Discussion Paper

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH
75 Chang-Hsing St., Taipei, Taiwan, 106
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No.9309 *December 1993*

Discussion Paper Series No. 9309

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Chung-Hua Institution for Economic Research

75 Chang-Hsing St., Taipei, Taiwan 106
Republic of China
FAX: 886-2-7356035
TEL: 886-2-7056006

Revised from the paper presented at the Conference on "Internationalization of Taiwan Industry," sponsored by Chung-Hua Institution for Economic Research and the Bureau of Industry, MOEA, held in Taipei, June 7, 1993.

Improvement of Capital Productivity and Technical Efficiency via DFI: Evidence from the Industrial Interaction between Taiwan and Mainland China

*Lee-in Chen Chiu**
Jr-Tsung Huang

Abstract

This study adopted translog production functions and a frontier-type technical efficiency (TE) index to measure changes in productivity and TE between Taiwan and Mainland China. By comparing industrial and regional data in 1985 and 1991, this study proved that both capital productivity and TE in Taiwan and China are being improved. In addition, there exists a significant area ranking correlation between DFI intensity and improvement in TE in mainland China. This proves the legitimacy and importance of DFI in promoting China's industrial productivity. However, the fact

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*Respectively research fellow and assistant research fellow at Chung-Hua Institution for Economic Research. The authors wish to acknowledge the research assistance of Ms. Mei-Jung Shue and Ms. Shiau-Wen Lin. Comments from Professors Wen-Fu Lee and Song-Guen Hsu improved the manuscript and are highly appreciated by the authors.

that incremental magnitudes over all industries in Taiwan are higher than those in China implies that the DFI-origin country is the greater winner.

I. Introduction

The rapid deterioration of industrial environment in Taiwan (e.g., shortage of labor and high wages, NT dollar appreciation, skyrocketing land prices) in the mid-1980s has caused a recent spate of indirect investment[1] in mainland China. This newly-opened investment heaven which has no language or cultural hindrances has attracted a great number of small- and medium-sized enterprises (SMEs) who wish either to pursue their dream of becoming multinational or to simply extend the life of their firms. The outward flood of SMEs within a very short period of time has caused concern in Taiwan about industrial hollowing-out and dependency on the mainland economy. Whether the ROC government should restrict these firms in certain respects or adopt a liberal attitude and let firms invest wherever and however they like has recently been hotly debated.

This paper intends to address this issue by examining the shift of factor productivity between the home and host economies so as to determine the appropriate policy course for Taiwan's industrial globalization.

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[1] The term indirect investment used here is in accordance the ROC policy of no direct contact with the mainland for investment or trade. Taiwan's investment in the mainland must be diverted via a third-party country/area. For a detailed description of the noneconomic factors behind DFI between Taiwan and mainland China, please refer to Chiu and Chung, 1993.

II. Existing Studies and Theories of DFI

Retracing the literature of direct foreign investment (DFI) over the past four decades, the received doctrine can be categorized into several strands:

(1) The defensive- or expansion-motivated outward investment of Multinational Enterprises (MNEs) (Hymer, 1960, 1970; Knickerbocker, 1973; Ray, 1977) explains ''why'' firms undertake foreign direct investment when they operate in an imperfect market environment. DFI is regarded as a necessary reaction of multinational oligopolists in the advanced countries for the purpose of acquiring and sustaining certain firm-specific advantages or intangible assets (e.g., technology, brand names, patents, marketing know-how, etc.).

(2) The product cycle theory (Vernon, 1966, 1979; Hirsch, 1967; Wells, 1968, 1969, 1972) added ''when'' to the theory of DFI.

(3) Internalization Theory (Buckley and Casson, 1976) analyzed "how" MNEs allocate or distribute internal resources, build production networks and manage market expansion, growing finally into multinationals.

(4) Advances in the theories of international production since the early 1970s have provided another avenue for identifying and evaluating ''which of the advantages'' are most likely to explain patterns of DFI (Caves, 1971, 1974; Horst, 1972; Wolf, 1977).

Regardless of content or approach, the above-mentioned DFI theories are based mostly on the findings of the DFI behavior of MNEs in imperfectly competitive markets and in the advanced countries.

A departure from accepted DFI theory was proposed by Kojima (1973, 1978) and Ozawa (1981). In contrast to previous studies which emphasized the microeconomic behavior of large enterprises trying to compete or expand within imperfectly competitive markets, these two Japanese scholars pointed out that Japanese firms' DFI was spurred by the macroeconomic conditions of host and home economies. Japanese firms found themselves in a comparatively disadvantageous domestic industrial environment and ventured overseas simply to exploit location-specific advantages (e.g., low-cost labor, fewer trade barriers, raw materials) in order to restore their international competitiveness. The firms moving abroad tended to be relatively small, labor-intensive enterprises, making standardized products with widely-diffused technologies.

A growing tide of interest in exploring the new DFI trend of the developing countries began in the late 1970s and early 1980s[2] Dunning (1980, 1981, 1988) made an effort to integrate conventional DFI theory with new findings from the newly-industrializing developing countries, creating an eclectic theory (1981) and paradigm (1988). He hypothesized that a firm will engage in foreign value-adding activities or international production under certain conditions. (1) It must possess net ownership advantages or intangible assets (necessary condition). (2) It must be more beneficial

[2]For a general review of multinational enterprises from the third world, please refer to Lall(1983), pp. 8-15.

to use the ownership advantages itself than to sell or lease them to foreign firms (internalization advantages). (3) Assuming conditions (1) and (2) are satisfied, it must be in the global interests of the enterprise to utilize these advantages in conjunction with at least some factor inputs outside its home country (locational advantages of host countries). These three advantages may vary according to country, industry and firm specific considerations. Within that framework, Dunning (1988) incorporated a factor-endowments/market-failure paradigm and explained the three main forms of international production, i.e., market-seeking (import substituting), resource-seeking (supply oriented), and efficiency-seeking (rationalized investment).

After reviewing the threads of DFI theory, we find no effort has been made to simultaneously compare the impact of DFI toward the host and home economies. This type of study is seldom done and difficult to execute due to the lack of appropriate methods and/or the coexistence of voluminous industrial data (including output, capital and labor) in both home and host countries. DFI-receiving countries are normally deficient in data during the beginning stage of economic development when they normally receive the greatest amounts of DFI. In this study we are lucky to be able to use the case of Taiwan's DFI in mainland China, both of which are industrial data-abundant countries. This allows the bilateral analysis of DFI impacts.

The orthodox method to evaluate productivity growth is to use total factor productivity (or multifactor productivity), which will be abbreviated as TFP hereafter. TFP is a relatively new method in Taiwan for testing the technical efficiency or factor productivity of industry, since officially-estimated capital stock data was not available until 1989[3]. Earlier work testing industrial performance was mostly adapted from input-output analysis or partial factor productivity. The earliest work measuring TFP was done by Lee (1989, 1991) using time-series data from 1978-89 for four rough manufacturing classifications, namely civil, chemical, metallic and machinery, and electronic and precision instruments. Complete TFP statistics with two-digit industrial codes have been available since 1990. To measure the impact on total factor productivity before and after the explosion of DFI from 1987 to 1991, this study utilized cross-sectional statistics of real GNP, net fixed capital stock and employees on payroll on 18 two-digit industries for the years 1985 and 1991.

The application of TFP to evaluate mainland China's industrial performance began much earlier. This owes to the nature of planned economies which provided a convenient industrial data bank for various input and output statistics. Earlier work performed by non-Chinese scholars and the World Bank produced disappointing results for China's state-owned industries, although some Chinese economists have proved TFP increases during the period of economic reform[4]. The first piece of work performed by foreign scholars showing positive multifactor productivity growth over the period 1953-85 (with acceleration from the late 1970s) was done by Chen et al. (1988). The key point allowing them to get successful results was that they

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[3] In fact, the first officially-reported statistical index of total factor productivity in the U.S. was published by the Bureau of Labor Statistics in 1983 (Lee, 1991). Therefore, 1990 should not be considered late to begin reporting on TFP.

[4] For a quick review of previous studies on China's industrial productivity, please refer to Chen, Wang, Zheng, Jefferson and Rawski (1988).

excluded nonindustrial fixed assets and the labor force from factor input data in their TFP estimation. Using this methodology, recent work on China's industrial productivity generally finds significant productivity growth regardless of whether the comparison is performed within certain industries (Jefferson, 1990; Jefferson and Xu, 1991; Cheung, Archibald and Faig, 1993), within certain areas (Perkin, 1991; Prime, 1992), or by using cross-sectional data for hundreds of cities or counties (Jefferson, 1989; Jefferson, Rawski and Zheng, 1992). Few comparisons have been done between heavy and light industries (Jefferson, 1989); most empirical studies have compared the factor productivity between state-owned and collectively-owned enterprises (Jefferson, 1989, 1991; Jefferson and Xu, 1991; Jefferson, Rawski and Zheng, 1992; Prime, 1992) with one adding a comparison to joint ventures (Perkins, 1991). Nonetheless, there has been little examination of total factor productivity executed on cross-sectional industrial data for 40 industries or over 30 provinces, municipalities and autonomous regions, nor a correlation test for foreign investment and growth of productivity. This study attempts to perform TFP estimation in this new direction and hopes to find a significant correlation between TFP performance in the mainland and DFI attraction. The comparison will be conducted both by industry and by area.

Methodology

Function specification is the crucial step in modeling total factor productivity. Previous studies have found significant results using Cobb-Douglas (Jefferson, Rawski, and Zheng, 1992; Prime, 1992; Cheung, Archibald, and Faig, 1993), translog (Dollar, 1990; Jefferson, 1990) and the two forms together (Chen et al., 1988; Perkins, 1991; Lee, 1991). Some studies tried to use a CES function form (Cheung, Archibald and Faig, 1993), however, that did not derive satisfactory results. The methods to identify technical efficiency (TE) were commonly based on the residual of the TFP function. Some models added the concept of production ''frontier'' or ''quasi-frontier'' to the estimation of TE (Lee, 1991; Jefferson, Rawski, Zheng, 1992) which requires the outward shifting of the production frontier to envelope all possible interior production sets. Mathematically, frontier-type technical efficiency requires deducting each sample's residual from the maximum of them. This study developed a ''frontier'' estimation procedure which seems appropriate for comparisons of TE on both sides of the Taiwan Strait. Furthermore, constant returns to scale was imposed for all of the estimation.

In specifying the model, we adopted the most popular translog production function[5] and put it in log-linear form,

$$lnY = \alpha + \alpha_l lnL + \alpha_k lnK + (1/2)\alpha_{ll}(lnL)^2 + (1/2)\alpha_{kk}(lnK)^2 + \alpha_{lk}(lnL)(lnK) + u \cdots\cdots(2)$$

where u is the disturbance term or residual.

To support the aim of measuring the TE index by industry or by area, it is necessary

[5] Among the various production functions, the translog function puts less constraint on empirical studies. It allows all observations or samples to self-decide the patterns of parameters, such as returns to scale, substitution elasticity or output elasticities. Those properties fit the nature of this cross-sectional study particularly well. We also tried the Cobb-Douglas function form, however the estimated results were not as good as those for the translog function.

to assume this translog production function is constrained by constant returns to scale. Thus we have the following three constraining equations:

$$\alpha_k + \alpha_l = 1 \cdots\cdots\cdots (3)$$

$$\alpha_{kk} + \alpha_{kl} = 0 \cdots\cdots\cdots (4)$$

$$\alpha_{ll} + \alpha_{lk} = 0 \cdots\cdots\cdots (5)$$

Taking the first derivative of equation (2) with respect to lnL and lnK, we get each observation's labor output elasticity (S_{li}) and capital output elasticity (S_{ki}) as,

$$\frac{\partial ln Y_i}{\partial ln L_i} = \frac{\partial Y_i}{\partial L_i} \bullet \frac{L_i}{Y_i} = S_{li} = \alpha_l + \alpha_{ll} ln L_i + \alpha_{kl} ln K_i \cdots\cdots (6)$$

$$\frac{\partial ln Y_i}{\partial ln K_i} = \frac{\partial Y_i}{\partial K_i} \bullet \frac{K_i}{Y_i} = S_{ki} = \alpha_k + \alpha_{kk} ln K_i + \alpha_{kl} ln L_i \cdots\cdots (7)$$

where $i = 1 \cdots 18$ industries for the Taiwan model and $i = 1 \cdots 39$ industries and $i = 1 \cdots 30$ areas for the mainland models.

Next, we derived the frontier of the estimated production function at the maximum boundary (or envelope) of all possible production sets:

$$\hat{u} = \max \{ u_i \geq 0 \mid u_i = ln Y_i - ln \hat{Y},\ i = 1 \cdots n\} \cdots\cdots (8)$$

where n is the total numbers of observations.

The frontier type of technical efficiency for each observation can be defined as

$$TE_i = EXP\,(u_i - \hat{u}) \cdots\cdots (9)$$

To compare the change of TE during the observation period $t=0$ to $t=m$, we can estimate one production function by polling cross-sectoral data of the two compared periods. We then get the change of TE for each observation i over periods m as

$$\Delta TE_{im} = TE_{im} - TE_{io} \cdots\cdots (10)$$

$$= EXP\ (u_{im} - \hat{u}) - EXP\ (u_{io} - \hat{u})$$

Data

The above model will to be applied to the data for two completely different industrial systems: the marketized and specialized economy of Taiwan, and the combined planned and market, traditionally self-contained economy of mainland China. The first difficulty encountered is the different classifications for manufacturing. Due to the complexity of integrating them into the same classifications we will investigate the change of factor productivity on each side's original two-digit industrial classifications only. The corresponding input and output variables in this comparative static study are defined below:

Data Set 1: (Taiwan's cross-sectional estimation of production function over 36 observations by pooling 18 subindustrial data of 1985 and 1991)

Y_i represented by year-end real GDP valued at 1986 prices for industry i.

K^i represented by year-end value of net fixed capital stock for industry i.

L_i represented by mid-year number of employees on payroll for industry i.

Data Set 2: (Mainland China's cross-sectional estimation of production function over 80 observations by pooling 40 subindustrial data of 1985 and 1991)

Y_i represented by year-end net output value at 1980 constant price for industry i[6].

K_i represented by year-end net fixed assets for industry i.

L_i represented by year-end employment for industry i.

Data Set 3: (Mainland China's cross-sectional estimation of production function over 58 observations by pooling industrial data of 29 areas for 1985 and 1991[7])

Y_i represented by year-end net output value at 1980 constant prices of all manufacturing industries in area i.

K_i represented by the year-end net fixed assets of all manufacturing industries in area i.

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[6] We calculate the price index at 1980 prices for industry i and use it to divide net output value at current prices for industry i, then we get year-end net output value at 1980 constant prices for industry i. The method for calculating price deflators at 1980 prices for industry i for 1985 and 1991 are different. In China's Statistical Yearbook on Industrial Economy, we get gross output value at 1991, 1990, 1985 and 1980 prices for industry i. We derived the 1985 price deflator for industry i as follows:

$$PD_{i1985} = \frac{TP^{1985}_{i1985}}{TP^{1985}_{i1980}}$$

We then calculated the 1991 price deflator for industry i as follows:

$$PD_{i1991} = \frac{TP^{1991}_{i1991}}{TP^{1991}_{i1990}} \times \frac{TP^{1990}_{i1990}}{TP^{1990}_{i1980}}$$

where TP^{k}_{ij} is gross output value at j prices for industry i of k year.

PD_{ik} is price deflator at 1980 prices for industry i of k year.

[7] Due to lack of data, Tibet Autonomous Region is not included.

L_i represented by year-end industrial employment in area *i*.

All above input and output values in Data Sets 2 and 3 are based on the statistics of independent accounting units within the state and collective segments of industry at or above the township level. All of these data are available in China's Statistical Yearbook on Industrial Economy (Chinese edition only). To compare the effects of TFP estimation under both constrained and nonconstrained translog production functions, each regression was done. For the estimated production function of the above three data sets (by OLS regression) please refer to Appendices I, II and III. The results presented in following section are the constrained set.

Hypothesis

With the above three sets of industrial data in hand and the DFI theories of developing countries in mind, we prepare to test the following two hypotheses.

H_1: If the emerging outward DFI dominated by small- and medium-sized enterprises were motivated by efficiency-seeking, especially with respect to their holding capital, a rise of capital productivity (or marginal returns of capital) in the DFI receiving economy should occur.

H_2: The technological efficiency should improve for both origin and destination countries/areas. The merit of DFI is that it improves international production efficiency.

Although not all DFI behavior pursues the objective of efficiency-seeking, it is the rationale of this study that DFI or international production prevails within perfectly competitive or labor-intensive industries in developing countries owing to free capital mobility between countries. DFI initiated by SMEs who pursue low-cost production sites contributes to the international improvement of partial factor productivity and technological efficiency.

Empirical Results

Table 1 and 3 list the estimated capital output elasticities and technical efficiency of Taiwan's 18 industries while Tables 2 and 4 do the same for mainland China's 40 industries. There is much to be elaborated on in these four tables analyzing them either one by one or pair by pair. However, we will focus only on what is relevant to test the above two hypotheses. The last column of Table 1 show the tendency of increasing capital output elasticities across-the-board which means marginal capital returns to Taiwan's manufacturing industries are overwhelmingly increasing. This explains the rising outflow in the form of capital of outward DFI from Taiwan in the second half of the 1980s. If we further compare the incremental magnitude of capital output elasticity industry by industry, the top three, Electric and Electronic Products, Wood and Bamboo Products, Wearing Apparel and Accessories, all feature the possibility of technology substitution between labor-intensive and capital-/technology-intensive. In addition, they are also industries with a high proportion of mainland investment.

On the other hand, most capital output elasticity in the mainland tends to increase over time (as shown in the last column of Table 2), except power generation, steam and hot water production and supply. In fact, capital productivity in the mainland is highly influenced by government policies of expansion or contraction because of the economy's planned nature. Although capital efficiency in the mainland China is believed to be more influenced by its economic reforms, the relatively high ranking of "*" signed industries (which denotes industries having attracted a higher proportion of Taiwan's and Hong Kong's small- and medium-sized enterprises) demonstrate the effects of DFI in promoting capital productivity. There is another interesting finding when we compare capital elasticity between Table 1 and Table 2. Mainland China's values tend to be very flat. Most capital output elasticities are between 0.5 and 0.7 in the mainland which is quite different from the widely diversified pattern (-0.02--1.35) in Taiwan. The range, as well as the incremental size, of capital output elasticity of Taiwan fluctuated much more than that of mainland China implying that DFI, though improving capital productivity for both sides, may contribute to the home economy to a greater extent. This reflects relatively dynamic industrial performance in the market economy of Taiwan.

In sum, comparison of Table 1 and Table 2 justifies Hypothesis I: The massive outflow of DFI by small- and medium-sized enterprises can have contributed to the positive growth of capital productivity in the host economy. It should be stressed that DFI also contributes to positive capital performance in the host economy. In other words, the efficiency-seeking motivation of DFI tends to enhance factor productivity internationally. Once the production efficiency of certain factor inputs begin losing their comparative advantages in the host economy, firms will search for new production sites. Such efficiency-seeking investment behavior occurs especially easily in industries which can relatively easily change the technology combination.

Next we compare changes in technological efficiency due to DFI. It is interesting to find that the tobacco and petroleum processing and related industries are among the few industries which had negative signs in last column of Table 3 and Table 4. Since these two industries are not popular DFI industries and do not possess the general production characteristic of competitive manufacturing, we will ignore their role in this DFI impact analysis. As to the other industries, most of them show increases for ΔTE. Again, the corresponding size of ΔTE in Taiwan is much greater than it is in the mainland. The increasing pattern of ΔTE in both Taiwan (the DFI origin country) and mainland China (the DFI receiving country) justifies Hypothesis II that DFI will improve technical efficiency for both home and host economies. This is why it is worth promoting international production via DFI.

Of the industries with negative growth of technical efficiency in the mainland, most are characterized by monopoly production (such as Mining, Petroleum and related industries, Tobacco, Timber processing, Power generation, Smelting and pressing of ferrous metals), or sectors with very slow progress in enterprise reform (such as Electric equipment and machinery, and Rubber manufactured goods). In fact, the industries with monopoly marketing power are normally the sectors with slowest enterprise reform due to the lack of competition.

The only exception is Textile manufacture which is a very competitive industry and has had good progress in enterprise reform. Its regression of technical efficiency during 1985-91 owes to the overintroduction of production lines. It is estimated that one-third of total production capacity in the mainland was idle in 1992[8].

So far, evidence of the DFI impact on the improving of technical efficiency are somewhat weak and not very convincing because of a lack of supporting statistical correlation tests. We therefore conducted the third and last experiment on the correlation of DFI intensity ranking with the ranking of technical efficiency in mainland China. Though the data listed in Table 4 are only the top ten areas of high TE in 1991, we ran the third set of TFP regressions by utilizing the third data set over 28 or 26 areas. We arranged three ranking data sets [(*i*) area ranking of TE in 1991, (*ii*) accumulated overall DFI up to 1991, and (*iii*) accumulated DFI from Taiwan] as partially listed in columns (2), (4) and (5). Table 11 shows a close match of area ranking DFI with performance of TE by area. Except for Yunnan province, where the high index of technical efficiency is believed to be contributed to mostly by the intensive and high quality investment in infrastructure and human resources during the period of the third front construction in the 1960s and 1970s and should be regarded as exceptional, most of the high industrial performance areas are high DFI attraction areas and are all coastal provinces or municipalities.

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[8] For detailed discussions of mainland China's industrial performance and overcapacity problems, please refer to Chiu et al., (1993). Industrial Structural Change and Trends in Interaction between Mainland China and Taiwan, Chapter 8.

Table 1 Capital Output Elasticity by Industry in Taiwan

Industries	1985	1991	1985-1991 Incremental
Food	0.52683[6]	0.62735[7]	0.10052[14]
Beverage and Tobacco	0.80713[4]	0.86349[4]	0.05636[16]
*Textiles	0.47393[8]	0.68315[5]	0.20922[3]
*Wearing Apparel and Accessories	0.17148[16]	0.32007[15]	0.14859[9]
*Leather	0.10093[17]	0.26287[16]	0.16194[8]
*Wood Products and Bamboo Products	0.34744[11]	0.56807[9]	0.22063[2]
Paper Products and Printing	0.50823[7]	0.61869[8]	0.11046[12]
Chemical Products	0.87134[2]	1.00204[2]	0.13070[10]
Petroleum and Coal Products	1.16516[1]	1.35148[1]	0.18632[6]
*Rubber and Plastic Products	-0.20484[14]	-0.02884[18]	0.17600[7]
Nonmetallic Mineral Products	0.53858[5]	0.64881[6]	0.11023[13]
Basic Metals	0.84137[3]	0.93218[3]	0.09081[15]
*Metal Products	0.26730[13]	0.45679[12]	0.18949[5]
Machinery	0.43849[9]	0.49234[11]	0.05385[17]
*Electric and Electronic Products	0.26311[12]	0.49488[10]	0.23177[1]
Transport Equipment	0.43592[10]	0.45539[13]	0.01947[18]
Precision Instruments	0.18474[15]	0.38179[14]	0.19705[4]
*Miscellaneous Industries	0.05461[18]	0.17643[17]	0.12182[11]

Notes: 1. Estimated by the definition of capital output elasticity in equation (7).

2. Smaller numbers in right-upper corner are rankings.

3. Industries marked with "*" represent the major DFI industries from Taiwan to the Mainland.

Table 2 Capital Output Elasticity by Industry in Mainland China

Industries	1985	1991	1985-1991 Incremental
Coal mining and preparation	0.57586	0.59392	0.01806[34]
Petroleum and natural gas extraction	0.69663	0.73809	0.04146[23]
Ferrous metals mining and preparation	0.57850	0.59420	0.01570[35]
Non-ferrous metals mining and preparation	0.59539	0.60052	0.00513[38]
Mining and preparation of building materials and other non-metal minerals	0.52492	0.56807	0.04315[20]
Salt mining	0.58183	0.60655	0.02472[31]
Mining of other minerals	0.48372	0.53044	0.04672[17]
*Logging and transport of timber and bamboo	0.54337	0.55042	0.00705[37]
Production and supply of running water	0.69476	0.71820	0.02344[32]
Food manufacture	0.56813	0.61159	0.04346[19]
Beverage manufacture	0.57065	0.61798	0.04733[16]
Tobacco manufacture	0.57204	0.67456	0.10252[1]
Forage manufacture	0.61692	0.65872	0.04180[22]
*Textile manufacture	0.55382	0.59169	0.03787[25]
*Clothing	0.46920	0.54793	0.07873[3]
*Leather,furs and manufactured goods	0.49510	0.56290	0.06780[6]
*Timber processing,bamboo,cane,palm fibre and straw products	0.52012	0.57519	0.05507[12]
*Furniture manufacture	0.49619	0.56044	0.06425[9]
Paper making and manufactured goods	0.56746	0.59920	0.03174[28]
Printing	0.53833	0.58278	0.04445[18]
Cultural,educational and sports articles	0.51289	0.56279	0.04990[14]
Arts and crafts	0.47115	0.54141	0.07026[5]
Power generation,steam and hot water production and supply	0.74299	0.73369	-0.00930[40]
Petroleum processing	0.68657	0.72291	0.03634[26]
Coking,gas and coal-related products	0.60483	0.66047	0.05564[11]
Chemical industry	0.61958	0.64111	0.02153[33]
Medical and pharmaceutical products	0.58493	0.65094	0.06601[8]
Chemical fibers	0.71178	0.74085	0.02907[29]
*Rubber manufactured goods	0.55802	0.60694	0.04892[15]
*Plastics manufactured goods	0.55676	0.62357	0.06681[7]
Building materials and other non-metal products	0.53159	0.57365	0.04206[21]
Smelting and pressing of ferrous metals	0.62760	0.63728	0.00968[36]
Smelting and pressing of non-ferrous metals	0.63975	0.64099	0.00124[39]
*Metal products	0.51328	0.56747	0.05419[13]
Machine building	0.56986	0.59696	0.02710[30]
Transportation equipment	0.57692	0.61024	0.03332[27]
*Electric equipment and machinery	0.54375	0.60638	0.06263[10]
*Electronic and telecommunications equipment	0.59499	0.67421	0.07922[2]
Instruments,meters and other measuring equipment	0.56029	0.59883	0.03854[24]
Other Industries	0.48926	0.56659	0.07733[4]

Notes: Same as Table 1.

Table 3 Technical Efficiency by Industry in Taiwan

Industries	1985	1991	1985-1991 △TE
Food	0.92518	0.93910 [3]	0.01392 [15]
Beverage and Tobacco	1.00000	0.90968 [4]	-0.09032 [17]
*Textiles	0.32568	0.38267 [17]	0.05699 [12]
*Wearing Apparel and Accessories	0.64897	0.94784 [1]	0.29887 [4]
*Leather	0.52210	0.71855 [8]	0.19645 [6]
*Wood Products and Bamboo Products	0.29490	0.26909 [18]	-0.02581 [16]
Paper Products and Printing	0.40523	0.48482 [12]	0.07959 [10]
Chemical Products	0.39553	0.44451 [13]	0.04898 [14]
Petroleum and Coal Products	0.78231	0.43201 [14]	-0.35030 [1]
*Rubber and Plastic Products	0.36237	0.79249 [6]	0.43012 [18]
Nonmetallic Mineral Products	0.31330	0.39691 [15]	0.08361 [9]
Basic Metals	0.46297	0.54754 [11]	0.08457 [8]
*Metal Products	0.33536	0.39235 [16]	0.05699 [13]
Machinery	0.40970	0.56824 [10]	0.15854 [7]
*Electric and Electronic Products	0.51850	0.78408 [7]	0.26558 [5]
Transport Equipment	0.53908	0.94666 [2]	0.40758 [2]
Precision Instruments	0.53271	0.59672 [9]	0.06401 [11]
*Miscellaneous Industries	0.54499	0.85574 [5]	0.31075 [3]

Notes: 1. Estimated by the definition of technological efficiency in equation (9) and (10).
2. Same as Table 1.

Table 4 Technical Efficiency by Industry in Mainland China

Industries	1985	1991	1985-1991 Incremental
Coal mining and preparation	0.03900	0.03716	-0.00184[28]
Petroleum and natural gas extraction	0.17866	0.08861	-0.09005[38]
Ferrous metals mining and preparation	0.05804	0.07307	0.01503[17]
Non-ferrous metals mining and preparation	0.05251	0.06613	0.01362[18]
Mining and preparation of building materials and other non-metal minerals	0.06754	0.08804	0.02050[6]
Salt mining	0.14456	0.12128	-0.02328[36]
Mining of other minerals	0.09387	0.10892	0.01505[16]
*Logging and transport of timber and bamboo	0.06576	0.06898	0.00322[25]
Production and supply of running water	0.04184	0.04590	0.00406[24]
Food manufacture	0.07755	0.09546	0.01791[10]
Beverage manufacture	0.11679	0.12168	0.00489[23]
Tobacco manufacture	1.00000	0.72084	-0.27916[40]
Forage manufacture	0.10134	0.12527	0.02393[4]
*Textile manufacture	0.11716	0.09346	-0.02370[37]
*Clothing	0.13695	0.14967	0.01272[19]
*Leather,furs and manufactured goods	0.10342	0.12121	0.01779[11]
*Timber processing,bamboo,cane,palm fibre and straw products	0.06666	0.06191	-0.00475[31]
*Furniture manufacture	0.09468	0.10586	0.01118[20]
Paper making and manufactured goods	0.09611	0.09395	-0.00216[29]
Printing	0.09470	0.11151	0.01681[14]
Cultural,educational and sports articles	0.15411	0.15566	0.00155[26]
Arts and crafts	0.13474	0.15350	0.01876[7]
Power generation,steam and hot water production and supply	0.07788	0.05895	-0.01893[35]
Petroleum processing	0.34625	0.15349	-0.19276[39]
Coking,gas and coal-related products	0.04587	0.02992	-0.01595[34]
Chemical industry	0.08857	0.10538	0.01681[14]
Medical and pharmaceutical products	0.16249	0.20697	0.04448[1]
Chemical fibers	0.10927	0.14736	0.03809[2]
*Rubber manufactured goods	0.20290	0.19276	-0.01014[32]
*Plastics manufactured goods	0.10264	0.11380	0.01116[21]
Building materials and other non-metal products	0.06972	0.07834	0.00862[22]
Smelting and pressing of ferrous metals	0.09070	0.08732	-0.00338[30]
Smelting and pressing of non-ferrous metals	0.09198	0.09263	0.00065[27]
*Metal products	0.11161	0.12747	0.01586[15]
Machine building	0.09287	0.11112	0.01825[8]
Transportation equipment	0.10125	0.12375	0.02250[5]
*Electric equipment and machinery	0.16874	0.15750	-0.01124[33]
*Electronic and telecommunications equipment	0.14661	0.17621	0.02960[3]
Instruments,meters and other measuring equipment	0.11940	0.13679	0.01739[12]
Other Industries	0.11170	0.12993	0.01823[9]

Notes: Same as Table 3.

Table 5 Correlation Test of DFI Intensity Ranking with Technical Efficiency in Mainland China

Areas	(1) TE in 1985	(2) TE in 1991	(3) ΔTE =(2)-(1)	(4) Overall DFI (--1991)	(5) DFI from Taiwan (--1991)
Shanghai Shi	1.000	0.681(1)	-0.32(29)	118815(4)	10862.5(3)
Zhejiang Province	0.380	0.674(2)	0.29(1)	24480(11)	1932.9(8)
Yunnan Province	0.422	0.663(3)	0.24(2)	2087(25)	6.5(26)
Beijing Shi	0.680	0.635(4)	-0.05(24)	143835(2)	3100.4(5)
Guangdong Province	0.529	0.625(5)	0.10(8)	600015(1)	1932.9(8)
Fujian Province	0.390	0.600(6)	0.21(3)	126667(3)	21548.7(2)
Jiangsu Province	0.476	0.584(7)	0.11(6)	57960(6)	3599.6(4)
Tianjin Shi	0.641	0.550(8)	-0.09(27)	35436(10)	1144.1(10)
Guangxi Province	0.400	0.508(9)	0.11(5)	15831(13)	388.2(15)
Hunan Province	0.409	0.484(10)	0.08(10)	5041(19)	282.8(17)

Spearman's Rank Correlation Test:

Area ranking of overall DFI and TE in 1991 [column (2)vs.(4)]	R_s=0.5828	(>0.496, at α=0.005, n=28)
Area ranking of DFI from Taiwan and TE in 1991 [column (2)vs.(5)]	R_s=0.4503	(>0.392, at α=0.025, n=26)
		(<0.515, at α=0.005, n=26)

Sources: 1. The (1) and (2) columns are estimated by the definition of technological efficiency in equation (9).
2. Data in column (4) are from China Statistical Year Book, 1988-1992.
3. Data in column (5) are provided by Investment Commission, MOEA, ROC, 1992.

Notes: 1. The figures in column (4) are regarded as accumulated investment from 1987 to 1991 and in column (5) are DFI values accumulated up to 1991.
2. Figures in parentheses are rankings.
3. Spearman's rank correlation coefficient is calculated as

$$R_s = 1 - \frac{6\sum D^2}{n(n^2-1)}$$

where D : the difference between the ranks of two data on the same area. n : number of observations

Spearman's rank correlation tests on the area ranking of technical efficiency with either overall DFI or DFI from Taiwan are all statistically significant. The fact of the ranking of the correlation coefficient with overall DFI (=0.60) being higher than that of DFI from Taiwan (=0.43) prove the importance of DFI intensity to the performance of TE.

III. Conclusions

Given the hypothesis that DFI behavior in developing countries is motivated by efficiency-seeking, this study proceeds to explore the shifting of factor productivity and technical efficiency between DFI home and host economies, specifically Taiwan and mainland China. The positive changes in direction of marginal returns to capital (or capital output elasticity) within high-DFI industries justify the efficiency-seeking behavior of DFI by small- and medium-sized enterprises. Furthermore, not only does the capital productivity shift in a positive direction, but technical efficiency is also improved for both home and host economies. Due to the complexity of production characteristics in different industries, there are still many issues worth exploring. The simultaneous increases of TE in both the home and host economies support the importance of DFI to promote production efficiency internationally. However, the fact that incremental magnitudes of capital output elasticities and TE over all industries in Taiwan are higher across-the-board than those in mainland China implies the DFI-origin countries are no doubt the greater winner. Finally, two Spearman's ranking correlation tests on the area ranking of TE with (1) overall DFI and (2) DFI from Taiwan proved the importance of DFI intensity to the improvement of TE in the host economy.

In fact, there are many reasons other than DFI factors behind the slow growth of total factor productivity in mainland China, including the differing speed and pace of economic reform in different sectors or areas, the rigid distribution system and the slowness of reform for industrial materials and intermediate goods, the heavy social service burden on state and collective enterprises, etc. The DFI share in most industries is relatively low in mainland China. However, the diffused effects of advanced technology and managerial systems from DFI firms is a major learning resource for townships and state enterprises. It worth keeping an eye on the future movement toward a socialist market economy which will certainly attract ever-greater amounts of DFI to mainland China.

Appendix I

Estimated Parameters of Translog Production Function in Taiwan

Variable	Nonconstrained	Constrained
INTERCEP	14.369358 (1.112)	0.752632* (8.881)
L	-2.069542 (-1.181)	0.350576* (5.390)
K	0.856455 (0.622)*	0.649424* (9.984)
LL/2	0.233241 (1.380)	0.200654 (1.375)
KK/2	0.184953 (1.330)	0.304411* (3.809)
LK	-0.215298* (-2.372)	-0.304411* (-3.809)
Adj.R-square:	0.7079	0.6815
DW:	1.769	1.676
Number of Obs.	36	36

Notes: 1. Numbers in parentheses are t statistics.
2. "*" denotes statistical significance at the 95% level.

Appendix II

Estimated Parameters of Translog Production Function in Mainland China (Industries Regression)

Variable	Nonconstrained	Constrained
INTERCEP	-0.635223 (-1.537)	-0.600035* (-7.347)
L	0.658387 (1.300)	0.384942* (4.922)
K	0.456241 (1.264)	0.615058* (7.864)
LL/2	-0.058333 (0.280)	0.081604 (0.536)
KK/2	0.044128 (0.280)	0.081604 (0.536)
LK	-0.014010 (-0.079)	-0.081604 (-0.536)
Adj.R-square:	0.8813	0.8818
DW:	1.845	1.848
Number of Obs.	80	80

Notes: Same as Appendix I.

Appendix III

Estimated Parameters of Translog Production Function in Mainland China (Area Regression)

Variable	Nonconstrained	Constrained
INTERCEP	-1.892037*	-0.821762*
	(-2.679)	(-18.441)
L	0.100028	0.335472*
	(0.129)	(2.138)
K	1.173087	0.664528*
	(1.387)	(4.235)
LL/2	0.814319	0.713901
	(1.484)	(1.162)
KK/2	0.715563	0.713901
	(1.125)	(1.162)
LK	-0.776944	-0.713901
	(-1.350)	(-1.162)
Adj.R-square:	0.9443	0.9295
DW:	1.481	1.326
Number of Obs.	58	58

Notes: Same as Appendix I.

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