Productivity Change and Sources of Technical Efficiency in Chinese Iron and Steel Industry, 1988-2000.

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Working Paper Series Vol. 2002-36
December 2002

The International Centre for the Study of East Asian Development, Kitakyushu

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Abstract

The paper evaluates the performance of state-owned enterprises (SOEs) in Chinese iron and steel industry by applying the stochastic frontier approach with panel data. Differences in technical efficiency between various groups of SOEs are examined, with rather a surprising finding that the largest steel producers do not have a significant efficiency advantage over smaller SOEs, even though the former were recently selected by the Chinese authorities to be the core of a vigorous centralized merger campaign. Moreover, even though SOEs experienced a steady upward shift in their production possibility frontier, we found that their technical efficiency did not improve during the examined period. The paper identifies several determinants of SOE inefficiency, and then discusses policy implications of reported findings.

JEL classification codes: D24, P31.

Keywords: Efficiency, technical progress, productivity, state-owned enterprises, China.

1. Introduction.

While China's economic reforms resulted in a remarkable economic growth and dramatic poverty reduction, reforms of state-owned enterprises (SOEs) have been much less impressive. From time to time, Chinese authorities were attempting to revitalize SOEs by yet another set of policy initiatives, but SOE performance remained disappointing. A typical example of such policy failures is the Company Law, adopted by the Chinese legislature in 1993. The Law introduced various new types of corporate governance that are characteristic for market economies, such as shareholders' general meetings, the board of directors, the supervisory board and the like. After the Law came into effect in 1994, numerous SOEs were swiftly corporatised, and listed on domestic and foreign stock exchanges. Yet the subsequent financial performance of Chinese SOEs deteriorated even further, with the proportion of loss-making SOEs increasing from 31 percent in 1994 to almost 50 percent in 1998 (OECD, 2000, p. 24). Moreover, the whole state-owned sector posted a net loss in 1996, for the first time since the beginning of economic reforms (Huchet and Richet, 1999).

In response to this precarious situation, the Chinese government announced in 1997 a new policy initiative that aimed to 'grasp the big, release the small' SOEs. The government declared that by 'grasping the big', it will no longer provide the blanket support for all SOEs, and instead would focus on only a few large ones, aiming to agglomerate them into larger enterprise groups that could compete on equal footing with foreign rivals, similarly to Japanese *keiretsu* or Korean *chaebol*. As for smaller SOEs, the government declared 'releasing' them from the state support, primarily by reforming their ownership pattern through mergers with other SOEs, conversions into limited liability companies or limited joint-stock companies that had been permitted by the Company Law. Bankruptcy was also considered as an option, but in practice, it was used much less frequently for the fear that increased unemployment could undermine social stability (OECD, 2000, p. 43). The campaign to solve SOE problems reached it climax in March 1998, when the newly appointed Chinese Premier Zhu Rongji pledged to introduce so-called ‘modern enterprise system’ in the majority of medium- and large-sized SOEs, so that by the end of 2000 they would restore their profitability.

Three years later, the Chinese government announced, with much fanfare, that the goal of reforming SOEs was finally achieved. According to official reports, the ‘modern enterprise system’ was introduced in 84 percent of large and medium-sized SOEs. Moreover, 70 percent of SOEs were making profits, and by the end of 2000, net profits were 230 billion yuan (US$28 billion), a staggering 185 percent increase compared with 1997 (*People’s Daily*, January 9, 2001). However, these official reports were questioned by Studwell (2002, p. 243), who claimed that the reported increase in SOE profits was predominantly due to short-term factors, with hardly any improvement in SOE performance *per se*[1].

In this paper, we re-examine the performance of Chinese SOEs during the reform period, focusing on their technological growth and improvements in productive efficiency. The paper pays a particular attention to SOE performance in the late 1990s, to verify the official claim that the widespread introduction of ‘modern enterprise system’ among Chinese SOEs produced a speedy and pronounced improvement in their performance. Though there were several studies that evaluated the performance of Chinese SOEs during economic reforms, see for example

[1] For example, the spike in oil prices in the late 1990s boosted profits of state-owned oil companies, while the massive write-off of SOE debt (amounting to about US$144 billion) helped to decrease their annual interest burden by at least US$7 billion (ibid).

Jefferson et al. (1992), Woo et al. (1994), Jefferson et al. (1996), Li (1997), Zheng et al. (1998) and Zheng et al. (2002), most of them dealt with efficiency and technological changes in China at the macro level, with much less attention to SOE performance at the micro-level. Though the inadequacy of excessive emphasis on statistical aggregates has been recognized by for instance Jefferson et al. (1996, p. 170), the evidence about productivity and efficiency changes of specific Chinese SOEs remains scarce.

To examine the success of China's reforms at enterprise level, we will focus on China's SOEs in iron and steel industry. Since the introduction of "profit contracts" in the early 1980s, this industry has been targeted by practically all major reform initiatives in China (Steinfeld, 1998). Moreover, as documented by Hogan (1999) and Woetzel (2001), the industry has already been exposed to the policy of "grasping the big, releasing the small" SOEs, with a sweeping campaign of mergers and acquisitions to create internationally competitive conglomerates around the largest steel-making enterprises Shougang Steel, Baosteel Group, Anshan Steel, and Wuhan Steel (hereafter, these core steel making SOEs will be referred as 'big-4'). Finally, the problem of data availability is less severe for this industry, with detailed data for a large number of steel-making SOEs regularly reported in the Yearbook of Iron and Steel Industry of China (*Zhongguo Gangtie Gongye Nianjian)*.

Though SOE performance in iron and steel industry was previously examined by Jefferson (1990), Kalirajan et al. (1993) and Wu (1996), these studies analyzed SOE efficiency with only cross-sectional data, without examining how SOE efficiency and productivity were changing over time. Moreover, most of these studies focused on SOE performance only in the letter half of the 1980s.

In contrast, this paper examines SOE performance during a longer and more recent period, from 1988 to 2000. By using stochastic frontier model of Battese and Coelli (1995), we decompose changes in total factor productivity (TFP) into efficiency and technological change, and examine how major SOE groups differ by levels of technical efficiency. In particular, we consider whether the current emphasis of Chinese authorities on the 'big-4' SOEs in the ongoing centralized campaign of mergers and acquisitions can be justified by their supposed outstanding performance.

This paper is organized as follows. Section 2 describes the specification of the stochastic frontier model with panel data and data collection. Major results are reported in Section 3. Section 4 concludes with policy implications of major findings.

2. Estimated Model and Data Sources.

2.1. Specification of Stochastic Frontier Model.

We examine SOE performance by estimating the stochastic frontier model of Battese and Coelli (1995), hereafter – the BC model. While the original stochastic frontier models of Aigner, Lovell, Schmidt (1977) and Meeusen, van der Broeck (1977) were devised for cross-sectional data, the BC model is formulated for a panel dataset, and does not require a balanced dataset[2]. Second, the BC model not only estimates inefficiency levels of particular enterprises, but also explains their inefficiency variation in terms of potentially important explanatory variables. Finally, the model can decompose TFP growth into two components: technological growth (which is essentially a shift of production possibility frontier) and inefficiency changes (*i.e.*, deviations of actual output level from the production possibility frontier, set by best-practice enterprises).

The stochastic frontier model is based on the following general specification of production function, which is augmented by the disturbance term $\varepsilon_{i,t}$:

$$\ln(Y_{i,t}) = \ln(f(X_{i,t};\beta)) + \varepsilon_{i,t} \tag{1}$$

where $Y_{i,t}$ is production for the ith company in year *t*; $X_{i,t}$ is the vector of independent variables (inputs, etc.) and β is the corresponding vector of unknown parameters to be estimated, $f(\cdot)$ is a production function (translog, Cobb-Douglas, etc.), and *ln* is natural logarithm.

The disturbance term is further defined by $\varepsilon_{it} = v_{it} - u_{it}$, where v_{it} is a conventional symmetric random disturbance term, associated with the impact of omitted variables on the output variable, and u_{it} is non-negative random term, representing various inefficiencies in production. The random disturbance term v_{it} is assumed to be *i.i.d.* normal with mean zero and variance σ_v^2, while u_{it} is obtained by non-negative truncation of the normal distribution with mean μ_{it} and σ_u^2.

In the BC model, the mean of the inefficiency term u_{it} is given by

$$\mu_{it} = z_{it}\delta \tag{2}$$

where $z_{i,t}$ is the vector of variables that explain technical inefficiency and δ is the corresponding vector of unknown parameters to be estimated.

The model can be estimated by the method of maximum likelihood, using computer program FRONTIER (version 4.1) of Coelli (1996), with variance parameters expressed by $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$. Technical efficiency $TE_{i,t}$ of the i*th* enterprise in the year *t* is calculated as the ratio of observed output level to the corresponding estimated frontier output:

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[2] This feature is important for this study, since several Chinese steel makers ceased to exist during the

$$TE_{i,t} = Y_{i,t} / \exp(f(X_{i,t};\beta)) = \exp(-u_{it}) \tag{3}$$

The inefficiency component u_{it} of ε_{it} is not observable, but can be estimated as suggested by Battese, Coelli (1988):

$$E[\exp(-u_{it} \mid \varepsilon_{it})] = [\exp(-\zeta_{it} + \frac{1}{2}\sigma_*^2)] \frac{\phi[(\zeta/\sigma_*) - \sigma_*]}{\Phi(\zeta/\sigma_*)} \tag{4}$$

where $\zeta_{it} = -\gamma\varepsilon_{it}$, $\sigma_*^2 = \gamma(1-\gamma)\sigma^2$, $\phi(\cdot)$ and $\Phi(\cdot)$ are probability density function and cumulative distribution functions of a standard normal distribution.

Since by definition $u_{i,t}$ is always non-negative, the index of technical inefficiency $TE_{i,t}$ lies between zero and unity, with $TE_{i,t} = 1$ implying that the i*th* enterprise is operating on the estimated production possibility frontier.

Using estimates of $TE_{i,t}$ from (4), efficiency change for the i*th* enterprise between time period *t* and *s* is calculated by

$$\Delta TE = TE_{i,t} / TE_{i,s} \tag{5}$$

Following Coelli, et al. (1998, p. 234), the index of technical change between periods *t* and *s* is obtained by

$$\Delta TCh = \left\{ \left[1 + \frac{\partial f(X_{i,s}, s, \beta)}{\partial s} \right] \times \left[1 + \frac{\partial f(X_{i,t}, t, \beta)}{\partial t} \right] \right\}^{1/2} \tag{6}$$

and the index of TFP growth is given by

$$\Delta TFP = \Delta TE \times \Delta TCh \tag{7}$$

We assume that the production function $\ln(f(X_{i,t}, \beta))$ is a translog function of two inputs, capital $K_{i,t}$ and labor $L_{i,t}$,

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merger and acquisition campaign in the late 1990s.

$$\ln(f(X_{i,t},\beta)) = \beta_0 + \beta_K \ln(K_{i,t}) + \beta_L \ln(L_{i,t}) + \beta_{KL} \ln(L_{i,t}) \ln(K_{it}) + (1/2)\{\beta_{KK} \ln(K_{i,t})^2 + \beta_{LL} \ln(L_{i,t})^2 + \beta_{tt} t^2\} + \beta_t t + \beta_{Kt} \ln(K_{i,t}) t + \beta_{Lt} \ln(L_{i,t}) t \quad (8)$$

so that the complete specification of stochastic frontier model becomes

$$\ln(Y_{i,t}) = \beta_0 + \beta_K \ln(K_{i,t}) + \beta_L \ln(L_{i,t}) + \beta_{KL} \ln(L_{i,t}) \ln(K_{it}) + (1/2)\{\beta_{KK} \ln(K_{i,t})^2 + \beta_{LL} \ln(L_{i,t})^2 + \beta_{tt} t^2\} + \beta_t t + \beta_{Kt} \ln(K_{i,t}) t + \beta_{Lt} \ln(L_{i,t}) t + (v_{i,t} - u_{i,t}) \quad (9)$$

If the null hypothesis $H_0 : \beta_{KK} = \beta_{LL} = \beta_{KL} = \beta_{Kt} = \beta_{Lt} = \beta_{tt} = 0$ is valid, then (9) collapses to the Cobb-Douglas function. The null hypothesis can be tested by the generalized likelihood ratio (LR) statistic

$$\lambda = -2 \ln[L(H_0) / L(H_1)] \quad (10)$$

where $L(H_0)$ and $L(H_1)$ are the values of likelihood function under the null and alternative specifications. The λ-statistic is one-sided, and follows χ^2 distribution[3] under the null, with degrees of freedom equal to the number of restrictions.

Besides checking the validity of production function, specification (9) can be used to test whether the technical change is Hicks-neutral (with the null $H_0 : \beta_{Kt} = \beta_{Lt} = 0$), or is taking place at all (with the null $H_0 : \beta_t = \beta_{Kt} = \beta_{Lt} = \beta_{tt} = 0$).

The inefficiency model (2) is specified by:

$$\mu_{it} = \delta_0 + \delta_1 \ln(Age_{it}) + \delta_2 t + \delta_3 D_1 t + \delta_4 D_2 t \quad (11)$$

where:

Age_{it} = enterprise age, equal to $t - t_{i,0} + 1$, where $t_{i,0}$ is the start-up year of i^{th} SOE,

$D_1 t$ = time dummy variable for 'big-4' SOEs (and zero otherwise),

[3] When the null hypothesis involves the restriction H_0: $\gamma = 0$, λ follows a mixed χ^2 distribution due to the non-negative values of parameter γ. The correct critical values for λ were obtained from Table 1 of Kodde and Palm (1986).

D_2t = time dummy variable for other 'key' SOEs (and zero otherwise).

It is important to note that estimated parameters δ_i ($i=1,...,5$) in (11) evaluate the impact of various z_i on technological *inefficiency*. So if one expects that increasing *Age* is associated with more efficiency (due to positive impact of better experience and various learning-by-doing effects), this implies $H_0 : \delta_1 < 0$ [4]. Similarly, if the group of 'big-4' SOEs is expected to experience a larger improvement in technical efficiency compared with other SOEs, then the null hypothesis is $H_0 : \delta_3 < 0$.

2.2. Data.

We analyzed enterprise-level data for Chinese iron and steel industry from 1988[5] to 2000, using the *Yearbook of Iron and Steel Industry of China*, released by the Ministry of Metallurgical Industry of China. For most years, the sample contained data for 82 enterprises, though during 1988-1989 and 1996-2000 a few of them were missing, making the panel dataset unbalanced.

As output measure, we used gross industrial output value at 1990 constant prices (with enterprise-specific deflators). Capital input was the net value of fixed assets, but it was available in only nominal terms. At present, official Chinese statistics is not reporting deflators for capital input, and as a substitute deflator, we used 'price index of investment in fixed assets' [6] from *China Statistical Yearbook*

[4] Conversely, one can argue that enterprises with older age may be more conservative in their management practice, implying that H_0: $\delta_1 > 0$.

[5] Though data for earlier years are also available from the same source, out sample starts from 1988, as this was the year when legal basis for SOEs was established (with the adoption of the *Law on Enterprises Owned by the Whole People*, which defined SOEs as a legal person to which the state property is entrusted).

[6] This deflator has two major shortcomings. First, it measures price changes of domestically produced capital goods in a given year (rather than during whole span of capital input service). Second, it does not account for changes in imported capital inputs.

(National Bureau of Statistics, various years). The deflator is available only since 1991, and for 1988-1990, we used the weighted ex-factory price indices for machine-building and building materials that were also taken from *China Statistical Yearbook*. Labor inputs were measured by the number of staff and workers at the year-end. *The Yearbook of Iron and Steel Industry of China* does not report company-level data for working hours, but this appears to be not a serious problem[7]. Since the BC model is of fixed-effect type, the original output and input data were mean-corrected prior to the estimation.

One particular feature of Chinese iron and steel industry is its high level of dispersion, with more than 1,500 registered enterprises in 1990. Though our sample contains only 82 steel-making enterprises, their shares in output, labor and capital are substantial, making the sample quite representative of the whole industry. For example, these 82 SOEs accounted for 68.9 and 73.6 percent of gross output in 1990 and 2000, respectively (Table 1). The corresponding shares in fixed assets was even larger (79.5 and 85.5 percent, respectively), while labor shares were lower than output shares, especially in 2000, reflecting the impact of extensive layoffs in the industry during the late 1990s (Ramstetter, Movshuk, 2003).

[INSERT TABLE 1 HERE]

We distinguish three groups of steel-making enterprises. First, we differentiate between 'key' and 'local major' enterprises, with the former supervised by the central government, while the latter are under control of local authorities[8]. Second, 'big-4' largest steel makers (all of which belong to 'key' enterprises) are analyzed as a separate group. By size, these SOEs greatly surpassed not only 'local

[7] According to Ito (1998), the variability of working hours remains insignificant across Chinese SOEs, probably due to the vigorous application of working time regulations, which are still typically set by the central government.

major' SOEs, but also other 'key' enterprises[9] (Table 2). As previously mentioned, these largest SOEs were at the center of vigorous consolidation campaign in the late 1990s. Baoshan Steel has already formed the core of the Baosteel group (after merging with Shanghai Metallurgical and Meishan Iron and Steel), while mergers centered around other 'big-4' SOEs are in preparation (Hogan (1999), Woetzel, 2001).

[INSERT TABLE 2 HERE]

Another particular feature of the 'big-4' SOEs was their drastic reduction of average labor force from 143 thousands workers in 1990 to 105 thousands in 2000 (Table 2). We will examine whether this dramatic restructuring produced any substantial productivity and efficiency improvements of these SOEs[10].

Section 3. Estimation results.

Results of maximum likelihood estimation of (9) are presented in Table 3. Most parameter estimates are statistically significant at 5 percent level. The null hypothesis of Cobb-Douglas production function was tested by the LR test statistic (10). The test statistic was 45.08, significantly in excess of the critical value 12.59 (Table 4). The null hypotheses of Hicks-neutral technology and no technological change were similarly rejected.

[INSERT TABLE 3 HERE]

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[8] Out of 82 enterprises examined in this study, 33 were 'key' and 49 were 'local major' ones.

[9] The four largest steel makers in China were especially distinctive in their average capital endowment. In 1990, their fixed assets per enterprise was 7.05 billion yuan, compared with 0.76 billion Yuan for other 'key' enterprises, and 0.23 billion yuan for 'local major' steel makers. Ten years later, the relative capital endowments changed very little.

[10] It is important to note that even after this substantial downsizing, the scale of employment of the 'Big Four SOEs still remains unusually high by international standards For example, the largest steel maker in the world – Posco from South Korea – employed only about 20,000 employees in 1990s. In consequence, there is a very large gap in average labor productivity between China's large firms and major American, Japanese and Korean steel makers (Ramstetter, Movshuk, 2003).

As shown in Panel (c) of Table 3, the variance parameter γ was 0. 946, indicating the high importance of the inefficiency component u_{it} in the variation of the disturbance term $\varepsilon_{i,t}$. It should be noted, however, that the ratio $\gamma = \sigma_u^2 / \sigma^2$ should not be interpreted as the share of the inefficiency term in the total variation of the disturbance term $\varepsilon_{i,t}$, since the latter variance is not σ^2, but $[(\pi - 2)/\pi]\sigma^2$ (Coelli et al., 1998, p. 188). Accordingly, the proper way to calculate the contribution of σ_u^2 to the total variance of $\varepsilon_{i,t}$ is $\gamma^* = \gamma / [\gamma + (1-\gamma)\pi / (\pi - 2)]$. Nevertheless, even with this adjustment, γ^* is still quite high (0.864).

According to Panel (c) of Table 3, the estimate of γ had also a very high t-ratio of 87.62. However, Coelli (1995) found that the t-statistic for testing the null hypothesis $H_0 : \gamma = 0$ had a very poor size, with too many rejections of the null compared with nominal test size. In contrast, the one-sided LR test statistic (10) had a correct size and superior power. Consequently, we will base the subsequent statistical tests of the BC model on the LR test statistic, even when t-statistics are also available.

The LR test statistic is used for testing the statistical significance of the inefficiency component u_{it}, where the null hypothesis is $H_0 : \gamma = \delta_i = 0 \; (i = 0, 1, \ldots, 4)$. If the null hypothesis is valid, the inefficiency component u_{it} of $\varepsilon_{i,t}$ has zero mean and variance, so that $\varepsilon_{i,t}$ contains only random component v_{it}, and the frontier model collapses to the average production model, with no output deviations due to inefficiency. As shown in Panel (b) of Table 4, the null hypothesis of average production function is rejected by the data, with the LR test statistic 204.63, far in excess of the critical value 10.37.

Panel (b) of Table 3 reports how specific variables in (11) affected technical inefficiency. The negative estimate of δ_1 implies that the technical inefficiency was lower in older SOEs, reflecting the positive impact of experience and learning-by-doing on enterprise efficiency. The positive estimate of δ_2 for time trend *t* indicates that inefficiency was increasing over time, and the increase was especially pronounced for other 'key' SOEs, due to the positive estimate for time dummy $t \times D_2$. On the other hand, negative estimate for $t \times D_1$ implies that the general increase in inefficiency was less prominent among 'big-4' steel-making enterprises.

[INSERT TABLE 4 HERE]

To test the statistical significance of these explanatory variables, the BC model was re-estimated with each z_i deleted. Then the null hypothesis $H_0 : z_i = 0$ $(i = 1,...,4)$ was tested by the generalized LR statistic λ (10), as discussed by Coelli et al. (1998, p. 215). Results of these tests are reported in Panel (b) of Table 4. The null hypothesis was rejected just once, implying that only time trend *t* was significant in explaining the variation in SOE inefficiency, while plant age and two time dummies (for 'big-4' and other 'key' SOEs, with 'local major' SOEs being controls) turned out insignificantly different from zero. Thus, the declining inefficiency of China's steel-making SOEs appears to be a general trend that was equally shared by all three major SOE groups.

Using formulas (5), (6) and (7), we computed annual changes in technical efficiency ΔTE, technological frontier (i.e., production possibility frontier) ΔTCh, and total factor productivity ΔTFP, and report them in Table 5. The average annual change in technical efficiency ΔTE was just -0.03 percent during 1988-2000. It is noteworthy that the start of centralized campaign to revitalize SOEs by spreading 'the modern enterprise system' in 1997-2000 did not significantly improve their efficiency, with the largest efficiency improvement achieved in only 1999/2000, but just by 2.2 percent. In previous years, SOE efficiency was either declining or rising marginally.

[INSERT TABLE 5 HERE]

On the other hand, the index of technical change ΔTCh[11] was gradually accelerating, and finally exceeded 3 percent in the late 1990s, while over the whole period, the average ΔTCh was 1.8 percent. Finally, the magnitude of TFP growth turned out slightly lower (mostly due to the poor growth in technical efficiency), 1.4 percent on average, but it picked up significantly in the late 1990s because of accelerated technical change ΔTCh in the late 1990s.

Cumulative changes in TE, TCh, and TFP are plotted in Figure 1. Starting from the early 1990s, production possibility frontier was moving upward, as indicated by the accelerating index of technical change TCh. On the other hand, the index of technical efficiency TE was moving in unison with TCh only until 1993, and then started to decline. The decline ended in 1997, and in 1997-2000, there was a slight pick-up in TE. Yet even in 2000, the efficiency still fell short of its level in the late 1980s.

[INSERT FIGURE 1 HERE]

To identify driving forces behind the deterioration in technical efficiency during 1994-1997 and its subsequent rebound during 1997-2000, Figure 2 plots the median index of technical efficiency TE for major groups of steel-making SOEs ('big-4', other 'key' SOEs and 'major local' SOEs). Between 1988 and 1993, these indexes

[11] It was evaluated at mean values of input variables, using only significant parameter estimates of the inefficiency model (11).

were clustered at quite high level, about 90 percent, indicating little efficiency differences across these SOE groups[12].

[INSERT FIGURE 2 HERE]

As indicated by accelerating index of technical change *TCh* in Table 5, it appears that various SOE reforms eventually accelerated the shift of production frontier upward, but some Chinese SOEs ran into difficulties when they tried to catch up with the best practice SOEs. This differentiation between the performance of best practice SOEs and industry laggards might widen the gap between potential and actual output of steel-making enterprises, with eventual increase in the average inefficiency level for the whole steel industry[13].

As shown in Figure 2, the downward drop in efficiency during 1994-1997 was very similar among major groups of SOEs. Yet subsequently, a noticeable disparity emerged in their performance. In particular, the efficiency decline of 'big-4' steel-making enterprises turned out the most persistent, with uninterrupted decline until 2000. On the other hand, 'local major' SOEs experienced a dramatic rebound in their efficiency during 1997-2000, and by 2000, their median efficiency level exceeded 'big-4' SOEs by about 10 percent. It is ironic that when China's authorities were counting on the biggest steel-making SOEs in the policy to 'grasp the big, release the small', these SOEs worsened their performance in terms of technical efficiency[14].

[12] The high level of TE does not imply, however, that most steel-making enterprises were fully efficient *per se*, since the efficiency benchmark in our study remains quite low by international standards. Note that our sample contains only Chinese enterprises, so that the production frontier is formed by the best-practice *domestic* enterprises. Accordingly, the initial clustering of SOEs close to the production frontier means that there was little differentiation between the best-practice SOEs and less efficient steel-making enterprises.

[13] The possibility of this outcome due to rapidly shifting production frontier was previously noted by Kong et al. (1999, p. 276-277).

[14] In previous analysis of Chinese steel industry, Jefferson (1990, p. 338) also found that the relative efficiency of locally supervised SOEs was higher compared with centrally supervised 'key' enterprises.

Why the performance of the largest steel-making SOEs turned out so poor? Likewise, why their performance started to worsen in the mid-1990s? A thought-provoking case study by Steinfeld (1998) of Shougang Steel (one of 'big-4' SOEs) provides some interesting insights.

During the 1980s, Shougang was a successful example of 'profit contract' system, which strictly enforced a hard-budget constraint, and by the late 1980s, Shougang achieved a financial self-sufficiency from the central authorities by various efficiency-promoting measures (*ibid*, p. 166-167). However, in the early 1990s, the hard budget constrain over the enterprise was substantially relaxed, and Shougang was able to get essentially unlimited access to financial resources, even establishing its own proprietary bank, Huaxia. Only during 1993-1994, Shougang borrowed about $1 billion from its affiliated banks, and made $1.6 billion investment in fixed assets. Due to the relaxed supervision of how Shougang was spending the generous bank credits, a substantial portion of this investment spree went to unproductive uses, such as the construction of a new Qilu mill in Shandong Province. After Shougang poured a large amount of money into the mill construction, it turned out that the mill not only lacked access to domestic ore mines, but also could not handle shipments of foreign ore. Eventually, an extremely wasteful scheme of ore supply to Qilu had to be adopted (*ibid*, p. 166-167). Similar ill-considered projected made Shougang technically bankrupt in mid-1990s, before Shougang and its 'pocket-bank' Huaxia were quietly bailed out by the Chinese government in the late 1990s.

Steinfeld (1998) also described how Anshan Steel – another 'big-4' SOE - went through a similar performance decline after the introduction of 'soft-budget' constraint in the mid-1990s. Once again, the emergence of weak financial supervision over investment projects led to unwarranted investments that repeatedly turned out highly unprofitable. By the mid-1990s, the accelerated debt accumulation rapidly made Anshan a technically bankrupt company. The provision of so-called ‘policy loans’ by affiliated state banks aggravated the situation even further, while Anshan managers had little incentives to improve the SOE performance (the managers were well aware that Anshan was ‘too big to fail’).

While Steinfeld (1998) documented the deteriorated performance among the largest steel-making SOEs *prior* to the late 1990s, we found that subsequently their efficiency performance again failed to improve[15]. Consequently, the recent campaign to introduce the ‘modern enterprise system’ in Chinese SOEs appears to be less successful than was officially claimed, and there is still a substantial room for efficiency improvement among Chinese steel-making enterprises, especially the largest ones.

Section 4. Conclusions.

In this paper, we examined changes in technological efficiency, technical progress and TFP growth in Chinese iron and steel industry during 1988-2000. While previous studies of this industry were based on cross-sectional data, and focused on the initial stages of the Chinese reform process (mostly the late 1980s), this study examined the impact of SOE reform over a much longer time span. Using the stochastic frontier model of Battese and Coelli (1995), we found that inefficiency effects were very important in the estimated inefficiency model. The technological change (i.e., the shift of production frontier) was accelerating during the examined period, exceeding 3 percent in the late 1990s. On the other hand, there was a rapid decline in the average technical efficiency of steel-making enterprises during the mid-1990s, which was only partially reversed during the late 1990s. A bit surprisingly, we found that the efficiency decline turned out the most pronounced among the ‘big-4’ steel-making enterprises. This result suggests that the current wave of “mergers from above”, with its almost invariable focus on the largest SOEs, may bring little, if any improvement in the performance of Chinese iron and steel industry.

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[15] Locally supervised SOEs were a notable exception to the efficiency decline, but these SOEs did not attract attention of Chinese authorities.

Table 1. Sample coverage (shares in total iron and steel industry of China)

	Gross output	*Fixed assets*	*Labor force*	*Gross output*	*Fixed assets*	*Labor force*
	1990			2000		
'Key' SOEs:						
(1) big-4	0.229	0.364	0.182	0.273	0.308	0.168
(2) other	0.309	0.286	0.290	0.252	0.342	0.301
'Local major' SOEs	0.151	0.145	0.195	0.212	0.206	0.194
Total sample	0.689	0.795	0.666	0.736	0.855	0.663

Note: gross output and fixed assets are at 1990 constant prices. The group of 'big-4' SOEs includes Baosteel, Anshan Steel, Shougang Steel, and Wuhan Steel.

Table 2. Average size of steel-making SOEs.

	Gross output	*Fixed assets*	*Labor force*	K/L ratio	*Gross output*	*Fixed assets*	*Labor force*	K/L ratio
	1990				2000			
'Key' SOEs:								
(1) big-4	7.52	7.05	143.05	115.05	14.97	15.18	105.98	377.63
(2) other	1.40	0.76	31.49	22.86	3.02	2.93	32.89	105.52
'Local major' SOEs	0.40	0.26	12.53	18.42	1.69	1.31	15.72	87.10
Total sample	0.48	0.30	15.10	18.98	1.89	1.22	16.13	95.71

Notes: gross output and fixed assets are in billion yuan at 1990 constant prices; labor force is in thousand persons at year-end, fixed assets per worker (K/L) are in million yuan (at 1990 prices) per employee.

Table 3. Maximum-Likelihood Parameter Estimates of the Stochastic Frontier and Inefficiency Models

		Translog production function		*Cobb-Douglas production function*	
Variable	*Parameter*	*Estimate*	*t-ratio*	*Estimate*	*t-ratio*
(a) Stochastic Frontier Model					
Constant	β_0	-0.019	-0.443	-0.172	-6.598
log(K)	β_K	0.429	5.699	0.226	8.627
log(L)	β_L	0.491	3.843	0.461	10.444
½ log(K)²	β_{KK}	0.314	4.153		
½ log(L)²	β_{LL}	0.202	0.649		
*log(K)*log(L)*	β_{KL}	-0.354	-2.264		
t	β_t	-0.012	-0.820	0.050	12.930
*Log(K)*t*	β_{Kt}	-0.034	-3.161		
*Log(L)*t*	β_{Lt}	-0.001	-0.037		
½ t²	β_{tt}	0.010	4.411		
(b) Inefficiency Model					
Constant	δ_0	-4.173	-3.260	-1.529	-2.421
Plant age	δ_1	-0.808	-2.748	-1.372	-3.233
t	δ_2	0.355	3.655	0.297	4.387
$t*D_1$	δ_3	-0.108	-2.775	-0.182	-3.369
$t*D_2$	δ_4	0.063	3.904	0.027	2.569
(c) Variance parameters					
	σ^2	0.847	4.885	0.825	5.874
	γ	0.946	87.620	0.941	88.110
Log-L		-112.46		-135.00	

Table 4. Hypothesis Tests of the Stochastic Frontier Model.

	Null hypothesis	Test statistic λ	Restrictions	Critical value	Decision
(a) Pattern of production function and technological change					
Cobb-Douglas production function	$\beta_{KK}=\beta_{LL}=\beta_{KL}=\beta_{Kt}=\beta_{Lt}=\beta t=0$	45.08	6	12.59	Reject
Hicks-neutral technological change	$\beta_{Kt}=\beta_{Lt}=0$	11.36	2	5.99	Reject
No technological change	$\beta_t=\beta_{Kt}=\beta_{Lt}=\beta_{tt}=0$	145.84	4	9.49	Reject
(b) Properties of the error term and significance of explanatory variables for technical inefficiency					
Average production function	$\gamma=\delta_i=0\ (i=1,\ldots,4)$	204.63	5	10.37	Reject
Age	$\delta_1=0$	0.20	1	3.84	Accept
t	$\delta_2=0$	11.63	1	3.84	Reject
$t*D_1$	$\delta_3=0$	1.96	1	3.84	Accept
$t*D_2$	$\delta_4=0$	0.85	1	3.84	Accept

Note: [a]critical value is taken from Table 1 of Kodde and Palm (1986).

Table 5. Changes in Technical Efficiency (Δ*TE*), Technological Frontier (Δ*TCh*), and Total Factor Productivity (Δ*TFP*)

	Δ*TE*	Δ*TCh*	Δ*T*FP
1988/1989	0.996	0.982	0.979
1989/1990	0.999	0.991	0.990
1990/1991	0.994	0.998	0.992
1991/1992	1.010	1.006	1.017
1992/1993	1.004	1.016	1.020
1993/1994	0.983	1.024	1.006
1994/1995	0.964	1.026	0.989
1995/1996	0.992	1.029	1.020
1996/1997	0.984	1.036	1.019
1997/1998	1.008	1.035	1.044
1998/1999	1.003	1.033	1.036
1999/2000	1.022	1.037	1.060
Average	0.997	1.018	1.014

Fig. 1. Cumulative change in technical efficiency, technological frontier and TFP (1988=1)

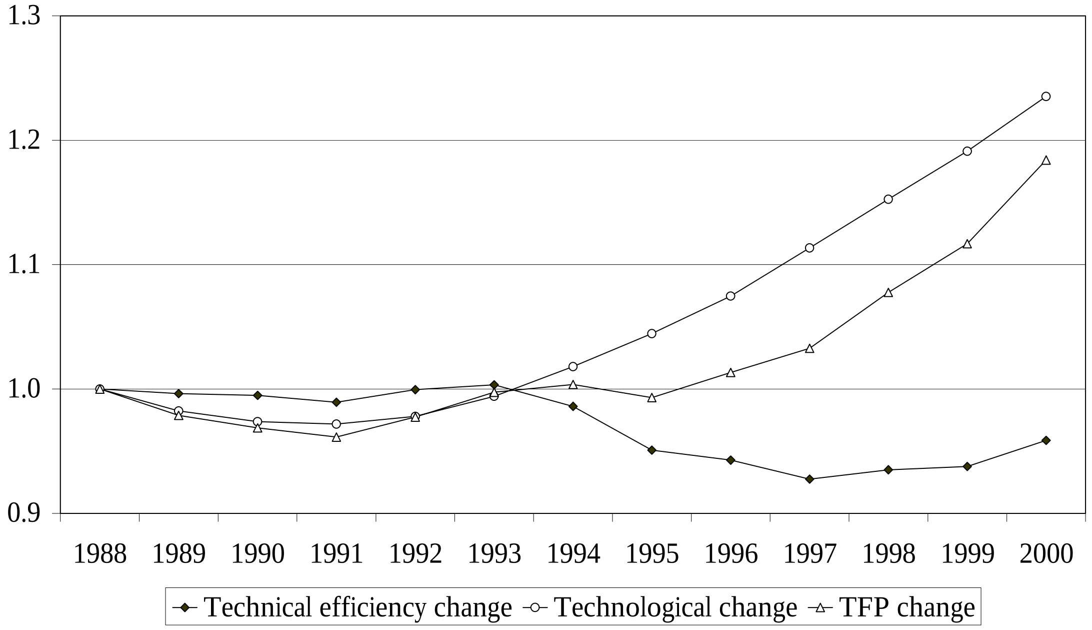
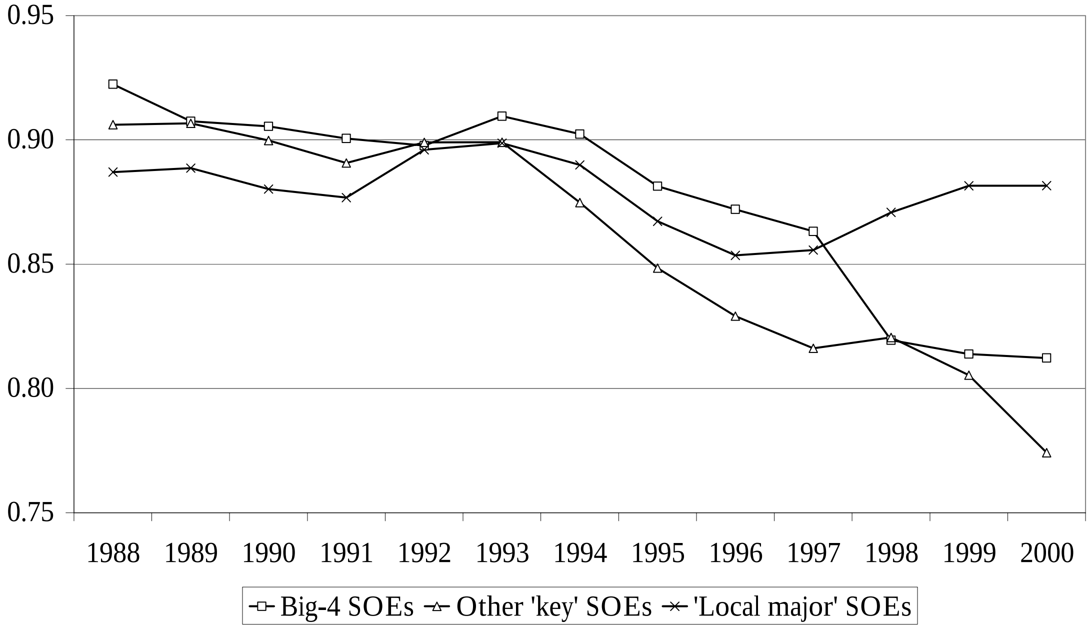


Fig. 2. Median efficiency levels of steel-making enterprises in China by enterprise type



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