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Firm Size, Technical Efficiency and Productivity Growth in Chinese Industry*

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Abstract

Since the mid-1990s, China's state leadership has adopted a policy of nurturing the competitiveness of large state-owned industrial enterprises. The implications of this policy have been a matter of debate in the literature. This paper seeks to provide some useful input into the debate. With a view of investigating into the potential of long-term development of large enterprises, we estimate the "sequential production technology" in computing the Malmquist productivity index for various size-groups of enterprises in Chinese industry. Our findings indicate that large enterprises did register the fastest productivity growth and improvement in technical efficiency in the 1994-97 period. It thus appears that large-scale, mainly state-owned Chinese enterprises have exhibited the potential of making noticeable improvements and the relevant state policy does have its justification.

Keywords: firm size, technical efficiency, productivity, China, industry

1. Introduction

A key feature of China's economic reform is the state's firm grip on large-scale, state-owned enterprises (SOEs). The leadership has unambiguously indicated that large SOEs are not to be privatized. The direction of reform is rather to nurture their capability of long-term development within the framework of public ownership broadly defined. This policy was first announced in November 1993, in the Third Plenum of the Central Committee of the Fourteenth Congress of the Chinese Communist Party (CCP). The reform in the subsequent years was the restructuring and corporatization of large SOEs, in sharp contrast to the widespread privatization of small-scale (and, to a lesser extent, medium-scale) SOEs. This contrast has been characterized as a reform strategy of "grasping the large and letting go of the small" (Cao *et al.*, 1999). The policy of "grasping the large" was re-affirmed in September 1997, in the Fifteenth Congress of the CCP. And its application has been accelerated thereafter, despite the widespread skepticism or even criticism over such a South Korean- or Japanese-style policy following the eruption of the East Asian financial crisis in 1997 (Lo and Smyth, 2005; Smyth, 2000; Sutherland, 2003, ch.2).

Theoretically, in the relevant literature, scholars have had different views on the policy pursuit of building up large business conglomerates in China. Nolan (1996) and Lo (1997, ch.4), among others, propose that the existence of well-performing large enterprises and with it the realization of static and dynamic increasing returns are necessary for China to successfully accomplish the task of late industrialization. Lee (1993), and more recently Zhang (2004), in contrast, submit that large Chinese enterprises are prone to problems of soft budget constraints, muddled property rights and multi-layered principal-agent relations.

Scholarly studies of the actual performance of China's large enterprises have also come out with diverse results. Naughton (1994) is probably the first to point out that China's large (and medium-scale) enterprises registered an outstanding growth performance in the first decade of the reform era, and that virtually all of these enterprises were in fact SOEs. Lo (1999), using aggregate national data, analyzes the productivity performance of large-and-medium enterprises, and finds that the total factor productivity (TFP) of these enterprises grew faster than that of the rest of Chinese industry during 1980-96. Zheng *et al.* (2003), analyzing a sample of SOEs, find that both large and small SOEs registered positive productivity growth during 1980-94, with the former having a much better performance. Cheng and Lo (2002), meanwhile, highlight the outstanding financial performance of large enterprises by showing the trend of increasing concentration of market sales and thus profits from small to large enterprises.

In contrast, Otsuka *et al.* (1998, ch.7), analyzing a sample of 48 enterprises in the machine tool industry in the year 1991, find that the industry was characterized by serious diseconomies of scale and, as a result, large SOEs had a significantly lower level of TFP than small SOEs and non-SOEs. Analyzing a much bigger sample of 300 large-and-medium SOEs and 200 collective township-and-village enterprises in the period 1984-88, Woo *et al.* (1994) find that the SOEs had a much slower growth in TFP. Steinfeld (1998, ch.1), in assessing the financial performance of SOEs, claims that the vast majority of both large and small SOEs were "net destroyers of assets". And, in a similar vein, the World Bank (1996, p.23) claims that "(China's state-owned industry) remains a drag on the economy during the reform era – even though their efficiency might be improving."

The empirical studies reviewed above do not directly address the issue as to whether the Chinese state leadership's policy for large SOEs, i.e., of "restructuring without privatization", is a reasonable pursuit. To address the issue requires clarifying the enterprises' potential of long-term development. This, in line with the contrasting theoretical perspectives indicated above, amounts to investigating into the sources of productivity growth of the enterprises and relate these sources to their specific moves in ownership and organizational restructuring. Earlier works such as Otsuka *et al.* (1998, ch.7) do attempt to analyze the importance of economies of scale in the TFP of large SOEs, while Lo (1999) attempts to analyze the significance of specialized division of labor in accounting for the TFP growth of various categories of enterprises including large-and-medium enterprises. In a study that is perhaps the most relevant thus far, Jefferson *et al.* (2003) explicitly analyze the impact on productivity growth of the three aspects of restructuring in large-and-medium SOEs in the period 1994-99: namely, ownership diversification, organizational reform, and the building up of research and development capability. And the finding is that both the first and third aspects are of significant impact while the second aspect is not. This does not fully agree with Lin and Zhu (2001) who find that organizational reform is also of positive impact on enterprise performance.

This paper seeks to provide some useful input into the inquiry indicated in the preceding paragraph. For the purpose of assessing the state policy of "restructuring without privatization", we attempt a study of the efficiency and productivity performance of large industrial enterprises vis-à-vis small and medium ones in a way that is directly relevant to the concern over long-term development. Specifically, we compute the Malmquist productivity index by which the TFP can be decomposed into technical progress and change in technical efficiency. While most nonparametric studies of production frontiers follow the method proposed by Färe *et al.* (1994) in computing the Malmquist productivity index, we adopt a new procedure for Data Envelopment Analysis (DEA) proposed by Nin, Arndt and Preckel (2003). The latter approach avoids the possibility of having a negative technical progress, i.e., technical regress. By helping to separate out long-term development from short-term fluctuations, this approach thus fits well into our concern over the potential of long-term development of China's large enterprises. And it is particularly appropriate for analyzing enterprise performance during the period of 1994-97, which is a period of macroeconomic tightening and slowing down in the growth of aggregate demand.[1]

There are two main reasons for focusing our study on the 1994-97 period. First, as indicated in the beginning paragraph of this section, this period is the first, experimenting phase of the policy of "restructuring without privatization". It was towards the end of the period, from late 1997 and early 1998, that the state leadership decided to accelerate the application of the policy and to continue with it over the long term.[2] This decision was, at least in part, based on a particular assessment of the actual performance of large SOEs during the 1994-97 period. And there are in fact no shortage of alternative assessments that are rather dismissive of the preceding experiments (see, e.g., Wu, 2004, ch.4). Our analysis is thus of value for addressing whether the state decision is justifiable. Meanwhile, the second reason for focusing on the 1994-97 period is technical in nature. This concerns the non-availability of consistent data after the period. Relevant industrial statistical data after 1998, published by the Chinese government, are of different definitions and coverage from those of previous years. Data of 1997 and before cover all the industrial enterprises with independent accounting status, while those of 1998 and after cover all state-owned and "above-scale (of five million yuan in sales revenue)" non-state-owned industrial enterprises. The comparability problem for the category of small enterprises is particularly serious – the number of small enterprises in 1997 was 444,568, while there were only 141,672 in 1998 under the new definition.

The rest of this paper is organized as follows. In Section 2, we discuss the importance of large enterprises in Chinese industry and relevant policy issues. Section 3 introduces the quantitative methods that we use for investigation. Section 4 describes our data set. We report and discuss the empirical results in Section 5. Apart from computing the technical efficiency scores and the components of the Malmquist index, we also attempt to identify the major determinants of the efficiency and productivity of Chinese industry by regression analyses. In particular, apart from the size of the enterprises, we investigate whether the location and the industrial size of a province affect the performance. Section 6 concludes the paper.

2. The role of large industrial enterprises in China

Discernibly, the Chinese state leadership's policy of "grasping the large (state-owned enterprises)" appears to be designated to serve three purposes: namely, to retain a significant degree of socialist character in the society, to maintain state control over the "commanding heights" of the economy, and to enable Chinese industry to withstand globalized market competition. A quick review on the evolution of reforms and actual development of large enterprises clearly shows this point.

To begin with, it should be noted that large enterprises have persistently formed the core of China's state industry and the industrial sector as whole.[3] Figure 1 presents the trends of evolution of the percentage shares of large enterprises in the value-added, labor employment and capital of Chinese industry as a whole. It can be seen that, between 1978 and 2002, the value-added share increased from 31% to 36%, the employment share increased from 17% to 21%, and the capital share remained unchanged at 44%. And notice that these occurred against the background of tremendous expansions in output and capital for Chinese industry as a whole during this period. It is also of note from Figure 1 that the capital share of large enterprises has persistently exceeded the employment share, by a wide margin throughout the reform era. This indicates that large enterprises are mostly in capital-intensive industries – these have often been considered as the "commanding heights" of the economy by the Chinese government.

[Figure 1]

A further important aspect of the nature of large enterprises is that they have remained mostly state-owned or state-controlled, even after a quarter-century of market reform. Formally, according to official statistics, strictly-defined SOEs accounted for the lion's share of 87% of the value-added of large industrial enterprises in 1993. The share subsequently decreased to 74% by 1997, amid the state-enforced drive of transforming large SOEs into shareholding firms (see below). In view of the fact that shareholding firms of which state agents formally have a controlling stake typically account for around 6% of total industrial value-added and that most of these firms are large enterprises, the value-added share in large enterprises of SOEs and state-controlled shareholding firms combined is likely to have remained at around 80% in 1997. The Chinese government has ceased to publish data of SOEs by firm sizes after 1997, but it could be reasonably estimated that the value-added share in large enterprises of SOEs would remain at 67%, and of SOEs plus state-controlled shareholding firms would remain at around 75%, in 2002.[4] Yet, it should be further noted that, for the vast majority of the shareholding firms of which state agents do not formally have a controlling stake, it is found that state agents have in fact remained as the ultimate controllers through a pyramid of shareholding relationships (Lin and Zhu, 2001; Liu, Sun and Liu, 2003).

The policy of "grasping the large" also reflects the state leadership's intention to promote the international competitiveness of China's large industrial enterprises. It is interesting to note that China's attempt to build up large business conglomerates in the spirit of the South Korean and Japanese "model" did not slow down in the wake of the East Asian financial crisis. On the contrary, it was precisely during the period of 1998-2002 that this attempt made considerable headway: the average scale of large enterprises (i.e., value-added per firm) relative to the industrial total increased from 290 times in 1998 to 369 times in 2002 (Lo and Smyth, 2005)[5]. Perhaps more importantly, a large proportion of China's research and development activities are conducted in large industrial enterprises. Official statistics show that, as of 2002, R&D expenditure in large and medium enterprises amounted to Rmb 56 billion yuan, which was equivalent to 43.5% of the national total. In terms of manpower in R&D activities, in the same year, there were a total of 813,000 scientists and engineers in large and medium industrial enterprises, or 37.4% of the national total (figures from *Zhongguo Tongji Nianjian* [China Statistical Yearbook], 2003, p.749 and p.751).

It is because of the three objectives indicated above that the state policy of "grasping the large" has encompassed a range of measures that have been subject to considerable controversies. At the heart of the policy is the decision that the target of reforming large SOEs is to establish the "modern enterprise system". And the main measures pertaining to this target concern both ownership and organizational restructuring. By ownership restructuring the Chinese leadership has referred to the transformation of SOEs into shareholding firms, with the (formal or informal) controlling shareholders being mainly state agents. Specifically for large SOEs, the reform has been to turn them into either limited liability companies or limited liability stock companies. With this reform, the state-owner has thus imposed a limit on its entitlement as well as its obligation vis-à-vis the reformed enterprises. This has formed the underpinning of a wide range of organizational restructuring measures particularly the setting up of a structure of corporate governance that is characterized by relationships of check and balance between the shareholders' congress (gudong dahui), the board of directors (dongshihui), the supervisory board (jianshihui), and the management. Other crucial measures have included shedding surplus labor, hiving off "non-productive" affiliates or operations, and liquidating idle properties and assets.

Significantly, the ownership and organizational restructuring measures described above have been implemented with clearly-defined and clearly-limited helps from the government. In particular, the re-capitalization of reforming large SOEs, through measures such as the state-owner's injection of new capital and the state-initiated program of debt-equity swaps, has been implemented in the context of a reciprocity relationship with the enterprises – that is, the SOEs have had to make themselves converging to the "modern enterprise system" in exchange for the re-capitalization measures. It is precisely such a character of "restructuring without privatization" that the state policy towards large SOEs has turned out to be controversial. Yet, it has also turned out that the state has actually accelerated the application of the policy after 1997, both in terms of promoting the establishment of the "modern enterprise system" and of helping the enterprises to strengthen their technological and financial capability. This reflects its belief that large SOEs by establishing the "modern enterprise system" would become sufficiently efficient and hence – in conjunction with the strengthening of their capability – internationally competitive.

How should the state leadership's policy towards large SOEs be assessed? In particular, does the actual performance of large SOEs in the period of 1994-97, that is, the experimental phase of the policy of "grasping the large", give confidence for the long-term prospects of the policy? For, it was at least in part based on its positive assessment of the performance that, by late 1997, the state leadership decided to accelerate the application of the policy and to make it a long-term one. Yet, as can be seen from Figure 1, 1994-97 was the period where large industrial enterprise have had the worst ever performance, with its output and capital share of the national total both falling very abruptly. It is conceivably that the fall in capital share reflects the on-going ownership and organizational restructuring of the enterprises. It is also conceivable that the fall in output share reflects, in addition to the restructuring, the unfavorable macroeconomic conditions during this period. But, is the performance a transitional phenomenon, or is it a reflection of long-term development? For, what is relevant to the justification of the state policy is, ultimately, the long-term developmental potential of the enterprises. This is the central issue which we attempt to address in the paper.

3. Measuring technical efficiency and productivity growth – a nonparametric approach

To evaluate the performance of China's large industrial enterprises relative to other enterprises, we estimate the technical efficiency and the productivity growth of each group of enterprises. Technical efficiency measures the output of a production as compared with the maximum possible output, that is, the output level on the production frontier. The level of technical efficiency thus indicates how efficient a production unit utilizes its inputs. Another important dimension of evaluating the performance of a production unit is the total factor productivity (TFP) growth, that is, the growth of output that is not attributable to the increase in inputs. Färe *et al.* (1994) suggest that TFP growth can be measured by the Malmquist productivity index, which can be decomposed into two factors, technical progress (which indicates the shift of production frontier) and the change in technical efficiency. Although this method has been widely used in empirical studies, it sometimes gives rise to the problematic result of having a negative technical progress (that is, technical regress). We will follow the procedure recently proposed by Nin, Arndt and Preckel (2003) to compute the efficiency and productivity scores that can avoid this problem. To explain the method, it is convenient to first introduce the approach of Färe *et al.* (1994). To start with, suppose that we have an output possibility set at time *t*:

$$(1) \quad P^t(x) = \{y^t: x^t \text{ can produce } y^t\},$$

where x^t and y^t are the input and output vectors respectively and t =1,…,T. To measure the technical efficiency of a production unit at time *t*, we can make use of output distance function, which can be defined as:

(2) $d_o^t(x^t, y^t) = \min\left\{\theta : \left(x^t, \frac{y^t}{\theta}\right) \in P^t(x)\right\}$

The distance function measures the maximum possible output that can be produced by a given amount of inputs x^t. Note that when θ is minimized, y^t/θ is maximized.

The idea can be shown diagrammatically by a simplified case of one-input and one-output with constant returns to scale (CRS) technology. Points D and E in Figure 2 represent the input-output combinations of a production unit in periods *t* and *t+1* respectively. In both periods, it is operating below the production possibility frontier. At time *t*, the frontier is determined by the best-performing unit which is producing at F. Correspondingly, at time *t+1*, the best-performing unit (not necessarily the same at the one at F) passes through the point F'. In period *t* (correspondingly, period *t+1*), with input x^t (x^{t+1}), it should be able to produce y^a (y^c) if it has full technical efficiency. Thus the technical efficiency is measured by y^t/y^a (y^{t+1}/y^c).

[Figure 2]

Productivity growth can be measured by the part of output growth that is not contributed by input growth. In Figure 1, we can calculate a productivity index by $(y^{t+1}/y^t)/(y^b/y^a)$, where (y^{t+1}/y^t) is the output growth and (y^b/y^a) represents a movement along the production frontier in period *t*. This can be rewritten as $(y^{t+1}/y^b)/(y^t/y^a)$, where the numerator is a distance function for output in period *t+1* with reference to the technology of period *t* and the denumerator is the distance function representing the technical efficiency in period *t*. This is precisely the Malmquist Productivity Index defined by Caves, Christensen and Diewert (1982a, 1982b), with reference to the technology of the initial period:

(3) $m_{CCD}^t = \frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)}$

However, we can also choose the technology in period *t+1* as the reference in defining a productivity index. The Malmquist Productivity Index in relation to the technology of the final period can be defined as:

$$(4) \qquad m_{CCD}^{t+1} = \frac{d^{t+1}(x^{t+1}, y^{t+1})}{d^{t+1}(x^t, y^t)}.$$

The two indices appear to be identical in the simple case represented by Figure 2. However, they may be different in the cases of multiple inputs or multiple outputs. To avoid the arbitrariness in choosing the benchmark, Färe *et al.* (1994) specify the Malmquist Productivity Index as the geometric mean of the above two indexes:

$$(5) \quad m\ (x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} \times \frac{d^{t+1}(x^{t+1}, y^{t+1})}{d^{t+1}(x^t, y^t)} \right]^{1/2}.$$

Färe *et al.* (1994) shows that this index is equivalent to:

$$(6) \quad m\ (x^{t+1}, y^{t+1}, x^t, y^t) = \frac{d^{t+1}(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} \times \left[\frac{d^t(x^{t+1}, y^{t+1})}{d^{t+1}(x^{t+1}, y^{t+1})} \times \frac{d^t(x^t, y^t)}{d^{t+1}(x^t, y^t)} \right]^{1/2},$$

where the ratio outside the square bracket measures the change in technical efficiency between the years *t* and *t+1*. The geometric mean of the two ratios inside the square bracket captures the shift in technology between the two periods evaluated at x^t and x^{t+1}.

In Figure 2, the two components of the Malmquist Index as in Equation (6) is represented by:

$$(7) \qquad \text{Efficiency change} = \frac{y^{t+1} / y^c}{y^t / y^a}; \text{ and}$$

(8) Technical change = $\left[\frac{y^{t+1}/y^{b}}{y^{t+1}/y^{c}}\times\frac{y^{t}/y^{a}}{y^{t}/y^{b}}\right]^{1/2}$.

For illustration of ideas, consider the situation when the new frontier at time *t+1* happens to be F" instead of F'. This can happen when, in the case of agricultural production, there is a natural disaster under which the best-performing unit produced less than before with the same inputs. In the case of industrial production, it can be that a general deterioration in the macroeconomic environment leads to a decrease in productivity. Under such situation, one can easily check that the production unit has a positive change in technical efficiency but a negative technical progress, following the decomposition method described above.[6] However, a negative technical progress creates uneasiness in the interpretation. A production technology (as represented by the production frontier) is determined by the stock of scientific and organizational knowledge we have in combining input factors to produce outputs. Such knowledge, once acquired, cannot be destroyed under normal circumstances. Thus, normally, the production frontier can either remain unchanged or shift upward. However, the method suggested by Färe *et al.* (1994) does not take care of this. The production frontier for a particular time period is constructed based only on the observation points in that period, representing a "contemporaneous production technology". That is why negative technical progress may appear in the case of having a F" in period *t+1*. To avoid this shortcoming, Nin, Arndt and Preckel (2003) invoke the concept of "sequential production technology" in the computation of the Malmquist productivity index. The underlying idea is that firms can do what they could do before. To capture the cumulative nature of technology, the "sequential production technology" in period *t* measures the maximum possible output that can be produced in or before period *t* with a given amount of inputs. Nin, Arndt and Preckel (2003) apply the method to analyze the agricultural productivity of developing countries and find very different results from those using the traditional method.

Most previous empirical studies follow Färe *et al.* (1994) to use DEA to estimate the distance functions.[7] To construct the “sequential production technology”, we have to modify the linear programming procedures. Suppose there are K regions (indexed by k) using N inputs (indexed by n) to produce M products (indexed by m). x_n^{ki} and y_m^{ki} denote the n[th] input and m[th] output in the k[th] region at time period i ($i=t$, $t+1$). We have to solve a linear programming problem to evaluate each of the distance functions in equation (6). Färe *et al.* (1994) estimate the distance function for a particular region k^*, assuming a constant returns-to-scale technology, by

$$\text{(9)} \quad \left[d^i(x^{k^*i'}, y^{k^*i'})\right]^{-1} = \max_{z,\theta} \theta^{k^*}$$

$$\text{s.t.} \quad \theta^{k^*i'} y_m^{k^*i'} \le \sum_{k=1}^{K} z^{ki} y_m^{ki}, \qquad m = 1,\ldots,M,$$

$$\sum_{k=1}^{K} z^{ki} x_n^{ki} \le x_n^{k^*i'}, \qquad n = 1,\ldots,N,$$

$$z^{ki} \ge 0, \qquad k = 1,\ldots,K,$$

where z^{ki} is a variable indicating the intensity at which a particular activity is employed in constructing the frontier of the production set. Note that when $i=i'=t$ (correspondingly, $i=i'=t+1$), solving the above linear programming yields the technical efficiency in period t ($t+1$).

In contrast, Nin, Arndt and Preckel (2003) suggest that the following linear programming be run:

$$\text{(10)} \quad \left[d^i(x^{k^*i'}, y^{k^*i'})\right]^{-1} = \max_{z,\theta} \theta^{k^*}$$

$$\text{s.t.} \quad \theta^{k^*i'} y_m^{k^*i'} \le \sum_{s=1}^{i} \sum_{k=1}^{K} z^{ks} y_m^{ks}, \qquad m = 1,\ldots,M,$$

$$\sum_{s=1}^{i} \sum_{k=1}^{K} z^{ks} x_n^{ks} \le x_n^{k^*i'}, \qquad n = 1,\ldots,N,$$

$$z^{ks} \ge 0, \qquad k = 1,\ldots,K, \text{and } s=1,\ldots, i.$$

It can be seen that the changes in the constraints ensure that the frontier so constructed for a time period will never fall below the best technology in the past.

Up to this point, we have concentrated our discussion on constant returns to scale (CRS) technology. It is certainly possible to construct a production frontier based on variable returns to scale (VRS) technology by DEA. This can be done by adding the constraint $\sum z^{ks} = 1$ to the linear programming. In our analysis, we do not have any *a priori* reason to assume a particular technology, so we do both for the analysis of technical efficiency. As will be seen below, the results do not differ much in the two cases. Färe *et al.* (1994) suggest that in the decomposition of the Malmquist index, the component "efficiency change" can further be decomposed into "scale efficiency change" and "pure technical efficiency change". However, as pointed out by Grifell-Tatjé and Lovell (1995), a Malmquist index may not correctly measure total factor productivity (TFP) changes when VRS is assumed for the technology. Ray and Desli (1997) also contend that there may be confusion in the simultaneous use of CRS and VRS technologies within the same decomposition of the Malmquist index. We do not perform this decomposition to avoid confusions.

4. Data description

We have collected the province-level data of the inputs and outputs of large-, medium- and small-scale enterprises for the years 1994 and 1997 (data for 1995 and 1996 are not available). We treat each province of Mainland China as having three production units, each for one size-group of enterprises. Since the data of Xizang is not available, we have data for 29 province-level administrative units, that is, provinces plus centrally-administered municipalities and autonomous regions. Thus, we have 87 production units for each year. The output is the industrial value-added registered in 1990 constant prices. As usual, we have labor and capital inputs. The former is represented by the average number of employees during the year. As for capital, we use the data of the average net value of fixed assets during the year, deflated to 1990 prices by the provincial deflator for investment in fixed assets. The deflator is obtained from the *Statistical Yearbook of China*, various issues. For all other variables, the data are obtained from *Industrial Statistical Yearbook of China*, 1995 and 1998. Descriptive statistics of the variables are listed in Table 1.

[Table 1]

5. Results and discussions

5.1 The Malmquist index and decomposition

Our quantitative analysis starts by applying the method of Färe *et al.* (1994). As the Malmquist index contains multiplicative elements, it is convenient to summarize the results by the geometric means (instead of the average) of the indexes of the provinces. In Table 2, the row for "whole industrial sector" reports the geometric means for the 87 observations, while the other three rows report the geometric means of the 29 observations (provinces) for the particular sector. All the three indexes for the "whole industrial sector" are smaller than one, indicating that there was negative growth in technical efficiency, technical progress and TFP during 1994-97. Note that the technical efficiency declined only slightly. The major problem lied in the technical regress. A breakdown of the enterprises of different sizes indicates that the problem mainly came from small- and medium-scale enterprises. In any case, as explained above, the result is at odds with common conception of technical progress, and, more specifically, does not fit into our concern over the potential of long-term development (separated out from short-term fluctuations) of China's large industrial enterprises. Thus, it is desirable that we take a further step to apply the procedures proposed by Nin, Arndt and Preckel (2003).

[Table 2]

Table 3 reports the results that are based on the analytics of the "sequential production technology". China's industrial sector as a whole registered a negative growth of 6.5% [i.e., (0.935 - 1) x 100%] in TFP. This is not surprising, as China was under a tight macroeconomic policy during 1994-97. However, during this same period, the industrial sector still managed to have a technical progress of 4.5%. In contrast, there was a deterioration of technical efficiency by 10.5% [i.e., (0.895 - 1) x 100%]. This pattern is different from the results that are based on the "contemporaneous production technology", in which case the frontier output in 1997 was under-estimated – thus resulting in the finding of a negative technical progress and smaller change in technical efficiency.

In the case of "sequential production technology", the performance of large enterprises registered the best performance in all the three indicators. It was the only group of enterprises that had an improvement in technical efficiency. Its technical progress of 11.9% was much faster than the 1.4% and 0.4% of the medium- and small-scale enterprises respectively. As a result, large enterprises registered a remarkable TFP growth of 18.7% during this period. Without the good performance of this sector, the overall performance of China's industrial sector could be worse in this period.

[Table 3]

5.2 Technical efficiency

Table 4 provides information about the levels of technical efficiency of each group of enterprises when the frontiers are constructed by CRS and VRS technologies, respectively. Consider the case of CRS. The first thing to note is that the technical efficiency of large enterprises on average was lower than the whole industrial sector in 1994. The geometric mean of provincial technical efficiency indices for large enterprises was 0.392, which was significantly below the geometric mean of 0.446 of the technical efficiency indices for the whole industrial sector. However, due to the substantial improvement of large enterprises, their technical efficiency (0.416) became higher than the whole industrial sector average (0.399) in 1997. This means that large enterprises were making significant improvements during this period. In contrast, medium- and small-scale enterprises suffered from big declines. The technical efficiency score of medium-scale enterprises in 1997 was only 0.323, the lowest among the three groups of enterprises. In both years, small enterprises registered the highest technical efficiency scores. This was probably because they were subject to less policy restrictions and burdens. In particular, under the state policy of “letting go the small”, small enterprises started much earlier than large and medium ones in shedding surplus labor.

[Table 4]

Meanwhile, as shown in the lower part of Table 4, there were only three production units on the frontier in 1994, namely, Yunnan-L, Beijing-S and Liaoning-S. By 1997, there were two more units that lied on the sequential production frontier. Both of them, Guangdong-L and Yunnan-L, were of the sector of large enterprises. Following Kumar and Russell (2002), we can exploit the nature of constant returns to scale and depict the production frontiers by plotting output per worker against capital per worker in a two dimensional diagram. As shown in Figure 3, the units that pushed the production frontier upward in 1997 were Guangdong-L and Yunnan-L. That means the large enterprises played an important role in improving the technical progress during this period.

[Figure 3]

When we assume a VRS technology, as expected, the geometric means for all the sectors are higher than in the case of CRS. With the more flexible technology of VRS, more observation points are found to be on the frontier and the frontier is closer to the production units inside. The numbers of production units on the frontier were eight and seven in 1994 and 1997, respectively. In both years, the large enterprise sectors of four provinces (Guangdong–L, Shanghai-L, Hainan-L and Yunnan-L) were on the frontier. The first three are located in the coastal region whereas the last one is located in the western region. The small enterprise sectors of three provinces also lied on the frontier in 1994 (Beijing–S, Liaoning–S and Jiangsu–S). All these are located in the coastal region. The performance of medium-scale enterprises seemed to be less impressive. Only one province of this sector was on the frontier in 1994 (Qinghai-M), and none in 1997. Similar to the case of CRS, the geometric mean of large enterprises (0.488) was lower than that of the whole industrial sector (0.511) in 1994. However, in 1997 the former increased to 0.520, while the latter dropped to 0.463. Thus, large enterprises made the greatest improvements in both cases of CRS and VRS.

Given these observation points on the production frontier, one would like to check whether the efficiency performance of the industrial enterprises has a clear location pattern. We break down each size-group of enterprises into coastal, central and western regions and report the geometric means in Table 5. It is obvious that in all the three size-groups of enterprises, the coastal region registered a higher level of technical efficiency in both years, regardless of what technology we assume. The relative performance of the central and the western regions is less clear. For small enterprises, the central region performed better in all the four cases. For large enterprises, the central region performed worse than the western region under CRS, but the reverse is true under VRS. As for medium enterprises, western provinces performed better than central provinces in 1994 under CRS and VRS, but the reverse is true in 1997 under CRS. However, the performances of the two regions were equally bad under VRS in 1997.

[Table 5]

5.3 Regression analysis

While the geometric means provide an overall yet rough picture of the performance of different size-groups of enterprises, a more rigorous test of the determinants of the indices can be conducted by regression analysis. Two sets of regressions are run. The first set uses ordinary least squares (OLS) to find out the determinants of the efficiency change, technical change and TFP growth. The second set of regressions employ Tobit models to find out the determinants of technical efficiency. Tobit models are used here because the value of technical efficiency ranges from 0 to 1.

We test the same exogenous variables in both sets of regressions. Firstly, we include two size dummies, one for large and one for medium enterprises, to examine whether different size-groups of enterprises have significant differences in the performance. Secondly, we include a dummy for coastal provinces and another one for central provinces. Coastal provinces have registered higher economic growth than inland areas, but their performance in terms of efficiency and productivity is less clear. Lastly, we include the industrial value of the province (Psize) to see if the total size of the industry sector of a province will affect the performance of its respective sectors (i.e., large, medium and small enterprises). It is well-known that the new economic geography suggests that firms will benefit if they can produce in nearby locations. This may generate some agglomeration effect that enhances the performance of the enterprises (Fujiti and Thisse, 2002).

Table 6 reports the results for the first set of regressions. In all the three regressions, the coefficients for large enterprises are all positive and significant, confirming that large enterprises indeed had better performance than smaller ones. In contrast, the dummy for medium enterprises were all insignificant, indicating that their performance was not much below that of small enterprises. The location dummies were also insignificant in most cases, except that the coastal dummy is positive and significant in the technical progress regression. Interestingly, the industrial size of the provinces (Psize) does not have any significant impact on any of the three indicators (see discussion below).

[Table 6]

The results for the second set of regressions are reported in Table 7. Under CRS technology, the technical efficiency of both large and medium enterprises was significantly worse than small enterprises in 1994. Although the dummy for large enterprises was still negative in 1997, it was no longer statistically significant. These findings suggest that large enterprises had an unambiguously lower level of technical efficiency than small enterprises in 1994, but they made so much improvement in the subsequent years so that the level became indistinguishable from that of small enterprises in 1997. In both years, the coastal dummy was positive and significant, implying that coastal provinces had higher technical scores than western provinces. However, the performance of central provinces was not significantly different from western provinces. Meanwhile, the size of the industrial sector of province did have very significant impact on the efficiency performance of the industrial enterprises. The larger the size of industrial sector, the higher the technical efficiency. This is quite different from the first set of regressions, in which Psize is insignificant in all the regressions. A possible explanation is that as the relative industrial sizes of the provinces did not change much during this period, this factor did not generate much change in technical efficiency and technical progress during this period.

[Table 7]

Under the assumption of VRS technology, the two size dummies are significant in 1994. However, similar to the case of CRS, the dummy for large enterprises became insignificant in 1997. Thus our result is not sensitive to the choice of technology in the DEA. The dummy for medium enterprises were negative and highly significant. Its coefficient decreased from -0.1248 to -0.2165 during 1994-97, reflecting the fact that medium enterprises were falling further behind small enterprises. An interesting phenomenon was that the coastal dummy was not statistical significant in 1994, but it became significant in 1997. In other words, the coastal provinces did not have much advantage in 1994, but they were able to take the opportunity of reforms during this period to improve their performance. Finally, similar to the case of CRS, the size of the industrial sector of a province also had positive and significant impact on the technical efficiency of enterprises.

6. Conclusions

Since the mid-1990s, whilst permitting the privatization of small enterprises, China's state leadership has persistently adopted a policy of nurturing the competitiveness of large state-owned industrial enterprises. The developmental implications of this policy, often characterized as "restructuring without privatization", has been a matter of debate in the literature. And one focus of the debate is on the assessment of the actual performance of large enterprises in the first phase of the implementation of the policy, i.e., in 1994-97. This is because the actual performance of large enterprises did not clearly appear to give confidence to the long-term prospects of the policy. Yet, it turned out that, since late 1997, the state leadership has re-affirmed the policy and decided to make it a long-term pursuit.

This paper seeks to provide some useful input into the debate. With a view of investigating into the potential of long-term development of large enterprises, we estimate the "sequential production technology" in computing the Malmquist productivity index for various size-groups of enterprises in Chinese industry. Our findings indicate that large enterprises did register the fastest productivity growth and improvement in technical efficiency in the 1994-97 period, although it is also true that these enterprises started with the lowest level of technical efficiency in 1994. The implication, therefore, is that large-scale, mainly state-owned, enterprises have exhibited the potential of making noticeable improvements and the relevant state policy does have its justification.

Notes

[1] In the latter half of 1993, China's state leadership adopted a tightening policy which was aimed at curbing the runaway inflation that arose from the economic overheating of 1992-93. The policy lasted until 1997. In the wake of the East Asian financial crisis, China turned to adopt an expansionary fiscal policy of unprecedented scales. See Cheng (1999) for an analysis of the drastic policy reversal, and the corresponding changes in the macroeconomic conditions, in 1997-98.

[2] Lin and Zhu (2001) provide a detailed documentation of the series of measures, pertaining to the policy of "restructuring without privatization", that have been rigorously applied to large SOEs from late 1997.

[3] China's large, medium and small-scale industrial enterprises are defined according to either some technical criteria or the value of their fixed assets. For instance, iron and steel integrated manufacturers with annual output of 600,000 toms or more are classified as large scale, those with output of 100,000-600,000 tons are classified as medium scale, and those with output below 100,000 tons are classified as small scale. See the explanations in *Zhongguo Tongji Nianjian* (1994, pp.463-79). Also see the discussions in Lo (1999).

[4] These figures are obtained in the following way. For SOEs alone, official statistics show that, in 1997, large SOEs accounted for 70% of the value-added of all industrial SOEs. Assuming that this ratio remained the same in 2002 – which is likely an under-estimation of the share of large SOEs given the policy of "grasping the large, letting go the small" – we can estimate the value-added of large SOEs from that of all SOEs. The estimate turns out to be equivalent to 67% of the value-added of all large enterprises in 2002. For state-controlled large shareholding firms, again given the state measures pertaining to the policy of "grasping the large", it is most likely that the value-added share of these enterprises in all large enterprises in 2002 exceeded the 1997 level of 6%. Hence the (conservative) estimate that SOEs plus state-controlled shareholding firms accounted for around 75% of the value-added of all large industrial enterprises in 2002. All the value-added data cited in this footnote are from *Zhongguo Gongye Jingji Tongji Nianjian* (China Industrial Economics Statistical Yearbook), various issues.

[5] Data are from *Zhongguo Tongji Nianjian* (China Statistical Yearbook), various issues. The Chinese government has ceased to publish data of the number of industrial production establishments (i.e., industrial enterprises) of the national total for the year 2000 and after. The data used here are estimates on the assumption that, between 1999 and 2002, this number grew at the same rate as that of the number of industrial enterprises of the formal sector.

[6] The simple example used here is for illustration of the problem. More generally, even when there is an upward shift of the production frontier, it is still possible to have a negative technical progress. The situation in the case of multiple inputs is more complicated. One can imagine that the output hyper-planes of different periods may intercept with each other, resulting in technical progress in some units and technical regress in others.

[7] Coelli, Rao and Battesse (1998) explain clearly how the estimation can be done.

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Table 1 Descriptive statistics of variables

	Industrial value added in 1990 constant prices (Rmb 100 million)	Net value of fixed assets in 1990 constant prices (Rmb 100 million)	Number of employees (10,000)
1994			
Mean	131.926	130.676	97.810
Maximum	776.736	526.091	495.580
Minimum	3.353	4.907	2.120
Stand. Dev	137.234	124.468	94.843
1997			
Mean	185.201	219.406	90.467
Maximum	939.568	906.465	405.090
Minimum	2.811	8.540	2.640
Stand. Dev	197.538	205.035	81.354

Table 2 Decomposition of Malmquist Index based on contemporaneous production technology

(Geometric means of provincial indices)

	Efficiency change	Technical change	TFP growth
Whole industrial sector (i.e. all the 3 size-groups of enterprises)	0.992	0.934	0.927
Large enterprises	1.120	1.024	1.146
Medium enterprises	0.893	0.894	0.799
Small enterprises	0.976	0.890	0.869

Table 3 Decomposition of Malmquist Index based on sequential production technology

(Geometric means of provincial indices)

	Efficiency change	Technical change	TFP growth
Whole industrial sector (All the 3 size-groups of enterprises)	**0.895**	**1.045**	**0.935**
Large enterprises	1.061	1.119	1.187
Medium enterprises	0.784	1.014	0.796
Small enterprises	0.862	1.004	0.866

Table 4 Technical efficiency index based on the sequential production frontier approach

(Geometric means of provincial indices)

	Constant returns to scale (CRS)		Variable returns to scale (VRS)	
	1994	1997	1994	1997
Whole industrial sector (All the 3 size-groups of enterprises)	**0.446**	**0.399**	**0.511**	**0.463**
Large enterprises	0.392	0.416	0.488	0.520
Medium enterprises	0.412	0.323	0.469	0.357
Small enterprises	0.548	0.472	0.584	0.535
Production units on the Frontier	Yunnan-L*	Guangdong-L	Guangdong-L	Guangdong-L
	Beijing-S*	Yunnan-L	Shanghai-L	Shanghai-L
	Liaoning-S*		Hainan-L*	Hainan-L
			Yunnan-L*	Yunnan-L
			Qinghai-M*	Guangdong-S
			Beijing-S*	Jiangsu-S
			Liaoning-S*	Hubei-S
			Jiangsu – S*	

Note: (1) The capital letters suffixing the province names indicate the enterprise size-groups, i.e., L for large, M for medium and S for small enterprises. (2) Observations of 1994 that are marked with * also appeared on the frontier of sequential production technology of 1997.

Table 5 The technical efficiency index across regions

(Geometric means of provincial indices)

	Region	TE94-CRS	TE97-CRS	TE94-VRS	TE97-VRS
Large enterprises	Coastal	0.512	0.539	0.684	0.691
	Central	0.317	0.331	0.403	0.436
	Western	0.334	0.365	0.364	0.413
Medium enterprises	Coastal	0.483	0.433	0.526	0.488
	Central	0.353	0.278	0.378	0.296
	Western	0.390	0.266	0.503	0.296
Small enterprises	Coastal	0.654	0.566	0.705	0.699
	Central	0.546	0.503	0.554	0.538
	Western	0.421	0.334	0.467	0.358

Note: The coastal region is composed of Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan. The central region is composed of Shanxi, Inner Mongolia Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region is composed of Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

Table 6 Determinants of efficiency change, technical change and TFP growth

Dependant variable	Efficiency change	Technical change	TFP growth
Constant	0.8424 ***	1.0056 ***	0.8458 ***
	(0.0545)	(0.0193)	(0.0605)
Dummy for coastal provinces	0.0302	0.0501 **	0.0732
	(0.0654)	(0.0231)	(0.0726)
Dummy for central provinces	0.0290	-0.0215	0.0031
	(0.0593)	(0.0210)	(0.0658)
Dummy for medium enterprises	-0.0792	0.0108	-0.0688
	(0.0544)	(0.0193)	(0.0605)
Dummy for large enterprises	0.1887 ***	0.1201 ***	0.3206 ***
	(0.0544)	(0.0193)	(0.0605)
Size of the industrial sector	6.4E-05	-3.8E-05	3.7E-05
(value-added in 1994)	(8.2E-05)	(2.9E-05)	(9.1E-05)
Adjusted R^2	0.2061	0.3898	0.3452
No. of observations	87	87	87

Figures in parentheses are standard errors

Note: * significant at 10%, ** significant at 5% and *** significant at 1%.

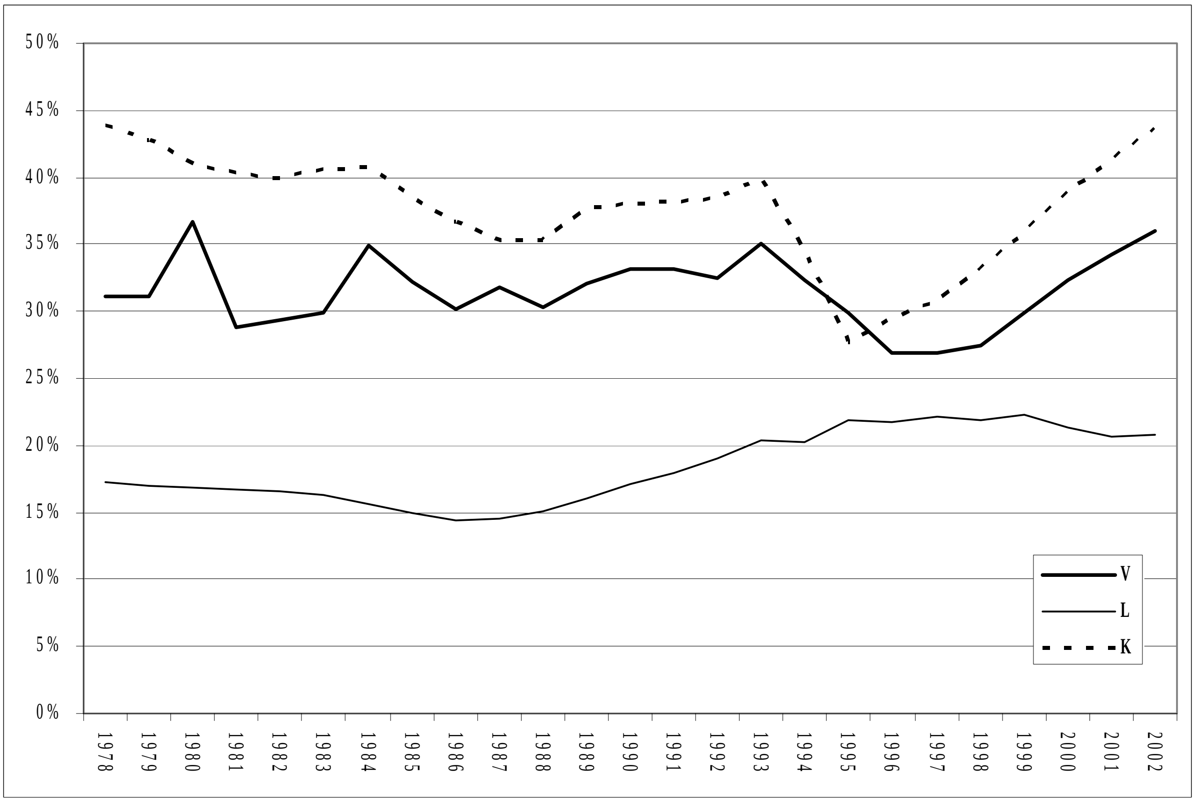
Table 7 Tobit analysis of technical efficiency

Dependant variable	TE94 (CRS)	TE97 (CRS)	TE94 (VRS)	TE97 (VRS)
Constant	0.4791 ***	0.3841 ***	0.5136 ***	0.3964 ***
	(0.0434)	(0.0397)	(0.0515)	(0.0428)
Dummy for coastal provinces	0.0859 *	0.0886 *	0.0862	0.1128 **
	(0.0520)	(0.0476)	(0.0619)	(0.0514)
Dummy for central provinces	-0.0174	0.0015	-0.0678	-0.0017
	(0.0471)	(0.0432)	(0.0560)	(0.0466)
Dummy for medium-sized	-0.1561 ***	-0.1652 ***	-0.1248 **	-0.2165 ***
Enterprises	(0.0433)	(0.0396)	(0.0516)	(0.0430)
Dummy for large enterprises	-0.1626 ***	-0.0503	-0.0888 *	-0.0271
	(0.0433)	(0.0397)	(0.0518)	(0.0432)
Size of the industrial sector	0.0002 ***	0.0002 ***	0.0003 ***	0.0004 ***
(value-added in the year	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Adjusted R2	0.3411	0.3787	0.3095	0.5737
Number of observations	87	87	87	87

Figures in parentheses are standard errors

Note: * significant at 10%, ** significant at 5% and *** significant at 1%.

Figure 1 The percentage shares of value-added, labour employment and net value of fixed assets of large enterprises in Chinese industry



Sources: *Zhongguo Tongji Nianjian* (China Statistical Yearbook) and *Zhongguo Gongye Jingji Tongji Nianjian* (China Industrial Economics Statistical Yearbook), various years.

Notes: V= industrial value-added; L = year-average labour employment; K = net value of fixed assets.

The total of Chinese industry refers to all industrial establishments in the country, including very small-scale rural industrial establishments. Its value-added figures are from data of the industry component of GDP. Its labour employment figures are from data of the industry component of total employment in the society. And its fixed assets figures are estimated on the basis of the capital-output ratio of the formal sector of Chinese industry – i.e., township-and-above independently accounting industrial enterprises for 1997 and before, and all state-owned industrial enterprises plus above-scale (of five million yuan in sales revenue) non-state-owned industrial enterprises for 1998 and after. Because informal industrial establishments are conceivably with a lower capital-output ratio than formal industrial enterprises, the K-curve in the graph is likely to over-state the total capital stock of Chinese industry and therefore under-state the capital share of large industrial enterprises.

Figure 2 Decomposition of Malmquist index

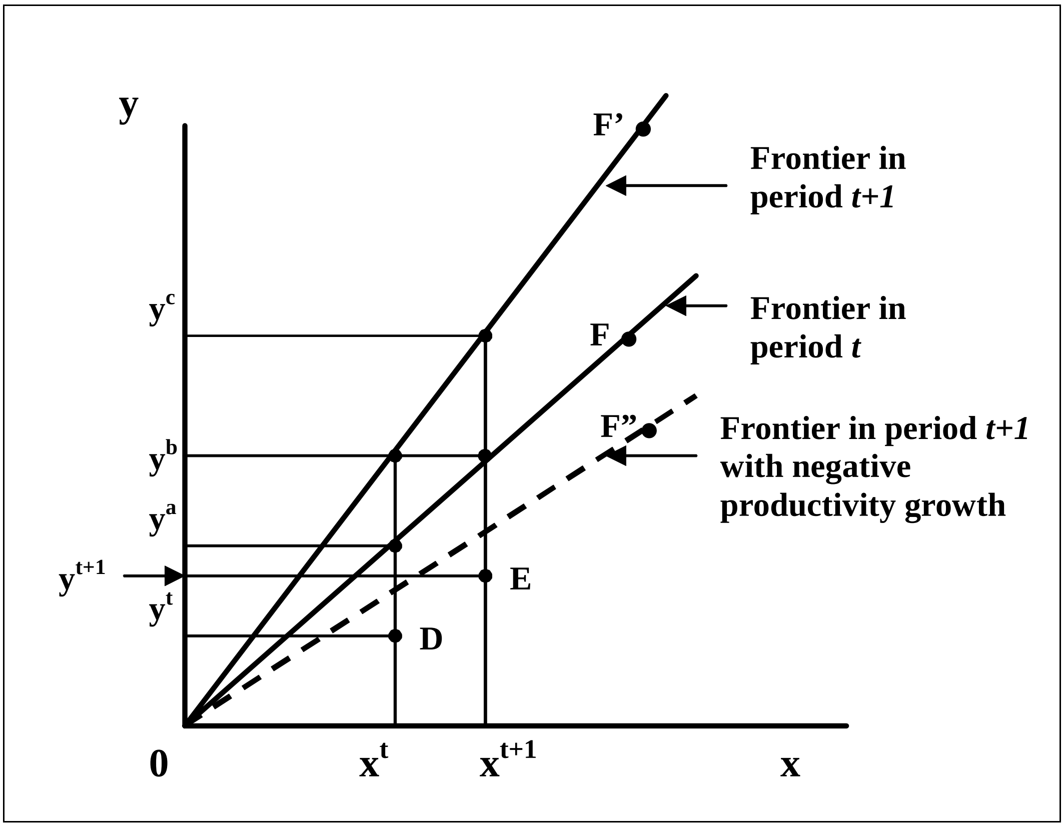


Figure 3 Production frontiersof Chinese industry (1994 and 1997, constant returns to scale)