EXPORTS, TECHNICAL PROGRESS AND PRODUCTIVITY GROWTH IN CHINESE MANUFACTURING INDUSTRIES

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Abstract

Theories suggesting either static or dynamic productivity gains derived from exports often assume the prior existence of a perfect market. In the presence of market failure, however, the competition effect and the resource reallocation effect 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 total factor productivity (TFP) 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. We have not found evidence 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.

JEL Codes: F10, O12, O30

Keywords: exports, industrial efficiency, technical progress, productivity

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1. 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. Nevertheless, recent research suggests that the opening up of export trade leads to a rationalization of plants within an industry, so that exports result in productivity gains at the level of the industry.

China opened up to international trade and investment in 1978. The Chinese government has introduced various policies to promote export growth. The major export promotion policies include depreciation of foreign exchange rates, export tax rebates, export credit and bonuses, and preferential policies favouring export-oriented FDI. As a result China's exports have grown rapidly in the post-reform period, from US$18 billion in 1980 to US$249 billion in 2000, ranking China as the 6th largest exporter in the world league table of exporters. Exports of manufactured products have experienced an even more impressive growth than exports as a whole. The value of manufactured exports increased from US$9 billion in 1980 to US$224 billion in 2000, with an average annual growth rate at 17 percent, accounting for 90 percent of China's exports in 2000. But the question remains: has this export expansion promoted productivity growth in the Chinese manufacturing sector? In the context of China, most empirical studies have focused on the relationship between exports and income growth, very few have investigated the relationship between exports and productivity growth. This paper empirically investigates the impact of exports on total factor productivity in the manufacturing sector of China at the industry level. The impact of exports on efficiency improvement, technical progress and productivity growth is analysed by using an industry-level panel data set for the Chinese manufacturing industries for the period 1990-1997.

The rest of the paper is organised as follows. Section 2 briefly reviews the literature. Section 3 estimates technical progress, efficiency change, and total factor productivity for Chinese manufacturing industries. Section 4 analyses the impact of exports on total factor productivity. Section 5 offers conclusions.

2. Exports, technical progress and efficiency improvement: the theoretical framework

International trade generates both static gains 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 her partners. Recent theoretical work also points to the gains from resource reallocation at the industry level. When heterogeneous firms are allowed to flourish within each industry, opening up external trade leads to a rationalization of plants. Resources are reallocated from less efficient to more efficient plants, with the less efficient firms exiting from the market (Melitz, 2002, Feenstra, 2001).

The dynamic gains from exporting include economies of scale, X-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, improve efficiency by eliminating managerial and organisational inefficiencies (Clerides, 1998; Egan and Mody, 1992; Baldwin and Caves, 1997). 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).

In sum, the argument goes, exporting may contribute to productivity growth via three channels:

(1) economies of scale;

(2) efficiency improvement of exporters through ‘learning by exporting’, X-efficiency promotion and resource re-allocation from less efficient to more efficient plants at the industry level;

(3) technical progress because of technology spillovers and investment in research and development (R&D).

However, the reasons for the relationships between exports and productivity may actually be the reverse of those suggested by the foregoing argument. A factor of the self-selection of firms may be important. After all, successful firms are more likely to export, because only the productive firms will find it profitable to enter the export market and only they can survive in the highly competitive export market. In other words, the causality may go from productivity to exports.

Although almost all empirical studies find 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 from the US, UK, Japan and Germany that supports the proposition that exports enhance productivity. Proudman and Redding (1998), based on evidence from cross-country and cross-industry analyses, conclude that trade facilitates productivity growth.

Recent research, however, finds evidence in support of the existence of a self-selection mechanism at the plant level (Henriques and Sadorsky, 1996; Yamada, 1998; Clerides *et al*., 1998; Liu *et al*., 1999; and Aw *et al*., 2000; Bernard and Jensen, 1999). Aw *et al*. (1998) use quinquennial Census data for five export-intensive industries in Taiwan and South Korea. Liu *et al*. (1999) use an annual panel data set of the Taiwanese electronics industry over the period 1989-1993. These studies have found considerable support for the self-selection hypothesis, but limited evidence for any process of learning by exporting in export-intensive industries in Taiwan and South Korea. Using data for a sample of 50,000-60,000 US manufacturing plants over the period from 1983-1992, Bernard and Jensen (1999) also find that the causation runs from productivity to exporting but not in the reverse direction. However, they also find that within a given industry, exporters do grow faster than non-exporters in terms of both shipments and employment. Exporting is indeed associated with the reallocation of resources from less efficient to more efficient plants. Such reallocation effects are found to make up over 40 percent of TFP growth in the US manufacturing sector. Using a panel data set of 20 Swedish manufacturing industries for the period 1980-1995, Andersson (2001) finds that more entry and exit activity is observed in the more open industries, which in turn raises the average productivity of these industries in Sweden.

Although the existing literature has pointed out the transmission mechanisms through which exports promote productivity, all this is based on an assumption of the prior existence of a perfect market. In the presence of market failure, however, these transmission mechanisms may not work effectively. 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 a 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. 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.

Such market failure can often be observed in the transitional economies. Such cheap labour cost orientation often occurs in labour-abundant developing countries. The Chinese economy that is in the process of transition has both of these two characteristics. It provides a typical case to test the above propositions. In the context of China, there is considerable literature on exports and income growth (Kwan and Kwok, 1995; Shan and Sun, 1998). There is also substantial literature on the impact of enterprise reforms and ownership on productivity growth. Empirical evidence on SOE productivity growth are mixed. 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*. (1993, 1994), Ren (1997) and Wu (1998) find that GDP growth of China is over-estimated, intermediate inputs are over-deflated 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, 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.

3. Methodology

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

3.1 Estimation of total factor productivity growth

The conventional technique for estimating total factor productivity (TFP) is the Solow residual method. It defines TFP growth as the residual of output growth after the contribution of labour and capital inputs are subtracted from total output growth. This method makes the following four assumptions:

(1) the form of production function is known;

(2) constant returns to scale;

(3) optimising behaviour on the part of firms, with no room for any inefficiency; and

(4) 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 paper we estimate TFP growth by using a nonparametric programming method developed by Fare *et al* (1994). Following Fare's approach, 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]. The distance functions of the Malmquist index are estimated by using non-parametric programming methods. A production frontier is constructed based on all the existing observations. The distance of each of the observations from the frontier is estimated and compared to that of the previous time period. 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,…, T.

$$S^t = \{(x^t, y^t) : x^t\_can\_produce\_y^t\} \quad (1)$$

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.

$$D_0^t(x^t, y^t) = \inf\{\theta : (x^t, y^t/\theta) \in S^t\} = (\sup\{\theta : (x^t, \theta y^t) \in S^t\}) \quad (2)$$

$D_0^t(x^t, y^t) \leq 1$ 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:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (3)$$

This equation 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

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (4)$$

where efficiency change (EFFCH) = $\dfrac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^{t}\left(x^{t}, y^{t}\right)}$ (5)

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

Thus total factor productivity 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 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,…., K industries using n = 1,…,N inputs $x_n^{k,t}$ at each time period t=1,…..T. Here inputs are used to produce m=1,……,M outputs $y_m^{k,t}$. To estimate the productivity change of each industry between t and t+1, we need 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]:

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

where θ is a scalar and λ is a nx1 vector of constants. The LP 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 scale (CRS) to technical efficiency calculated under the assumption of variable returns to scale (VRS) (Fare *et al.*, 1985). 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.

3.2 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), we classify the industries whose export-output ratios are higher than the national average ratio as the export industries. And 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:

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

where L is the logarithm operator, i and t denote industries and time respectively, and υ and ε are disturbance terms, which vary across industries and time and possess the usual properties. *pch* is productivity growth, in which we enter 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. According to the ‘law of proportionate effect’ that suggests the change in the variant at any step of the process is a random proportion of the previous value of the variant, the initial level of technical efficiency of each industry at the beginning of the sample period (TE_0) is included as a control variable. Innovation has often been regarded as an engine that drives productivity growth. Product or process innovations may induce technical change and thus push the production frontier upward; 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. Technical change of an industry may be a result of increase in investment in advanced machinery and equipment. The average firm size of an industry may affect its efficiency because larger firms may benefit from economies of scale. Hence, capital intensity (CI) and average firm size (*WS*) are also used as control variables.

Because of the possible endogeneity between exports and productivity, we first apply Wu-Hausman specification test 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 utilised for estimation. Because the TE_0 variable is time invariant, the fixed-effects model for panel data is not applicable because regressors are collinear. Therefore, we use a random-effects model for estimation.

4. Data and results

The data used for estimation are collected from various issues of China Statistical Yearbook and China Industrial Statistical Yearbook for a panel of 26 manufacturing industries for the period 1990-1997[4]. The data after 1997 are excluded because of changes in categorization of industrial enterprise by the State Statistical Bureau. The data are the sum of all enterprises with independent accounting systems in an industry. The tobacco processing industry has been excluded because it is an outlier. Exports data are derived from various issues of the International Trade Statistical Yearbook (ITSY). Classification of export and non-export industries are based on the output and exports data collected from the Third National Industrial Census of China in 1995.

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 of the industries. Labour is measured by number of employees in the industry. Capital is measured by annual average balance of net value of fixed assets deflated by the price index of investment in fixed assets. Deflation of capital is conducted in the following steps taking 1990 as the base year. We first use available statistics to calculate the undeflated annual value of newly added fixed assets; we then deflate these annual increments by the price index of investment in fixed assets; and we finally add the deflated increments to the figure for the base year[5].

Exports are measured by export-output ratio derived from the compiled data set. We first estimate the export-output ratio using the compiled data set; and secondly, improve the accuracy of the estimated ratio by adjusting the results with the export-output ratio derived from the 1995 National Industrial Census data[6]. Capital intensity (CI) is measured by capital labour ratio. Firm size (FS) is measured by average output per firm in industry i to 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, we 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, garment, 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 were 0.29, while that for the non-export industries were 0.07.

This classification is based on one-year data. Admittedly this is not an ideal measure as export-intensity of every industry changes through time. 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 set 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/technology content, low labour-cost, low labour-skills, high-FDI-funded features of China's exports (Table 1).

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	1.00	1.00	51528	3.75	12639	0.92	13750	5042	2%	54%
Garments and Other Fiber Products	0.55	811	0.94	0.91	53807	4.26	12701	1.01	12628	4608	2%	47%
Leather, Furs, Down and Related Products	0.50	485	0.76	0.74	63247	4.57	13084	0.95	13831	4526	2%	45%
Electronic and Telecommunications Equipment	0.36	923	1.00	1.00	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	0.50	58339	3.07	13569	0.71	19011	4763	4%	26%
Rubber Products	0.18	110	0.70	0.69	62817	3.20	13982	0.71	19656	4742	4%	25%
Plastic Products	0.17	191	0.50	0.50	69845	2.52	13932	0.50	27740	4355	3%	31%
Furniture Manufacturing	0.17	38	1.00	0.81	44752	3.05	11168	0.76	14653	3960	2%	29%

(cont/d…..)

Table 1. *Characteristics of Chinese Manufacturing Industries (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
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	0.90	0.85	83141	3.41	19359	0.79	24391	5359	7%	23%
Timber Processing, Bamboo, Cane, Palm Fiber	0.13	54	0.61	0.60	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	0.50	26273	3783	4%	31%
Ordinary Machinery Manufacturing	0.10	229	0.90	0.77	48683	2.58	13786	0.73	18848	5099	7%	12%
Smelting and Pressing of Ferrous Metals	0.10	348	0.88	0.55	94330	1.70	27139	0.49	55567	7165	9%	3%
Smelting and Pressing of Nonferrous Metals	0.09	119	0.60	0.60	111545	2.24	24553	0.49	49837	6341	9%	5%
Raw Chemical Materials and Chemical Products	0.09	325	1.00	0.55	78258	2.16	19324	0.53	36168	5154	7%	9%
Food Processing	0.08	258	0.59	0.52	120833	3.67	19722	0.60	32897	4139	4%	14%
Chemical Fiber	0.08	63	1.00	1.00	143110	1.44	35866	0.36	99117	6731	8%	12%
For Special Purposes Equipment Manufacturing	0.07	115	0.76	0.74	49050	2.74	12542	0.70	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	1.00	0.82	78643	3.14	19167	0.76	25071	5976	10%	15%
Non-metal Mineral Products	0.06	174	0.82	0.43	37631	1.70	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	0.60	0.58	76053	2.07	23289	0.63	36711	4145	5%	21%

Source: The Third National Industrial Census of China, 1995

Table 2 compares technical efficiency levels of the export and the non-export industries. On an average, export industries enjoy higher technical efficiency than non-export industries. The average technical efficiency for export industries over the period 1990-1997 is 0.75, about 10 percent higher than that for the non-export industries. The cultural, educational and sports goods industries and the garments industry, which are the top 2 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 an average, the export industries exhibit a superior performance to that of the non-export industries (Table 3). Statistical tests show that the difference is statistically significant[7]. 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 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 Fiber 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 Fiber	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 Fiber	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 The Third National Industrial Census of China, 1995

Table 3. *Scale efficiency of Chinese manufacturing industries, 1990-97*

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 Fiber 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*
Industry	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1990-97**
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 Fiber	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 Fiber	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 reports the summary of means of the Malmquist index for individual years. On an average, the Chinese manufacturing industries exhibit a relatively low total factor productivity (TFP) growth over the 1990-1997 period. The average change in Malmquist productivity index is 1.9 percent per year for our 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 onto 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 total factor productivity change at around 12 percent 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.

Table 4. *Annual average of Malmquist index, 1990-1997*

Year	Total factor productivity 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

Table 5. *Malmquist TFP index by industry, 1990-97*

	Total factor productivity 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 Fiber 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 Fiber	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 Fiber	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

Results of econometric tests on the interaction between exports and technical progress, efficiency change and TFP growth are presented in Table 6[8]. Results of 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, 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 (Column 1). 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-

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

	A		
	Dependent variables		
	Efficiency change EFFCH	Technical change TECH	TFP change TFPCH
	(1)	(2)	(3)
Export-output ratio	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)
Initial technical efficiency level	-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
Number 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 percent level, * significant at the 10 percent level. -- p-values are in parentheses.

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 percent 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. First, the emphasis on low labour costs and the concentration of the export industries on the relatively undifferentiated low-price goods may render technical innovation unnecessary. R&D investment involves considerable uncertainty and usually raises fixed cost of products. 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. Therefore, their pace for technology progress may be lower than that in 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 and government investment in innovation, which are important channels for technology promotion. In China foreign exchange earned by the export industries is mostly allocated by the central government. They are mainly used for importation of machinery and equipment by non-export heavy industries such as the metallurgical industry, the electrical and machinery industries and the chemical industry. These industries are capital- and technology-intensive. 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[9], most of them are engaged in processing-trade activities. 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[10]. Foreign capital in these industries has not provided many new techniques, but merely markets and trade facilities. As a result, exports have not contributed significantly to 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, our results suggest that, in the case of Chinese manufacturing industries, although export industries are more efficient than non-export industries, greater export-orientation does not appear to lead to significant total productivity 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 (Porter and Stern, 1999; Love, Ashcroft and Dunlop, 1996). Innovation is not a simple linear transformation with basic science and other inputs at one end of a chain and commercialisation 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 organisations. 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 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.

5. Conclusions

This paper has investigated the impact of exports on technical progress, efficiency improvement and total productivity growth in the Chinese manufacturing industries. In general, the Chinese manufacturing industries experienced a low level of total factor productivity 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. But I have not found evidence 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 due to market imperfections. The competition effect and resource reallocation effect of exporting on productive efficiency appear not to have come into play because of lack of incentives to promote efficiency. 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, as well as a neutral, outward-oriented policy environment that is not biased either in favour of import-substitution or export-promotion.

Notes

1 They named the index after Sten Malmquist (1953) who had proposed constructing quantity indexes as ratios of distance functions.

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).

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. We estimated labour productivity growth of the Chinese manufacturing industries using both the official data and the non-official data processed by Wu in Wu (2001). The estimated average real labour productivity growth rate of the export-industries are 11.5 percent for the official data and 14.2 percent for Wu's data, while that for the non-export industries for the official and Wu's data are 8.8 and 7.5 percent, respectively (Appendix A1). The general picture of growth of productivity for export and non-export industries presented by the official and non-official data are similar, but the non-official data reveals larger labour productivity growth gap between the two sectors than the official data. 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.

6 We multiply the estimated export-output ratio by the ratio of industrial census export-output ratio to the estimated 1995 export-output ratio.

7 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.

[8] Pairwise correlation coefficients of variables in equation (8) are presented in Appendix A2.

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

[10] A survey conducted by Young and Lan suggests that on an average level of technology embodied in FDI was only two years ahead of that in place in China (Huang, 2001).

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Appendix

Table A1. *Comparison of labour productivity using both official and non-official data*

Real Labour Productivity Growth Rate				
H.X. Wu (2001)			Official data	
	1980-97	1990-97		1990-97
Total manufacturing	**0.066**	**0.113**	**Total manufacturing**	**0.098**
Export Industries Average	**0.078**	**0.142**	**Export Industries Average**	**0.115**
Textile products	0.034	0.106	Textile Industry	0.072
Wearing apparel	0.123	0.190	Garments and Other Fiber Products	0.114
Leather products	0.080	0.164	Leather, Furs, Down and Related Products	0.131
Wood products	0.047	0.149	Furniture Manufacturing	0.187
Rubber & plastics	0.100	0.159	Rubber Products	0.077
Metal products	0.047	0.068	Metal Products	0.072
Electrical equipment	0.125	0.187	Electronic and Telecommunications Equipment	0.184
			Plastic Products	0.082
			Cultural, Educational and Sports Goods	0.141
			Instruments, Meters, Cultural & Office Machinery	0.085
Non-export Industries Average	**0.045**	**0.075**	**Non-export Industries Average**	**0.088**
Food products & beverages	0.056	0.063	Food Production	0.001
Tobacco products	-0.002	-0.003	Beverage Production	0.111
Paper & printing	0.066	0.088	Papermaking and Paper Products	0.077
Petroleum Refineries	0.005	0.025	Petroleum Processing and Coking	0.000
Chemicals	0.045	0.076	Raw Chemical Materials and Chemical Products	0.076
Building materials	0.072	0.102	Nonmetal Mineral Products	0.093
Machinery & transport eq.	0.084	0.137	Electric Equipment and Machinery	0.084
Other manufacturing	0.036	0.107	Ordinary Machinery Manufacturing	0.021
			Transport Equipment Manufacturing	0.094
			Timber Processing, Bamboo, Cane, Palm Fiber	0.225
			Medical and Pharmaceutical Products	0.100
			Chemical Fiber	0.016
			Smelting and Pressing of Ferrous Metals	0.041
			Smelting and Pressing of Nonferrous Metals	0.042
			Printing and Record Medium Reproduction	0.098

Data source: H.X. Wu (2001), 'China's comparative labour productivity performance in manufacturing, 1952-1997', China statistical Yearbook, China Industrial Statistical Yearbook.

Table A2. *Pairwise Correlations of Variables in Table 6*

	LEFFCH	LTECH	LTFPCH	LEXS	LRDS	LKL	LFS
LEFFCH	1.000	-0.109	0.727	0.023	-0.022	-0.166	-0.015
LTECH	-0.109	1.000	0.603	-0.232	0.045	0.228	-0.049
LTFPCH	0.727	0.603	1.000	-0.142	0.013	0.024	-0.045
LEXS	0.023	-0.232	-0.142	1.000	-0.457	-0.176	-0.005
LRDS	-0.022	0.045	0.013	-0.457	1.000	0.116	0.176
LKL	-0.166	0.228	0.024	-0.176	0.116	1.000	0.201
LFS	-0.015	-0.049	-0.045	-0.005	0.176	0.201	1.000

Note: L denotes logarithms.