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Exports, technical progress and productivity growth in a transition economy: a non-parametric approach for China

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Theories suggesting either static or dynamic productivity gains derived from exports often assume the prior existence of a competitive market. In the presence of market imperfection and distortion, however, the competition and resource reallocation effects of exports on productive efficiency may be greatly reduced; and there may actually be disincentives for innovation. This paper analyses the impact of exports on aggregate productivity growth in a transition economy using a panel of Chinese manufacturing industries over the period 1990–1997. TFP growth is estimated by employing a non-parametric approach and is decomposed into technical progress and efficiency change. No evidence has been found suggesting significant productivity gains at the industry level resulting from exports. Findings of the current study suggest that, for exports to generate significant positive effect on TFP growth, a well-developed domestic market and a neutral, outward-oriented policy are necessary.

I. Introduction

The relationship between exports and productivity growth is a much-debated topic, and in recent years there has been a considerable volume of research on this issue. Although it is widely believed that export-oriented firms exhibit higher levels of productivity than non-exporting firms, evidence suggesting the direction of causality between exports and productivity is mixed. Some argue that there is a process of 'learning-by-exporting'. Exports serve as a conduit for technology transfer from abroad and generate technological spillovers into the rest of the economy. Others, however, argue that the relatively high productivity of exporters reflects no more than the fact that it is the relatively efficient producers who enter and survive in highly competitive export industries. In other words, there is a self-selection mechanism at work in the export industries.

More recently a theoretical literature has emerged investigating why exporting and productivity might be linked at firm level. This literature provides a theoretical framework suggesting that the opening up of export trade leads to a rationalization of plants within an industry. Resources are reallocated from less efficient to more efficient plants, so that exporting results in aggregate productivity gains at the industry level (Melitz, 2002; Bernard *et al.*, 2003; and

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Helpman *et al.*, 2003). These studies provide important insights into the transmission mechanism between exporting and productivity growth. However, their theoretical framework is based on the assumption of the prior existence of a competitive market. The impact of market failure on the effectiveness of the suggested transmission mechanisms has not been taken into account.

This study investigates the relationship between exports and industry-level productivity growth in Chinese manufacturing industries. The impact of exports on efficiency improvement, technical progress and total factor productivity (TFP) growth is analysed by using an industry-level panel data set for the Chinese manufacturing industries for the period 1990–1997. China is an interesting case to take given the increasing openness of the economy to international trade, its remarkable export growth and the transition nature of its economy. This paper is the first study testing the 'new' exporting theory in the context of a transition economy and analysing the impact of market failure on the suggested transmission mechanisms. The non-parametric Malquist TFP approach is used, which has not been used in the existing exporting literature, to examine the impact of exports on technical progress and efficiency change of the industries.

The rest of the paper is organized as follows. Section II briefly reviews the literature. Section III discusses the methodology. Section IV estimates TFP growth for Chinese manufacturing industries and analyses the impact of exports on TFP growth. Section V offers conclusions.

II. Exports, Market Failure and Industry-Level Productivity Growth: A Theoretical Framework

International trade generates both static and dynamic gains in the domestic economy. Static gains accrue from the reallocation of resources between the traded and non-traded sectors following the opening up of the economy to trade. Reallocation of resources enables the country to specialize in those lines of activity in which it possesses a comparative advantage and also enables it to benefit from exchange gains by trading with its partners. The dynamic gains from exporting include economies of scale, cross-efficiency promotion, knowledge accumulation and innovation. By widening the extent of the market, the process of exports raises the skill levels and dexterity of the labour force; it generates economies of scale and generally enables exporters to enjoy increasing returns. The pressures of international competition will force exporters to cut costs and improve efficiency by eliminating managerial and organizational inefficiencies (Egan and Mody, 1992; Baldwin and Caves, 1997; Clerides *et al.*, 1998). Exports may also serve as a conduit for technology and knowledge transfers. Contacts with trade partners or competitors may generate knowledge spillovers – for instance, ideas for product differentiation or production design improvement. This leads to the accumulation of knowledge capital. Exporting also provides opportunities for the exploitation of research success, enhances the incentives to invest in R&D, and encourages technical innovation because of the expansion of markets that international trade creates (Grossman and Helpman, 1991). However, the reasons for the relationships between exports and productivity may actually be the reverse of those suggested by the foregoing argument. The self-selection of firms may be important. In other words, the causality may go from productivity to exports.

Although almost all empirical studies find the productivity of exporters to be higher than that of non-exporters, the causal relationship between exports and productivity growth is not clear. Empirical evidence concerning the export–productivity relationship is mixed. Marin (1992) and Yamada (1998) provide evidence that supports the proposition that exports enhance productivity. However, most empirical studies at the firm level find evidence in support of the existence of a self-selection mechanism rather than export-led productivity growth (Henriques and Sadorsky, 1996; Clerides *et al.*, 1998; Bernard and Jensen, 1999; Aw *et al.*, 2000). In addition, Greenaway *et al.* (2003) find that the performance characteristics of exporters and non-exporters are remarkably similar in a study of a panel of Swedish manufacturing firms.

Recently a stream of theoretical work has emerged suggesting the gains from export-induced resource reallocation at the industry level. By using a dynamic industry model in a general equilibrium setting, Melitz (2002) shows that when heterogeneous firms are allowed to flourish within each industry, opening up external trade leads to a rationalization of plants. The exposure to trade will induce only the more productive firms to enter the export market and will simultaneously force the least productive firms to exit. Resources are reallocated from less efficient to more efficient plants, with the less efficient firms contract or exit from the market. Aggregate industry productivity growth is thus generated through such inter-firm resource reallocations. This theory is reinforced by the model developed by Bernard *et al.* (2003) which suggests that aggregate productivity rises as employment shifts from low productivity plants driven out by import competition to high productivity plants turning towards export markets.

Therefore, exporting may contribute to productivity growth via three channels: (1) economies of scale; (2) efficiency improvement of exporters through 'learning by exporting', cross-efficiency promotion and resource reallocation from less efficient to more efficient plants at the industry level; (3) technical progress because of technology spillovers through foreign contacts and encouragement of investment in research and development (R&D).

Although the existing literature has pointed out the transmission mechanisms through which exports promote productivity, all this are based on an assumption of the prior existence of a perfect market, where there are no barriers to entry or exit, perfect information for all the participants in the market, the absence of monopoly power and rationality in behaviour for all participants. In the presence of market imperfection and distortions, however, these transmission mechanisms may not work effectively. Market imperfections and distortions refer to any deviation from the assumptions of perfect competition. In this paper, we focus on the imperfections and distortions in the form of barriers to market entry and exit, soft budget constraints for firms, the presence of externalities and public goods. First, when the inefficient firms are owned by the state and have a soft budget constraint, they will be bailed out by the state. Such soft budget constraint relaxes the competition pressure of exports on these inefficient firms. The resource reallocation effect of exports cannot work effectively as well. Second, when the economy lack of a well-developed market exit mechanism, inefficient firms remain in the economic system and continue to be financed by the state-owned banks, the resource reallocation effect of exports cannot work effectively.

Third, innovation involves considerable uncertainty and, in practice, many R&D activities failed to achieve commercial success (Pavitt, 1991). Moreover, there may be considerable externalities and knowledge spillovers from innovations that benefit the non-innovators. In an economy where intellectual properties are not effectively protected, incentives for innovation may be weak. When export competitiveness is based on cheap labour cost rather than technological advantage, export expansion will not provide incentive for innovation. Consequently, export growth will not lead to technological progress. In sum: (1) in the presence of market failure, the competition effect and the resource reallocation effect of exports on productive efficiency may be greatly reduced; (2) when export competitiveness is based on cheap labour cost rather than technological advantage, export expansion does not provide incentive for innovation and technical progress.

Market imperfections and distortions can often be observed in the transition economies. Low labour cost oriented exports exist widely in labour-abundant developing countries. The Chinese economy, which is in the process of transition, possesses both of these two characteristics. In the early and mid-1990s, the state-owned enterprises (SOEs) played an important but decreasing role in the Chinese economy. Their share in the country's gross industrial output was about 60% in 1990 and 32% in 1999. Individual-, private- and foreign-owned companies have grown considerably. Moreover, since it opened up to international trade and investment in 1978, China's exports have grown rapidly from US$18 billion in 1980 to US$438 billion in 2003, ranking China the third largest exporter in the world exporters' league table. The value of manufactured exports increased from US$9 billion in 1980 to US$404 billion in 2003, accounting for 92% of China's exports. Thus, the Chinese economy provides an interesting case to test the above propositions.

In the context of China, there is a considerable literature on exports and income growth (Kwan and Kwok, 1995; Shan and Sun, 1998), which find mixed results. There is also substantial literature on the impact of enterprise reforms and ownership on productivity growth, which again provide mixed results. Jefferson *et al.* (1996), Groves *et al.* (1994) and Li (1997) find positive total factor productivity growth in the SOE sector, and enterprises reforms exhibit positive effect on TFP growth. In contrast, Woo *et al.* (1994) and Wu (1998) find that GDP growth of China is over-estimated, intermediate inputs are overdeflated and there is little TFP growth. Contrary to the evidence on SOEs, the empirical evidence on TVEs all point to considerable TFP growth in the TVE sector (Zheng *et al.*, 1998; Jefferson, 1999; and Fu and Balasubramanyam, 2003). However, empirical study of the impact of exports on productivity growth in China, as well as in other transition economies, is rare. Therefore, a systematic empirical study is needed to investigate the impact of exports on productivity growth and the transmission mechanisms in economies that may suffer from considerable market failure and government intervention. This paper has the objective of conducting such an exercise.

III. Methodology

The impact of exports on productivity growth in a two-stage process is examined. First, total factor productivity (TFP) growth via a frontier approach is investigated by using the Malmquist index, and decomposing it into technical progress and efficiency change. Second, the impact of exports on TFP growth is examined using regression techniques. In this exercise the estimated Malmquist TFP growth index is used as the dependent variable.

Estimation of TFP growth

The conventional technique for estimating TFP is the Solow residual method. It defines TFP growth as the residual of output growth after the contribution of labour and capital inputs have been subtracted from total output growth. This method makes the following four assumptions: (1) the form of production function is known; (2) there are constant returns to scale; (3) there is optimizing behaviour on the part of firms, with no room for any inefficiency; and (4) there is neutral technical change. If these assumptions do not hold, TFP measurements will be biased. (Coelli *et al.*, 1998; Arcelus and Arocena, 2000).

Because of the above limitations of the conventional approach, in this study estimates TFP growth by using a non-parametric programming method developed by Fare *et al.* (1994). Following Fare's approach, a production frontier is constructed based on all the existing observations. The distance of each of the observations from the frontier is estimated by using non-parametric programming methods. Technical efficiency is defined as the distance of each observation relative to the frontier. TFP growth is defined as a geometric mean of two Malmquist productivity indexes, which is to be estimated as the ratios of distance functions of observations from the frontier.[1] This approach is capable of measuring productivity in a multi-input, multi-output setting, does not require the assumptions of the Solow method, and avoids the corresponding measurement problems.

It also has another advantage in that it allows for the decomposition of productivity growth into two mutually exclusive and exhaustive components: (1) changes in technical efficiency over time, which is a measurement of catching-up with the best performance; and (2) shifts in technology over time, which is a measure of innovation (Fare *et al.*, 1994). This decomposition of TFP growth enables us to investigate the impact of exports on technical progress and efficiency improvement. The methodologies of estimation and decomposition are as follows.

Assuming a production technology S^t which produces a vector of outputs, $y^t \in R_+^M$, by using a vector of inputs, $x^t \in R_+^N$, for each time period $t = 1, \dots, T$.

$$S^t = \{(x^t, y^t) : x^t \ can \ produce \ y^t\} \tag{1}$$

The output-based distance function at t is defined as the reciprocal of the 'maximum' proportional expansion of the output vector y^{t}, given inputs x^t.

$$\begin{aligned} D_0^t(x^t, y^t) &= \inf\{\theta\colon (x^t, y^t/\theta) \in S^t\} \\ &= \sup\{\theta\colon (x^t, \theta y^t) \in S^t\} \end{aligned} \tag{2}$$

$D_0^t(x^t, y^t) \leq 1$ if and only if $(x^t, y^t) \in S^t$. $D_0^t(x^t, y^t) = 1$ if and only if (x^t, y^t) is on the frontier. The output-based Malmquist productivity change index is defined as the geometric mean of two Malmquist productivity index as follows:

$$\begin{aligned} &M_0(x^{t+1}, y^{t+1}, x^t, y^t) \\ &= \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{1/2} \end{aligned} \tag{3}$$

Equation 3 represents the productivity of the production point (x^{t+1}, y^{t+1}) relative to the production point (x^t, y^t). A value greater than 1 indicates positive TFP growth in period $t + 1$. When performance deteriorates over time, the Malmquist index will be less than 1.

Equation 3 can be rewritten as

$$\begin{aligned} M_0(x^{t+1}, y^{t+1}, x^t, y^t) &= \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \\ &\times \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{1/2} \end{aligned} \tag{4}$$

where efficiency change

$$(EFFCH) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \tag{5}$$

technical change

$$(TECHCH) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{1/2} \tag{6}$$

Thus TFP change is decomposed into two components: efficiency change and technical change. Efficiency change measures the change in relative efficiency between year t and $t + 1$. It reflects whether production is getting closer to or farther away from the frontier. Technical change captures the shift in

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[1] The index is named after Sten Malmquist (1953) who had proposed constructing quantity indexes as ratios of distance functions.

technology between the two periods. It indicates whether or not technical progress occurred at the input–output combination for a particular industry. A value of greater than 1 indicates efficiency improvement or technical progress. A value of less than 1 indicates a deterioration in performance.

The Malmquist productivity index is estimated by using non-parametric linear-programming techniques. Assuming $k=1,\ldots,K$ industries using $n=1,\ldots,N$ inputs $x_n^{k,t}$at each time period $t=1,\ldots,T$. Here inputs are used to produce $m=1,\ldots,M$ outputs $y_m^{k,t}$. To estimate the productivity change of each industry between t and $t+1$, one needs to solve four different linear-programming problems for $D_0^t(x^t,y^t)$, $D_0^{t+1}(x^t,y^t)$, $D_0^{t+1}(x^{t+1},y^{t+1})$ and $D_0^t(x^{t+1},y^{t+1})$.

The output-oriented LP problem for estimation of $D_0^t(x^t,y^t)$ under variable returns to scale is as follows:[2]

$$\begin{aligned} \left[d_0^t(x_t,y_t)\right]^{-1} &= \max_{\phi,\lambda}\theta, \\ \text{st} \quad -\theta y_{it} + Y_t\lambda &\geq 0 \\ x_{it} - X_t\lambda &\geq 0, \\ \lambda_i &\geq 0, \\ \sum \lambda_i &= 1, \quad i=1,\ldots,n \end{aligned}$$

where θ is a scalar and λ is an $n\times 1$ vector of constants. The linear-programming problems for estimation of $D_0^{t+1}(x^t,y^t)$, $D_0^{t+1}(x^{t+1},y^{t+1})$ and $D_0^t(x^{t+1},y^{t+1})$are similar to the above formulation with corresponding adjustment.[3]

Scale efficiency is defined as the ratio of technical efficiency calculated under the assumption of constant returns to scale (CRS) to technical efficiency calculated under the assumption of variable returns to scale (VRS) (Fare *et al.*, 1984). It measures how close an industry is to the most productive scale size. A firm may be scale inefficient if it exceeds the most productive scale size or if it is smaller than the most productive scale size.

According to the definition,

$$SE = \frac{TE_{CRS}}{TE_{VRS}} \tag{7}$$

where SE is scale efficiency, TE_{CRS} is technical efficiency calculated under the assumption of constant returns to scale, TE_{VRS} is technical efficiency calculated under variable returns to scale.

Exports and TFP growth

We examine the impact of exports on scale efficiency by comparing scale efficiencies of export to non-export industries. Following Waehrer (1968), the industries whose export–output ratios are higher than the national average ratio are classified as the export industries. Those industries whose export–output ratios are lower than the national average ratio are classified as the non-export industries.

The impact of exports on productivity growth is tested with the following panel data model:

$$\begin{aligned} Lpch_{it} = \delta + \beta LXS_{it} + \lambda LRD_{it} + \chi LCI_{it} \\ + \psi LFS_{it} + \delta LTE0_{it} + \upsilon \end{aligned} \tag{8}$$

where L is the logarithm operator, i and t denote industries and time respectively, and υ is a disturbance term, which vary across industries and time and possess the usual properties. *pch* is productivity growth, which enters the estimated Malmquist TFP index, technical progress (*TECH*) and efficiency change (*EFFCH*) alternatively. *XS* is the export–output ratio of each industry over the sample period. Innovation has often been regarded as an engine that drives productivity growth. Product or process innovations may induce technical change and thus push upward the production frontier; they may also serve to reduce production cost depending on the nature of innovation. Therefore, an innovation variable (*RD*) is also included as one of the major determinants of productivity growth. In addition to domestic R&D, international R&D spillovers through imported intermediate inputs and foreign direct investment (*FDI*) are also important sources for TFP growth (Coe and Helpman, 1995). Ideally the proportion of imported intermediate inputs would be included, weighted by its knowledge intensity and the proportion of *FDI* in each industry as control variables. However, such industry-level data for China are not available. Alternatively, capital intensity (*CI*) that reflects an industry's overall investment in machinery and equipment, and the one-year lagged technical efficiency (*TE0*) are included as control variables. The lagged technical efficiency provides a proxy variable for many omitted variables (Nair-Reichert and Weinhold, 2001). The average firm size of an industry may affect its efficiency because larger firms may benefit from economies of scale. Hence, average firm size (*WS*) is also used as a control variable.

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[2] Output distance function is reciprocal to the output-based Farrell measure of technical efficiency.

[3] For details see Fare *et al.* (1994) and Coelli (1996).

Because of the possible endogeneity between exports and productivity, the Wu–Hausman specification test is first applied to test for endogeneity between exports and productivity. One-year lagged pch_{it} and XS_{it} , and other exogenous variables (*RD*, *CI* and *FS*) are used as instrumental variables because of the short time period of the data set (Nair-Reichert and Weinhold, 2001). If there is endogeneity between exports and productivity, an instrumental variable method should be utilized for estimation. Because the TE_0 variable is time invariant, the fixed-effects model for panel data is not applicable as regressors are collinear. Therefore, a random-effects model is used for estimation.

IV. Data and Results

The data used for estimation are collected from various issues of the *China Statistical Yearbook* (SSB, 1992a–1998a) and *China Industrial Statistical Yearbook* (SSB, 1992b–1998b) for a panel of 26 manufacturing industries for the period 1990–1997.[4] Data after 1997 are excluded due to the changes in categorization of industrial enterprise by the State Statistical Bureau. Exports data are derived from various issues of the *International Trade Statistical Yearbook* (ITSY) (UN, 1992–1998). These trade data are reclassified into various industries at International Standard Industrial Classification two-digit level using the concordance table provided by the Eurostat (Eurostat, 2004). The second set of data relates to a pooled sample of 358 sub-industries, including 179 SOE industries and 179 comparable TVE industries for the year 1995. It is derived from 'The Data of The Third National Industrial Census of P.R. China' (SSB, 1996). This data set provides comprehensive information about each industry. It enables one to control for some managerial factors that also affects industrial productive efficiency. The classification of export and non-export industries is based on the output and exports data collected from this data set.

For the estimation of TFP, we use a simple one output and two inputs (labour and capital) model. The output of each of the 26 industries is measured by the value-added of the industry deflated by the index of ex-factory prices of industrial products for each industry collected from the *China Statistical Yearbook*. Labour is measured by number of employees in each industry. Capital is measured by annual average balance of net value of fixed assets deflated by the price index of investment in fixed assets collected also from the *China Statistical Yearbook*. Deflation of capital is conducted in the following steps, taking 1990 as the base year. Available statistics are first used to calculate the undeflated annual value of newly added fixed assets. These annual increments are then deflated by the price index of investment in fixed assets; and the deflated increments are finally added to the figure for the base year.[5]

Exports are measured by the export–output ratio derived from the compiled data set. Capital intensity (CI) is measured by the capital labour ratio. Firm size (FS) is measured by the average output per firm in industry *i* to the total output of industry *i*. Ideally innovation should be measured by innovation outputs such as the number of patents or the value of new sales. However, due to data restriction, innovation of each industry is proxied by its R&D intensity measured as the ratio of R&D expenditure to net fixed assets for each industry. Nevertheless, one should bear in mind its limitation in that R&D expenditure is only one of the major inputs of innovation.

Table 1 reports the classification of export and non-export industries and a comparison of their characteristics; 10 out of a total of 27 industries are classified as export industries. They are the cultural, educational and sports goods industries, garments, leather products, electronics, textiles, instruments and office machinery, metal products, rubber products, plastic products and furniture manufacturing industries. The average export-output ratio of the export-industries was 0.29, while that for the non-export industries was 0.07. This classification is based on one-year data. Admittedly this is not an

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[4] Recently some economists have argued the official data for China is not accurate and the GDP growth rates are overestimated. Chow (1993) discussed the quality of official Chinese statistics and concluded that, although there are a number of potential problems in data collecting and processing, the official data were valid overall for macroeconomic research. Labour productivity growth of the Chinese manufacturing industries was estimated using both the official data and the non-official data processed in Wu (2001). The estimated average real labour productivity growth rate of the export-industries are 11.5% for the official data and 14.2% for Wu's data, while that for the non-export industries for the official and Wu's data are 8.8 and 7.5%, respectively. The general picture of growth of productivity for export and non-export industries presented by the official and non-official data are similar. This suggests that the official data should be valid for the examination of the impact of exports across industry branches.

[5] The steps of deflation of fixed assets follow Jefferson *et al.* (1996); the price index used as deflators are collected from China Statistical Yearbook.

Table 1. Characteristics of Chinese manufacturing industries

Industry	EX/Y	Exports (100mil¥)	Technical efficiency (VRS)	Technical efficiency (CRS)	Output per worker (¥/worker)	Output per Fixed-asset	Value-added per worker (¥/worker)	Value-added per fixed-asset	Fixed-asset per worker (¥/worker)	Wage rate (¥)	College graduates as percent of total	FDI/Fixed asset
Total industries	0.15	7162	0.77	0.68	68098	2.5	16569	0.61	27221	4911	6%	15%
Export industries average	0.29	449	0.81	0.73	64455	3.09	14383	0.69	20882	4669	4%	34%
cultural, educational and sports goods	0.56	209	1	1	51528	3.75	12639	0.92	13750	5042	2%	54%
Garments and other Fibre products	0.55	811	0.94	0.91	53807	4.26	12701	1.01	12628	4608	2%	47%
Leather, furs, down and related products	0.5	485	0.76	0.74	63247	4.57	13084	0.95	13831	4526	2%	45%
Electronic and telecommunications equipment	0.36	923	1	1	129082	3.67	32398	0.92	35153	6286	13%	39%
Textile industry	0.28	1294	0.92	0.46	52449	2.51	10230	0.49	20905	4078	3%	13%
Instruments, meters, cultural and office machinery	0.27	115	0.73	0.72	44468	2.37	12839	0.68	18789	5209	11%	27%
Metal products	0.19	312	0.51	0.5	58339	3.07	13569	0.71	19011	4763	4%	26%
Rubber products	0.18	110	0.7	0.69	62817	3.2	13982	0.71	19656	4742	4%	25%
Plastic products	0.17	191	0.5	0.5	69845	2.52	13932	0.5	27740	4355	3%	31%
Furniture manufacturing	0.17	38	1	0.81	44752	3.05	11168	0.76	14653	3960	2%	29%
Non-export industries average	0.07	157	0.74	0.64	65639	1.73	20203	0.53	37947	5279	6%	14%
Electric equipment and machinery	0.14	352	0.9	0.85	83141	3.41	19359	0.79	24391	5359	7%	23%
Timber processing, bamboo, cane, palm fibre	0.13	54	0.61	0.6	37546	2.39	8796	0.56	15741	3194	2%	24%
Medical and pharmaceutical products	0.13	127	0.75	0.73	82137	2.65	22650	0.73	31026	5291	11%	13%
Food production	0.12	121	0.43	0.43	61801	2.35	13106	0.5	26273	3783	4%	31%
Ordinary machinery manufacturing	0.1	229	0.9	0.77	48683	2.58	13786	0.73	18848	5099	7%	12%
Smelting and pressing of ferrous metals	0.1	348	0.88	0.55	94330	1.7	27139	0.49	55567	7165	9%	3%
Smelting and pressing of nonferrous metals	0.09	119	0.6	0.6	111545	2.24	24553	0.49	49837	6341	9%	5%
Raw chemical materials and chemical products	0.09	325	1	0.55	78258	2.16	19324	0.53	36168	5154	7%	9%

(Continued)

Table 1. Continued

Industry	EX/Y	Exports (100mil¥)	Technical efficiency (VRS)	Technical efficiency (CRS)	Output per worker (¥/worker)	Output per Fixed-asset	Value-added per worker (¥/worker)	Value-added per fixed-asset	Fixed-asset per worker (¥/worker)	Wage rate (¥)	College graduates as percent of total	FDI/Fixed asset
Food processing	0.08	258	0.59	0.52	120833	3.67	19722	0.6	32897	4139	4%	14%
Chemical fibre	0.08	63	1	1	143110	1.44	35866	0.36	99117	6731	8%	12%
Special purposes equipment manufacturing	0.07	115	0.76	0.74	49050	2.74	12542	0.7	17905	4975	8%	8%
Papermaking and paper products	0.06	64	0.49	0.48	54811	2.28	12541	0.52	24000	4227	3%	20%
Transport equipment manufacturing	0.06	200	1	0.82	78643	3.14	19167	0.76	25071	5976	10%	15%
Nonmetal mineral products	0.06	174	0.82	0.43	37631	1.7	11222	0.51	22195	4136	3%	11%
Printing and record medium reproduction	0.04	18	0.48	0.48	37694	1.75	11253	0.52	21500	4282	4%	17%
Petroleum processing and coking	0.04	74	0.78	0.77	255094	2.57	70566	0.71	99371	7950	14%	1%
Beverage production	0.03	34	0.6	0.58	76053	2.07	23289	0.63	36711	4145	5%	21%

Source: Third National Industrial Census of China (1995).

ideal measure as the export intensity of every industry changes through time, and this caveat should be borne in mind in interpreting the results. However, this criterion is only for classification and preliminary comparison. Econometric tests based on panel data sets are not affected by this classification.

Compared with non-export industries, export industries in China have much lower capital–labour ratios. Wage rates, ratios of college graduates to total employees and labour productivity are also lower in the export industries than those in the non-export industries. The export industries, however, enjoy much higher capital productivity and FDI-total assets ratio than the non-export industries. These facts indicate the low-capital and technology content, low-labour cost, low-labour skills, high-FDI-funded features of China's exports (Table 1).

Table 2 compares technical efficiency levels of the export and the non-export industries. On average, the export industries enjoy higher technical efficiency than the non-export industries. The average technical efficiency for export industries over the period 1990–1997 is 0.75, about 10% higher than that for the non-export industries. The cultural, educational and sports goods industries and the garments industry, which are the top two leading industries in terms of export–output ratio, enjoy the highest average technical efficiency as well.

Comparing the scale efficiency of the export industries with that of the non-export industries, on average, the export industries exhibit a superior performance to that of the non-export industries, and the difference is statistically significant[6] (Table 3). The cultural, educational and sports goods industries and the electronic and telecommunications equipment industries, which are fast growing export industries, reveal a significant improvement in scale efficiency. This fact suggests that exporting enables the export industries to enjoy economies of scale.

Table 4 reports the summary of means of the Malmquist index for individual years. On average, the Chinese manufacturing industries exhibit a relatively low TFP growth over the 1990–1997 period. The average change in the Malmquist productivity index is 1.9% per year for the sample as a whole. Much of the growth is due to technical progress, which is a shift in technology, rather than improvements in efficiency that move inefficient firms on to or closer to the frontier.

Table 5 reports the average performance of each industry over the entire 1990–1997 period. The electronic and telecommunications equipment industry has the highest TFP change, at around 12% per year. This growth is due to both progress in technology and improvements in efficiency. Interestingly, the garments industry, which is one of the major export industries in China, is the only industry that does not exhibit any technical progress.

Results of econometric tests on the interaction between exports and technical progress, efficiency change and TFP growth are presented in Table 6. Results of the Wu–Hausman tests indicate that there is no significant endogeneity between exports and efficiency change, technical progress and TFP growth at the 1% significance level in the sample. Therefore, the instrumental variable approach is not utilized.

Column 1 displays the estimated results of the efficiency change equation. Controlling for the initial efficiency level, the estimated coefficient of exports variable is positive but is statistically insignificant. This suggests that exports do not impart a significant positive impact on efficiency improvement at the industry level. The competition and resource reallocation effects of exports at the industry level are insignificant in the case of China. This is likely due to the existence of market failure in China, as is the case in other transitional economies. In the state sector, the motivation for cost cutting and efficiency improvement may be weak in the presence of government subsidies and a soft budget constraint. The resource reallocation effect of exports through rationalization of heterogeneous firms within the industry may be limited because of the lack of well-established legal systems for market exit and because of concerns over any loss of state-owned assets. Therefore, the suggested transmission mechanisms from exports to productive efficiency do not work effectively in China.

For the technical progress equation (Column 2), the estimated coefficient of export variable is statistically insignificant at the 10% level and displays a negative sign. This result suggests that exporting does not lead to innovation and technical progress in the Chinese manufacturing industries. In other words, there is no significant difference between exporting and non-exporting industries in technological advancement. There may be several explanations for this. First, R&D investment involves considerable uncertainty. About 90% of R&D projects fail to achieve commercial success (Pavitt, 1991).

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[6] The *p*-value of the *t*-test for paired sample is 0.009, suggesting the mean of the scale efficiencies of the two industry groups are significantly different from each other.

Table 2. Technical efficiencies of export and non-export industries, 1990–1997

Industry	Export–output ratio	Value of exports	1990	1991	1992	1993	1994	1995	1996	1990–97
Total industries	0.15	7162	0.756	0.737	0.735	0.748	0.759	0.654	0.661	*0.707*
Export industries	0.29	449	0.792	0.780	0.772	0.763	0.808	0.714	0.715	*0.754*
Cultural, educational and sports goods	0.56	209	0.933	0.982	0.942	0.914	1.000	1.000	1.000	*0.971*
Garments and other fibre products	0.55	811	1.000	0.999	1.000	1.000	1.000	0.901	0.805	*0.933*
Leather, furs, down and related products	0.50	485	0.713	0.740	0.682	0.773	0.877	0.731	0.691	*0.741*
Electronic and telecommunications equipment	0.36	923	0.826	0.753	0.704	0.813	0.966	1.000	1.000	*0.883*
Textile industry	0.28	1294	0.617	0.533	0.547	0.660	0.592	0.418	0.426	*0.527*
Instruments, meters, cultural and office machinery	0.27	115	0.670	0.734	0.782	0.670	0.738	0.691	0.576	*0.680*
Metal products	0.19	312	0.818	0.725	0.677	0.566	0.585	0.487	0.515	*0.606*
Rubber products	0.18	110	1.000	1.000	1.000	0.799	0.811	0.639	0.636	*0.816*
Plastic products	0.17	191	0.657	0.626	0.657	0.816	0.769	0.514	0.688	*0.645*
Furniture manufacturing	0.17	38	0.685	0.711	0.730	0.623	0.743	0.757	0.816	*0.738*
Non-export industries	0.07	157	0.733	0.710	0.712	0.738	0.729	0.617	0.627	*0.677*
Electric equipment and machinery	0.14	352	1.000	0.902	0.905	0.885	0.885	0.830	0.836	*0.877*
Timber processing, bamboo, cane, palm fibre	0.13	54	0.391	0.387	0.420	0.553	0.578	0.565	0.635	*0.524*
Medical and pharmaceutical products	0.13	127	0.951	1.000	1.000	1.000	0.928	0.702	0.819	*0.897*
Food production	0.12	121	0.865	0.874	0.827	0.524	0.508	0.369	0.471	*0.610*
Ordinary machinery manufacturing	0.10	229	0.797	0.787	0.830	0.555	0.601	0.576	0.481	*0.638*
Smelting and pressing of ferrous metals	0.10	348	0.652	0.578	0.602	0.751	0.722	0.530	0.499	*0.592*
Smelting and pressing of nonferrous metals	0.09	119	0.711	0.632	0.632	0.683	0.631	0.628	0.576	*0.617*
Raw chemical materials and chemical products	0.09	325	0.737	0.630	0.595	0.677	0.678	0.568	0.649	*0.631*
Food processing	0.08	258	0.473	0.560	0.570	1.000	1.000	0.600	0.722	*0.693*
Chemical fibre	0.08	63	1.000	1.000	1.000	1.000	1.000	1.000	0.884	*0.949*
Papermaking and paper products	0.06	64	0.624	0.553	0.522	0.485	0.586	0.461	0.500	*0.520*
Transport equipment manufacturing	0.06	200	0.713	0.706	0.823	0.800	0.831	0.788	0.701	*0.746*
Nonmetal mineral products	0.06	174	0.545	0.530	0.545	0.609	0.597	0.453	0.492	*0.521*
Printing and record medium reproduction	0.04	18	0.603	0.649	0.646	0.661	0.657	0.452	0.400	*0.564*
Petroleum processing and coking	0.04	74	0.933	0.803	0.722	0.762	0.635	0.713	0.634	*0.710*
Beverage production	0.03	34	0.734	0.763	0.751	0.860	0.824	0.634	0.731	*0.742*

Source: Exports data are derived from Third National Industrial Census of China (1995)

Table 3. Scale efficiency of Chinese manufacturing industries, 1990–1997

Industry	1990	1991	1992	1993	1994	1995	1996	1997	1990–97
Export / non-export industries	1.012	1.038	1.008	1.004	1.026	1.027	1.011	1.084	*1.026*
Export industries	0.932	0.931	0.909	0.908	0.926	0.897	0.849	0.881	*0.904*
Cultural, educational and sports goods	0.933	0.982	0.942	0.914	1.000	1.000	1.000	1.000	*0.971*
Garments and other fibre products	1.000	0.999	1.000	1.000	1.000	0.946	0.805	0.879	*0.954*
Leather, furs, down and related products	0.989	0.997	0.987	0.977	0.997	0.961	0.848	0.914	*0.959*
Electronic and telecommunications equipment	0.974	0.906	0.905	0.990	0.996	1.000	1.000	1.000	*0.971*
Textile industry	0.617	0.606	0.657	0.660	0.592	0.456	0.466	0.432	*0.561*
Instruments, meters, cultural and office machinery	0.990	0.996	0.982	0.978	0.984	0.966	0.861	0.919	*0.960*
Metal products	0.925	0.876	0.912	0.964	0.973	0.955	0.820	0.909	*0.917*
Rubber products	1.000	1.000	1.000	0.974	0.991	0.971	0.897	0.965	*0.975*
Plastic products	0.981	0.959	0.973	0.996	0.986	0.957	0.977	0.954	*0.973*
Furniture manufacturing	0.911	0.985	0.730	0.623	0.743	0.757	0.816	0.841	*0.801*
Non-export industries	0.921	0.897	0.902	0.904	0.903	0.873	0.840	0.813	*0.881*
Electric equipment and machinery	1.000	0.902	0.905	0.928	0.939	0.921	0.836	0.865	*0.912*
Timber processing, bamboo, cane, palm fibre	0.987	1.000	0.988	0.970	0.998	0.967	0.860	0.933	*0.963*
Medical and pharmaceutical products	0.971	1.000	1.000	1.000	0.979	0.999	0.967	0.979	*0.987*
Food production	0.865	0.874	0.827	0.987	0.998	0.992	0.983	0.965	*0.936*
Ordinary machinery manufacturing	0.797	0.787	0.830	0.744	0.732	0.702	0.620	0.596	*0.726*
Smelting and pressing of ferrous metals	0.738	0.734	0.773	0.751	0.722	0.614	0.698	0.594	*0.703*
Smelting and pressing of nonferrous metals	0.967	0.940	0.938	0.969	0.997	0.998	0.973	0.944	*0.966*
Raw chemical materials and chemical products	0.802	0.788	0.826	0.720	0.678	0.568	0.649	0.516	*0.693*
Food processing	0.985	1.000	0.988	1.000	1.000	0.969	0.908	0.935	*0.973*
Chemical fibre	1.000	1.000	1.000	1.000	1.000	1.000	0.894	0.817	*0.964*
Papermaking and paper products	0.987	0.942	0.953	1.000	0.988	0.987	0.952	0.982	*0.974*
Transport equipment manufacturing	0.930	0.829	0.836	0.800	0.831	0.788	0.701	0.604	*0.790*
Nonmetal mineral products	0.768	0.724	0.747	0.716	0.682	0.547	0.642	0.508	*0.667*
Printing and record medium reproduction	0.998	1.000	0.995	0.982	0.992	0.956	0.818	0.900	*0.955*
Petroleum processing and coking	0.933	0.913	0.890	0.904	0.910	0.973	0.948	0.903	*0.922*
Beverage production	0.999	0.916	0.932	0.993	0.999	0.988	0.985	0.973	*0.973*

Table 4. Annual average of Malmquist index, 1990–1997

Year	TFP change *TFPCH*	Efficiency change *EFFCH*	Technical change *TECH*
1991	0.999	0.974	1.026
1992	1.085	0.999	1.086
1993	1.215	1.021	1.190
1994	0.927	1.016	0.913
1995	0.782	0.848	0.922
1996	1.119	1.017	1.101
1997	1.070	0.905	1.182
Mean	1.019	0.967	1.055

Therefore firms whose core competitiveness relies on low labour costs may have little motivation for innovation. Second, the skill and technology content of most of China's export commodities is low. In 1997, the R&D expenditure in the export industries accounted for only 14% of the country's total industrial R&D expenditure (SSB, 1998). Therefore, their pace for technology progress may be lower than that in the technology-intensive non-export industries.

Third, the export industries in China are not the main beneficiaries of the large-scale importation of machinery and equipment, which are important channels for technology promotion. The importation of machinery and equipment has mainly gone to the capital and technology-intensive, non-export industries such as the metallurgical industry, the electrical and machinery industries and the chemical industry. They are the industries that the Chinese government is eager to develop in order to promote the nation's overall competitiveness. Finally, although the export industries have attracted substantial FDI,[7] most of them are engaged in processing-trade activities. In 1999, more than 57% of China's and about 84% of foreign-invested enterprises' (FIEs) exports are on account of processing trade (MOFTEC, 2000). The level of technology that is embodied in FDI in these labour-intensive industries is reported to be only slightly higher than that in the domestic firms (Huang, 2001). Foreign capital in these industries has not provided many new techniques, but merely markets and trade facilities. As a result, exports have

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[7] The average foreign capital to net fixed asset ratio for export industries was 0.34 in 1995.

Table 5. Malmquist TFP index by industry, 1990–1997

	TFP change *TFPCH*	Efficiency change *EFFCH*	Technical change *TECH*
Total industries	1.019	0.967	1.055
Export industries	1.009	0.976	1.034
Electronic and telecommunications equipment	1.120	1.028	1.090
Plastic products	1.041	0.943	1.103
Furniture manufacturing	1.039	1.030	1.009
Cultural, educational and sports goods	1.035	1.010	1.025
Leather, furs, down and related products	1.002	1.001	1.001
Textile industry	0.986	0.947	1.041
Instruments, meters, cultural and office machinery	0.981	0.979	1.001
Rubber products	0.969	0.939	1.033
Metal products	0.955	0.926	1.031
Garments and other fibre products	0.948	0.962	0.986
Non-export industries	1.032	0.958	1.079
Petroleum processing and coking	1.100	0.981	1.122
Timber processing, bamboo, cane, palm fibre	1.097	1.079	1.017
Food processing	1.078	1.040	1.037
Beverage production	1.070	0.890	1.200
Transport equipment manufacturing	1.060	0.956	1.109
Raw chemical materials and chemical products	1.060	0.950	1.116
Medical and pharmaceutical products	1.046	0.972	1.077
Papermaking and paper products	1.033	0.976	1.058
Smelting and pressing of nonferrous metals	1.027	0.934	1.100
Smelting and pressing of ferrous metals	1.021	0.934	1.093
Electric equipment and machinery	1.012	0.964	1.050
Chemical fibre	1.003	0.952	1.053
Food production	0.995	0.907	1.097
Ordinary machinery manufacturing	0.983	0.930	1.057
Nonmetal mineral products	0.969	0.956	1.014
Printing and record medium reproduction	0.961	0.908	1.058

Table 6. Determinants of TFP growth in Chinese manufacturing: estimation results

	Dependent variables		
	Efficiency change *EFFCH* (1)	Technical change *TECH* (2)	TFP change *TFPCH* (3)
Exports	0.017	−0.012	0.006
	(0.120)	(0.110)	(0.597)
R&D	0.005	0.008	0.013
	(0.750)	(0.375)	(0.425)
Capital intensity	−0.029*	0.052***	0.023
	(0.065)	(0.000)	(0.199)
Firm size	0.015*	−0.017***	−0.002
	(0.076)	(0.001)	(0.858)
Technical efficiency (−1)	−0.110***	0.011	−0.101***
	(0.001)	(0.573)	(0.003)
Constant	0.153*	−0.164***	−0.004
	(0.090)	(0.005)	(0.971)
Adj *R* Square	0.320	0.659	0.608
No. of observations	168	168	168
Wu–Hausman (*p*-value) (H0: Exogeneity of *x*)	0.76	0.23	0.53

Note: All variables are in logarithms.
*** significant at the 1% level; * significant at the 10%.
p-values in parentheses.

not made significant direct contribution to the technical progress in these industries.

As a combination of efficiency change and technical progress, TFP growth of the Chinese manufacturing industries does not appear to be significantly associated with its export activity. The results of the TFP growth equation show that the estimated coefficient of export variable is positive but statistically insignificant (Column 3). In sum, the results suggest that, in the case of Chinese manufacturing industries, although the export industries are more efficient than the non-export industries, greater export-orientation does not appear to lead to significant TFP growth.

The estimated coefficient of R&D intensity variable is positive but statistically insignificant in all cases. This may be explained by the fact that R&D investment is not innovation outcome. It is only one of the major inputs of innovation in addition to human capital, innovation collaboration, technological opportunity and government support (Love *et al.*, 1996; Porter and Stern, 1999). Innovation is not a simple linear transformation with basic science and other inputs at one end of a chain and commercialization at the other (Hughes, 2003). There is an efficiency issue in the innovation process. How to manage innovation efficiently is one of the most important challenges faced by organizations. It is found that R&D efficiency is low in the Chinese SOE sector (Zhang *et al.*, 2003). Therefore, the insignificance of the estimated coefficient of the R&D variable is very likely due to the inefficient use of R&D resources in China. Capital intensity shows significant positive effect on technical change as expected, suggesting the importance of technology embodied in machinery and equipment. Its impact on efficiency change is, however, negative, which suggests that raising capital intensity does not lead to efficiency improvement in the presence of over investment in the Chinese manufacturing sector. Interestingly, while firm size demonstrates a significant positive effect on efficiency change, indicating the importance of economies of scale, the impact of firm size on technical change is negative and statistically significant. This result suggests that innovation and technical change occurs more in the industries of small average firm size than in the industries of large average firm size.

Table 7. Estimates of technical efficiency in TVE and SOE sectors

Independent variables	Dependent variable: Technical Efficiency TVE	SOE
Exports	0.028**	0.005
	(0.040)	(0.693)
Bonuses per employee	0.166***	0.117***
	(0.000)	(0.005)
Wage rates	0.113***	0.145
	(0.000)	(0.182)
Capital intensity	−0.309***	−0.166***
	(0.000)	(0.007)
Firm size	0.014	0.004
	(0.447)	(0.869)
Constant	0.501	−2.257**
	(0.157)	(0.020)
No. of observations	179	179

Note:* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.
p-values shown in parentheses.

In order to further examine the impact of market failure on the export–productivity promotion linkage, the impact of exports on technical efficiency in the SOE sector is compared with that in the TVE sector. The township and village enterprises (TVEs) are economic units in rural China. They include collective-, individual-, private- and foreign-owned enterprises. Different from the SOEs, which have soft budget constaints, the TVEs have hard budget constraints and enjoy greater openness to international trade and FDI than the SOEs. They may go bankrupt if they lose money. In 1995, they accounted for 45% of the country's gross industrial value-added, and this share increased to 53% in 2001. As Table 7 indicates, exports exert a significant positive impact on technical efficiency in the TVE sector, but not in the SOE sector. One can infer from this fact that the soft budget constraints for the SOEs and the barriers for market exit for the inefficient firms in the SOE sector have reduced the effectiveness of the productivity-promotion effect of exports significantly.

V. Conclusions

This paper has investigated the impact of exports on industry-level productivity growth in the Chinese manufacturing industries in the early and mid-1990s. The remarkable export growth and the transition feature of the economy make this an interesting case to research. A non-parametric Malmquist TFP approach has been used, decomposing TFP growth into technical change and efficiency improvement, to investigate the transmission mechanisms.

In general, Chinese manufacturing industries have experienced a low level of TFP growth over the period 1990–1997. This growth was due to technical progress rather than improvements in relative efficiency. The export-oriented industries do appear to be more efficient than the non-export industries.

Exporting also enables the export-oriented industries to enjoy higher scale efficiencies. However, no evidence has been found in favour of significant productivity gains caused by exports at the industry level. Exports exhibit a positive but insignificant effect on efficiency improvement at the industry level. The resource reallocation and competition effects of exports on industry-level productivity growth suggested by the 'new' exporting literature are not significant due to market failure in the state-owned sector. Both the soft budget constraint and heavy subsidies to SOEs, along with the absence of a market exit mechanism in the domestic economy, may have stood in the way of efficiency improvements.

Exports do not appear to have promoted innovation and technical progress in the case of China. The low skill and low technology content of export products, the emphasis on cheap unskilled labour and low-price competitiveness in export industries may have discouraged the incentives for innovation. Findings of the current study suggest that for exports to generate a significant, positive effect on efficiency improvement, technical progress and thereby TFP growth, two elements are necessary: both a well-developed domestic market and a neutral, outward-oriented policy environment that is not biased either in favour of import-substitution or export-promotion.

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