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Impact of Ownership and Competition on the Productivity of Chinese Enterprises[1]

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Exploring a new, firm-level data set, this paper attempts to quantify the effect of ownership and market competition on the productive efficiency and efficiency growth of Chinese industrial firms. Empirical results reveal a strong ownership impact on efficiency, with foreign-owned enterprises exhibiting the highest efficiency scores and state-owned enterprises exhibiting the lowest. However, while the degree of competition in export markets is positively associated with enterprise efficiency, no such association is found between domestic competition and productive efficiency. The ownership effect is robust to market competition and industry factors. Finally, state-owned enterprises showed on average a higher growth in technical efficiency than collective-owned enterprises during 1996 to 1998. *J. Comp. Econ.*, June 2001, **29**(2), pp. 327–346. Department of Economics and Finance, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong; and Department of Accountancy, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong. © 2001 Academic Press

Key Words: efficiency; ownership; competition; data envelopment analysis.

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1. INTRODUCTION

As China moves from a centrally planned economy to a market economy, many sectors have witnessed either policy liberalization or a shift in decision-making power from government agencies to enterprise management over the last two decades. By 1993, China's economy had become essentially a market economy in the sense that more than two-thirds of national output was produced by profit-seeking economic units. Despite the success of its rural reform, China's industrial reforms, consisting of a series of attempts to tackle the poor performance of state-owned enterprises (SOEs), have proved to be much more difficult. While the government appears to have found ways to reform small SOEs,[2] it is still searching for means to reform large and medium-sized SOEs. The policies in the 1980's and early 1990's were to revitalize SOEs through decentralization, improvement of internal managerial and incentive systems, and introduction of market competition. Since the mid-1990's, the government has decided to further its previous effort by building the so-called modern enterprise system. Specifically, the government attempts to improve the performance of large and medium-sized SOEs by encouraging mergers and acquisitions, standardizing bankruptcy procedures, laying off redundant workers, and converting traditional SOEs into limited liability companies or joint stock companies (Zhu, 1999). At the same time, the government has made clear its intention to continue to control a majority stake in the country's largest SOEs.

Assessment of the SOE reform has become the focus of a large number of studies. Economists outside of China focus mainly on the effects of reform on improvement in the level of technical efficiency, as measured by total factor productivity (TFP) growth. The results have been mixed. Woo *et al.* (1994), for example, found that TFP growth in SOEs was zero at best in the 1984–1988 period. This is in contrast to several other studies (Chen *et al.*, 1988; Dollar, 1990; Jefferson *et al.*, 1992; World Bank, 1992; Grove *et al.*, 1994; Gordon and Li, 1995; Li, 1997) that found significant improvements in SOE productivity. Their estimates of annual TFP growth in the late 1970's and 1980's ranged from 2 to 5%, compared with almost 0% growth prior to the reform. Consistent with the productivity growth of SOEs, the Chinese economy grew at an average annual rate of 9.9% over the past two decades. Since high growth rates had occurred under the dominance of public ownership, the Chinese experience was cited by some economists as evidence of why privatization is not a necessary precondition for efficiency (e.g., Stiglitz, 1994).

On the other hand, the prevalent view among Chinese economists seems to be that the SOE reform has not been very successful, at least in terms of profit rate measures (Zhang, 1997). The number of SOEs operating at a loss has been rising and the amount of losses has been increasing. In 1996, total losses by industrial

[2] The adopted measures include sales, leasing arrangements, mergers, and forming joint stock cooperatives through employee buy-outs, with stock cooperatives being the most popular approach. While not without problems, stock cooperatives appear to be quite successful both in selling state assets to SOE employees and in transforming enterprise behavior (Zhu, 1999).

SOEs were 79 billion yuan, while the losses in 1978 were only 4.2 billion yuan, with an annualized growth rate of 17.7%.[3] These losses were absorbed mainly by government subsidies and loans from the state banks. Furthermore, the SOEs' contribution to government revenue has been declining. The ratio of profit plus tax over sales revenue for the SOEs dropped from 26% in 1980 to 12% in 1992.

From the social perspective, the increase in SOEs' TFP indicates the success of the SOE reform. However, the state, as the owner of SOEs, does not seem to directly benefit from the reform. The productivity improvement and the decline of profit rate may be reconciled. One such interpretation, found in Zhang (1997), is as follows. Since the SOE reform may be characterized as a process of reassigning decision rights and residual claims from the state to the enterprise insiders, this motivates managers and workers to improve efficiency and pursue profits. On the other hand, the managerial discretion resulting from decentralization can be abused to the extent that managers become actual residual claimants, although the state is the legal residual claimant of the enterprise. Due to an information asymmetry and high monitoring cost, managers may reduce the profits submitted to the state by overstating costs and/or underreporting revenues. They also have many opportunities to spend the enterprise's resources for their own benefit. As a result, we see a simultaneous improvement in SOEs' efficiency and a decline in profits reported in official statistics.

The above discussion suggests two alternatives for deepening China's SOE reform. One solution to the managerial discretion problem is to create a competitive product market and to expose SOEs to market competition. An enterprise's profit level in a fair, competitive product market will constitute a sufficient indicator of the managers' performance (Lin, 1996). More generally, this competition-oriented approach assumes that, if the market for products, factors of production, and corporate control is created and functions well, competitive force will improve the efficiency of SOEs.

Another option is to have the residual claim and control rights better aligned. This ownership-oriented approach calls for the privatization of the state enterprises. It argues that private ownership is necessary for enterprise efficiency because it provides a better incentive and reward system. While the market-competition approach aims to retain the current structure of public ownership and thus represents a more partial and gradual reform policy, the ownership approach advocates a more radical change in property rights. In a broad sense, the two approaches are not necessarily mutually exclusive.

With much of the previous literature focusing on the productivity growth of SOEs, the present paper attempts to compare levels of productivity, as well as changes in productivity level, between SOEs and enterprises of other ownership structures. Such an analysis is warranted because, if the productivity of state enterprises grew at a lower rate than that of private enterprises, privatization of state firms would be more effective than revitalization of SOEs. We explore a new,

[3] Unless noted otherwise, all the figures are from *China Statistical Yearbook*, various issues.

firm-level data set to examine the effect of ownership and market competition on the efficiency of Chinese industrial firms. Our sample consists of a panel of some 2,000 firms in 26 industries for the period 1996 to 1998. We use data envelopment analysis (DEA) to compute the efficiency scores for each firm by industry. We then run regressions to examine the effects of ownership and market competition on the firms' productive efficiency.

Our empirical results reveal a strong ownership impact on enterprise efficiency, with foreign-owned firms and Hong Kong–Macao–Taiwan owned firms (HMTs) exhibiting the highest and SOEs the lowest, efficiency scores. The average efficiency score of domestic joint ventures among SOEs or between SOEs and collective-owned enterprises (COEs) lies between but closer to that of SOEs. However, while competition in export markets is associated positively with enterprise efficiency, no such association is found between competition in domestic markets and productive efficiency. The ownership effect is robust to market competition and industry factors. Finally, we use the Malmquist index method to investigate the effect of ownership and competition on the change in efficiency. We find that, on average, SOEs had faster growth in efficiency than both COEs and HMTs from 1996 to 1998. The catch up in efficiency by SOEs is attributable to technical efficiency improvement only in the case of COEs, while it is attributable to both technical efficiency improvement and technological progress in the case of HMTs.

The paper is organized as follows. Sections 2 and 3 describe, respectively, the methodology and data employed in the paper. Section 4 reports the empirical results on efficiency levels, and Section 5 examines the changes in efficiency. Section 6 contains concluding remarks.

2. METHODOLOGY

The productive efficiency of a firm is reflected by the relationship between the outputs the firm produces and the inputs the firm uses in a given period of time. One way to measure the efficiency of a firm is to compare it with other firms in the same industry. In the simple case where firms in an industry produce a single output with a single input, efficiency may be measured in terms of potential input per unit of output. Here the most efficient firm in an industry is used to define the potential input/output. The efficiency measure for any firm in the industry is then defined as the ratio of the potential input to the actual input the firm is using to produce one unit of output. In the more complicated case where firms use multiple inputs to produce multiple outputs, similar measurements can still be obtained with the most efficient firms forming an efficient frontier.

Empirical applications of such efficiency measurements are feasible by a nonparametric technique known as data envelopment analysis (DEA). Useful references on DEA include Farrell (1957), Banker *et al.* (1984, 1989), Charnes *et al.* (1978, 1981), Seiford and Thrall (1990), and Lovell (1993). A DEA model gives an efficiency score for each firm in a given industry. For the input-oriented model, the efficiency score has a value between zero and one. Firms with an efficiency score of unity (100%) are located on the efficient frontier in the sense that their inputs cannot be reduced without a corresponding decrease in output. Firms with an efficiency score below 100% are inefficient. The DEA model defines the efficiency score of any firm as the fraction of the firm's inputs that is necessary for a firm on the efficient frontier to produce the same level of output.

We use the DEA approach to assess the productive efficiency of industrial firms in China. The efficiency score of a firm is obtained by solving for the following linear programming problem, i.e., an input-oriented, constant returns to scale model:

$$\begin{aligned} &\max_{u_j, v} e_o = v y_o \\ \text{s.t.} &\sum_j u_j x_{ji} - v y_i \geq 0; \quad i = l, \ldots, N \\ &\sum_j u_j x_{jo} = 1 \\ &u_j \geq 0, v > 0. \end{aligned} \tag{1}$$

In (1), the subscript o indicates the firm whose performance relative to the other firms in a given industry is under investigation. Specifically, e_o is the efficiency score, y_o is the output, and x_o is the input vector of the firm being evaluated. The variable N is the number of firms in the industry, whereas u_j and v are, respectively, the weights of the inputs and the output, defining the efficiency frontier. Solving the linear programming gives the efficiency score for one firm. To estimate efficiency scores for all the firms, the linear programming must be solved N times by adjusting index o each time.

To investigate the effect of ownership and market competition on the productivity of the firms, we use a two-stage procedure. See, for example, Ali and Flinn (1989) and Kalirajan (1990) for an application of the two-stage analysis. In the first stage, we calculate the efficiency scores for each firm by industry. In the second stage, we run regressions to examine effects of ownership and market competition on the productive efficiency of firms while controlling for industry and other factors.

3. DATA

The data set used in this study includes all industrial enterprises located in Shanghai. Shanghai, with a population of 13 million, is the most important business and industrial center in China. It accounts for 5% of national GDP and 10% of China's external trade. A sample from Shanghai would present a comprehensive panorama of enterprise performance while controlling for the impact of regional factors on productivity in China.[4]

[4] Chen (1996) and Li *et al.* (2000) found that there is a significant regional impact on enterprise productivity in China.

The data were obtained from the State Statistic Bureau of China (SSBC).[5] Its computerized microeconomic data base stores firm-level statistics from the mandatory annual reports of all government and business organizations in China. Our data set covers a three-year period between 1996 and 1998. This data period was determined because significant revisions were made to the classification criteria and statistic presentation categories in 1996. The revisions made pre- and post-1996 data incomparable. The reporting format has, however, remained unchanged since 1996. Three major changes in the 1996 revision are worth noting. First, the cost of direct material input became available for the first time in 1996, without which material input efficiency cannot be estimated. Second, revenue, which had not been adjusted for value-added tax before 1996, was adjusted afterward. Finally, the SSBC publicized its ownership definitions in that year (*China Statistics Yearbook*, 1996). A clear ownership classification is of prime importance for investigating the ownership effect on firm performance.

Based on the SSBC's categorization scheme, we divide Chinese enterprises into six groups. State-owned enterprises (SOEs) are enterprises, institutions, government administrative organizations at various levels, and social organizations with state ownership of production means. Collective-owned enterprises (COEs) are enterprises and institutions with collective ownership of production means, including rural economic organizations, township and village enterprises (TVEs), collective enterprises, and institutions run by cities, counties, and town and street committees. Private-owned enterprises (POEs) are economic units owned by private individuals, including individually owned private enterprises, jointly owned private enterprises, and privately owned limited liability companies. Foreign-owned enterprises (FOEs) are enterprises established by foreigners in the Chinese mainland, including equity joint ventures, cooperative joint ventures, and solely owned subsidiaries. Hong Kong–Macao–Taiwan owned enterprises (HMTs) are enterprises established by overseas Chinese from Hong Kong, Macao, and Taiwan on the Chinese mainland, including equity joint ventures, cooperative joint ventures, and solely owned subsidiaries. Domestic joint ventures (DJVs) are economic entities jointly invested by domestic enterprises of different ownership or by enterprises and institutions, and the joint ownership can be a closed, semiclosed, or open partnership.

COEs used to be similar to SOEs in the sense that they were also under government control, albeit by local governments, and were encouraged to provide stable employment to their employees. On the other hand, COEs had greater autonomy and harder budget constraints than SOEs. After economic reforms began, the management of COEs came been under increasing pressure to be efficient so that COEs

[5] Previous research on China was based mostly on macroeconomic, industrial aggregate statistics from publications such as *China Statistics Yearbook*. Chow (1993) discussed the quality of official Chinese statistics and concluded that they were valid overall for macroeconomic research despite a number of potential problems, including the pressure on reporting units to falsify data and limited government resources for data processing.

TABLE 1
Summary Statistics of Sample Firms

Ownership	Number of firms	Panel A: Average assets (thousand yuan)		Panel B: Average revenue (thousand yuan)		Panel C: Average number of employees per firm	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
State-owned	937	99,744	229,332	66,740	152,578	667	950
Collective	213	12,988	29,973	9,428	16,561	172	18
Private	105	54,469	113,927	48,798	112,889	348	506
Foreign	276	51,838	104,197	39,827	98,829	192	329
HMT	407	132,116	240,606	109,943	208,833	279	399
DJVs	51	32,612	38,358	24,180	31,652	251	314
Overall	1,989	86,319	200,704	63,670	151,089	441	734

Note. Assets, revenue, and number of employees per firm are average values taken over the three years 1996–1998. HMT: Hong Kong–Macao–Taiwan enterprises. DJVs: domestic joint ventures.

are required to lay off employees. Zhang *et al.* (2000) contains a detailed discussion on the evolution of different forms of enterprise ownership in the context of China's industrial reform.

A firm's nominal sales revenue is used as a measure for its output in a given year. Three inputs are assessed to determine the firm's efficiency, labor, capital, and materials. We measure labor by the number of employees, capital by the nominal value of net productive assets, and materials by the nominal value of direct materials input of each firm in a given year. After deleting firms with missing values for the variables described above and industries that have fewer than 20 firms, our sample consists of a panel of 1,989 firms in 26 industries for the period 1996 to 1998. Descriptive statistics of the sample are given in Table 1.

SOEs from the largest group in the sample with a total of 937 firms, followed by 407 HMTs, and 276 FOEs. There are 213 COEs and 105 POEs. The smallest group is DJVs, which contains 51 sample firms. On average HMTs are largest, by both assets and revenue, followed by SOEs, POEs, FOEs, DJVs, and COEs, although SOEs have the largest number of employees. Using Panels B and C, we can compute average revenue per employee for each group. HMTs have, on average, the highest revenue per employee (394,060 yuan), followed by FOEs (207,430), POEs (140,220), SOEs (100,060), DJVs (96,330), and COEs (54,810). By a simple measure, the labor productivity of HMTs was about four times that of SOEs and DJVs, and seven times that of COEs.

4. EMPIRICAL RESULTS

We test the two alternative propositions about the driving force for productive efficiency in Chinese enterprises. We obtain the efficiency scores of each firm

TABLE 2
Mean Efficiency Scores (%)

Group	1 State-owned	2 Collective	3 Private	4 Foreign	5 HMT	6 DJVs
1996	57.52	66.48	69.15	71.49	69.72	60.47
	(25.25)	(27.73)	(23.73)	(24.46)	(25.42)	(22.68)
1997	53.49	67.68	66.59	69.77	69.92	58.65
	(25.89)	(27.29)	(25.62)	(24.90)	(24.81)	(21.29)
1998	55.01	72.15	64.62	68.06	70.20	61.62
	(26.66)	(26.33)	(23.95)	(25.58)	(25.26)	(24.55)
Pooled	55.34	68.77	66.78	69.77	69.95	60.25
	(25.98)	(27.19)	(24.44)	(24.99)	(25.15)	(22.77)

Note. Standard deviations of efficiency scores are in parentheses. HMT: Hong Kong–Macao–Taiwan enterprises. DJVs: domestic joint ventures.

using the DEA model, and then calculate the mean and standard deviation of efficiency scores for each ownership group in each year. The results are given in Table 2. Although the sample size of the groups varies widely, from 937 SOEs to 51 DJVs, the standard deviations of the efficiency scores in each group are quite similar. Thus, the comparison of the means of efficiency scores across groups is valid.

Table 2 shows that the pooled mean efficiency score of SOEs (group 1) is 55.34%, the lowest of all the groups. The most efficient groups are HMTs and FOEs, with mean efficiency scores of 69.95 and 69.77%, respectively. COEs and POEs are close behind, with mean efficiency scores of 68.77 and 66.79%, respectively. The last group, DJVs, appears to be in the middle between SOEs and the other groups, with a mean score of 60.25%. This may be explained by the fact that, in this study, DJVs, as opposed to Chinese–foreign joint ventures that are classified as FOEs and HMTs, are joint ventures among SOEs or between SOEs and COEs. Therefore, they have operation and ownership profiles similar to these of SOEs. The similar performance of COEs and POEs may be explained by the fact that COEs include TVEs that are closer to private ownership than collective ownership per se.[6]

From our sample, the distribution of ownership groups across industries is not even. For example, about two-thirds of the firms in the general machine-building

[6] There have been reported cases where individual and private enterprises have registered as SOEs and COEs in order to secure preferential tax treatment and/or material supply. Furthermore, more POEs have been known to take advantage of the loopholes in tax laws, accounting standards, legal systems, and audit regulations than enterprises under other types of ownership. Therefore, the reported productivity measures for POEs may be downward biased compared with actual numbers, and the difference between SOEs, COEs, and POEs in terms of these measures would be affected accordingly.

industry are SOEs, whereas SOEs account for only 20% in the garment and fabric manufacturing industries. To control for the effect of industry-specific factors, such as conditions of technological change, market for specific assets and skilled labor, and government industrial policy, we run the following regression:

$$e = a_0 + \sum_j a_j I_j + \sum_k b_k O_k. \qquad (2)$$

In the above equation, e is the average efficiency score of a firm from 1996 to 1998, I_j is the industry dummy, and O_k is a dummy representing ownership category. To avoid perfect correlation, the industry dummy for the general machine-building industry and the ownership dummy for SOEs are dropped. Therefore, the coefficient estimates should be interpreted with reference to SOEs in general machine building as the base case. The results of the regression are reported in the first column of Table 3.[7]

The results show that there are considerable interindustry variations in the efficiency scores of firms. Specifically, the industries of furniture manufacturing, nonferrous metals, rubber products, fur and leather products, paper products, food processing, and ferrous metals have mean efficiency scores higher than that of general machine building by a minimum of 30%. On the other hand, and perhaps surprisingly, the electronic and communication equipment industry, which is considered more technologically advanced than the above-mentioned industries, is found to have the lowest mean efficiency score. It is lower than the general machine-building industry by about 10%. However, a closer examination reveals that the electronic and communication equipment industry has the highest concentration of FOEs and HMTs, which together account for 81 out of 131 firms in the industry. SOEs account for 35 firms. The efficiency gap between SOEs and FOEs in this industry may be further widened by the different generations of technology respectively employed by them. Since the efficiency scores are upper-bounded by unity (100%), the wide gap between SOEs and FOEs in this industry results in a lower average score for the industry as a whole. After controlling for the industry-specific factors by industry dummies, the coefficients of ownership dummies show the same pattern of effects on productive efficiency. Specifically, SOEs and DJVs remain the least efficient, and firms of other types of ownership have, on average, 10 to 16% higher mean efficiency scores than SOEs and DJVs.

The degree of market competition is considered as an alternative explanation for productive efficiency, so we now test the effect of market competition

[7] Both by-year and three-year average efficiency scores were estimated for each firm. While the nominal values may be subject to biases from accounting practices and imperfect markets, the DEA efficiency score gives an estimate of the deviation of each firm's productivity from the efficiency frontier for a given industry as long as these biases are not systematic. Only regression results based on three-year average efficiency scores are reported for analysis, which are similar to the results based on by-year efficiency scores.

TABLE 3
Regression Analysis of Efficiency Scores

Models	1	2	3	4	5
R^2	0.274	0.025	0.093	0.288	0.141
Intercept	43.60	61.24	55.11	43.80	49.12
	(1.57)	(0.55)	(0.74)	(1.56)	(0.92)
Ownership dummy:					
Collective	14.43		13.49	14.57	13.60
	(1.58)		(1.72)	(1.57)	(1.67)
Private	10.31		11.56	10.32	10.62
	(2.11)		(2.33)	(2.09)	(2.27)
Foreign	14.34		13.38	13.13	12.61
	(1.44)		(1.57)	(1.44)	(1.53)
HMT	16.62		12.46	13.88	12.21
	(1.24)		(1.44)	(1.31)	(1.40)
Domestic joint ventures	1.96		4.49	2.01	4.12
	(2.97)		(3.26)	(2.94)	(3.17)
X/A		0.17	0.10	0.14	0.10
		(0.02)	(0.02)	(0.02)	(0.02)
Herfindahl index					98.59
					(9.38)
Industry dummy:					
Special equipment	6.16			6.16	
	(2.16)			(2.13)	
Transport equipment	14.16			13.98	
	(2.52)			(2.50)	
Instruments	5.15			4.07	
	(2.53)			(2.52)	
Other manufacturing	16.44			15.59	
	(3.70)			(3.67)	
Chemicals	7.88			8.03	
	(2.37)			(2.35)	
Pharmaceutical	21.43			21.13	
	(3.36)			(3.32)	
Printing	16.41			16.56	
	(2.76)			(2.73)	
Plastic	18.77			18.68	
	(3.11)			(3.08)	
Furniture	32.15			32.07	
	(4.23)			(4.19)	
Sport equipment	18.13			17.07	
	(2.96)			(2.94)	
Nonferrous metals	31.64			30.89	
	(3.79)			(3.76)	
Garment and fabric	13.18			11.82	
	(2.78)			(2.76)	
Wooden products	21.71			21.73	
	(4.44)			(4.40)	

TABLE 3—*Continued*

Models	1	2	3	4	5
Rubber products	31.75			31.49	
	(4.22)			(4.18)	
Electronic and communication equipment	−9.80			−11.49	
	(2.39)			(2.39)	
Electrical engineering	5.30			4.91	
	(2.34)			(2.32)	
Fur and leather	33.97			33.81	
	(4.53)			(4.49)	
Textile	12.94			12.20	
	(2.23)			(2.21)	
Paper products	35.19			35.44	
	(4.22)			(4.18)	
Metallic products	11.67			11.22	
	(2.35)			(2.33)	
Nonmetallic mineral	15.17			15.13	
Products	(2.94)			(2.91)	
Food manufacturing	.29			7.77	
	(3.10)			(3.07)	
Food processing	34.25			34.71	
	(4.15)			(4.12)	
Beverage manufacturing	21.74			22.38	
	(4.63)			(4.59)	
Ferrous metals	38.81			38.77	
	(4.82)			(4.78)	

Note. Efficiency score, X/A (export revenue to total assets), and Herfindahl index are average values taken over the three years 1996–98. To avoid perfect correlation, the state-owned enterprises dummy and the general machine-building industry dummy are dropped. Standard errors of estimation are in parentheses. HMT: Hong Kong–Macao–Taiwan enterprises.

on enterprise efficiency in a given industry. We distinguish between international competition and domestic competition. During the period of the centrally planned economy from the 1950's to the 1980's, industrial firms acted as cost centers to fulfill production quotas and had little pressure from market competition. Only after the economic reform have the newly established private firms and foreign firms brought competitive forces to the Chinese market. Nevertheless, some SOEs had exported their products to international markets long before the economic reform in order to earn much-needed foreign currencies. Chinese firms had been exposed to competition in the export market prior to competition in the domestic market. Thus, we first introduce a new variable, X/A, the ratio of a firm's export revenue to its total assets, as a proxy for the firm's exposure to international market competition, and then regress the efficiency score on this variable:[8]

$$e_{ij} = a_0 + c(X/A). \tag{3}$$

The results of the regression are reported in the second column of Table 3. It may be argued that international markets are more competitive than domestic markets for Chinese enterprises. Therefore, firms that compete in the export market should face greater competitive pressure than those that only sell in the domestic market. The estimated coefficient c is positive and has a t-ratio of 7.13, indicating that firms that earn export revenues are more efficient than firms that only serve domestic markets.

Some FOEs and HMTs are under government regulations that prohibit them from domestic sales and many of these firms are located in special economic zones, such as Shanghai, for processing and re-export businesses. For the firms in these groups, the weight of their export revenues would be higher than that for other groups. Hence, the extent of export market exposure and specific ownership categories may be correlated. Consequently, the effect of ownership structure on efficiency presented earlier may be attributed, to some extent, to the effect of international market competition.

To separate out this possible interrelation, we run a regression again with both the variables, X/A, and ownership dummies. The results are shown in column 3 of Table 3. With the addition of ownership dummies, the coefficient on X/A is still positive and has a t-ratio of 4.04. This suggests that the pressure from export markets is not limited to firms of specific ownership categories. On the other hand, after controlling for the exposure to export markets, the ownership effect retains the same pattern as the average SOEs' efficiency score lags behind those of firms belonging to other ownership groups. Specifically, exporting SOEs have higher productive efficiency than nonexporting SOEs, but not higher than enterprises under other ownership categories.

Beside the fact that firms with specific ownership types such as FOEs and HMTs have more exposure to the export market, some industries may also be more export-oriented owing to the nature of their products. Hence, the differences in the value of industry dummies shown earlier may also have been biased by the differential effect of international competition across industries. To account for this possibility, we add industry dummies to the above regression and report the results in column 4 of Table 3. It appears that there are no significant changes in industry dummies after controlling for the exposure to export markets. This indicates that the extent of participation in export markets does not account for the interindustry variations of productive efficiency of Chinese firms in any significant way.

[8] An alternative proxy is the fraction of a firm's export revenue to total revenue. However, since total revenue is used as the output measure in the computation of the efficiency score, we decided to use total assets as the scaler to avoid the endogeneity problem.

After examining the effect of international market competition, we use the Herfindahl index as a proxy for the degree of domestic market competition to test its effect on enterprise efficiency. The Herfindahl index for each industry is

$$H_j = \sum_{i}^{N_i} S_{ij}^2, \tag{4}$$

where N_j is the number of firms in industry j and s_{ij} is firm i's market share in j. We regress the mean of efficiency scores in each industry on its Herfindahl index:

$$\overline{e_j} = a_0 + d_0 H_j, \qquad j = 1, 2, \ldots, 26. \tag{5}$$

Since a higher Herfindahl index indicates less market competition, a negative association between Herfindahl index and productivity is expected to show the positive effect of market competition on enterprise efficiency. The regression coefficient d_0 is positive (0.825) and has a t-ratio of 2.82. This seems to suggest that firms in industries with a high level of concentration would have higher efficiency scores, on average, than firms in less concentrated industries, which is counterintuitive.

Since the efficiency scores are upper-bounded, the average efficiency score may not reflect fully the performance of firms on the efficient frontier. On the other hand, if market competition puts greater disciplinary pressure on the firms at the lower end, competition should reduce the span of efficiency scores between firms at the upper end and firms at the lower end. To test this possibility, we further regress the standard deviation of efficiency scores of firms in each industry on its Herfindahl index:

$$\sigma_j = a_1 + d_1 H_j, \qquad j = 1, 2, \ldots, 26. \tag{6}$$

A positive association is expected between σ_j and H_j because market concentration would stifle competition and allow inefficient firms to stay in business. Contrary to our expectation, the estimated d_1 is negative (−0.053), although it is not statistically significantly different from zero. Consequently, the result points to the same conclusion that a high degree of concentration, rather than competition, seems to enhance the performance of the firms at the inefficient end.

Finally, in order to examine to what extent industry factors are reflected by the degree of industry concentration, we include the Herfindahl index in the regression of efficiency scores in addition to ownership categories and export market exposure. The results are presented in column 5 of Table 3. In column 5, inclusion of the Herfindahl index does not change significantly the effect of ownership categories and export market exposure. The Herfindahl index does have a positive coefficient with a t-ratio of 10.52, which is still a puzzling result. When industry dummies are added to the regression, however, the results show inflated standard errors of estimation, which are indicative of the collinearity problem because the Herfindahl value is industry specific.

The differential effects between international and domestic market competition on enterprise efficiency may be due to the absence of an effective competitive mechanism in the Chinese socialist market economy. The SOE reform was conducted largely in an environment of partially reformed institutions, inadequate corporate governance, and incomplete accounting standards. For example, there were no laws to force insolvent SOEs into bankruptcy; instead, state banks continued to pump funds into them to avoid their closure.[9] Furthermore, the government policy to maintain the monopoly positions of large SOEs in selected industries would also give them unfair advantages in both factor and product markets.

5. GROWTH OF PRODUCTIVE EFFICIENCY

Ehrlich *et al.* (1994) distinguished between the influence of ownership on a firm's productivity level and on its rate of productivity growth. They argued that, if there is endogenous growth in some firm-specific assets, enterprises of different ownerships, even those facing the same production possibilities and having access to similar markets, may have systematic differences in productivity growth rates. Using a sample of international airlines, these authors found that a switch from state to private ownership raised unambiguously the rates of productivity growth, or cost decline, whereas its effect on the levels of productivity and unit cost may be ambiguous in the short run.

We have thus far examined the effects of ownership and market competition on the level of productivity as measured by the efficiency index using the DEA model. Now, we turn to productivity growth or the change in the efficiency level. We use the Malmquist index to analyze the efficiency change for each firm. The Malmquist index is defined as

$$M_o^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right]^{1/2}, \qquad (7)$$

where D_o is an input distance function. The distance function is the inverse of the input-oriented efficiency score, which can be calculated using the DEA method as in Eq. (1) (Fare *et al.*, 1994). The superscripts on D_o indicate the time period within which the efficiency scores are calculated. The superscripts on x and y indicate the time period of the data used in the calculation of the efficiency scores.[10]

[9] Approximately 80% of bank loans were made to SOEs over the years. Total debts of SOEs stood at approximately 800 billion yuan in 1995.

[10] Specifically, $D_o^{t+1}(x^t, y^t)$ is the inverse of the efficiency index that is computed using the observation of firm o in period t while the production frontier is based on period $t+1$. Similarly, $D_o^t(x^{t+1}, y^{t+1})$ is the inverse of the efficiency index that is computed using the observation of firm o in period $t+1$ in reference to the production frontier based on period t.

Equation (7) is commonly expressed in the following form:

$$M_o^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right]^{1/2}. \tag{8}$$

This represents a decomposition of efficiency change of firm o from period t to period $t+1$. The ratio outside the brackets on the right-hand side of (8) measures the change in technical efficiency of firm o from period t to $t+1$. Since the distance function is the inverse of the efficiency index, a ratio of $D_o^{t+1}(x^{t+1}, y^{t+1})/D_o^t(x^t, y^t)$ greater (smaller) than unity implies that the technical efficiency of firm o has declined (improved) in reference to the production frontier from t to $t+1$. On the other hand, the bracketed term in (8) represents the geometric mean of the shift in production frontier. Specifically, the first ratio in the brackets, $D_o^t(x^{t+1}, y^{t+1})/D_o^{t+1}(x^{t+1}, y^{t+1})$, is the change in the efficiency index of firm o due to a change in technology between t and $t+1$, where firm o is observed in period $t+1$. The second ratio in the brackets, $D_o^t(x^t, y^t)/D_o^{t+1}(x^t, y^t)$, has the same interpretation with firm o being observed in period t. When the value of this ratio is less (greater) than unity, it implies that the technology of the industry has progressed (regressed) from t to $t+1$.

As a measure of overall efficiency change, the Malmquist index is decomposed into the change in technical efficiency of the firm and the technological change of the industry. Similar to the interpretation of its components, a Malmquist index greater (less) than unity indicates that overall efficiency of firm o has declined (increased) from t to $t+1$.

Using our panel data from 1996 to 1998, we first compute the distance functions for each firm; $D_o^t(x^t, y^t)$ and $D_o^{t+1}(x^{t+1}, y^{t+1})$ are readily available by taking the inverse of the efficiency scores obtained earlier. Then we add observation (x_o^t, y_o^t) of firm o to the data set (x_j^{t+1}, y_j^{t+1}) of all the firms in the same industry and compute the efficiency score of firm o. The inverse of this efficiency score gives the distance function $D_o^{t+1}(x^t, y^t)$. The distance function $D_o^t(x^{t+1}, y^{t+1})$ is obtained in a similar fashion. The Malmquist index can be constructed from the four distance functions for the periods 1996/1997 and 1997/1998.

To examine the effects of ownership and market competition on the change in efficiency, we run the regression

$$M = a_0 + \sum_j a_j I_j + \sum_k b_k O_k, \tag{9}$$

where M is the average value of a firm's Malmquist indices over the periods 1996/1997 and 1997/1998. As in Eq. (2), the general machine-building dummy and the SOE dummy are dropped, so that the coefficient estimates should be

TABLE 4
Regression Analysis of Malmquist Index and Its Components

Models	1	2	3	4
	Panel A: Malmquist index			
R^2	0.029	0.011	0.029	0.011
Intercept	0.991	1.024	0.991	1.030
	(43.402)	(104.870)	(43.396)	(82.736)
Ownership dummy:				
Collective	0.071	0.080	0.071	0.080
	(3.098)	(3.538)	(3.105)	(3.533)
Private	−0.006	−0.008	−0.006	−0.007
	(−0.191)	(−0.262)	(−0.191)	(−0.232)
Foreign	0.004	0.016	0.003	0.016
	(0.205)	(0.749)	(0.130)	(0.785)
HMT	0.057	0.067	0.054	0.067
	(3.178)	(3.522)	(2.808)	(3.534)
Domestic joint ventures	0.046	0.039	0.046	0.040
	(1.061)	(0.916)	(1.063)	(0.924)
X/A		0.000	0.000	0.000
		(1.289)	(0.537)	(1.279)
Herfindahl index				−0.097
				(−0.765)
	Panel B: Technological progress			
R^2	0.343	0.009	0.344	0.013
Intercept	0.953	1.026	0.953	1.037
	(98.853)	(204.307)	(98.831)	(162.397)
Ownership dummy:				
Collective	−0.010	−0.006	−0.010	−0.006
	(−1.044)	(−0.487)	(−1.065)	(−0.505)
Private	−0.000	−0.001	−0.000	0.001
	(−0.036)	(−0.081)	(−0.037)	(0.034)
Foreign	−0.004	0.026	−0.002	0.027
	(−0.399)	(2.412)	(−0.197)	(2.553)
HMT	0.012	0.035	0.016	0.035
	(1.543)	(3.560)	(1.946)	(3.617)
Domestic joint ventures	−0.004	−0.021	−0.004	−0.020
	(−0.199)	(−0.960)	(−0.203)	(−0.929)
X/A		0.000	−0.000	0.000
		(0.433)	(−1.458)	(0.396)
Herfindahl index				−0.191
				(−2.925)
	Panel C: Technical efficiency change			
R^2	0.038	0.006	0.038	0.006
Intercept	1.077	1.049	1.077	1.040
	(45.253)	(102.314)	(45.253)	(79.562)
Ownership dummy:				
Collective	0.059	0.078	0.060	0.078
	(2.477)	(3.277)	(2.486)	(3.284)

TABLE 4—*Continued*

Models	1	2	3	4
Private	−0.020	−0.021	−0.020	−0.023
	(−0.628)	(−0.657)	(−0.627)	(−0.701)
Foreign	−0.020	−0.031	−0.022	−0.033
	(−0.907)	(−1.440)	(−0.995)	(−1.493)
HMT	0.024	0.020	0.020	0.020
	(1.299)	(1.002)	(0.982)	(0.982)
Domestic joint ventures	0.014	0.029	0.014	0.028
	(0.317)	(0.644)	(0.319)	(0.631)
X/A		0.000	0.000	0.000
		(0.448)	(0.709)	(0.463)
Herfindahl index				0.153
				(1.144)

Note. Malmquist index, technological progress, and technical efficiency change are the average values of 1996/1997 and 1997/1998. The industry dummy estimates for models 1 and 3 of the three panels are omitted to save space and are available in Zhang *et al.* (2000). The X/A and Herfindahl index are average values taken over the three years 1996–1998. To avoid multicollinearity, the state-owned enterprises dummy and the general machine-building industry dummy are dropped. The t-statistics of estimation are in parentheses. HMT: Hong–Kong–Macao–Taiwan owned enterprises.

interpreted with reference to SOEs in the general machine-building industry. The regression results are reported in Panel A of Table 4 (model 1). On average, COEs have a Malmquist value that is 0.071 higher than that of SOEs, and the HMTs' is 0.057 higher than the SOEs'. Both differentials are statistically significantly different from zero.[11] The Malmquist value for DJVs is on average 0.046 higher than that for SOEs but is not statistically significant. POEs and FOEs are close to SOEs and the differentials are statistically insignificant. Thus, the analysis suggests that the overall efficiency of SOEs improved, on average, relative to that of COEs and HMTs from 1996 to 1998, although as shown in Section 4 the efficiency level of SOEs was still lower than that of COEs and HMTs.

The decomposition of the Malmquist index provides a way of measuring the sources of the efficiency catch up by SOEs. In Panels B and C of Table 4, we report the results of similar regressions of the technological change, i.e., a shift of the production frontier and technical efficiency change, respectively. From the first column of these panels, it can be seen that, on average, the technological progress of SOEs in fact lags behind the firms in other ownership categories except for HMTs, although none of the differentials are significant. For technical efficiency, however, SOEs have improved relative to COEs, HMTs, and DJVs. The largest differential is with respect to COEs (0.059) and is statistically significant. Thus, the catch up in efficiency by SOEs is attributable to technical efficiency improvement,

[11] Here and in the following text, by statistically significant we mean that the t-ratio of the coefficient exceeds the 5% critical value.

rather than technological progress, in the case of COEs. However, it is attributable to both technical efficiency improvement and technological progress in the case of HMTs. Our result that growth in efficiency in SOEs exceeded, on average, that of COEs, contrasts with the finding, based on data from the earlier period, that township and village enterprises (TVEs), a major form of COEs, enjoyed a faster productivity growth than SOEs (Weitzman and Xu, 1994; Jefferson *et al.*, 1996). This may suggest that the more recent corporation drive, i.e., the modern enterprise system, which is a major component of the deepening of the SOE reform, has been effective in improving SOEs' productivity.

We now turn to the variations of efficiency change among different industries.[12] For the Malmquist index, instruments, communications, and food manufacturing are the only industries with a significantly slower average efficiency change than the general machine-building industry. The rest do not have significant differentials of efficiency change when they are compared with the general machine-building industry. For technological change, only 3 industries, electrical engineering, fur and leather, and food processing, have technological progress faster than general machine building, but the differentials are all insignificant. The 22 other industries have technological progress slower than the general machine-building sector, and the differentials for the 15 industries that include instruments, communications, and food manufacturing are significant. Finally, for the technical efficiency change, 17 industries have average growth faster than the general machine-building industry, of which 7 industries, including instruments, communications, and food manufacturing, are significant. The remaining 8 industries have a smaller growth rate, on average, than the general machine-building sector, of which the differentials of 2 industries, including electrical engineering, are significant.

From the above observation, we may speculate that the production frontiers have shifted for most industries, but the efficiency of the average firms has not changed much, because the shift of the production frontier is attributable to the most efficient firms only. As the production frontiers progress, the efficiency scores of the less efficient firms may become worse, resulting in deterioration in technical efficiency. The overall efficiency change of average firms in most industries is insignificant due to the joint effect of the technological progress of the more efficient firms and the deteriorating technical efficiency, relative to the production frontier, of the less efficient firms.

Similar to our efficiency level analysis, we next include proxies for competition, i.e., the exposure of firms to the international market and the Herfindahl index of each industry, in the regression. Table 4 shows that these proxy variables do not have significant effects on average efficiency changes. The coefficients of the ownership and industry dummies do not change significantly after the inclusion of the proxy variables.

[12] The industry dummy estimates for models 1 and 3 in Table 4 are omitted to save space; they are available in Zhang *et al.* (2000).

6. CONCLUDING REMARKS

Our main purpose in this paper is to assess the effect of ownership and market competition on both the level and change of productive efficiency of Chinese enterprises. As indicated in the Introduction, China's industrial reform began with the revitalization of state-owned enterprises. Initially, the establishment of a private ownership system was not contemplated. Therefore, the dramatic development of a vital nonstate sector is a surprisingly unintended consequence of the reform.[13] Our empirical results suggest that the nonstate sector has a higher average level of productive efficiency than SOEs, and that ownership appears to be a more significant determinant of efficiency than competition. The efficiency gains of SOEs, and even some efficiency catch up by SOEs in comparison with nonstate firms in recent years, provide evidence of limited success of the partial and gradual industrial reform policy. More fundamental changes in ownership structure seem necessary for more significant improvements in SOEs' productive efficiency.

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[13] For an interesting analysis of some of the driving forces behind the unintended rise of a private ownership system in China, see Li *et al.* (2000).

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