the tendencies of technical efficiency change, technical progress and total factor productivity (TFP) growth of Chinese SOEs in the early 1990s. How the reform measures affected technical efficiency and TFP growth, what the sources of TFP growth are, and what is responsible for slow or stagnant growth are the questions we attempt to answer.

A large amount of literature on Chinese industrial reform and productive efficiency has appeared in various journals and books since the mid-1980s. Most studies have adopted the conventional production function approach, which assumes that all firms succeed in maximizing output, so that the discrepancies between actual output and potential output can be attributed to a symmetric error with zero mean. Technical inefficiency is not allowed for in this approach. Hence, technical change, technical efficiency and TFP are seen as equivalent. Most studies using this approach conclude that there was a significant improvement in productive efficiency, measured by TFP growth: for example, Chen et al. (1988) estimated that the average TFP growth was about 5.9 per cent per annum in the period 1978–85; Jefferson et al. (1992) concluded that this rate was 2.4 per cent per annum from 1980 to 1988.

A few studies have used the stochastic frontier production function framework. This method admits the possibility of technical inefficiency and distinguishes technical efficiency, technical change and TFP, positing that the growth in TFP is the sum of the change in technical efficiency and the shift of the production frontier. The former represents the change in output to the 'best practice' production technique or equivalent to the production frontier, while the latter represents the change in the production frontier itself. Early applications of the stochastic frontier production function to Chinese data include Lau and Brada (1990), Kalirajan and Cao (1993), Kalirajan and Zhao (1994), Wu (1993, 1996), and Chen (1994). Most of these studies used pre-1990 data. The findings are similar: low initial efficiency scores in the early 1980s and continuing improvement in the efficiency level, with a number of reform measures found to be significant in promoting efficiency levels.

More recently, Liu and Liu (1996) analysed efficiency in Chinese industries and concluded that reform-induced gains in technical efficiency (TE) were significant and that the bonus system had impressive efficiency effects. Conversely, Huang et al. (1998) decomposed TFP growth into technical efficiency change (TEC) and technical change (TC). They found that while TE had improved, technical regress was present in the industries under consideration. As a consequence, TFP growth was found to be stagnant or even declining.

This study attempts to combine the stochastic frontier production function with the Malmquist productivity index (MPI). In doing so we not only obtain technical efficiency estimates but technical change and TFP growth. A stochastic frontier production function for panel data proposed by Battese and Coelli (1995) is first used to estimate the production frontier and efficiency function. Then distance functions are calculated and technical change and the MPI are estimated. The study contributes to the efficiency and productivity analysis literature in that (1) the MPI is combined with the parametric production frontier to estimate the TFP; and (2) a new method to calculate distance functions from the parametric production frontier is proposed. The results of the study provide insights into the Chinese industrial reform and shed some new light on the controversy issue – Chinese SOEs' productivity growth and the effects of industrial reform.

The chapter is organized as follows: the second section briefly introduces the theoretical model; in the third section the data set and variables used are described; the empirical analysis is presented in the fourth section; a fifth section concludes the chapter.

STOCHASTIC FRONTIER PRODUCTION FUNCTION AND MPI

Stochastic Frontier Production Function

Neoclassical production theory does not usually admit of the long-term existence of inefficiency, holding that if a firm is operating inefficiently, it will eventually be squeezed out of the market. But this conclusion is reached in a perfectly competitive market, which does not exist in reality. Inefficiency not only exists in practice but sometimes is prevalent. Recognizing this, Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) first introduced the stochastic production function model. Their basic idea was to introduce a non-positive component in the error term of the production function, which captures the inefficiency effect. Mathematically, it can be expressed as follows.

$$Y_i = f(X_i, \beta)e^{v_i - u_i},$$

where Y_i is the output of firm i, X_i is a vector of the inputs (time could be one of the inputs); and β is a vector of parameters to be estimated. In terms of error, v is distributed as $N(0, \sigma_v^2)$ and captures random variation in output due to factors outside the control of the firm. On the other hand, $u \geq 0$ reflects technical inefficiency.

A stochastic frontier production function for panel data can be defined as follows:

$$\ln(y_{it}) = \ln f(x_{it}, t, \beta) + v_{it} - u_{it}, \quad i = 1, 2, \ldots, N, \quad t = 1, 2, \ldots, T, \qquad (5.1)$$

where y_{it} is the output of the i-th firm in the t-th year; x_{it} denotes a $(1 \times k)$ vector of inputs; $f(\cdot)$ is a suitable functional form (for example, Cobb–Douglas or translog); the v_{it}'s are random errors, assumed to be i.i.d. (independent indentical distributed) and have $N(0, \sigma_v^2)$ distribution, independent of the u_{it}'s; and the u_{it}'s are the technical inefficiency effects. Following Battese and Coelli (1995), u_{it}'s are assumed to be distributed independently of v_{it}'s, such that u_{it}'s are the non-negative truncation of the $N(m_{it},\ \sigma_u^2)$ distribution, where m_{it} is defined as

$$m_{it} = \delta_0 + \sum_{k=1}^{n} \delta_k z_{kit}, \tag{5.2}$$

where z_{it} are firm-specific factors that influence technical inefficiency, and δ's the unknown parameters to be estimated.

The technical efficiency of production for the i-th firm at the t-th period of observation, TE_{it}, is defined by:

$$TE_{it} = \exp(-u_{it}) = \exp(-z_{it}\delta - w_{it}), \tag{5.3}$$

where w_{it} is a random variable defined by the truncation of the normal distribution, with zero mean and variance σ_μ^2.

The variance parameters are defined as $\sigma_s^2 = \sigma_\upsilon^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma_s^2$.

Derivation of MPI in Parametric Stochastic Frontier Framework

Nishimizu and Page (1982) proposed for the first time a methodology to decompose TFP growth into TEC and TC using the parametric frontier analysis framework. But the production frontier they used is deterministic frontiers. Besides, they suggested estimating technical change by finding the arithmetic mean of two technical change rates at adjacent periods, t and $t + 1$. Perelman (1995) estimated TFP growth in an international and sectoral setting by decomposing TFP into TC and TEC. But he only considered the situation where technical change is Hicks neutral, and the concept of the distance function was not used to combine TC and TEC in his parametric approach. Wu (1995) advanced a way to combine TC and TEC into TFP, and analysed TFP growth in three sectors in China: state, rural and agriculture. But again he considered only Hicks-neutral technical change in the production frontier.

Coelli, Rao and Battese (1998) combined TEC and TE by the MPI and estimated TFP growth for Australian electricity generation plants. This study is very similar to their work in many ways, except that a different method of estimating technical change is applied.

A simple example of one input, one output is used to demonstrate the concepts of the deviation of the MPI when the stochastic frontier production function for panel data is used to estimate technical efficiency and technical change.

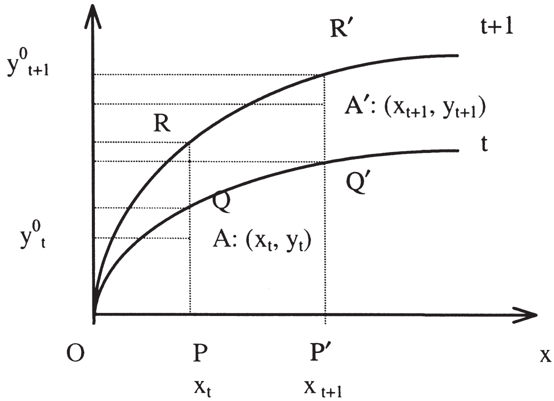

Figure 5.1 An example of MPI

In Figure 5.1, Ot and $Ot + 1$ represent the production frontiers in period t and $t + 1$ respectively. The $f(x_{it}, t, \beta)$ and $f(x_{it}, t + 1, \beta)$ are used to denote these two frontiers without losing generality.

From equation (5.1), $y_{it} = \exp[\ln f(x_{it}, t, \beta) + v_{it} - u_{it}]$ is the actual output in period t, which is equivalent to PA, whereas $y^p_{it} = \exp[\ln f(x_{it}, t, \beta) + v_{it}]$ (superscript p means 'potential') is the potential output at t, namely PQ. At period $t + 1$, the actual output is equal to $y_{it+1} = \exp[\ln f(x_{it+1}, t + 1, \beta) + v_{it+1} - u_{it+1}]$ and potential output is $y^p_{it+1} = \exp[f(x_{it+1}, t + 1, \beta) + v_{it+1}]$, namely $P'R'$ and $P'A'$. So at period t the technical efficiency (TE) is

$$\begin{aligned} TEx_{it} &= \text{actual output/potential output} \\ &= \exp[\ln(y_t / y^p_{it})] = \exp[\ln(y_t) - \ln(y^p_{it})] \\ &= \exp(-u_{it}) \end{aligned}$$

For the same reason, at the period $t + 1$, $TEx_{it+1} = \exp(-u_{it+1})$. Therefore, the TEC from period t to $t + 1$ is

$$TEC_{t+1,t} = TEx_{it+1} / TEx_{it} == \exp(-u_{it+1}) / \exp(-u_{it}) \tag{5.4}$$

The technical progress index between two adjacent period $t + 1$ and t can be estimated as follows. When input is x_t, the technical change rate TC_A is

$$TC_A = \frac{PR}{PQ} = \frac{f(x_{it}, t+1, \beta)}{f(x_{it}, t, \beta)} = \exp[\ln f(x_{it}, t+1, \beta) - \ln f(x_{it}, t, \beta)]$$

For the same reason, TC_A when input is x_{t+1} is

$$TC_A = \frac{f(x_{it+1}, t+1, \beta)}{f(x_{it+1}, t, \beta)} = \exp[\ln f(x_{it+1}, t+1, \beta) - \ln f(x_{it+1}, t, \beta)]$$

Therefore, the technical change index TC from period t to $t + 1$ can be calculated as

$$TC_{t+1,t} = (TC_A \cdot TC_A)^{1/2} \tag{5.5}$$

The MPI can be calculated as

$$MPI_{t+1,t} = TEC_{t+1,t} \cdot TC_{t+1,t} \tag{5.6}$$

Two alternative ways are usually used to estimate the MPI. One is the nonparametric approach, that is, data envelopment analysis (DEA). Another is the parametric approach, that is, the stochastic frontier production function. The two approaches have their advantages and disadvantages. The nonparametric approach has the advantages of not requiring the specification of a distributional form for the inefficiency term or of a functional form for production. But it suffers from not accounting for managerial error and other noise, and hence being very sensitive to errors and noise, not being able to conduct conventional tests of hypotheses and so on. The parametric stochastic frontier approach, on the other hand, filters out managerial error and white noise to some degree and hence may improve the quality and accuracy of the estimation, especially where the quality of the data set is not very high. This is one reason why we apply the parametric approach in this paper.

In principle, one can calculate the MPI relative to any type of technology. It could be the constant returns to scale (CRS) or the variable returns to scale (VRS) technology. In this chapter we choose first to calculate the MPI relative to the CRS technology. Then, an enhanced decomposition of the MPI developed by Färe, Grosskopf and Lovell (1994) is used. This enhanced decomposition takes the efficiency change component calculated relative to the CRS technology and decomposes it into a pure technical efficiency change (PTEC) component (calculated relative to the VRS) and a residual scale component that captures changes in the deviation between the VRS and the CRS technology. The latter is called scale efficiency change (SEC). In order to do this, we need to estimate the stochastic frontier production functions with and without CRS restrictions.

Functional Form Selection and Inefficiency Effect Tests

The translog production function is chosen as the default production functional form, but a series of statistical tests are used to test its suitability. The functional forms that passed the tests are used to conduct further estimation. The translog production function can be expressed as

$$\ln(Y_{it}) = \beta_0 + \sum_{j}^{m} \beta_j \ln x_{jit} + \beta_T t + \beta_{TT} t^2 + \sum_{j}^{m} \beta_{Tj} t \ln x_{ijt} + 2 \cdot \sum_{j \le}^{m} \sum_{k}^{m} \beta_{jk} \ln x_{jit} \ln x_{kit} + (v_{it} - u_{it}) \tag{5.7}$$

where Y_{it} , v_{it}, u_{it} and βt have been defined above. Subscripts j and k index inputs (j, k =1, ..., m).

The Model (5.7) includes the year of observation in such a way that non-neutral technical change is specified. Neutral technical change, however, is represented if the coefficients of the interactions between the year of observation and the other input variables are zero, for example, $\beta_{Tj} = 0$, ($j = 1, \ldots, m$). There would be no technical change among the firms if the coefficients of all variables involving the year of observation were zero, for example, $\beta_T = \beta_{TT} = \beta_{Tj} = 0$, ($j = 1, ..., m$). Further, the Cobb–Douglas production frontier is a special case of the translog frontier in which the coefficients of the second-order terms are zero, that is, $\beta_{TT} = \beta_{Tj} = \beta_{jk} = 0$, $j \le 1, ..., m$. The test for the inefficiency effect includes testing whether or not there exists inefficiency (H_0:$\gamma = \delta_0 = \ldots \delta_n = 0$).

OUTPUT, INPUTS AND DATA DESCRIPTIVE STATISTICS

Output, Inputs and Factors Determining the Performance of Firms

Output (Y) is total output in value terms at constant 1990 prices. Three inputs are used in this chapter.

K: Capital stock is measured using the perpetual inventory method, with 1990 as the benchmark year. The value of net assets for 1990 was used as the initial capital stock. The relationship between investment and capital stock at the end of any year is given by

$$K_{it} = (K_{it-1} - D_{it}) + p_t I_{it}$$

where i indexes the firm; t denotes year; D_{it} is depreciation for firm i in year t; I_{it} denotes the investment of firm i in year t; p_t is the investment price index in year t. Note that p_t was adopted from Jefferson, Rawski and Zheng (1996) for the years 1990–92 and updated to 1994 using the price index for capital goods from SSB (1997).

L: Labour is measured as full-time equivalent employee numbers. In this study, unproductive employees (those listed as service and other kinds of staff) are subtracted from the total labour force.
M: Material input is measured by total material expenditure deflated to 1990 constant prices by the price indices for the raw materials industry. The price indices for the industry are from SSB (1996).

The factors influencing firms' technical efficiency, which concern firm attributes and reform measures, include the following.
AGE: There are two potential offsetting impacts of plant age on efficiency. On the one hand, there may be a positive relationship between age and efficiency, to the extent that plant age reflects accumulated experience or learning by doing in production. On the other hand, if the age of the enterprise mainly captures the effect of plant vintage on efficiency, and if newer plants embody higher productivity capital, the age of the plant may have a negative impact on efficiency. The effect is unknown. This study may shed some light on this issue. *AGE* is measured by years since establishment of a firm.
E/L: The proportion of employees who graduated from college or above. It is argued that the quality of the workforce influences the firm's efficiency.
PBOW: The proportion of bonuses and overtime payments in the total wage bill. The bonus was the main means adopted by management in the 1980s to motivate workers. A number of previous studies have confirmed that it is a significant factor affecting SOEs' efficiency.
K/L: Factor intensity, the capital–labour ratio.
Size: Two dummy variables – *LARGE*, *SMALL* – are used to capture the size effect. The size follows the Chinese industrial statistical classification.
Region: Difference in region means many things. It means a different quality of workers, a different technical level and different availability of information. All of these may imply a different efficiency level. The effect of being located in a particular region on firm efficiency is captured by the regional dummies, *SICHUAN*, *SHANXI*, *JILIN*, compared with the reference group, Jiangsu.

The effects of reform measures after 1990 – a series of managerial mechanisms and ownership structure changes – are captured by a group of dummy variables: the managerial responsibility system dummy (*MANAGER*), the corporate system dummy (*CORP*) and the share-holding system dummy (*SHARE*) are compared with the most popular managerial form, the contract system.

Time *t* is included in the model to capture changes in average efficiency levels.

Data and Descriptive Statistics

The data used are from a survey conducted by the Institute of Economics, Chinese Academy of Social Science, in 1995. The firms surveyed were mainly SOEs. Four industries – building materials, chemicals, machinery and textiles, with the four largest sample sizes for the period of 1990–94 – are considered. A description of the data is presented in Tables 5.1 and 5.2.

Table 5.1 Description of sample composition for four industries

	Building Materials	Chemicals	Machinery	Textiles
Sample size	52	72	156	104
Large	8	17	52	24
Medium	30	30	73	54
Small	14	25	31	26
Jiangsu	12	20	46	50
Sichuan	9	8	26	20
Shanxi	13	31	43	14
Jilin	18	13	41	20
Share	3	0	0	5
Contract	27	53	92	54
Manager	18	9	47	35
Corporate	4	10	17	11

Note: Firm numbers for different managerial forms are for 1994.

As can be seen, all the sample firms are from Jiangsu, Sichuan, Shanxi and Jilin Jiangsu is one of the most advanced provinces in China; Sichuan and Shanxi are middle and Jilin an upper middle province. Intuitively, therefore, the average productivity growth estimated from this data set should be higher than for the country as a whole. This point should be kept in mind when interpreting the results.

EMPIRICAL RESULTS

To estimate model (5.7) and its variations for the Chinese building materials, chemicals, machinery and textiles industry, the FRONTIER 4.1 programme

Table 5.2 Descriptive statistics for inputs and output

	Y	*M*	*K*	*L*
Building materials (n = 52, t = 5)				
Mean 1990	3 667.24	1 412.38	1 714.19	1 400.70
Mean 1991	3 917.71	1 532.17	2 207.17	1 404.00
Mean 1992	3 867.69	1 623.54	2 115.32	1 413.91
Mean 1993	4 367.92	1 323.99	2 084.76	1 428.66
Mean 1994	4 254.15	1 286.19	2 275.97	1 438.23
Total mean	4 014.94	1 435.65	2 079.48	1 417.10
Minimum	41.00	7.00	29.37	53.00
Maximum	84 413.00	39 703.94	35 386.75	16 477.00
Chemicals (n = 72, t = 5)				
Mean 1990	4 464.73	1 821.23	1 761.83	1 382.01
Mean 1991	4 364.93	1 948.50	1 867.58	1 449.36
Mean 1992	4 593.17	2 005.11	1 948.71	1 637.18
Mean 1993	4 662.61	1 549.29	1 880.88	1 466.78
Mean 1994	6 043.57	1 748.14	2 692.67	1 868.53
Total mean	4 825.80	1 822.05	2 030.33	1 560.77
Minimum	24.6	19.32	138.16	130.00
Maximum	101 319.90	29 043.71	55 968.77	29 717.00
Machinery (n = 156, t = 5)				
Mean 1990	3 774.85	1 720.32	1 704.76	1 794.43
Mean 1991	4 001.88	2 118.06	1 772.14	1 815.19
Mean 1992	4 671.54	2 471.11	1 855.27	1 830.79
Mean 1993	5 295.05	2 047.19	2 005.78	1 842.49
Mean 1994	5 489.39	1 998.21	2 154.18	1 842.20
Total mean	4 646.54	2 070.98	1 898.42	1 825.02
Minimum	26.90	20.20	32.25	88.00
Maximum	48 382.00	30 568.87	26 540.23	14 738.00
Textiles (n = 104, t = 5)				
Mean 1990	6 703.59	3 307.74	1 741.65	2 039.33
Mean 1991	6 454.94	3 484.22	1 832.64	2 060.56
Mean 1992	6 347.39	3 452.47	1 962.39	2 075.37
Mean 1993	7 275.48	2 801.39	2 173.89	2 050.24
Mean 1994	7 219.43	2 905.21	2 368.97	2 011.92
Total mean	6 800.164	3 190.207	2 015.906	2 047.483
Minimum	9.2	3.922705	107.8432	102
Maximum	87 232.45	22 563	13 839.39	11643

Note: The unit for *Y*, *K* and *M* is RMB 10 000 in constant 1990 prices; the unit for *L* is people.

written by Coelli (1996) is used. The basic features of the empirical results are summarized in Table 5.3.

Frontier Estimation and Technical Efficiency

We first tested the possible production functional form, the type of technical change and the inefficiency effect for each industry using a likelihood ratio test. We found that (1) the translog without technical change is accepted for the building materials industry; (2) the full model with translog functional form and non-neutral technical change is accepted for the machinery industry; (3) the translog with neutral technical change is accepted for both chemicals and textiles industries; (4) the stochastic frontier production function is better representative than the ordinary econometric production model for all four industries.

Table 5.4 presents the estimates for the parameters of the stochastic production frontiers without imposing the restrictions of CRS for the building materials, chemicals, machinery and textiles industries. The functional forms applied are those that passed the model selection tests. The scale effect is calculated based on the estimated production frontiers and sample means for four industries and is presented in the last row of Table 5.3.

In column PTE in Table 5.4 we report the resultant measure of technical efficiency from the above models. However, this measure only contains the element of pure technical efficiency (PTE) if the technology reveals non-constant returns to scale, and the element of scale efficiency (SE) is missing. To gauge the size of SE, we re-estimated the translog frontiers, imposing restrictions of CRS for three industries revealing non-constant returns to scale. The resultant efficiency measure is an overall one (reported in column TE in Table 5.4), comprising both pure technical efficiency and scale efficiency. The SE is calculated as SE = PTE/ TE. It is presented in column SE in Table 5.4.

The TECs over time for the four industries are presented in Table 5.5. We compare all other years' efficiencies with the base year (1990).

The Determinants of Technical Efficiency

Table 5.3 reported the results of the efficiency functions for four industries. They were estimated with the production frontiers at the same time. The estimation of the production frontier and efficiency function at one stage avoids many of the problems of a two-stage estimation.

Consistent with our previous study (Kong, Marks and Wan 1999, 2000), we find that (1) the efficiency levels of firms in the three comparatively backward provinces – Sichuan, Shanxi and Jilin – are significantly lower than

Table 5.3 VRS production frontier function estimation results

	Building materials		Chemicals		Machinery		Textiles	
	coeff	*t*-ratio	coeff	*t*-ratio	coeff	*t*-ratio	coeff	*t*-ratio
Production function								
Constant	7.5312	7.79	4.0879	4.92	–0.2629	–0.56	0.9067	0.95
L	–3.3082	–5.52	–0.4033	–1.18	0.7383	3.09	–0.5118	–1.99
K	0.8602	2.01	–0.4657	–1.92	–0.0933	–0.52	0.0872	0.35
M	1.7968	6.21	0.9790	5.48	0.7860	7.21	1.4102	8.02
T			–0.1883	–4.15	–0.1241	–1.75	–0.1342	–2.73
*L*2	0.4393	4.25	–0.1342	–2.63	0.0429	1.02	0.1401	4.28
*K*2	0.0115	0.21	–0.0831	–1.92	–0.0778	–2.94	0.0164	0.56
*M*2	0.0614	1.88	0.0188	1.26	–0.0011	–0.10	0.0256	1.65
*T*2			0.0434	5.61	0.0364	5.50	0.0399	3.29
LK	–0.1085	–0.83	0.3541	4.39	0.0238	0.46	–0.0184	–0.32
LM	–0.2745	–3.31	0.0079	0.16	–0.1674	–4.92	–0.1610	–5.05
LT					–0.0002	–0.01		
KM	–0.0211	–0.31	–0.0938	–2.27	0.1475	5.26	0.0024	0.08
KT					–0.0158	–1.00		
MT					0.0181	1.99		
Efficiency function								
CONST	0.4054*	2.22	–4.3641*	–2.29	0.2400	1.08	–0.4321*	–2.15
K/L	–0.1580*	–2.62	0.1253	0.95	–0.2011*	–2.08	0.0601*	2.20

PBOW	–0.3570	–1.20	–2.7936*	–2.95	0.0427	0.43	–0.2882*	–1.99
AGE	0.0003	0.11	0.0017*	2.50	0.0013	1.00	–0.0009	–0.81
E/L	–1.0158	–0.93	–7.9571*	–4.69	–0.5005	–1.35	–1.0449	–0.84
LARGE	–0.3745*	–3.58	–0.1024	–0.80	–0.0853*	–2.30	0.0567	1.05
SMALL	0.1469	1.90	0.2094	1.95	0.0768*	2.02	0.0716	1.32
SICHUAN	0.3313*	3.12	3.8961*	2.64	0.3702*	5.21	0.5588*	6.44
SHANXI	0.2018	1.86	3.5399*	2.57	0.2883*	4.23	0.3784*	4.09
JILIN	0.1595*	2.01	2.7406*	2.49	0.2769*	4.23	0.5263*	5.41
SHARE	–0.3122*	2.24					–0.3155*	–2.97
MANAGER	0.0864	1.43	0.1506	1.37	–0.0626	–1.23	0.0040	0.09
CORP	–0.8367*	–2.12	–0.7150*	–2.26	0.0997*	1.99	–0.2396*	–2.73
t	–0.0082	–0.36	0.1323*	3.21	0.0430	1.28	0.1373*	2.34
Variance parameters								
σ^2	0.1202*	10.44	0.4378*	2.72	0.0778*	13.45	0.0857*	12.88
γ^2	0.0955*	2.47	0.9491*	42.11	0.3849*	3.12	0.1564*	2.03
Log likelihood function	–92.13		–75.16		–29.15		–82.86	
Scale economy coefficient	0.83**		1.41**		0.84**		1.09	

Notes:
* Means statistically significant at the 5 per cent level, two-tail test.
** Means significantly different from 1.

Table 5.4 Efficiency rate for four industries

	Building Materials			Chemicals			Machinery			Textiles		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
1990	0.66	0.69	0.96	0.78	0.82	0.95	0.80	0.76	0.95	0.91	0.91	1.0
1991	0.68	0.70	0.97	0.75	0.78	0.96	0.78	0.74	0.95	0.85	0.85	1.0
1992	0.70	0.72	0.97	0.75	0.77	0.96	0.75	0.73	0.97	0.80	0.80	1.0
1993	0.70	0.75	0.93	0.79	0.82	0.96	0.75	0.71	0.95	0.75	0.75	1.0
1994	0.73	0.77	0.95	0.77	0.78	0.99	0.73	0.70	0.96	0.70	0.70	1.0

Table 5.5 Cumulative efficiency change for four industries

	Building Materials			Chemicals			Machinery			Textiles		
	TEC	PTEC	SEC	TEC	PTEC	SEC	TEC	PTEC	SEC	TEC	PTEC	SEC
1990	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1991/90	1.03	1.01	1.01	0.96	0.95	1.01	0.98	0.97	1.0	0.93	0.93	1.0
1992/90	1.06	1.04	1.01	0.96	0.94	1.01	0.94	0.96	1.02	0.86	0.86	1.0
1993/90	1.06	1.09	0.97	1.01	1.0	1.01	0.94	0.93	1.0	0.80	0.80	1.0
1994/90	1.11	1.12	0.99	0.99	0.95	1.04	0.91	0.92	1.01	0.78	0.78	1.0

those in Jiangsu, one of the most advanced provinces in China; (2) the corporate and share-holding dummies have a significant positive effect in improving firms' efficiency in all four industries; (3) the large SOEs are more effective than the medium ones, which in turn are marginally more effective than small ones; (4) although the effect of the bonus system on firms' efficiency is still positive, it is not as important as found in previous studies. In this study the positive effect of the bonus is significant only in the chemicals and textiles industries; it is positive but no longer significant in the building materials industry; and negative but not significant in the machinery industry. This may imply that the effects of using bonuses as the main way to stimulate workers to improve efficiency are diminishing. The bonus may gradually be seen by workers as a normal part of their income rather than as a reward for improving efficiency.

Factor intensity and educational levels do not show consistent results in the four industries.

Technical Change and the MPI

The technical changes for the four industries are presented in Table 5.6.

Table 5.6 Technical change for four industries

	Building Materials	Chemicals	Machinery	Textiles
1990	1.00	1.00	1.00	1.00
1991/90	1.00	0.92	1.01	0.97
1992/90	1.00	0.94	1.09	1.02
1993/90	1.00	1.03	1.16	1.19
1994/90	1.00	1.12	1.28	1.34

The rates of TFP represented by the MPI for the four industries are presented industry by industry below. We calculated the cumulative indexes. They are the comparison of all other years' data to the first year's data. The advantage of a cumulative index is that it is easier to present graphically.

Table 5.7 shows the results for the building materials industry. Because there is no technical change in this industry, the MPI is decided solely by the technical efficiency change. As can be seen in Table 5.7, the annual rate of efficiency changes. Hence productivity growth is 2.64 per cent from 1990 to 1994, all from pure technical efficiency change. The contribution of scale economy is negative, but the absolute value is very small (0.25 per cent).

Table 5.7 Building materials industry

	TEC	PTEC	SEC	TC	MPI
1990	1.00	1.00	1.00	1.00	1.00
1991/90	1.03	1.01	1.01	1.00	1.03
1992/90	1.06	1.04	1.01	1.00	1.06
1993/90	1.06	1.09	0.97	1.00	1.06
1994/90	1.11	1.12	0.99	1.00	1.11
Annual rate	2.64%	2.87%	–0.25%	0.00	2.64%

Table 5.8 Chemicals industry

	TEC	PTEC	SEC	TC	MPI
1990	1.00	1.00	1.00	1.00	1.00
1991/90	0.96	0.95	1.01	0.92	0.88
1992/90	0.96	0.94	1.01	0.94	0.90
1993/90	1.01	1.00	1.01	1.03	1.04
1994/90	0.99	0.95	1.04	1.12	1.10
Annual rate	–0.25%	–1.30%	0.99%	2.87%	2.41%

The situation in the chemicals industry is the opposite (Table 5.8). The pure technical efficiency is decreasing, so its contribution to technical efficiency change is negative. But this is offset by the positive contribution of scale economy, so overall the technical efficiency change is negligible (–0.25 per cent). Technical progress is the main driving force of TFP growth, which is 2.41 per cent per annum in 1990–94.

Strong technical progress is seen in the machinery industry (Table 5.9). In five years, the production frontier shifted out 28 per cent compared to the 1990 frontier. This means that the best firms in 1994 could produce 28 per cent more output using the same amount of inputs as in 1990. Hence it is no surprise to see that there was a tendency for decreasing mean efficiency levels, since rapid technical progress usually makes it more difficult for ordinary firms to catch up to the 'best practice' firms. Strong technical progress gave the Chinese machinery industry 4 per cent per annum TFP growth in 1990–94.

The textiles industry was similar to the machinery industry (Table 5.10). The best firms in this industry pushed the production frontier out 34 per cent

Table 5.9 Machinery industry

	TEC	PTEC	SEC	TC	MPI
1990	1.00	1.00	1.00	1.00	1.00
1991/90	0.98	0.97	1.00	1.01	0.99
1992/90	0.94	0.96	1.00	1.09	1.03
1993/90	0.94	0.93	1.02	1.16	1.09
1994/90	0.91	0.92	1.01	1.28	1.17
Annual rate	–2.33%	–2.06%	0.25%	6.37%	4.00%

Table 5.10 Textiles industry

	TEC	PTEC	SEC	TC	MPI
1990	1.00	1.00	1.00	1.00	1.00
1991/90	0.93	0.93	1.00	0.97	0.90
1992/90	0.86	0.86	1.00	1.02	0.88
1993/90	0.80	0.80	1.00	1.19	0.95
1994/90	0.78	0.78	1.00	1.34	1.05
Annual rate	–6.02%	–6.02%	0%	7.59%	1.23%

more in 1994 than in 1990. But one concern is the fast-decreasing mean efficiency level, which fell more than 20 per cent during the same period. Because of the fast decline in the mean efficiency level, despite large technical progress, total TFP increased by only 5 per cent during the five-year period, representing 1.23 per cent growth annually. It is argued that the main reason for the quick fall in the mean efficiency level of the Chinese textiles industry – except for the fast technical progress taking place in this industry – was competition from non-state firms. It is true that the textiles industry is one of the industries facing strong competition from township and village enterprises (TVEs) and private firms. During the early 1990s, especially after 1992 as the result of Deng Xiaoping's trip to south China, TVEs and private firms developed very quickly. As a result, state-owned textiles firms faced stronger and stronger competition from these new entrants. Our results show that, on average, state-owned firms were in a very unfavourable position due to this competition: their efficiency in the face of increased competition fell rather than rose – they appear to have been unable to adjust to the challenge.

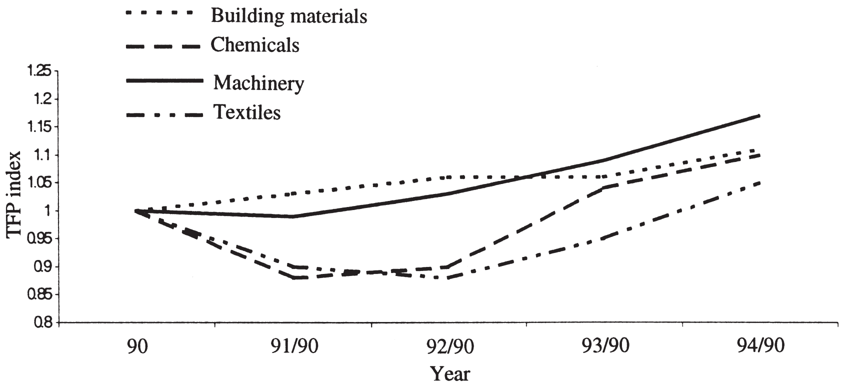

Figure 5.2 TFP growth

Figure 5.2 presents productivity growth for the four industries. All four industries had positive productivity growth during the research period. The average growth rate of the four industries was 2.57 per cent per annum. But the pattern and rate of growth is different across the industries. Whereas the productivity growth of the building materials and chemicals industries is nearly monotonic and the growth rates are higher, in the machinery and textiles industries, productivity had an initial dip in the first two years, and overall productivity growth is comparatively low. This diversity of the productivity growth rate and pattern reflected the characteristics of Chinese economic reform. Chinese economic reform is characterized by gradualism; it is a gradual process. The government usually experimented with a reform measure in selected industries and firms in the first instance. If it proved to be successful, then it spread to other industries and firms. This policy unavoidably resulted in unbalanced development among industries. So it is no surprise to see that TFP growth rates are diversified among the industries analysed.

Firm Scale, Geographic Location, Managerial Forms and TFP Growth

To examine the influence of scale, geographic location and managerial form on TFP growth, MPI values are grouped by scale, location and managerial forms. The results are presented in Table 5.11.

As can be seen, the large SOEs outperform the medium ones, which in turn outperform small state firms. The comparatively better performance of larger firms explains why the Chinese government took ‘emphasizing the big and liberalizing the small’ as one of its main policies for SOE reform after 1996.

The influence of geographic location is obvious. The firms in Jiangsu province are most productive. The firms in Sichuan and Jilin follow. The

Table 5.11 TFP growth grouped by scale, location and managerial forms

	1991/90	1992/90	1993/90	1994/90
Scale				
DLARGE	0.97	0.98	1.13	1.16
DSMALL	0.95	0.94	1.10	1.11
MEDIUM	0.92	0.91	1.04	1.07
Location				
DSICHUAN	0.95	0.95	1.10	1.12
DSHANXI	0.90	0.91	1.00	1.03
DJILIN	0.94	0.96	1.11	1.09
JIANGSU	0.98	0.98	1.14	1.16
Managerial form				
SHARE	0.97	0.96	1.08	1.15
MANAGER	0.88	0.93	0.99	1.05
CORP	0.99	1.04	1.18	1.22
CONTRACT	0.94	0.95	1.08	1.09

firms in Shanxi province are worst in productive performance. The result is quite consistent with the regional economic development level in China. The firms in advanced regions are more productive than those in comparatively backward regions.

In terms of the influence of managerial forms on TFP growth, corporatized and share-holding SOEs had a higher TFP growth rate during the research period. The firms adopting the manager responsibility system are the least productive.

CONCLUDING REMARKS

This chapter combines the stochastic frontier with the Malmquist productivity index and estimates the efficiency and productivity of Chinese SOEs in four industries from 1990 to 1994. We confirmed that there is TFP growth in the Chinese state industrial sector. We found that TFP grew fast in the machinery industry, moderately in the building materials and chemicals industries, and slowly in the textiles industry. On average, TFP growth was 2.57 per cent per annum for the four industries. We further found that firms in

Jiangsu province enjoyed the fastest rate of TFP growth, and corporatized and share-holding firms generally outperformed firms with other managerial forms.

To determine the sources of TFP growth, we analysed its two components: technical efficiency change and technical change. We found that mean efficiency scores tended to increase for building materials, to remain almost unchanged for chemicals, and to fall in both machinery and textiles. Technical progress was fast for the machinery and textiles industries, and moderate for the chemicals industry. There was no technical change in the building materials industry. So, for building materials, TFP growth is solely from efficiency change. For the chemicals industry, TFP growth is nearly all from technical change, since technical efficiency is nearly unchanged in this industry. For the machinery and textiles industries, efficiency change makes a negative contribution to TFP growth. TFP grew because of strong technical progress in these two industries.

At the 15th Chinese Communist Party Plenary Congress in 1994, corporatization and share-holding were chosen as the main directions of Chinese SOE reform. Our study provides the empirical evidence to support this decision.

NOTE

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