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East Asia

***Impact of Market-oriented Reforms on the
Chinese Iron and Steel Industry***

Cao Yong

92/5

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Impact of Market-oriented Reforms on the Chinese Iron and Steel Industry

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Key to symbols used in tables

- | | |
|------|----------------|
| n.a. | Not applicable |
| .. | Not available |
| - | zero |
| . | insignificant |

Cao Yong has completed his thesis, 'The Chinese Iron and Steel Industry in Transition: Toward Market Mechanism and Economic Efficiency', at the National Centre for Development Studies. It was funded by the Centre's China Project.

China Project at the National Centre for Development Studies. The Centre is nearing completion of a three year program of research and training funded by the Australian International Development Assistance Bureau. A large part of this project has funded the writing of eight dissertations by Chinese students. Earlier results have been issued in the Centre's China Working Paper series and a concluding seminar was held in Xiamen in 1991. Professors Dong Fureng and Helen Hughes chaired this meeting.

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abstract

Inefficient utilization of factor inputs and poor productivity performance whilst central planning prevailed in the Chinese industrial sector gave impetus to market-oriented reforms. These reforms were expected to improve industrial productivity.

This study develops a measure of industrial productivity performance through decomposing it into technical, allocative and scale efficiencies. The effect of the partial introduction of elements of a market system aimed at overcoming inefficient resource allocation, and hence improving productivity, are empirically tested in relation to the iron and steel industry.

An improvement is found in technical efficiency and a slight improvement in allocative efficiency although estimates indicate distortion in the factor markets. The estimations of scale efficiencies suggest that there is an inefficient allocation of production share amongst plants of different scale.

The methodology of the econometric estimation is presented along with a discussion of the data used. In addition, some stylized facts about market imperfections in the Chinese economy are noted and their impact on productive efficiency assessed.

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Abstract

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Key words in base industry to

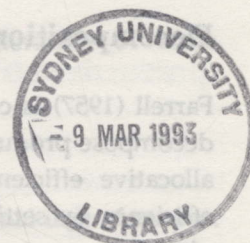
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impact of market-oriented reforms on the Chinese iron and steel industry



This study focuses on the impact of market-oriented economic reforms on performance in the Chinese iron and steel industry during the reform period of the 1980s.

Impetus was given to market-oriented economic reforms by pervasive inefficient utilization of factor inputs and the resultant poor productivity performance of the Chinese industrial sector whilst central planning prevailed. Under central planning, economic resources were not allocated according to their marginal productivities. This inefficient resource allocation was related to the lack of incentive for plants and individual workers to use factors of production effectively. Distorted factor and goods markets meant that signals for resource allocation were inappropriate and there was a lack of mobility of resources across industrial sectors, plants and regions.

Reforms had the potential to influence productivity in three ways

- through the creation of greater incentives for plants and individual workers to utilize factors of production more effectively and hence improve productivity
- through the creation of undistorted factor and goods markets in which economic resources could be more efficiently allocated in accordance with their marginal productivities
- through introduction of measures to improve the mobility of economic resources across regions, industrial sectors and plants.

The aim of this study is to develop measures of industrial performance for use in assessment of the impact of reforms with regard to these three aspects. The methodology applied decomposes industrial productivity performance into technical, allocative and scale efficiencies. These distinctive efficiency measures provide detailed and unbiased estimates of the impact on industrial productivity of the introduction of a market mechanism.

Decomposition of productive efficiency

Farrell (1957) is considered the pioneer of the use of the production frontier to decompose productive efficiency into two sub-categories: technical efficiency and allocative efficiency. Forsund et al. (1980) further decomposed productive efficiency by setting out scale efficiency in addition to technical and allocative efficiencies.

The following standard formulations of production (Y), cost $C(Y, X)$ and profit $\pi(P, W)$ functions are assumed

$$Y = f(X)$$

$$C(Y, X) = \min_X \{WX \mid f(X) \geq Y, X \geq 0\}$$

$$\Pi(P, W) = \max_{Y, X} \{PY - WX \mid f(X) \geq Y, Y \geq 0, X \geq 0\} \quad (1)$$

where, Y is the vector of outputs, X is the vector of inputs, W is the vector of input prices, and P is the vector of output prices.

If a production unit is observed (Y^0, X^0), then for

$$\text{technical efficiency} \quad Y^0 = f(X^0)$$

$$\text{technical inefficiency} \quad Y^0 < f(X^0)$$

Technical inefficiency is characterized by excessive input usage for a given output and if this is the case costs are then

$$WX^0 > C(Y^0, W)$$

Since costs are not minimized, profits are not maximized

$$(PY^0 - WX^0) < \Pi(P, W)$$

If costs are minimized, then we can define

$$\text{allocative efficiency} \quad f_i(X^0) / f_j(X^0) = W_i / W_j$$

$$\text{allocative inefficiency} \quad f_i(X^0) / f_j(X^0) \neq W_i / W_j$$

where $f_i(X^0)$ and $f_j(X^0)$ are the marginal products of inputs i and j , and W_i and W_j are the prices of inputs i and j respectively. Allocative inefficiency occurs when inputs are employed in the wrong proportions relative to their prices

Obviously, if and only if $WX^0 = C(Y^0, W)$ and $(PY^0 - WX^0) = \Pi(P, W)$, can the production unit ensure its overall efficiency. As neither the arguments of technical nor allocative efficiency involve the vector of output prices, they are not sufficient to ensure

$$(PY^0 - WX^0) = \Pi(P, W)$$

Measurement of overall efficiency also requires consideration of scale efficiency, defined as

$$\text{scale efficiency} \quad P = C_Y(Y^0, W)$$

$$\text{scale inefficiency} \quad P \neq C_Y(Y^0, W)$$

where $C_Y(Y^0, W)$ is the marginal cost of producing an additional unit of output. A production unit is scale inefficient if it produces above or below the optimum output level (dictated by prevailing technology and prices of production and of inputs and outputs) and hence fails to equalize its marginal cost to output price.

Unlike the so-called 'residual' estimations of productivity, such as the estimation of total factor productivity, the decomposition of efficiency isolates the different aspects of a plant's performance by relating them to their respective causes. Therefore, estimates of decomposed efficiency can reveal more specific economic information on why plants' productive efficiency has or has not improved. For example, plants might be technically inefficient, due to insufficient incentives, such as profit-related incentives. Alternatively, plants may be found to be technically efficient but allocatively inefficient. This suggests that factor markets are distorted and that relevant economic policies should be adopted to minimize these distortions. Furthermore, a considerable number of plants might be technically and allocatively efficient but not scale efficient, suggesting that the industrial market structure is distorted and that plants with potential scale economies can not fully exploit their potentially lower production costs. On the other hand, scale-inefficient plants may be able to expand even though they have a cost disadvantage. Therefore, industrial and liberalization policies that are neutral regarding the development of plants with economies of scale are a means of improving industrial performance.

The theory of decomposed productive efficiency has recently been widely applied to plants in market economies (Kalirajan and Shand 1985; van den Broeck 1988; Kumbhakar et al. 1989). In most of these studies, evidences of differences in productive efficiency between plants was found in the decomposed estimates of efficiency. Because these efficiency measures correspond to plants' profit maximizing behaviour under given market conditions, the resultant differences in plant-specific efficiencies were interpreted as an indication of market imperfection. As far as Chinese plants are concerned, estimates of decomposed productive efficiency allow one to judge not only individual plants' performance but also the constraints market distortions place on plants' performance.

The stylized facts about market imperfections and their impact on productive efficiency: hypotheses for empirical testing

Although there was no comprehensive blueprint for economic reforms in the Chinese industrial sector in the 1980s, fundamental changes were introduced in almost every area of the economy. Asset ownership, industrial planning, financing, pricing, commodity distribution and labour allocation and worker income determination all underwent some change.

The reforms aimed to replace the previously highly centralized planned economy with a system containing elements of both planning and market orientation. The primary purpose of the reforms was to provide incentives to local governments and plants to utilize their assets more effectively in order to further their own self-interest and thereby improve national economic efficiency. However, the reforms were contradictory in many respects.

Following the introduction of the reforms, the principle of self-interest governed the behaviour of workers, plants and even local governments while a hierarchical structure of government bureaucratic control remained. Local governments became more important in the new hierarchical control structure and tried to protect local industrial development from national competition. This change led to local industrial markets developing in a segmented manner.

The efforts to separate ownership and control rights between state agencies and state-owned plants did little to alter the traditional structure of socialist ownership. As a result, the economic activities of plants continued to be subject to direct intervention from government agencies. The mobility of capital and other resources between plants and regions became even more constrained as local governments introduced restrictions to protect their revenue sources.

The central goal of the economic reforms was to increase profit-maximization behaviour (Tidrick and Chen 1987:1-11; Wilson and Gordon 1989; Kosta 1990; Kornai 1990). The sequencing of this change in firms' behaviour was very critical for the economic reforms. If firms exhibited profit-maximizing behaviour and actively responded to the market-based reform policies, one would expect evidence of an efficiency gain in the Chinese economy. This gain would have occurred as firms began considering the costs and benefits associated with their investment and production decisions. Justification of the perceived feasibility or desirability of the market-oriented economic reforms requires determination of whether or not they achieved an efficiency gain.

It has, however, been widely argued among Chinese economists that firms did not show market-based behaviour in their responses to the reform policies but

primarily sought rents from the reform process itself (Zhang Shaojie et al. 1987; Den Yengtao and Lo Xiaopeng 1987; Dai Yuanchen and Li Hanmin 1988; Du Haiyan et al. 1990). The partial introduction of a market mechanism resulted in seriously distorted income redistribution input and output markets, leading to concern that any further reform would engender enormous economic and social uncertainty. The current debate about economic reform in China and other centrally planned economies, focuses on whether they can be reformed at all (Kosta 1989; Petr 1990). Nordhaus (1990) even proposed a Murphy's law for economic reforms in centrally planned economies: partial reformation of an internally consistent planned economy makes things worse before they get better.

The above concerns seem to confuse the effects of microeconomic reforms on plant behaviour with the effects of market imperfections on industrial performance. The focus of the empirical study of microeconomic reforms in China is on whether there was any systematic difference in industrial performance during the reform period as plants started to maximize profit rather than quantity.¹ In relation to market imperfections, empirical study focuses on how plants achieved profit maximization within the prevailing distorted market system. Market-oriented behaviour by plants potentially improves industrial performance, but market imperfections may restrict plants' effort in doing so. If this is the case, evaluation of the effects of economic reforms on industrial performance may be misleading unless a distinction is made between plants' productive efficiency improvement due to the emergence of their market-oriented behaviour and the restriction on plants' productive efficiency by the distorted factor and goods markets.²

A more detailed illustration of the impact of economic reforms on plants' behaviour with regard to factor allocation, and therefore on plant productive efficiency, can be made by considering capital and labour.

¹Kornai (1980) argued that typical plants in centrally planned economies were not normally restrained by fears of loss or failure of production because their production was externally decided by a central plan. The central decision makers took all responsibility for ensuring input supply to support the production and commercial distribution of the final products. Therefore, the survival of plants in centrally planned economies was not contingent on their ability to cover all costs out of sales proceeds as grants, subsidies and tax favours could be negotiated to fill the gap. The basic motivating force for plants was a strong quantity drive, that is, an incentive to increase output as far as possible given available resources. In relation to investment, there was an incentive to initiate and undertake investment projects to expand the scale of operation by seeking more favourable offers from a central economic plan, without any concern for whether this expansion produced net economic benefits for the country.

²Some studies (Chen Kuan et al 1988a; 1988b; Dollar 1990; Li Xiaowei 1990, Lau and Brada 1990) indicate that the total factor productivity of the Chinese industrial sector improved during the reform period. However, some studies (Lardy 1987; Du Haiyan et al. 1990) found that the productivity gains due to the reforms were rather poor and that they even deteriorated in some years. Different methodologies used for these studies may be the cause of this divergence. But it might also be that all these estimates are more or less biased in favour of one of the two effects discussed in the text. The optimistic estimates were biased toward the effects on the transition in plants' behaviour; the pessimistic ones, towards the effect of imperfections related to the Chinese market mechanism.

Capital

Accounts for Chinese plants divide capital into fixed and working capital. Fixed capital consists of capital stock accumulated from centrally allocated investment during the pre-reform period, investment undertaken from plants accumulated funds following the first introduction of reforms, from investment financed by bank loans and investment from local government and, in some instances, the central government during the reform period. Working capital consists of capital determined by central plans before economic reforms and, since economic reforms, loans provided from banks to plants with very low interest rates and plants' own accumulation. Among these sources of capital, the only truly endogenous variable over which plants had full control was their own accumulation of funds. More importantly, these funds involved an opportunity cost. Plants also incurred costs using bank loans, but whether bank loans were efficiently allocated among plants or if plants paid the true economic cost of these funds, depended on whether interest rates were at equilibrium levels and whether plants were actually required to repay the loans. Plants' behaviour regarding capital formation and utilization can be examined in relation to the different sources of capital funds.

In attempting to minimize production costs or maximize profits, plants should effectively utilize capital stock allocated to them regardless of its source. An improvement in technical efficiency should result. Furthermore, provided plants and workers retain part of the benefits from a more efficient utilization of production capacity, it should occur as a result of their response to economic incentives introduced by the reforms.

In attempting to minimize production costs or maximize profits, plants should seek to economize on capital purchases from their accumulated funds so that the marginal productivities of such capital inputs equal their marginal costs. An improvement in plants' allocative efficiency in the use of capital investment under their control should occur. Plants should also use the capital investment under their control to correct existing misallocation of resources. For example, plants could implement investment from their own funds to improve the compatibility of different types of production equipment. Plants' effort in this regard would contribute to improved technical efficiency.

The change from banks granting funds to plants free of charge during the pre-reform period to charging plants interest rates during the reform period put some constraint on plants obtaining funds from banks. Plants' behaviour towards bank loans was mainly determined by the interest rate policy implemented during the reform period. As nominal bank lending rates were lower than the inflation rate,

the real cost of borrowing was negative (Cao 1990). Hence, plants sought as many bank loans as they could with little consideration of efficient utilization. Consequently, scarce capital resources were thinly spread across numerous plants by the decentralized banking system, and were insufficient to meet demand. Non-price rationing occurred, resulting in poor allocative efficiency in relation to bank loans.

The remaining planned investment in capital inputs, not under plants' control, was allocated among plants in relation to their bargaining power with relevant government authorities. Therefore, plants' behaviour with respect to these capital inputs remained as it had been in the pre-reform period.

No basic ownership reforms were initiated, so capital remained immobile between regions and plants. Plants' ability to adjust their production scale to suit market conditions was largely restricted by their own accumulation of funds. Moreover, every plant, no matter whether it should have expanded its production capacity or not, had to implement an annual increase in capital investment using its own accumulation of funds according to the contract between plants and government authorities. As a result, industrial investment was spread more thinly across plants and a deterioration of scale efficiency occurred in a considerable number. In these circumstances it is unlikely that scale efficiency of plants could have improved.

Labour

The labour market was the least developed market in China's industrial sector. Prior to the reforms, there was no real market wage rate to allocate labour and workers had *de facto* job tenure (White 1983; 1985; 1988). The ability of a plant's manager to use labour effectively was very limited. To minimize costs in relation to labour inputs, managers should be able to relate the cost of labour to its marginal revenue product. However, their efforts in the pre-reform period were limited by an inability to retrench unnecessary workers and strong pressure from workers to increase their income in excess of their marginal productivity.

The 'bonus incentive' policy was one of the most important policies implemented in an attempt to reform the labour and wage system. The Chinese government and economists optimistically expected that, if plants were allowed to issue bonuses to workers from retained profits, this would provide a greater incentive for workers to increase their work effort and improve their productivity, that is, there would be an improvement in the plants' technical efficiency.

However, after a few years, the implementation of this bonus incentive policy merely resulted in a 'competitive bonus spiral' across plants. Workers' bonus levels in individual plants were not differentiated according to achieved productivity gains but rather converged (Chinese Institute of Economic System Reform 1987; Dai Yuanchen and Li Hanmin 1988). The 'competitive bonus spiral' within plants was mainly due to the fact that managers were not given the power to change or adjust workers' basic wage levels, which continued to be regulated by central planning. Managers' authority to set the level of workers' bonuses was strictly limited by government regulations, introduced mainly because of the 'soft' nature of the financial constraints on plants and the undue pressure workers placed on plant managers to increase bonuses. Thus, workers' income continued to lie outside the control of plant managers in the sense that they could not determine workers' income according to their marginal contributions to revenue and the effect of the 'bonus incentive' policy on workers' effort may have been diminished.

The 'competitive bonus spiral' resulted mainly from workers' pressure to increase remuneration. In so far as managers had the autonomy to issue bonuses, it was inevitable that workers would pressure management to increase total wages not only to the highest level within their plant, but also relative to other plants. Moreover, inadequate accounting and taxation systems that failed to audit plants' financial spending enabled managers to match their workers' bonus level to that of other plants, regardless of productivity.³

Although the workers' bonus policy may have had a positive impact on workers' effort, and hence on plants' technical efficiency, the consequent 'competitive bonus spiral' led to an increase in the cost of labour. Factor allocation became distorted in the sense that labour, the most abundant resource in China, became relatively more expensive while the cost of capital was held at an artificially low level.

³Numerous studies have been conducted on the worker's role in determining plant's investment patterns in Yugoslav labour-managed plants (Bonin, 1985; Mitchell, 1989). The main finding was that workers in labour-managed plants cannot recover the principal remaining on self-financed investment upon leaving the plant. Therefore, all benefits from self-financed investment must accrue through increased salaries during the workers' tenure with the plant. This requirement gives rise to a horizon problem, which refers to the relative unwillingness of workers who are nearing the end of their association with the plant to retain earnings for self-financed investment. The effect of behaviour of Chinese workers on plant's investment is very similar to that of the labour-managed plants' workers in the sense that Chinese workers only take the income increase in the contracted period as their own benefit, but treat the plant's long-run profitability as something beyond their control and even as a contrary factor to the increase in their income.

The econometric models for analysis of efficiency

The stochastic frontier method is used to estimate decomposed productive efficiencies (see Forsund et al. 1980 for a survey of different estimation methods).

In the estimation of technical efficiency, the principal advantage of this method is that the impact of factors under plants' control, in relation to technical efficiency, can be distinguished from the impact of various external uncertainties. Plants in the iron and steel industry face different production conditions according to their production location, their status in the bureaucratic hierarchy, their amount of privileged access to supplies of production inputs and bank credit, and even their bargaining power with government in deciding on their shares from profit distribution. All of these external uncertainties reflect market imperfections. As plants' performance can be affected by these external uncertainties, their impact should be netted out from the estimation of technical efficiency, which would leave an estimate of plant-specific technical efficiency, giving a better indication of a plant's performance. The estimation of technical efficiency arrived at using the stochastic method does distinguish the factors under plants' control from the external effects included as random variables. It thus ensures that estimation of plant-specific technical efficiency can be related to plants' efforts in utilizing production factors effectively. The effects of external uncertainties on plants' productive efficiency can be captured by the estimates of allocative and scale efficiencies.

Technical efficiency

The following presentation of the econometric model which incorporates the existence of technical inefficiency is based on the work of Aigner et al. (1977), Meeusen and Van den Broeck (1977), Forsund et al. (1980), Jondrow et al. (1982) and Kalirajan and Flinn (1983). As the detailed specification of the stochastic frontier model for estimating enterprise-specific technical inefficiency is well presented in these references, I will simply summarize the main structure of the model. The estimation models for allocative and scale efficiencies are based on the parameters derived from specification of technical efficiency.

Let the production function be represented by

$$y^* = f(x_1, \dots, x_j, \dots, x_m) \quad (2)$$

where y^* is the maximum possible output a plant can produce using the inputs (x_j) in a technically efficient way. It is reasonable to assume that not all plants will be technically efficient and, consequently, not all plants will be operating on the

industry's production frontier. The stochastic production frontier could then be represented by an unconstrained Cobb-Douglas production function

$$\ln y_i = a_0 + \sum_{j=1}^m a_j \ln x_{ij} + u_i + v_i \quad (3)$$

where

y_i = actual output for the plant i and $y_i \leq y^*$;

u_i = a plant-specific technical efficiency parameter which captures the impact of factors under a plant's control on that plant's technical efficiency and $u \leq 0$ by taking a half normal distribution and then is iid $N(0, \sigma_u^2)$, that is, if $u_i = 0$, plant i operates with technical efficiency and, if $u_i < 0$, it operates with technical inefficiency; and

v_i = a random variable which captures the effect of the external uncertainties on a plant's production and takes a normal distribution $N(0, \sigma_v^2)$.

In the above specification, plant-specific technical efficiency, concerned with factors under the plants' control, can be distinguished from the effects of external uncertainties on overall efficiency (Forsund et al. 1980). The distinctive characteristic of the stochastic production frontier method is its ability to isolate unobservable technical efficiency for each plant according to the conditional mean: u_i given $(u_i + v_i)$. The density functions of u_i and v_i respectively can be written as

$$f(u_i) = \frac{1}{\pi/2} \frac{1}{\sigma_u} \exp\left(-\frac{u_i^2}{2\sigma_u^2}\right) \quad u_i \leq 0 \quad (4)$$

$$f(v_i) = \frac{1}{2\pi} \frac{1}{\sigma_v} \exp\left(-\frac{v_i^2}{\sigma_v^2}\right) \quad -\infty \leq v_i \leq \infty \quad (5)$$

The joint probability density function (pdf) of $(u_i + v_i)$, obtained using the convolution formula, can be written as:

$$f(u_i + v_i) = \frac{1}{\pi/2 (\sigma_u^2 + \sigma_v^2)} \exp\left[-\frac{(u_i + v_i)^2}{2(\sigma_u^2 + \sigma_v^2)}\right] \left[1 - F\left(\frac{(u_i + v_i) \sigma_u}{\sigma_v}\right) - \right] \quad (6)$$

where, $F(\cdot)$ is the cumulative distribution function of the standard normal random variable.

With the specifications that

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\lambda = \frac{\sigma_u}{\sigma_v}$$

$$e_i = u_i + v_i$$

The density function of y_i is

$$f(y_i) = \frac{1}{\sigma \pi^{1/2}} \exp \left(-\frac{1}{2} \frac{e_i^2}{\sigma^2} \right) \left[1 - F \left(\frac{e_i}{\sigma} \lambda \right) \right] \quad (7)$$

The likelihood function of the sample can now be written as

$$L(y, h) = \prod_{i=1}^n \left[\frac{1}{\sigma \pi^{1/2}} \exp \left(-\frac{1}{2} \frac{e_i^2}{\sigma^2} \right) \left(1 - F \left(\frac{e_i}{\sigma} \lambda \right) \right) \right] \quad (8)$$

where h is the parameter to be estimated from the maximum likelihood (ML) method and is equal to the parameters (a_i, σ, λ) . The plant-specific technical efficiency for each plant, TE , can then be estimated from the expected value of u_i

$$E(u_i / (u_i + v_i)) = - \frac{\sigma_u \sigma_v}{\sigma} \left[\frac{f(\cdot)}{1 - F(\cdot)} - \frac{e_i}{\sigma} \sqrt{\lambda} \right] \quad (9)$$

$$TE = \exp(u_i)$$

where $f(\cdot)$ is the standard normal density function and both $f(\cdot)$ and $F(\cdot)$ are evaluated at

$$\frac{e_i}{\sigma} \cdot \lambda$$

The estimate of u_i is obtained from replacing e_i in equation (9) by the residual which is the difference between the estimated and the actual frontiers. Since u_i is defined as a non-positive random variable in the econometric model of equation (3), the domain of the technical inefficiency parameter, $TE_i = \exp(u_i)$, will be within

the range of 0 to 1. Accordingly, $TE_i=1$ indicates the achievement of 100 per cent of potential production and hence, technical efficiency, and $TE_i < 1$ indicates the failure to achieve potential production and hence, technical inefficiency.

Allocative efficiency

Allocative efficiency can also be estimated as:

$$MP_{ji} / MP_{1i} = W_j / W_1 \exp(\alpha_{j1})_i$$

By taking logs and rearranging, this can be rewritten as

$$(\alpha_{j1})_i = \ln(MP_{ji}) - \ln(MP_{1i}) - \ln W_j + \ln W_1$$

or, using the estimated production parameters from the estimated production function

$$(\alpha_{j1})_i = -\ln(a_1/a_j) + \ln x_{1i} - \ln x_{ji} - \ln W_j + \ln W_1 \quad (10)$$

where,

MP_{ji} = the marginal product of input x_j ($j = 2, \dots, m$);

W_j = the price of input x_j ;

$(\alpha_{j1})_i$ = the allocative efficiency parameter between input 1 and j for the observation of i and α is identically and independently distributed (iid) $N(\mu, \Sigma)$. If $\alpha_{j1} = 0$, plant i is allocatively efficient; if $\alpha < 0$ or > 0 , then it is allocatively inefficient;

a_1 and a_j = the production parameters estimated from the above ML method.

Since all variables in the right-hand side of equation (10) are economic variables and a_j and a_1 are available from the estimated stochastic frontier production function, allocative efficiency parameter (α_{j1}) can then be directly calculated.

Scale efficiency

Scale inefficiency can be defined as

$$dC_i / dy_i = p \exp(\xi_i)$$

where,

dC_i / dy_i = the marginal cost of production in plant i ;

P = the price of y_i ;

ξ_i = the scale inefficiency parameter for plant i and is iid $N(0, \sigma_\xi^2)$. If $\xi_i = 0$, plant i is scale efficient; if $\xi_i < 0$, scale inefficient in the sense that production is less than the optimal output level; and if $\xi_i > 0$, the plant is also scale inefficient, but in the sense that production is greater than the optimal output level.

By using the parameters estimated from the production function, the parameters of technical efficiency (in the domain $0 \leq u_i \leq 1$) and the parameters of allocative efficiency, scale efficiency can be estimated as

$$\xi_i = -\ln a_1 + \ln W_1 + \ln x_1 - \ln Y - \ln P - \sum_j (a_j (\alpha_{j1})_i / \sum_i a_i) + (u_i + v_i) / \sum_i a_i \quad (11)$$

$i = 1, \dots, n$
 $j = 2, \dots, n$

This specification of scale efficiency is based on technically efficient outputs and allocatively efficient inputs (see Kumbhakar et al. 1989 for details of the derivation). It defines scale efficiency as being conditional on technical and allocative efficiency. Since only technically efficient output and allocatively efficient input levels are considered, the estimates of scale efficiency from this estimation will have distinctive economic meaning alongside those for technical and allocative efficiencies.

Equations (9), (10) and (11) form the system of equations employed for incorporating technical, allocative and scale inefficiencies into a profit-maximizing stochastic frontier framework.

Variables used in the estimation and an explanation of the data used

Plant level data for the Chinese iron and steel industry for the years 1980, 1985 and 1988 were used in the estimation as these years were the most crucial in the past decade of reforms. The data are taken from *Quanguo Gongye Pucha Zilao* (Nation-wide Industrial Investigation Documents) published by the Nation-Wide Industrial Investigation Office, State Economic Commission of China in 1987 and *Gangtie Gongye Nianjian* (The Year-book of Chinese Iron and Steel Industry) published by the Ministry of Metallurgical Industry of China for the years 1986 and 1989. The estimation based on data for 1980 has been used to represent the situation in the early stage of the economic reforms. As few reform measures were implemented by 1980, it seems likely that plants' behaviour and performance were still mainly influenced by the traditional planned system.

The year 1985 was chosen because China's State Council issued provisional regulations expanding the autonomy of plants in 1984. The regulations

authorized plants' decisions on pricing, production levels and sales, investment planning, internal organization, personnel management and the disposition of wages and loans. It is expected that these regulations had an impact on plants' performance one year later, that is, by the end of 1985. The year 1988 was chosen because substantial reform measures have not been implemented since that year. The estimations based on the data in 1985 and 1988 are compared with those based on the data for 1980, representing the beginning of the reform period. Hence, it is possible to investigate whether there was any systematic change in efficiency of plants during the reform period.

Ninety-nine different scale plants were chosen as the sample population. The total annual gross output value of the 99 plants amounted to 81, 79 and 78 per cent of the total gross output value for the whole industry for 1980, 1985 and 1988 respectively. This sample is therefore used as a proxy to represent the situation in the whole industry.

In the following analysis, observations are separated by size, based on the magnitude of the plant's gross output value. Plants which had annual gross output values above 300 million yuan were taken to be the sub-group of large-scale plants. Plants which had annual gross output values between 50 to 300 million yuan were medium-scale plants. Those that remained comprised small-scale plants.

The variables used in the estimated production function are gross output, fixed capital, labour force, working capital and plant-size dummy variables. Gross output is the dependent variable and the remaining variables are independent.

The independent variables cover almost all production factors directly used in production. Fixed capital stock and labour force are the standard production factors in most production function analyses and working capital is a proxy for the cost of purchased industrial materials in plants' accounting frameworks.

The plant-size dummy variables need more explanation. As far as cross sectional analysis is concerned, the difference in plant size can sometimes have a substantial effect on a plant's productivity (van den Broeck 1988). This is particularly relevant to the iron and steel industry. This industry is well known as having substantial economies of scale (Isard 1949; Cockerill and Silbersson 1974; Gupta and Fuss 1979; Crandall 1981; Hilly 1989). By international standards, the minimum efficient scale of an integrated steel plant is 2 million tonnes of finished steel per year and that of a non-integrated plant is 1 million tonnes (Scherer 1974; Scherer and Ross 1990). However, only 10 out of more than 100 iron and steel plants in the Chinese industry achieved 1 million tonnes of finished steel in 1980s. Our concern is on those small plants which operated under the minimum

efficiency scale by international standards. The effect of plants' scale is captured directly by the plant-size dummy variables. Specifically, the following estimation model makes medium-scale plants the benchmark and contains dummy variables for large and small-scale plants. It is expected that the cost advantage of the large-scale plants due to economies of scale will be captured by a positive coefficient on the plant-size dummy variable, and, conversely, the cost disadvantage of the small-scale plants due to the lack of economies of scale will be captured by a negative coefficient on the plant-size dummy variable.

It should be noted that the estimate of scale effects from the plant-size dummy variable is somewhat different from the estimate of plant-specific scale efficiency defined by equation (11). Plant-specific scale efficiency, as defined by equation (11), was derived from comparison of output price and marginal cost. By equating marginal cost to output price, every plant has a specific optimal production scale. Hence, a plant in an industry might be relatively more efficient in scale than other plants but might still not be able to achieve its optimal size. The plant-size dummy variable captures plants' relative efficiency in scale but the estimate of scale efficiency from equation (11) indicates whether a plant has achieved its optimal scale.

In the derivation of allocative efficiency, the costs of working capital and fixed capital are compared with the cost of labour. Since reforms in industrial finance in 1984, most working capital has been in the form of bank loans, which are subject to repayment and carry a cost in the form of interest. Thus, there is a cost involved for plants to use working capital. Plants retained part of their profit under a contract system, and continuously added new investment to their fixed capital stock from retained profits, thus fixed capital stock might gradually come under plants' control, as their total capital formation was adjusted towards the realization of profit maximization. Fixed capital stock might have become responsive to output as an increasing part of fixed capital stock came to have an opportunity cost for plants. The estimates of allocative efficiency allow empirical investigation of the above situation.

The estimates for allocative and scale efficiencies are sensitive to the input and output prices used in the estimation, so considering that factor and goods markets were seriously distorted in China, actual input and output prices and hypothesized market clearing prices were used. Comparative analysis can therefore be conducted using the different price-based estimates. The hypothesized market clearing prices for the average allocative efficiency of all sample plants were estimated by an iteration process: different prices were tried and the set finally chosen was that under which the average allocative efficiency of the 99 plants was zero, that is, on average the plants were allocatively efficient.

As small-scale plants are hypothesized to be the most scale inefficient in the iron and steel industry, the hypothetical market clearing price for scale efficiency is simulated for small-scale plants. Under the simulated output prices small-scale plants, on average, are scale efficient, that is, their marginal costs equal the hypothetical prices. Although this method is more or less an arbitrary means of identifying a correct set of potential market clearing prices, it can, nevertheless, correctly indicate whether the actual input and output prices were lower or higher than the potential market clearing prices. Hence, the policy implications of the estimates of allocative and scale efficiency are easily verified.

The actual price for working and fixed capital is taken from loan rates set by China's Industrial and Commercial Bank and were 4.8 per cent for 1980, 7.3 per cent for 1985 and 7.8 per cent for 1988. The average annual income of workers was calculated from workers' average wage. Average welfare expenditure in the industry was used as a proxy for the cost of employing labour. Considering that 'bonus spiral' activity among plants led to a more or less equivalent income level among workers within a plant as well as across plants, this industrial average income is a reasonable proxy for the cost of additional labour for each plant. The annual labour costs were 1,200 yuan, 1,550 yuan and 2,200 yuan for 1980, 1985 and 1988 respectively. The actual output price used in the estimation is the weighted unit value of pig iron, crude steel and finished steel from the large-scale plants. This unit value is taken as a base price that every plant should have been able to charge for its output. It is used because the large-scale plants were subject to greater government planning and proportionately more of their output was sold at lower, planned, prices. Thus, the weighted unit value of gross output from large-scale plants was the lowest in the industry.

The analysis of empirical results

The stochastic production frontier, equation (3), was estimated using the maximum likelihood (ML) method from the program 'Frontier 2.0' (Coelli 1991). 'Frontier 2.0' was specially designed for the estimation of a frontier production function by the ML method. The estimation procedure involves three steps: first, calculation of ordinary least-square estimates (OLS); second, a grid search involving the values of γ ($\gamma = \sigma^2 / (\sigma_u^2 + \sigma_v^2)$) and a_0 (intercept term) along with adjustment of the estimate of σ^2 ; and third, the estimates from grid search are used as starting values for an iteration procedure to approximate the maximum likelihood estimates. The coefficient τ is also provided by the program as the

⁴This is the case when the restricted mode with μ set to zero is estimated. When this restriction is relaxed, the grid search involving values of γ and μ along with adjustment of estimates for a_0 and s^2 .

reference for testing the significance of time-varying technical inefficiencies of the observations. If t is statistically significant, it indicates that technical inefficiencies of the observations are varying over time. The statistic model used in the program is in Battese and Coelli (1991) and will not be presented here for simplicity.

There are two reasons for using ML estimation. First, OLS of the production function (equation 3) provides an unbiased estimate of the $k \times 1$ vector of production elasticities, a_i , but not of the intercept, a_0 , due to the non-zero expectation of $(v_i + u_i)$. The ML method outlined above can provide an unbiased estimate for a_0 . Second, the OLS estimate of the variance, denoted by σ^2_{OLS} , is often an underestimate of the sum of the variances of V_i and U_i , σ^2 . Thus, when the grid search is carried out (over $0 < \gamma < 1$ and $-2\sigma_{OLS} < \mu < 2\sigma_{OLS}$) the values of the intercept and variance parameters are adjusted accordingly.

Table 1 Maximum likelihood estimation results (dependent variable = gross output and observation numbers = 99×3)

Coefficients	Independent variables	Estimates
a_0	Constant	2.24 (20.66) ^a
a_1	Fixed capital	0.32 (6.13)
a_2	Working capital	0.33 (6.40)
a_3	Labour	0.11 (2.70)
a_4	Dummy (Large-scale plants)	0.38 (5.99)
a_5	Dummy (Small-scale plants)	-0.20 (-3.68)
γ^b		0.94 (122.97)
σ^2_b		0.57 (7.24)
τ^b		0.15 (7.78)
Log-likelihood		-60.73

Notes:

^a Figures in brackets are t-ratios and all are statistically significant at the 5 per cent level.

^b σ_u and σ_v in equations 6.3 and 6.4 can be calculated using the formula $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda = \sigma_u / \sigma_v$ (Jondrow et al. 1982).

The 'Frontier' program was chosen because the iterative method used for approximating the ML estimates, the Davidon-Fletcher-Power method, is one of the more successful Quasi-Newton methods (Himmelblau 1972).

The estimation used panel data of 1980, 1985 and 1988 and the estimation results are reported in Table 1.

From Table 1, it can be seen that the coefficients of all observable variables, fixed capital, working capital and labour force, have reasonable positive magnitudes and are statistically significant. The parameters for plant-size dummy variables in particular are statistically significant and have the expected signs, that is, the large-scale plant dummy variable has a positive sign and the small-scale plant dummy variable has a negative sign. This supports the finding that, due to their economies of scale, the large-scale plants had greater total factor productivity. On the other hand, the lack of economies of scale in the small-scale plants had a negative impact on their total factor productivity. Accordingly, it can be argued that a loss of scale economies would be most likely when the small-scale plant group expanded faster than the large-scale plant group under the constraint of scarce resources in the iron and steel industry.

It should also be pointed out that the parameters of λ and σ of the ML estimation are statistically significant and the log-likelihood value is high enough to surpass the critical value. τ is statistically significant from zero and indicates a time-varying technical inefficiencies of the observations. Hence, the ML estimation is reliable.

Technical efficiency

As stated above, a plant is said to be technically efficient if the estimated technical efficiency coefficient is 100 per cent and technically inefficient if it is less than 100 per cent. This means that, if an inefficient plant could utilize its production factors as effectively as an efficient plant, it would be able to increase its current output to the output level that an efficient plant could achieve using the same factor inputs without increasing its current factor inputs. The average technical efficiencies of different scale plants as calculated from the estimates are presented in Table 2. Some plants which were on a margin between the three defined scales moved into other plant-scale groups over the three years. To obtain a consistent result for average technical efficiency according to the estimates of individual plant's technical efficiency, the plant's scale in 1985 is chosen as the base for the calculation.

Comparing the average technical efficiency of all the sample plants with the three plant groups over the three years, there was an obvious improvement in technical efficiency in all plants during the reform period. This finding supports the hypothesis that, to maximize profits, plants utilized their production factors more effectively and improved their technical efficiency. However, the average technical efficiency of all plants in 1988 was only 0.53 and thus low. This indicates that the improvement in technical efficiency during the reform period was not sufficient to move plants' output close to their potential output level.

The obvious differences between the technical efficiency of different-scale plants should be noted. In the three years studied, while technical efficiency levels of medium-scale plants were at the average level of all plants, the large-scale plants' levels were above average and the small-scale plants' levels were well below. This is a clear indication of economies of scale in iron and steel, that is, large-scale plants could achieve their potential efficient output more easily than could small-scale plants.

Table 2 Average technical efficiency among different sized plants, 1980, 1985, 1988

	1980	1985	1988
All sample plants	0.46	0.49	0.53
In which			
Large-scale plants	0.55	0.59	0.62
Medium-scale plants	0.47	0.51	0.55
Small-scale plants	0.25	0.29	0.33

Source: Derived from the estimated plant-specific technical efficiency indexes, Cao Yong 'The Chinese Iron and Steel Industry in Transition: Toward Market Mechanism and Economic Efficiency', PhD dissertation, National Centre for Development Studies, The Australian National University, 1992.

The technical efficiency gap between plants of different scale is still a serious concern for the development of the Chinese iron and steel industry even though the improvement in technical efficiency of all plant groups during the reform period was impressive. Under the protection of local governments and especially with the advantage of being able to sell a larger portion of their products at higher

market prices, some local medium and small-scale plants were still able to increase their profit margin even though they had an obvious technical, and hence cost, disadvantage in production expansion. Table 3 compares the more technically efficient plants, plants in the category $0.80 < t < 1.00$, where t represents technical efficiency level, with the least technically efficient plants, those in the category $0.20 < t < 0.40$, in terms of their growth rates and ratio of profit to gross output. The most technically inefficient plants had a higher output growth rate, and more importantly, they had a slightly higher ratio of profit over gross output. This suggests that the technically inefficient plants had an advantage in charging higher prices for their product or through obtaining more inputs at controlled prices, or both. If this were not the case, their profit margin would have been lower. Therefore, it can be concluded that the distorted price system, and possibly local authority protection of inefficient small-scale plants, was one of the driving forces behind the distorted expansion pattern experienced in the Chinese iron and steel industry in the reform period.

Table 3 Growth rate and ratio of profit to output for plants with different levels of technical efficiency^a

	$0.80 < t < 1.00$	$0.20 < t < 0.40$
Number of plants	12	34
Growth rate (per cent)	0.19	0.25
Profit/gross output (per cent)	0.23	0.25

Note: ^a Plants' average rate of gross output growth between 1985 and 1988.

Source: The Ministry of Metallurgical Industry of China, *Gangtie Gongye Nianjian* (The Yearbook of Chinese Iron and Steel Industry), 1986 and 1989.

Allocative efficiency

Equation (10) was used to calculate allocative efficiency. According to this equation, a plant is said to be allocatively efficient if the estimate of a_{ij} for the relevant inputs i and j , is equal to 0 and allocatively inefficient if the estimate is not equal to 0. This means that plants which are allocatively efficient have chosen an input combination such that the ratio of the marginal productivities of inputs is equal to the ratio of the prices of these inputs. In other words, costs of plants

which are allocatively efficient cannot be further reduced by substitution between production factors.

The economic implications of negative or positive values of estimated allocative efficiency can be explained by reference to a comparison of inputs. Using a comparison between labour and fixed capital as an example, equation (10) becomes

$$MP_K/MP_L = r/w \exp(\alpha)$$

where MP_K and MP_L are the respective marginal products of fixed capital and labour, r is the interest rate for fixed capital, w is the wage rate, and α is the estimate of allocative inefficiency.

The economic implication of a negative α can be explained as follows. Given r and w , a plant can only change MP_K and MP_L to correct the inequality between marginal product of inputs and input prices to achieve allocative efficiency. Hence, MP_L , the marginal product of labour, must be higher than MP_K , the marginal productivity of capital. In other words, capital is being over-utilized and labour under-utilized (Kumbhakar et al. 1989:597). The rational adjustment of factor combinations would then be to use proportionately less capital relative to labour so that a plant could take advantage of the higher marginal product of labour. Costs can accordingly be reduced. The opposite conclusion can be drawn regarding a positive value of the estimates for the allocative inefficiency parameter within the above framework. However, the distorted prices of inputs should also be considered as one of the causes for the allocative inefficiency. If MP_K and MP_L are given, allocative efficiency can be achieved either by increasing the interest rate, r , or decreasing wage level, w . Hence, the allocative inefficiency of plants, as described above, may be due to distortions in factor market prices, encouraging over-utilization of one factor relative to another. Therefore, implications of the estimates derived for allocative inefficiency must be carefully considered depending on their likely causes.

In the estimations of allocative efficiency presented below, labour and wages were chosen as the numerators of equation (10) to enable comparison with the other inputs: fixed capital and working capital. The average allocative efficiency of different-scale plant groups is calculated from the estimates of individual plants' allocative efficiency parameters (Table 4).

The consistent negative signs for the estimates of the allocative efficiency parameters clearly indicate a general pattern of distortion in Chinese factor markets with over-priced labour and under-priced capital.

However, an improvement in allocative efficiency can be observed between 1980 and 1985. The average allocative efficiency of all sample plants changed from -0.77 to -0.60 for the labour/fixed capital comparison and from -1.18 to -1.07 for the labour/working capital comparison over this period. This indicates that the plants had become more able to economize on the use of fixed and working capital in production.

Table 4 Average allocative efficiency between labour, fixed capital and working capital for different-scale plant groups, 1980, 1985, 1988

	1980	1985	1988
Allocative efficiency between labour and fixed capital			
All sample plants	-0.77	-0.60	-0.65
in which			
large-scale plants	-0.60	-0.44	-0.44
medium-scale plants	-0.80	-0.62	-0.67
small-scale plants	-0.83	-0.64	-0.72
Allocative efficiency between labour and working capital			
All sample plants	-1.18	-1.07	-1.09
in which			
large-scale plants	-1.19	-1.08	-1.07
medium-scale plants	-1.19	-1.07	-1.08
small-scale plants	-1.16	-1.05	-1.17

Source: Derived from the estimated plant-specific technical efficiency indexes, Cao Yong 'The Chinese Iron and Steel Industry in Transition: Toward Market Mechanism and Economic Efficiency', PhD dissertation, National Centre for Development Studies, The Australian National University, 1992.

The key to understanding this trend was the changing nature of sources of investment for upgrading and innovation. These contributed to newly established fixed capital and working capital. Reforms in industrial financing had barely begun in 1980 and finance for investment in upgrading and innovation was channelled mainly through government planning. It was rational for plants to try to obtain large amounts of investment funds from government authorities as the cost to plants was negligible. However, following 1984, plants had to provide a considerable part of investment funds from their own accumulated revenue. Plants' behaviour towards investment was expected to change. Clearly, plants now had to consider the opportunity cost of this investment as the same funds

could be used for other purposes, providing returns at full market value. Therefore, plants should have tried to maintain the marginal product of investment at the same level as its opportunity cost. The improvement in allocative efficiency of fixed capital was reflected in the changed nature of investment during the reform period.

As far as working capital is concerned, interest rate charges on plants' working capital began in 1984 and provided plants with an incentive to use working capital more effectively compared with the situation in 1980, when working capital was mainly provided free of charge through government planning sources.

Nevertheless, it must be noted that allocative efficiency between labour and capital was still poor in 1985 and, more importantly, the improvement in average allocative efficiency for all sample plants over the period 1980-85 was followed by a deterioration of allocative efficiency between 1985 and 1988 (although, for the large-scale plant group, the level of average allocative efficiency of fixed capital over labour remained the same in 1988 as in 1985 and its level of average allocative efficiency of working capital over labour improved slightly). As indicated in Table 4, parameters for average allocative efficiency of labour/fixed capital and labour/working capital of all sample plants changed from -0.60 to -0.65 and from -1.07 to -1.09 respectively between 1985 and 1988. This finding suggests that plants' ability to improve allocative efficiency was largely restricted by the distortions existing in factor markets.

A considerable part of plants' fixed capital was inherited from the pre-reform period and plants incurred no financial cost for its use. This contributed to their capital-biased allocative inefficiency. More importantly, the virtually zero cost, plan-allocated, fixed capital investments were still provided during the reform period. Even if interest rates were charged for these investment funds, they were low or even negative in real terms, making these investments 'free gifts' to the plants.

Biased capital investment in the iron and steel industry was also encouraged by self-reliant regional development. Regional segmentation of the industry increased during the reform period and the lack of reforms regarding ownership of industrial assets continued to restrict capital mobility between regions, sectors and plants. Every region attempted to ensure its own iron and steel production capacity. Because the basic capital investment for an iron and steel plant is usually larger than that for other plants, huge amounts of capital had to be invested by each region into these plants. Moreover, other industrial resources, such as coal and iron ore, are not equally distributed across regions and, more

importantly, are scarce relative to the number of plants. Therefore, there were always plants which could not maintain normal production because of the shortage of industrial materials. Working capital had to be over-used to store the industrial materials that were in short supply, but at the same time the working capital of these plants had a low marginal productivity.

Although the reforms provided banks with the right to charge interest rates for working capital, banks failed to set interest rates according to economic rationale and thus failed to stimulate plants to operate efficiently. The interest rate that banks charged remained subject to mandatory administration from either the central government or local governments and thus, the interest rate on working capital was low and did not reflect the shortage of its supply. According to Chinese statistics (State Statistical Bureau of China 1990), the annual inflation rate for industrial material in 1988 was 12 per cent. Compared with the nominal interest rate for working capital of 9.6 per cent, banks incurred a net cost by providing plants with working capital. Plants benefited by borrowing as much working capital as they could from banks. Since the cost plants faced for working capital was essentially negligible, it was rational for plants to use working capital even if its marginal product was low. This factor, and the shortage of industrial materials outlined above, contributed to poor utilization of working capital and hence substantially larger negative magnitudes for the estimated parameters of allocative efficiency for working capital. These factors can also explain why the simulated market interest rates for working capital are very high (Table 5).

The economic reforms failed to create a labour market in the industrial economy. Workers retained their job tenure and managers could not easily decide individual workers' bonus levels through reference to a market determined rate. The 'competitive bonus spiral' took effect and during the period 1985 to 1988, the share of the wage bill in total net value of output increased from 18.7 per cent to 23.6 per cent in 1988 (Nation-wide Industrial Investigation Office, State Economic Commission 1987; the Ministry of Metallurgical Industry of China 1988, 1989). This indicates that the real cost of labour increased over the late reform period due to the increase in the real wage level of workers. The higher wage rates of 1988 were one of the key factors in the deterioration of allocative efficiency.

To shed more light on the extent of distortions in Chinese industrial factor markets, the market clearing prices of capital and labour have been simulated according to the structure of plants' marginal factor productivity. The simulation results are compared with the actual factor prices in Table 5. It is clear that a much higher interest rate and a lower wage level would have been necessary to achieve average allocative efficiency of plants in the industry. As mentioned above, the simulated interest rates for working capital are very high, but

compared to the rates for fixed capital, the higher rates for working capital could be contributed to their short-term nature.

Table 5 Comparison of actual factor prices and simulated market-clearing factor prices, 1980, 1985, 1988

	1980	1985	1988
Wage rate (yuan)			
actual	1200	1500	2200
simulated	600	700	920
Interest rate for fixed capital (per cent)			
actual	4.3	7.3	7.8
simulated	14.0	14.5	15.0
Interest rate for working capital (per cent)			
actual	4.3	7.3	7.8
simulated	36.0	39.5	40.0

Source: Actual wages rates are from Ministry of Metallurgical Industry of China, 1988-89, *Zhongguo Gangtie Gongye Nianjian* (The Yearbook of Chinese Iron and Steel Industry); 1985-88, Chinese Metallurgy Press, Beijing. Actual interest rates are from : China People's Bank, *Zhongguo Jinrong* (China's Finance), 1987/10:9; 1989/4:10; 1990/1:22, China's Finance and Economy Press, Beijing. Simulated factor prices are derived from estimates.

Scale Efficiency

Equation (11) was used to calculate the parameters of scale efficiency. According to the formulation, a negative value of the scale efficiency parameter for a plant indicates an excess of output price over marginal cost. This implies that such plants are operating below their optimum production scale. On the other hand, a positive estimate of the scale efficiency parameter indicates a plant producing marginal cost above output price and operating above its optimal production scale.

Price discrimination between plants of different scale under the two-tier price system, and its impact on plants' scale efficiency, is captured by estimates based on two different kinds of output prices. The weighted unit value of iron and steel products from large-scale plants, as mentioned before, will be used as the base price, i.e. that which every plant should be able to charge. A hypothetical market clearing price will be decided for the small-scale plants. More specifically, if small-scale plants charge this hypothetical price, their marginal cost on average will equal the hypothetical price and hence, on average, scale efficiency would be

achieved. Since most small-scale plants were profitable over the period studied, this hypothetical price would be the bench-mark price the small plants would have to charge. It is then possible to compare this bench-mark price with the base price and obtain an indication of the extent of price distortion (Table 6).

Considering the average scale efficiency of each plant group over the studied period, the estimates based on the base price for iron and steel in Table 6 indicate that, on average, the large-scale plants were operating under their optimal scale. That is, their marginal costs were lower than the output prices, and if they had increased their output levels, they could have increased their profits. On the other hand, the medium and small-scale plants on average were operating above their optimal scale. That is, their average marginal costs were higher than the output prices, and profitability could have been improved through a reduction in output. Overall, the scale efficiency in the iron and steel industry would have been improved if large-scale plants, on average, had increased their production and medium and small-scale plants, on average, had reduced their production. This finding indicates that the production of the iron and steel industry was not scale efficient because production was not optimally allocated between different-sized plants.

Table 6 Average scale efficiency of different-scale plant groups, 1980, 1985, 1988

	1980		1985		1988	
	P^a	MP^b	P	MP	P	MP
Large-scale plants	-0.17	-0.42	-0.21	-0.41	-0.10	-0.63
Medium-scale plants	0.22	-0.04	0.16	-0.04	0.27	-0.26
Small-scale plants	0.26	0.00	0.19	0.00	0.49	0.00

^a Estimates from weighted unit value of iron and steel products from large-scale plants.

^b Estimates from the hypothetical market clearing price at which small scale plants would on average achieve scale efficiency.

Source: Derived from the estimated plant-specific technical efficiency indexes, Cao Yong 'The Chinese Iron and Steel Industry in Transition: Toward Market Mechanism and Economic Efficiency', PhD dissertation, National Centre for Development Studies, The Australian National University, 1992.

What enabled medium and small-scale plants to operate at levels above their optimal scale and produce at a marginal cost greater than the output price? One

advantage was that under the prevailing system of public asset ownership, plants did not need to pay any form of interest on their fixed capital allocated through the government planning process. This meant that the part of plants' net output which should have been counted as a financial cost, for the use of government allocated fixed capital, was instead counted as profit. Therefore, despite the poor scale economies achieved by these plants, they often did not reveal the economic losses they should have because they were disguised by the fact that they paid no charge for the use of allocated assets.

However, the estimates based on the hypothetical market clearing prices necessary for small-scale plants, on average, to achieve scale efficiency, provide further insight into this problem. The hypothetical prices were 580, 510 and 1100 yuan for 1980, 1985 and 1988 respectively, with base prices at 321, 324 and 326 yuan in 1980, 1985 and 1988 respectively. The divergence between the two different types of prices was very great, especially in 1988. The implication of these estimates is clear. If small-scale plants had charged higher market prices, they would have avoided economic losses. If medium-scale plants had charged such prices, they could even have earned economic profits.

The absolute difference between the scale efficiency of large-scale plants and that of small-scale plants may be understood as an indication of the distortion in the distribution of production share across different-cost plants. This difference was about 40 per cent in 1980 and 1985 but about 60 per cent in 1988, reflecting the increasing distortion in production share distribution due to production segmentation in the iron and steel industry in the late reform period.

Conclusion

Technical efficiency for most plants was found to have improved over the economic reform period. This basically supports the hypothesis that, as various incentives, such as profit retention and bonus policies, were provided to plants and workers, they utilized production factors more effectively and achieved higher productivity. Large-scale plants are found to have been relatively more technically efficient than medium and small-scale plants.

The estimates of allocative inefficiency indicate that factor markets were distorted with over-priced labour and under-priced capital. Nevertheless, allocative efficiency over all studied inputs was found to have improved slightly over the reform period. This finding seems to support the hypothesis that plants should seek to economize on their production factors to improve their allocative efficiency. However, caution should be taken in consideration of the absolute

level of allocative inefficiency in the estimated reform years and the trend of deterioration of allocative efficiency in the late reform years (1985-88). A more realistic explanation of the estimated result is that the ability of plants to improve their allocative efficiency was restricted by distortions in factor markets. Moreover, increasing distortion in factor markets would lead to the failure of plants to rationalize their use of production factors. The simulation for the hypothetical situation of allocative efficiency of all sample plants, on average, indicates that capital should have been valued much higher, and labour, on the other hand, should have been valued much lower. In particular, the interest rate for working capital should have been much higher than the prevailing rate. Hence, the policy implication of these results is that giving plants the right to maximize profits was a necessary but not a sufficient condition for optimal resource allocation. The sufficient condition would have been to create functioning factor markets which would have given correct market signals to plants.

From the estimates of scale inefficiency based on the base prices, large-scale plants were found to operate below their optimal production scale and medium and small-scale plants were found to operate above their optimal production scale. From the estimates based on the hypothetical market clearing prices for small-scale plants, it is revealed that medium and small-scale plants should have charged much higher prices for their output to make profits. The substantial differences in scale inefficiency between different plant groups could be an indication that, under the two-tier price system and local government protection, production share was not optimally allocated among different-sized plants.

Technical efficiency for most plants was found to have improved over the economic reform period. This basically supports the hypothesis that as various incentives, such as profit retention and bonus policies, were provided to plants and workers, they utilized production factors more effectively and achieved higher productivity. Large-scale plants are found to have been relatively more technically efficient than medium and small-scale plants. The estimates of allocative inefficiency indicate that factor markets were distorted with over-priced labour and under-priced capital. Nevertheless, allocative efficiency over all studied inputs was found to have improved slightly over the reform period. This finding seems to support the hypothesis that plants should seek to maximize their production factors to improve their allocative efficiency. However, caution should be taken in consideration of the absolute

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