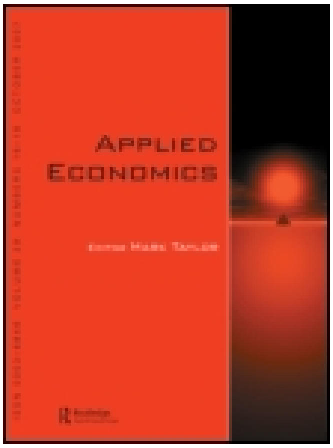

Applied Economics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/raec20

FDI, trade, and spillover efficiency: evidence from China's manufacturing sector

Yih-Chyi Chuang & Pi-Fum Hsu [b]

[a] Department of Economics , National Chengchi University , Taipei, Taiwan

[b] Department of Finance , I-Shou University , Kaohsiung, Taiwan

[c] Department of Economics , National Chengchi University , Taipei, Taiwan E-mail:

Published online: 21 Aug 2006.

Applied Economics, 2004, **36**, 1103–1115

FDI, trade, and spillover efficiency: evidence from China's manufacturing sector

YIH-CHYI CHUANG* and PI-FUM HSU‡

Department of Economics, National Chengchi University, Taipei, Taiwan and
‡*Department of Finance, I-Shou University, Kaohsiung, Taiwan*

Using firm data from the 1995 Third Industrial Census of China, this paper finds that the presence of foreign ownership has a positive and significant effect on domestic firms' productivity. Moreover, trading with more advanced countries helps China gain access to new technology and information, which improves its productivity and enables it to compete in international markets. It is found that China's imports from OECD and the four Asian Tigers, and exports to OECD have positive effects on domestic firms' productivity. By dividing industries into high-technology-gap and low-technology-gap groups, it is found that the spillover effects of FDI are larger for the low-technology-gap group than for the high-technology-gap group. However, the estimation results of the trade-induced technology spillover effect support the technology-gap learning theory and the significance of importing appropriate technology.

I. INTRODUCTION

Since China adopted its open trade policy in 1979, its annual growth rate of GDP has been 9.8% between 1979 and 1997, 7.9% from 1986 to 1990, and 11.2% from 1991 to 1997. For the past 5 years, China's average economic growth rate has been the highest in the world. In 1997 the total value of China's GDP was $902.2 billion (7th in world ranking), the total value of trade was $325.1 billion (10th in world ranking), and flow of foreign capital was $64.4 billion (2nd in world ranking). Therefore, international trade and foreign direct investment (FDI) has played an important role in China's recent rapid economic development. This paper intends to investigate the contribution of international trade and FDI on China's domestic production efficiency since the advent of the open trade policy.

International trade and FDI can be very effective ways of stimulating technological change for a less-developed country. Due to a shortage of resources and a lack of domestic savings to fuel capital investment, foreign capital can become a critical factor for the early evolutionary stages of a developing country. It bridges the capital gap and speeds up the technology transfer and upgrade of domestic industries. By selling off merchandise in the domestic market, a foreign-invested company transfers technology, including operation and maintenance or after-sale services, to domestic companies. By employing local managers and workers, foreign-invested companies teach management, production, and marketing skills to local employees.

International trade may also foster technology transfer. Exposure to an international market helps domestic firms gain access to new technology, while keen international competition forces domestic firms to adopt technology that is more efficient. Opening up trade not only produces a more efficient allocation of domestic resources, but also fosters technology transfer. Chuang (1998) points out that trading partners and learning characteristics of

*Corresponding author. E-mail: ycchuang@nccu.edu.tw

Applied Economics ISSN 0003–6846 print/ISSN 1466–4283 online © 2004 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/0003684042000246812

traded goods play a very important role in the technology diffusion from an advanced country to a less-developed country.[1]

Using China's 1995 Third Industrial Census data, this paper examines production efficiency among Chinese firms to see whether different types of ownership, industry, location, production scale, and production variety produce differences in performance efficiency. This also concerns whether it is true that foreign-invested firms are more productive. If they are, then does FDI increase the technology efficiency of domestic firms? As for international trade, does trading with more-advanced countries bring significant technology diffusion and learning to the domestic firms? If this is so, then does this trade-induced technology learning effect favour a low- or high-technology-gap industry? These issues will be focused on later in the paper.

The rest of the paper is organized as follows. Section II analyses the properties of FDI and international trade in China. Section III performs the production efficiency test. Section IV examines the roles of foreign-invested firms and the learning effect of international trade in technology diffusion. Concluding remarks are made in Section V.

II. THE PROPERTIES OF CHINA'S FDI AND INTERNATIONAL TRADE

Foreign investment enterprises (FIEs) in China

China's FDI in 1997 was $45.3 billion, 70% of the $64.4 billion in foreign investment in China. In the 1980s and 1990s, the main sources of FDI were Hong Kong and Macao (over 50%), followed by the USA and Japan in the 1980s, and Japan and Taiwan in the 1990s. Since 1989, foreign investment from Taiwan has surged and surpassed that of the foreign investment from the USA, and Japan after 1992. As of 1995, total FDI in China was $37.5 billion in which Hong Kong and Macao took a share of 54.64%, Taiwan 8.43%, Japan 8.28% and USA 8.22%. The share of actual FDI to domestic fixed asset investment increased from less than 1% in 1983 to a high of 17.08% in 1994, and then slightly decreased to 14.83% in 1997. This suggests that foreign investment was an important source of China's domestic capital accumulation.

In foreign trade, all three types of foreign investment enterprises (FIEs), Sino-overseas joint ventures, Sino-overseas cooperative ventures, and sole-foreign enterprises, focused on the domestic market in the early stages, but then they quickly switched to the international market. Their exports as a share of total exports was less than 2% in 1986, however, they increased rapidly to 31.5% by 1995. From 1983 to 1998, the value of China's exports grew at an average of 14.1% per year while that of imports grew at an average of 12.55% per year. The import shares of FIEs have surpassed 20% since 1990 and reached 47.65% in 1995, because most of the materials and production equipment for FIEs were imported from their foreign host companies.[2] As a result, the import of more advanced machinery and equipment helped in the technology transfer and upgrade of domestic industries as higher technology has been used in domestic production. Therefore, the inflow of FDI has widened the international market for China and created China's international competitiveness.

From the China Statistical Yearbook 1998, in 1995 and 1996 FIEs produced 19% of China's total industrial output, among which 50% were from overseas Chinese-invested firms, which occupied a 36% share of total capital compared to a 24% capital share owned by sole-foreign investors. This shows the relative importance of overseas Chinese investors in China's foreign direct investment and their contribution to China's industrial production. Over 40% of FIEs' output were in the clothing and textile industries, leather and fur products, electrical and electronics machinery, and precision equipment. Among them, the order in FIEs' output share was electrical and electronics industry (20.06–22.25%), food industry (8.62–8.70%), textile industry (7.69–6.84%), and clothes and other textile products (6.88–6.43%).

By using the 1995 census data on FIEs, we further classify the properties of FDI into seven types of business; namely, Sino-overseas joint ventures, Sino-overseas cooperative ventures, sole-foreign enterprises, village level venture capital firms, joint ventures of HMT, cooperative ventures of HMT, and sole-HMT enterprises. Table 1 records the basic statistics of the FIEs. From Table 1, the share of exports to total sales was highest (59%) for sole-foreign and sole-HMT enterprises and lowest (27%) for joint ventures of HMT. Thus, regardless of the ownership type, exports are an important market for FIEs.

As for the profit rate or sales revenue per worker, the highest rate was Sino-overseas joint ventures and HMT joint ventures, and the lowest rate was Sole-foreign and sole-HMT enterprises. The reason why sole-foreign and sole-HMT enterprises have lower profits may be due to local market information, for example, culture difference and unfamiliarity in the local environment. Moreover, there is much red tape and kinship customs in Chinese society and such bureaucracy requires some local network connections. Thus, without any local participants,

[1] Chuang (2002) find empirical evidence from a cross-country analysis.

[2] The inflow of FDI was relatively short of the outflow of foreign exchange in purchasing imported goods. For example, in 1996 foreign firm's imports was $75.6 billion, a 55% share of total imports. At the same time, foreign direct investment was $41.7 billions. However, the exports of foreign firms were $61.5 billion, a net export of −$14.1 billion.

Table 1. *Basic statistics summary of foreign investment enterprises (FIEs)*

	FIEs	Sino-overseas joint ventures	Sino-overseas co-operative ventures	Sole-foreign enterprises	Village-run FIEs	HMT joint ventures	HMT cooperative ventures	Sole-HMT enterprises
Number of enterprises	49004	12405	1498	2506	8201	16020	3029	5345
	[100%]	[25.31%]	[3.06%]	[5.11%]	[16.74%]	[32.69%]	[6.18%]	[10.91%]
Employees per firm	172	184	175	183	162	171	712	157
Exports/Revenue	0.36	0.29	0.39	0.58		0.27	0.52	0.59
	(0.44)	(0.41)	(0.45)	(0.46)		(0.39)	(0.46)	(0.46)
Exports/Investment	3.00	3.41	2.87	2.40		3.05	3.38	1.99
	(17.16)	(15.73)	(17.10)	(7.94)		(17.60)	(27.41)	(14.55)
Profits/Investment	0.13	0.23	0.03	0.00		0.16	−0.05	0.00
	(3.49)	(2.76)	(2.32)	(0.96)		(4.81)	(2.28)	(1.04)
Revenue/Employee	128.46	139.57	130.99	132.26		127.66	119.01	107.03
	(346.80)	(316.79)	(307.89)	(299.92)		(407.42)	(361.65)	(208.41)
Fixed Assets/Employee	83.93	93.52	93.54	81.39	56.51	90.14	95.27	77.24
	(250.82)	(221.52)	(204.87)	(149.10)	(107.74)	(341.11)	(288.05)	(159.84)
(Unit: RMB1,000)								
Sales revenue	24653	31101	23557	31894		22799	17150	16415
Export value	9437	8297	8047	23406		7492	9385	11780
Total amount of capital	11668	15299	11658	12622		10382	8573	9019
	[100%]	[100%]	[100%]	[100%]		[100%]	[100%]	[100%]
Chinese capital	4666	7436	4145	84		5570	2676	71
	[39.99%]	[48.60%]	[35.55%]	[0.67%]		[53.65%]	[31.21%]	[0.79%]
Foreign capital	2812	6279	3627	11259		115	104	306
	[24.10%]	[41.04%]	[31.11%]	[89.20%]		[1.11%]	[1.21%]	[3.39%]
HMT capital	4190	1584	3886	1279		4697	5793	8642
	[35.91%]	[10.35%]	[33.33%]	[10.13%]		[45.24%]	[67.57%]	[95.82%]
Fixed assets	13180	17805	12794	13598	5731	15148	11335	8934
Liquid assets	14203	20665	13339	14351	6126	15475	10714	9932

Note: Figures in ( ) are standard deviations.
Source: 1995 Third Industrial Census of China.

sole-foreign enterprises will encounter many perceivable and nonperceivable transaction difficulties.[3]

Joint ventures overall are more capital intensive than single owner firms. Foreign investment in an industry is also found to be different among the seven types of businesses. Sino-overseas joint ventures focused their investment in electronics and telecommunication equipment, transportation equipment, and the non-metallic mineral products industry. Sino-overseas or HMT cooperative enterprises and HMT joint ventures concentrated on electricity, steam, hot water production, and textiles. Sole-foreign enterprises focused on electronics and telecommunication, electrical machinery and equipment, and textiles. Sole-HMT enterprises focused on electronics and telecommunication, textiles, clothes and other textile products.

Most FIEs are in electronics and telecommunication, textiles, clothes, and other textile products industries. Because all these are labour-intensive, an abundant labour force and cheap wages seem to be the major incentive for FDI in China. As for location and direction of trade, most of the FIEs are located in coastal areas, for example, Guangdong, Fujian, Jiangsu, Shanghai, Zhejiang and Shandong and most of their exports go to the USA, Japan and Hong Kong.

China's international trade

After China adopted its open trade policy, its exports as a share of GDP surged from 6.0% in 1980 to 20.3% in 1997. China's exports to industrial countries increased gradually and steadily from 44.76% in 1980 to 51.29% in 1997, while exports to Asia remained at around 40%. China's imports from industrial countries, however, decreased from 73.69% in 1980 to 50.18% in 1997, while its imports from Asia increased significantly from 8.72% in 1980 to 36.86% in 1997.

[3] For example, Chinese Government policy towards wholly foreign-owned enterprises was relatively more restrictive and the Government prohibited wholly foreign-owned enterprises from specified sectors and restricted them in others, see Lin and Png (2001). Foreign investors in China also encountered difficulties in enforcing their rights, see Nyaw (1993).

In terms of commodity structure, manufactured products are the major items, comprising over 80% of both imports and exports. The leading items among these manufactured products are textile materials and products (24.11% in exports and 11.98% in imports) and machinery, equipment, and their parts (18.60% in exports and 35.58% in imports). However, imports from advanced countries are mainly machinery and equipment and their parts, while imports from the four Asian Tigers included machinery and equipment, textile products and plastic products.

To sum up, in terms of output or fixed capital formation, FDI has played an important role in China's economy. Most FDI has concentrated on labour-intensive industries like electronics and telecommunication equipment, textiles, clothes and other textile products, and their major sale revenues are from exports. Therefore, FDI has helped create an international market for China. Furthermore, the heavy imports of machinery and equipment by these FIEs from their overseas host companies has accelerated the technology upgrade of domestic industry. As for international trade, the exports of FIEs have been concentrated in textile products and machinery equipment. Most imports were machinery equipment and parts from industrial countries. Imports from the four Asian Tigers include machinery equipment and parts, and textiles and plastic products.

III. PRODUCTIVITY ANALYSIS

The data for productivity analysis are from the 1995 Third Industrial Census, published by the China National Statistics Bureau, containing 450,000 firms.[4] Due to data limitations, as in the case of Caves (1974), Globerman (1979), and Blomstrom and Persson (1983), labour productivity is used as the measure of production efficiency. As there is a large stock of inventory accumulation in the Chinese economy, sales per worker are used as the measure of labour productivity.[5] The reason for the recent build-up of inventories in China is the unexpected decline in current consumption. For example, final consumption as a share of GDP dropped from 62.03% in 1990 to 58.12% in 1995, due to increased savings for housing, an increase in precautionary savings for health insurance, and an increase in savings for education investment as a result of privatization and reform of conventional social welfare programmes in China. It may also partly be because under a command economy, the production of many public or semi-public enterprises, comprising about 80% of the whole sample, is not guided by the market. Moreover, China's government has tried to stimulate production, especially by public-owned enterprises, so as to guarantee a high economic growth rate to reach the economic growth target (e.g. 8%) set by the economic plan of central government.

Jorgenson (1995) and McGuckin and Nguyen (1993) point out that when using micro firm level data to conduct productivity analysis, the output value model is more appropriate than the value-added model, however, intermediate inputs need to be included. Since the census data did not contain information on intermediate inputs, as with Wu (1995) working capital is used as a proxy for intermediate inputs. Note that some intermediate products such as machinery and equipment, whether domestic or imported, are considered fixed assets and classified as part of fixed capital. Thus, the fixed capital variable already includes these kinds of inputs.

Other intermediate products like raw materials are classified as current assets, which are part of working capital. Working capital usually includes costs of raw materials and bills. Therefore, working capital can be used as a proxy for intermediate inputs.

In the empirical literature, there are many factors affecting firms' production efficiency, including capital intensity, the age of firms, production scale and diversity, ownership and types of business, and geographic location. It is well understood that capital accumulation enhances labour productivity in the neoclassical growth model. For example, Forsund and Jansen (1977) and Albach (1980) find that more capital-intensive firms are more efficient. Moreover, Lang (1991) and Leamer and Thornberg (1998) discover that firms using capital-intensive technologies pay higher wages, which ensures greater effort and efficiency. The older a firm is, the more likely it is to be efficient, because it has learned from experiences and is thus more likely to survive under keen competition.

Kopp and Smith (1980), Pitt and Lee (1981), and Green, Harris and Mayes (1991) see that production efficiency and the age of firms are positively correlated. However, newly-established firms may have the advantage of adopting new technology and thus can become more efficient. Tyler (1979), Page (1984), and Seale (1990) find that large firms are used to taking advantage of scale economies and thus become more efficient. Panzar and Willing (1981) point out that when factor inputs are shared in different production processes or when there exists cost complementarity between factor inputs, firms can take advantage of economies of scope to reduce their unit production costs.

Using data covering international operations of the top European and US electronics companies over the period 1984–1995, Castellani and Zanfei (2002) show that multinational corporations create linkages with local firms

[4] There are 750 000 firms in the original data bank. Firms with insufficient data or sales revenue or fixed assets less than $1000 RMB are excluded.

[5] See also Chen (1998) for the same argument.

Table 2. *Basic statistics for productivity analysis*

	State- and collective-owned	Private and individual	Foreign investment	HMT investment	Others
Samples	406602	2446	14376	22147	10118
Y/*L* (RMB1000/person)	51.38	97.80	137.91	120.74	83.62
K/*L*	24.58	26.47	91.88	87.73	49.82
M/*L*	27.66	38.00	114.25	100.04	53.31
AGE (year)	13.494	4.487	3.091	3.366	9.299
SCOPE	0.267	0.161	0.259	0.251	0.312
AREA					
Southeast (%)	31.64	33.77	58.38	73.72	48.48
East coast	16.88	38.18	23.39	13.66	14.83
West	17.00	8.91	5.16	3.17	15.93
Central	34.48	19.13	13.08	8.90	20.76
IND					
Mining (%)	6.31	3.97	0.58	0.65	4.03
Food and Beverage	12.43	10.75	12.35	8.19	10.48
Textile	9.44	13.21	24.07	27.90	10.62
Furniture	11.85	13.45	9.81	11.34	8.37
Chemical and Plastics	11.64	11.16	14.72	14.88	15.69
Basic Metal	21.48	24.20	11.41	10.76	21.54
Machinery	13.95	13.37	9.41	7.08	15.13
Electronics Machinery	5.77	6.75	12.26	12.97	9.71
Water, Electricity and Gas	2.83	0.41	0.38	0.44	2.05
Other Manufacturing	4.29	2.74	5.01	5.78	2.38
RANK					
Under Central Government (%)	1.01	—	1.26	0.51	0.61
Provincial and Prefectural Government	11.74	3.19	29.45	24.41	20.28
At and Below County Level	29.21	6.99	21.26	22.85	26.38
Township and Urban	52.45	24.08	25.77	26.39	43.06
Village and other	5.59	65.74	22.36	25.83	9.68
SIZE					
Large (%)	1.21	—	2.75	1.38	4.79
Medium	3.43	0.25	4.34	2.93	7.45
Small	95.36	99.75	92.93	95.69	87.75

Source: The 1995 Industrial Census of China.

to learn, accumulate, and exploit knowledge.[6] However, Pitt and Lee (1984) find that due to culture differences and unfamiliarity in the local environment, multinational corporations tend to be less efficient. Sterner (1990) did not discover multinationals to be more efficient and cooperatives to be less efficient than ordinary enterprises, while Levy (1981) sees that private enterprises, in general, are more efficient than public ones.

The empirical model for production efficiency analysis can thus be specified as follows:

$$\begin{aligned}\mathrm{Ln}(Y/L) = {} & \alpha_0 + \alpha_1 \mathrm{Ln}(K/L) + \alpha_2 \mathrm{Ln}(M/L) + \alpha_3 TYPE \\ & + \alpha_4 AREA + \alpha_5 IND + \alpha_6 RANK + \alpha_7 SIZE \\ & + \alpha_8 SCOPE + \alpha_9 AGE + \varepsilon \qquad (1)\end{aligned}$$

where Ln denotes the natural logarithm, Y/L is labour productivity, K/L is the ratio of fixed capital to labour, M/L is the ratio of working capital to labour, and *TYPE, AREA, IND, RANK, SIZE,* and *SCOPE* are dummy variables for types of ownership, location, industry, official affiliation, firm size, and production scope, respectively. Term *AGE* denotes the age of the firm. Appendix A summarizes the description of all variables.

Table 2 presents the basic statistics of the sample by different types of businesses. On average, foreign and HMT investment firms have higher labour productivity and are more capital intensive than domestic firms. In addition, foreign firms' location evidently has concentrated on six provinces of the southeastern part of China, and their products are mostly attributed to the textile, clothing, leather, and electronic machinery industries. As expected, foreign firms are more newly established than domestic firms, however, there is no difference in production diversification among different types of business.

[6] See also Pain (2001) for an extensive study of the UK and other developed countries over the last decade to identify channels through which multinational corporations can affect host economies.

Table 3. *Estimation results of productivity analysis*

	Coefficient	*t* value
Constant	1.796**	(106.57)
K/L	0.131**	(86.80)
M/L	0.437**	(286.116)
TYPE		
State- & Collective-owned	−0.041**	−(4.07)
Private & Individual	0.331**	(25.01)
Foreign Investment	0.198**	(6.58)
HMT Investment	0.102**	(2.05)
AREA		
Southeast	0.193**	(50.80)
East Coast	0.033**	(6.46)
West	−0.231**	−(50.95)
IND		
Mining	0.032**	(10.14)
Food and Beverage	0.350**	(54.51)
Textile	0.227**	(12.74)
Furniture	0.081**	(21.52)
Chemical and Plastics	0.248**	(29.30)
Basic Metal	0.147**	(18.53)
Machinery	0.118**	(14.16)
Electronics Machinery	0.227**	(13.52)
Water, Electricity, and Gas	−0.065**	−(15.00)
RANK		
Central Government	0.150**	(9.06)
Provincial & Prefectural	−0.007**	−(10.21)
At and below County level	−0.004**	−(6.43)
Township & Urban	0.430**	(69.21)
SIZE		
Large	0.282**	(18.41)
Small	−0.309**	−(35.54)
SCOPE	0.086**	(2.43)
AGE	−0.012**	−(84.00)
Observations	455,689	
Adj. R^2	0.360	

Notes: The reference groups for the dummy variables are other enterprises for *TYPE*; other manufacturing for *IND*; Central for *AREA*; Village and others for *RANK*; Medium for *SIZE*.

Table 3 presents the estimation results of efficiency analysis. All the explanatory variables are significant at the 5% level. The capital intensity variable has a significantly positive (0.131, $t = 86.80$) effect, while dummy variables of different types of ownership are all significant. The effects are the highest (0.331, $t = 25.01$) for private and single-owner firms, foreign or HMT investment firms are next ($0.198 - 0.102$, $t = 6.58 - 2.05$), while state- and collective-owned firms are the worst (−0.041, $t = -4.07$). As for location, firms located in the six provinces in the southeastern part of China have the highest positive effect (0.193, $t = 50.80$), followed by eastern coastal area (0.033, $t = 6.46$), while the west has the worst effect (−0.231, $t = -50.95$).

The effects on different types of industries are also significantly different. The highest is the food industry (0.350, $t = 54.51$), followed by chemical and plastics (0.248, $t = 29.30$), electronics (0.227, $t = 13.52$), textile (0.227, $t = 12.74$), basic metal (0.147, $t = 18.53$), machinery (0.118, $t = 14.16$), furniture (0.081, $t = 21.52$, and water, electricity, and gas (−0.065, $t = -15.00$). Firms affiliated with the central government or townships have positive effects (0.150 or 0.430), and firms affiliated with a province or county have negative effects (−0.007 or −0.004). Large firms have a positive effect (0.282, $t = 18.41$) compared to a negative effect (−0.309, $t = -35.54$) for small firms, implying the existence of economies of scale to a certain degree.

Firms that produce more than one product also tend to be more productive (0.086, $t = 2.43$), which may suggest the existence of economies of scope. However, the age of a firm has a negative effect (−0.012, $t = -84.00$). That is, newly established firms are, in general, more productive than older firms. This favours the argument that newly established firms tend to adopt more efficient production technologies.

The estimation results imply that private, individually owned, foreign or HMT investment firms in general tend to be more productive. Those that are large scale, newly established, diversified in production, centrally or town affiliated, located in the southeast area, and related to industries such as food, chemicals, electronics, machinery, and textiles also tend to be more productive. These characteristics mostly coincide with the features of FIEs and are consistent with the surge of international trade analysed in Section II. Likewise, FIEs may spillover their know-how to domestic firms and thus promote the technology upgrade of the domestic industry. The next section will further investigate the technology diffusion effects of FIEs and trade-induced learning from trading with more advanced countries.

IV. TECHNOLOGY DIFFUSION OF FOREIGN FIRMS AND LEARNING EFFECTS OF INTERNATIONAL TRADE

The effect of FDI on technology spillover in the literature is inconclusive. Using cross-sectional data, Caves's (1974) study of Australia, Globerman's (1979) study of Canada, Blomstrom and Persson's (1983) and Kokko's (1994) study of Mexico, and Chuang and Lin's (1999) study of Taiwan all found a positive and significant effect of FDI on domestic firms' productivity by the host country. In contrast, Kokko *et al.*'s (1996) study of Uruguay found an insignificant effect. Using time series data, Blomstrom and Wolff (1989) show a productivity convergence trend between Mexico's local firms and foreign firms. However, Haddad and Harrison (1993) conclude that the rapid productivity growth of Morroco's local firms could not be attributed to its foreign-invested firms.

Following empirical works by Caves (1974), Globerman (1979), Blomstrom and Persson (1983), Kokko (1994), Kokko *et al.* (1996), and Chuang and Lin (1999), factors that affect production efficiency include capital intensity, market concentration, scale economies, and export performance. To analyse the effect of technology diffusion by FDI and the possible learning effect of international trade, the share of foreign capital is further included to capture the FDI effect and distinguish the share of imports and exports by two groups of trading partners, OECD countries and the Four Asian Tigers (FATS), namely Hong Kong, Korea, Singapore and Taiwan.[7] For the test of technology spillover, firm data is further aggregated into industrial data.

As China is a huge economy and its industrial development is more regionally oriented, the sample is divided by provinces.[8] Thus, the empirical model for tests of industry-wide technology spillovers and trade-induced learning is specified as

$$\begin{aligned}\mathrm{Ln}(Y/L)_{ij} = \beta_0 + \beta_1 \mathrm{Ln}(K/L)_{ij} + \beta_2 \mathrm{Ln}(M/L)_{ij} + \beta_3 H_{ij} \\ + \beta_4 SCALE_{ij} + \beta_5 FDI_{ij} + \beta_6 IOECD_j \\ + \beta_7 IFATS_j + \beta_8 EOECD_j + \beta_9 EFATS_j + v_{ij}\end{aligned} \tag{2}$$

where Ln denotes the natural logarithm, i is an index for industry, j is an index for province, Y/L is the sales revenue per worker, K/L is the capital labour ratio, M/L is the working capital per worker, H is a measure for market concentration, $SCALE$ is a measure for scale economies, FDI is a measure of foreign direct investment in the industry, and $IOECD$, $EOECD$, $IFATS$, and $EFATS$ are import and export shares for OECD countries and FATS, respectively. See Appendix B for a complete definition of all variables. Note that as the imported fixed capital or intermediate products are already taken into account by variables of fixed and working capital, our import variable in Equation 2 should not show any significant effect on productivity unless it captures some effects of technology transfer as proposed in this paper.

Data analysis

All data except trade variable are from the 1995 Third Industrial Census of China. The 455 689 original samples are further divided into 26 two-digit industries and 30 provinces and cities.[9] As some provinces and cities may not have all 26 industries, a total of 766 sample points are available. As pointed out by Caves (1974), the proxy for FDI is more appropriate to measure in terms of input rather than output. Likewise, two proxies, the share of foreign firms in fixed assets and the share of foreign firms in employment, are used as alternative measures of FDI in the industry. The data on international trade are from the China Custom Statistics, and the commodity trade of 26 industries is obtained from an aggregation of a four-digit HS classification.

Table 4 summarizes the basic statistics of the 26 industries. Higher labour productivity is found for food, petroleum refinery and coal and tobacco industries, while the tobacco and petroleum refinery and coal industries also present higher capital intensity. As for the share of foreign firms in terms of fixed assets, the chemical fibre industry has the highest (36.9%), followed by plastic materials (31.4%) and textiles (31.1%). In terms of labour employed, the leaders are chemical fibre (17.0%), fur and leather products (15.3%), and clothes and other textile products (15.0%). Both market concentration and production scale are found to be highest for tobacco and chemical fibre products. Exports to OECD countries as a share of total sales are highest among stationary and sportswear products (91.7%), furniture (88.7%) and clothes and other textile products (82.3%), while that to the FATS are mainly clothes and other textile product (47.6%) and precision equipment (29%). Imports from OECD are highest among precision equipment (65.2%) and general and specific machinery (42.5%), while those of the FATS are chemical fibre products (40.3%) and plastic materials (31.5).

Estimation results

We first check the correlation coefficient of all explanatory variables of Equation 2 and find that China's trade with OECD and FATS is highly correlated, 0.557 for imports and 0.826 for exports. To avoid a multicollinearity problem in regression, first, a regression is run on the imports (exports) of FATS to that of OECD and take the residuals as the proxies for imports (exports) of FATS. This procedure excludes the possible indirect trade effect of OECD through its trade with FATS on Chinese firms. The two proxies for FDI are also highly correlated around 0.857, implying that the input measures of FDI are rather consistent whether in terms of fixed assets or employment level.

The estimation results in Table 5 show that the two proxies for FDI are positive and significant, which means the existence of positive spillovers from FDI. As argued in most studies, foreign-invested firms may transfer technology so as to foster domestic production efficiency through imports of advanced machinery and better materials, inter-

[7] According to the 1995 China Custom Statistics, Taiwan, Korea, Hong Kong, and Singapore rank 2, 4, 5, and 7 in China's imports and 9, 4, 1, and 7 in China's exports.
[8] Zhu and Lu (1998) find significant technology spillover in the provincial boundary of China. Berthelemy and Demurger (2000) confirm the fundamental role played by foreign investment in provincial economic growth in China.
[9] The 26 two-digit industry classification can be found in Table 4. The 30 provinces and cities are Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shannxi, Gansu, Qinghai, Ningxia, and Xinjiang.

Table 4. *Summary of basic statistics for technology diffusion analysis*

	Sample	*Y/L* (RMB	*K/L*	*M/L* $1000)	*FK*	*FL*	*H*	*SCALE*	*EOECD*	*IOECD*	*EFATS*	*IFATS*
Manufacturing	766	55.31	24.35	30.98	0.200	0.085	0.064	0.107	0.214	0.111	0.105	0.073
		(46.41)	(23.34)	(26.29)	(0.186)	(0.107)	(0.145)	(0.135)	(0.291)	(0.143)	(0.111)	(0.096)
Food processing	30	117.51	40.08	52.59	0.140	0.063	0.018	0.047	0.170	0.135	0.086	0.007
		(48.00)	(15.26)	(32.56)	(0.127)	(0.057)	(0.033)	(0.057)				
Food manufacturing	30	45.59	26.50	25.97	0.210	0.089	0.030	0.070	0.026	0.010	0.020	0.002
		(18.82)	(7.57)	(9.91)	(0.170)	(0.083)	(0.066)	(0.079)				
Beverage	30	43.51	32.74	33.84	0.215	0.098	0.046	0.082	0.004	0.002	0.018	0.000
		(17.29)	(15.94)	(12.01)	(0.180)	(0.097)	(0.076)	(0.100)				
Tobacco	25	140.74	69.34	96.76	0.07	0.052	0.475	0.459	0.004	0.021	0.035	0.002
		(99.77)	(57.38)	(70.59)	(0.234)	(0.202)	(0.286)	(0.255)				
Textile	30	43.89	18.76	25.78	0.311	0.141	0.041	0.094	0.039	0.058	0.092	0.060
		(21.52)	(5.29)	(9.53)	(0.220)	(0.167)	(0.094)	(0.092)				
Garment and other fibres	30	32.19	10.07	16.31	0.278	0.150	0.021	0.081	0.823	0.026	0.476	0.045
		(20.12)	(2.58)	(4.89)	(0.209)	(0.141)	(0.026)	(0.075)				
Leather, and fur products	30	48.30	15.29	28.80	0.272	0.153	0.061	0.097	0.757	0.07	0.132	0.124
		(26.74)	(4.49)	(10.17)	(0.179)	(0.124)	(0.134)	(0.120)				
Wood products	30	44.72	17.99	20.29	0.197	0.078	0.029	0.091	0.264	0.03	0.091	0.030
		(21.16)	(6.08)	(8.16)	(0.150)	(0.058)	(0.050)	(0.083)				
Furniture	30	39.56	14.59	20.94	0.187	0.073	0.034	0.08	0.887	0.04	0.269	0.037
		(18.98)	(6.35)	(7.52)	(0.166)	(0.079)	(0.050)	(0.050)				
Paper and paper products	29	43.83	19.93	19.78	0.156	0.053	0.02	0.092	0.020	0.132	0.036	0.094
		(18.77)	(6.31)	(7.65)	(0.155)	(0.071)	(0.033)	(0.071)				
Printing	30	29.45	18.86	17.86	0.191	0.044	0.02	0.075	0.017	0.022	0.012	0.012
		(14.99)	(7.23)	(7.02)	(0.165)	(0.058)	(0.033)	(0.066)				
Education and stationary	29	31.51	12.38	18.79	0.251	0.105	0.06	0.126	0.916	0.067	0.259	0.047

(*continued on next page*)

(*continued from previous page*)

		(14.50)	(4.77)	(6.78)	(0.211)	(0.133)	(0.075)	(0.096)				
Petroleum and coal	28	132.81	38.92	55.66	0.07	0.032	0.115	0.122	0.118	0.018	0.072	0.071
		(91.13)	(23.11)	(41.71)	(0.099)	(0.042)	(0.174)	(0.071)				
Chemical materials and products	30	61.43	28.82	33.18	0.177	0.07	0.033	0.074	0.088	0.116	0.044	0.052
		(28.79)	(7.26)	(11.19)	(0.141)	(0.063)	(0.119)	(0.113)				
Pharmaceutical products	30	57.14	34.87	49.26	0.229	0.142	0.062	0.134	0.026	0.019	0.012	0.002
		(39.96)	(15.18)	(25.09)	(0.141)	(0.121)	(0.102)	(0.102)				
Chemical fibre products	28	61.76	26.95	28.75	0.369	0.170	0.249	0.294	0.059	0.219	0.203	0.402
		(25.31)	(16.41)	(12.40)	(0.315)	(0.173)	(0.277)	(0.207)				
Rubber products	29	39.75	19.99	21.18	0.104	0.045	0.059	0.137	0.037	0.035	0.018	0.034
		(19.09)	(7.39)	(4.91)	(0.129)	(0.068)	(0.073)	(0.115)				
Plastics products	30	51.00	25.58	26.63	0.314	0.105	0.039	0.091	0.147	0.227	0.093	0.315
		(22.43)	(22.11)	(13.46)	(0.164)	(0.083)	(0.109)	(0.130)				
Non-metallic products	30	31.73	18.66	15.75	0.098	0.025	0.008	0.053	0.053	0.03	0.052	0.011
		(13.85)	(8.87)	(7.36)	(0.095)	(0.029)	(0.026)	(0.040)				
Base metal and Coal	29	109.62	45.07	47.98	0.113	0.054	0.038	0.086	0.030	0.052	0.032	0.017
		(71.03)	(69.58)	(47.68)	(0.085)	(0.046)	(0.101)	(0.085)				
Metal products	30	48.38	17.84	25.76	0.163	0.047	0.019	0.055	0.182	0.165	0.121	0.096
		(19.14)	(5.89)	(6.86)	(0.153)	(0.064)	(0.049)	(0.068)				
Machinery	30	40.45	19.98	26.27	0.11	0.038	0.022	0.068	0.086	0.425	0.053	0.119
		(18.26)	(11.83)	(8.39)	(0.098)	(0.040)	(0.065)	(0.103)				
Transportation and equipment	30	44.13	19.66	27.11	0.168	0.062	0.026	0.062	0.041	0.107	0.032	0.019
		(21.15)	(9.44)	(11.68)	(0.142)	(0.062)	(0.043)	(0.056)				
Electrical and electronics machinery	30	50.87	24.35	36.63	0.263	0.103	0.062	0.092	0.158	0.212	0.118	0.090
		(22.98)	(21.32)	(14.15)	(0.178)	(0.104)	(0.185)	(0.178)				
Precision instruments	29	35.67	14.75	28.79	0.292	0.126	0.114	0.162	0.531	0.652	0.290	0.181
		(18.16)	(5.92)	(10.46)	(0.221)	(0.136)	(0.165)	(0.167)				
Other Manufacturing	30	34.86	11.20	18.94	0.251	0.095	0.05	0.052	0.056	0.015	0.054	0.027
		(19.35)	(4.02)	(8.14)	(0.176)	(0.099)	(0.103)	(0.032)				

Note: Figures in parentheses are standard deviations.
Sources: 1. The 1995 Industrial Census of China. 2. China Foreign Economics Statistical Yearbook, 1996.

Table 5. *Regression results for technology diffusion and trade-induced learning*

	Model (1)	Model (2)
Constant	1.496** (0.00)	1.620** (0.00)
KL	0.206** (0.00)	0.152** (0.00)
ML	0.543** (0.00)	0.569** (0.00)
FK	0.478** (0.00)	
FL		0.721** (0.00)
H	−0.971** (0.00)	−0.982** (0.00)
SCALE	−2.694** (0.00)	−2.809** (0.00)
EOECD	0.205** (0.01)	0.184** (0.00)
IOECD	0.355** (0.03)	0.394** (0.00)
EFATS	0.020 (0.94)	0.001 (0.98)
IFTAS	0.664** (0.00)	0.872** (0.00)
Observations	673	673
Adj. R^2	0.679	0.677

Notes: Each regression also includes an industry dummy; figures in the parentheses are *p* values; * and ** represent statistically significant at 10% and 5% level, respectively.

national competition, and training of local managers and workers. Therefore, one expects to see that the larger the share of FDI in the industry, the greater the technology diffusion and hence the higher the production efficiency of the industry.

The coefficients of market concentration and production scale are negative and significant. These imply that a higher market concentration reduces competition and incentive to cut costs and upgrade efficiency,[10] and they also mean that large firms encounter diseconomies of scale. The reason here is that China is still a centrally-controlled/planned economy, centred in state-owned and collective enterprises, which are not guided by the market. State-owned and collective enterprises also tend to be large organizations with complex hierarchical structures and hence may encounter diseconomies when the production scale increases.

As for the trade-induced productivity effect, China's imports from both OECD and FATS have positive and significant productivity effects. However, the effect of FATS is greater than that of the OECD; the former is 0.664–0.872 and the latter is 0.335–0.394. From previous data descriptions, we know that most of China's imports from FATS are in the form of chemical and fibre products, plastic products, and machinery and equipment, while its imports from the OECD are mainly in the form of machinery and equipment (46.2%). These results imply that imports of materials and machinery from advanced countries are conducive to the upgrading of its domestic technology. However, the larger effect from FATS (versus that from OECD) suggests that the imports of appropriate technology are more important than merely imports of state-of-art technology from the most advanced countries.

As for exports, only exports to OECD have a significant positive effect.[11] By trading with more advanced countries and being exposed to keen international competition, a country can learn skills, including management, production, and marketing from its trading partner. In order to meet the quality requirement and product specifications of the advanced country, the advanced country also teaches or guides the domestic firms: for example, the case of original equipment manufacturing (OEM) by many brand-name companies from the OECD illustrates this fact. Hence, these results support the argument of the trade-induced productivity effect that a country can promote its productivity via trading with more technologically-advanced countries.

Technology gap and technology diffusion

As trading with advanced countries may foster a country's productivity, the next question is to what extent does the technology gap between the two trading countries matter? Is it true that there always exists the advantage of backwardness? For this purpose, we further divide our sample into two groups: a group with a high technology gap and a group with a low technology gap. Following Kokko (1994) and Kokko *et al.* (1996), the difference of average sales revenue per worker between foreign-invested firms and domestic firms is used as the measure for the technology gap. Samples with calculated technology gap higher than average are taken as the group with a high technology gap, while samples with a value lower than average are classified as the group with a low technology gap. The average value of the technology gap is 1.9, resulting in 286 samples in the high-technology-gap group and 387 samples in the low-technology-gap group.

The estimation results in Table 6 show that FDI has a significant and positive productivity effect on both groups, however, the effect is significantly higher for the low-technology-gap group (0.959–0.608) than for the high-technology-gap group (0.431–0.363).[12] These results imply that the higher the technical capability of the domestic firms, the easier it is for them to absorb new technology and hence have a larger effect of technology diffusion. This finding supports the claim of Cantwell (1989) whereby only

[10] In the literature, the effects of market concentration on production efficiency are inconclusive. Blomstrom and Persson (1983) and Kokko (1994) consider higher market concentration as greater market power, which may have a positive impact on productivity. Caves and Barton (1990) find a non-linear relationship between market concentration and production efficiency; positive when the market concentration ratio is below 35% and negative when it is above 35%.

[11] The insignificant effect of China's exports to FATS may imply that FATS also learn from their exports to OECD, too.

[12] In Table 6, comparing two regression models, we perform the Chow test (1960) to test the equality of the estimated coefficients. See, for example, Gujarati (1995, Chapter 8.8). These results can be obtained by request from the author.

Table 6. *Estimation results of technology spillovers and trade-induced learning effects*

	Model (1)		Model (2)	
	Low technology gap	High technology gap	Low technology gap	High technology gap
Constant	1.752** (0.00)	1.357** (0.00)	1.834** (0.00)	1.361** (0.00)
KL	0.199** (0.00)	0.165** (0.03)	0.143** (0.03)	0.170** (0.04)
ML	0.472** (0.00)	0.606** (0.00)	0.525** (0.00)	0.655** (0.00)
FK	0.608** (0.00)	0.431** (0.00)		
FL			0.959** (0.00)	0.363 (0.13)
H	−0.868** (0.00)	−0.499 (0.22)	−0.837** (0.00)	−0.428 (0.31)
MES	−2.935** (0.00)	−3.415** (0.00)	−3.015** (0.00)	−3.553** (0.00)
EOECD	0.144** (0.05)	0.165 (0.13)	0.114 (0.14)	0.202 (0.11)
IOECD	0.419** (0.00)	0.424** (0.01)	0.437** (0.00)	0.483** (0.00)
EFATS	0.110 (0.73)	0.073 (0.88)	0.127 (0.70)	0.020 (0.96)
IFTAS	0.285** (0.02)	0.937** (0.02)	0.484* (0.07)	1.320** (0.00)
Observations	387	286	387	286
Adj. R^2	0.697	0.719	0.697	0.714

Notes: Each regression also includes an industry dummy; figures in the parenthesis are *p* values;
* and ** represent statistically significant at 10% and 5% level, respectively.

domestic firms with higher technical capability can enjoy the technology diffusion from foreign-invested firms.[13] As in the previous analysis, market concentration and production scale have negative effects on both groups.

The results of the trade-induced productivity effect on both groups are in a state of divergence. Imports from OECD and FATS have a positive and significant productivity effect for both groups; however, the effect is significantly higher from OECD for the low-technology-gap group and from FATS for the high-technology-gap group. These results reinforce the previous findings of appropriate technology assertion. Moreover, the import learning effects jointly from both OECD and FATS were significantly larger for the high-technology-gap group than for the low-technology-gap group. These results support the technology-gap learning theory, for example, in Chuang (1998).

Only the group with a low technology gap had the export learning effect, which was mainly derived from exports to OECD. This finding suggests that exports to more advanced countries are a necessary, but not sufficient, condition to promote technology learning. A threshold of technical capability may be required so that products can survive under strong international competition and hence the country enjoys export-induced learning. In contrast, firms with low technical capability will struggle in the international market and thus hinder the extent of learning from advanced countries.

V. CONCLUDING REMARKS

By using data from the 1995 Third Industrial Census of China to examine manufacturing firms' production efficiency, it is found that firms which are private, individually owned, foreign-invested from Hong Kong, Macao, and Taiwan, large scale, newly established, more production diversified, centrally or township located, in the southeastern area, and in the food, chemical, electronics, and machinery industries are all more productive. Two proxies of FDI, measured by the share of fixed assets or number of employees, both show positive and significant productivity spillover effects. Hence, the higher the ratio of FDI in the industry, the greater the technology spillover and the higher the productivity of the industry. However, market concentration and production scale exhibit negative effects on productivity.

Positive trade-induced technology diffusion effects are also identified for China's imports from OECD and FATS and for exports to OECD. Imports of machinery and equipment from advanced countries enable a country to upgrade its technology and streamline domestic production. Exports to more advanced countries also enable a country to learn and gain access to new technologies, including management, production, and marketing skills.

The sample is further divided into two groups, a high-technology-gap group and a low-technology-gap group, to test to what extent the effect of technology diffusion depends on the technology gap between foreign and domestic firms. Significant technology spillovers by FDI are found on both groups of low and high technology gaps. However, the effect on the low-technology-gap group is stronger than that on the high-technology-gap group. This implies that the technology spillover effect of FDI is positively correlated with the capability level of domestic firms. The negative effects of market con-

[13] These results are also consistent with Kokko *et al.*'s (1996) study for Uruguay. However, Kokko's (1994) study of Mexico found different results.

centration and production scale are also found in both groups.

As for the trade-induced learning effect, results are inconsistent. The import learning effect is found for both groups; however, the effect is larger from OECD for the low-technology-gap group, while the effect is larger from FATS for the high-technology-gap group. This implies the significance of importing the appropriate technology. The importing of material and equipment from more advanced countries provides solid examples for domestic firms to follow, and the learning of appropriate technology provided from less advanced countries is more efficient than that from more advanced ones.

The learning effects of imports, whether from OECD or FATS, are larger for the high-technology-gap group than for the low-technology-gap group. Thus, the results support the technology-gap learning theory. In contrast, the export learning effect can only be found in exports to OECD for the low-technology-gap group. The reason may be that learning from more advanced countries requires certain thresholds of technical capability.

The findings suggest that for trade-induced learning, imports of appropriate technology are more effective than imports of state-of-art technology; although exports to more advanced countries are a prerequisite condition for export learning, however, a threshold of local technical capability is indeed required. Summarizing, FDI increases the productivity of domestic firms, while opening trade with more advanced countries provides additional channels for domestic firms to learn and gain access to new technology. Thus, China's case study provides a developmental strategy for less developed countries to follow.

REFERENCES

Albach, H. (1980) Average and best-practice production functions in German industry, *Journal of Industrial Economics*, **29**(1), 55–70.

Berthelemy, J. C. and Demurger, S. (2000) Foreign direct investment and economic growth: theory and application to China, *Review of Development Economics*, **4**(2) 140–55.

Blomstrom, M. and Persson, H. (1983) Foreign investment and spillover efficiency in an underdeveloped economy: evidence from the Mexico manufacturing industry, *World Development*, **11**, 493–501.

Blomstrom, M. and Wolff, E. (1989) Multinational Corporations and Productivity Convergence in Mexico, NBER Working Paper No. 3141.

Cantwell, J. A. (1989) *Technological Innovation and Multinational Corporations,* Basil Blackwell, Oxford.

Castellani, D. and Zanfei, A. (2002) Multinational experience and the creation of linkages with local firms: evidence from the electronics industry, *Cambridge Journal of Economics*, **26**(1), 1–25.

Caves, R. E. (1974) Multinational firms, competition and productivity in host-country markets, *Economica*, **41**, 176–93.

Caves, R. E. and Barton, D. R. (1990) *Efficiency in US Manufacturing Industries*, MIT Press, Cambridge, MA.

Chen, L. I. (1998) Industrial competition and cooperation across Taiwan Strait, *The Third International Conference on South China Economic Prospect and the Challenge of 21st Century*, Institute of Japanese Research and Development, Okinawa, Japan, September 11 (in Chinese).

Chow, G. C. (1960) Tests of equality between sets of coefficients in two linear regressions, *Econometrica*, **28**, 591–605.

Chuang, Y. C. (1998) Learning by doing, the technology gap, and growth, *International Economic Review*, **39**, 697–721.

Chuang, Y. C. (2002) The trade-induced learning effect on growth: cross-country evidence, *Journal of Development Studies*, **39**, 137–54.

Chuang, Y. C. and C. M. Lin (1999) Foreign direct investment, R&D, and spillover efficiency: evidence from Taiwan's manufacturing firms, *Journal of Development Studies*, **35**, 117–37.

Cory, P. F. (1981) A technique for obtaining improved proxy estimates of minimum optimal scale, *Review of Economics and Statistics*, **63**(1), 96–106.

Forsund, F. R. and Jansen, E. (1977) On estimating average and best practice homothetic production functions via cost functions, *International Economic Review*, **18**, 463–76.

Globerman, S. (1979) Foreign investment and 'spillover' efficiency benefits in Canadian manufacturing industries, *Canadian Journal of Economics,* **12**, 42–56.

Green, A., Harris, C. and Mayes, D. (1991) Estimation of technical inefficiency in manufacturing industry, *Applied Economics*, **23**, 1637–47.

Gujarati, D. N. (1995) *Basic Econometrics*, McGraw-Hill, New York.

Haddad, M. and Harrison, A. (1993) Are there positive spillovers from direct foreign investment: evidence from panel data for Morocco, *Journal of Development Economics*, **42**, 51–74.

Jorgenson, D. W. (1995) *Productivity*, Vol. 2, MIT Press, Cambridge, MA.

Kokko, A. (1994) Technology, market characteristics, and spillovers, *Journal of Development Economics*, **43**, 279–93.

Kokko, A., Tansini, R. and Zejan, M. C. (1996) Local technological capability and productivity spillovers from FDI in the Uruguay manufacturing sector, *Journal of Development Studies*, **32**, 602–11.

Kopp, R. and Smith, V. K. (1980) Frontier production function estimates for steam electric generation: a comparative analysis, *Southern Economic Journal*, **46**, 1045–59.

Lang, K. (1991) Persistent wage dispersion and involuntary unemployment, *Quarterly Journal of Economics*, **106**(1), 181–202.

Leamer, E. E. and Thornberg, C. (1998), Efforts and wages: a new look at the inter-industry wage differentials, National Bureau of Economic Research Working Paper no. 6626.

Levy, V. (1981) On estimating efficiency differentials between the public and private sector in a developing economy – Iraq, *Journal of Comparative Economics*, **5**, 235–50.

Lin, C. C. and Png, I. (2001) Monitoring costs and the mode of international investment. Manuscript, Office of the Provost, National University of Singapore, http://www.comp.nus.edu.sg/~ipng/.

McGuckin, R. H. and Nguyen, S. V. (1993) Post-reform industrial productivity performance of China: new evidence from the 1985 Industrial Census Data, *Economic Inquiry*, **31**, 323–41.

Nyaw, M. K. (1993) Direct foreign investment in China: trends, performance, policies, and prospects, in *China Review* (Ed.) Y. S. Cheng, Chinese University Press, Hong Kong.

Page, J. M. Jr. (1984) Firm size and technical efficiency: application of production frontiers to Indian survey data, *Journal of Development Economics*, **16**, 129–52.

Pain, N. (2001) *Inward Investment, Technological Change and Growth: The Impact of Multinational Corporations on UK Economy*, Palgrave, New York.

Panzar, J. C. and Willing, R. D. (1981) Economic of scope, *American Economic Review*, **72**, 268–72.

Pitt, M. and Lee, L. F. (1981) The measurement and sources of technical inefficiency in the Indonesian weaving industry, *Journal of Development Economics*, **9**, 43–64.

Seale, J. M. Jr. (1990) Estimating stochastic frontier with unbalanced panel data: the case of floor tile manufactories in Egypt, *Journal of Applied Economics*, **5**, 59–74.

Sterner, T. (1990) Ownership, technology, and efficiency: an empirical study of cooperatives, multinationals, and domestic enterprises in the Mexican cement industry, *Journal of Comparative Economics*, **14**, 286–300.

Tyler, W. (1979) Technical efficiency in production in a developing country: an empirical examination of the Brazilian plastic and steel industries, *Oxford Economic Papers*, **31**, 477–95.

Wu, Y. (1995) Productivity growth, technological progress, and technical efficiency change in China: a three-sector analysis, *Journal of Comparative Economics*, **21**, 207–29.

Zhu, G. and Lu, D. (1998) Evidence of spill-over efficiency: implication on industrial policies towards foreign direct investment in China, *Singapore Economic Review*, **43**(1), 57–73.

APPENDIX A: DEFINITIONS OF VARIABLES FOR PRODUCTIVITY ANALYSIS

Variables	Definitions
Y/L	Sales per employee
K/L	Fixed assets per employee
M/L	Working capital per employee
TYPE	Types of ownership dummies include state- and collective-owned, private and individual, foreign investment, HMT investment, and other enterprises.
AREA	Area dummy includes Southeast, East coast, Central, and West. Southeast: Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, and Guangdong; East coast: Beijing, Tianjin, Hebei, Liaoning, Guangxi, and Hainan; Central: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan; West: Sichuan, Guizhou, Yunnan, Tibet, Shannxi, Gansu, Qinghai, Ningxia, and Xinjiang.
IND	Industry dummy includes mining, food and beverage, textile, clothing and leather, wood, furniture, and paper, petroleum, chemical, and plastics, basic metal, machinery, electric machinery, other manufacturing, and water, electricity, and gas industries.
RANK	Dummy for ranks in administrative relationship includes central, provincial and prefectual, county and street, township, and village and others.
SIZE	Dummy for firm size includes large, medium, and small.
AGE	The age of a firm is defined as 1995 minus the established year of the firm.
SCOPE	Dummy = 1 for producing more than one products, 0 otherwise.

APPENDIX B: DEFINITIONS OF VARIABLES FOR TECHNOLOGY DIFFUSION AND TRADE-INDUCED LEARNING

Variables	Definitions
Y/L	Sales per employee
K/L	Fixed assets per employee
M/L	Working capital per employee
FK	Fixed assets of foreign investment enterprises as a share of fixed assets in the industry
FL	Number of employees in foreign investment enterprises as a share of the total number of employees in the industry
H	Industry concentration ratio is defined as the square of the relative market share of firms in the industry (see Blomstrom and Persson, 1983)
SCALE	Industry's scale economy is defined as the average of firms' sales revenue relative to the minimum efficient scale (MES) of the industry. The MES of an industry is defined as the average sales revenue of firms with a market share greater than 50% (see Cory, 1981)
EOECD	Value of exports to OECD as a share of total industry sales
IOECD	Value of imports from OECD/total industry sales
EFATS	Value of exports to FATS/total industry sales
IFATS	Value of imports from OECD/total industry sales