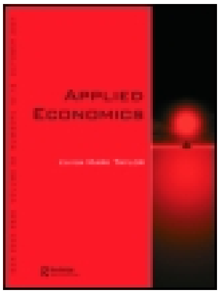

Applied Economics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/raec20

Returns to scale, productive efficiency, and optimal firm size evidence from Taiwan's firm data

Yih-Chyi Chuang

Version of record first published: 04 Oct 2010

To cite this article: Yih-Chyi Chuang (1999): Returns to scale, productive efficiency, and optimal firm size evidence from Taiwan's firm data, Applied Economics, 31:11, 1353-1364

To link to this article: http://dx.doi.org/10.1080/000368499323238

Applied Economics, 1999, **31**, 1353–1364

Returns to scale, productive efficiency, and optimal firm size evidence from Taiwan's firm data

YIH-CHYI CHUANG

Department of Economics, National Chengchi University, Taipei, Taiwan, ROC

By using Taiwan's census firm data, this paper estimates and tests the variable returns to scale hypothesis for aggregate manufacturing and two-digit industries. An efficiency measure is constructed to further examine the size-efficiency relations among two-digit industries. Analysis indicates that increasing returns exist at the aggregate manufacturing level and its magnitude is higher for exporting firms than for non-exporting firms. Moreover, trade is beneficial only for small firms. However, the property of increasing returns diminishes for most of the industries at the two-digit level, particularly for the exporting firms. This sharp comparison between aggregate and two-digit level results suggests that trade is conducive to productivity, and provides an indication of the specific form of technology spillovers among firms and across industries. Further investigation of the relationship between productive efficiency and firm size renders the result that optimal firm size is small for exporting firms in most industries, particularly in the most export-oriented ones. The technology spillover effect among firms and across industries is likely the reason for being small and efficient. Our results also indicate that an industry-wide spillover effect across firms within the same industry is roughly one-sixth of the firm-specific export-induced learning effect. Findings in this study provide valuable insight into Taiwan's economic development and also provide a development strategy for developing countries to follow.

I. INTRODUCTION

Economic development generally implies a process of industrialization during which predominance within the industrial structure shifts from the traditional agricultural sector to modern manufacturing. Moreover, the dynamic process of industrialization involves a shift in production structure within the manufacturing sector. Both facets of this persistent structural change are keys to sustaining economic growth. Thus, investigating the productivity and size-efficiency relations among different industries becomes essential to more thoroughly understanding economic growth.

After the surge of endogenous growth theory in the mid 1980s, numerous models have pointed out the importance of increasing returns or externalities to sustain a country's long run growth (see, for example Romer, 1986; Grossman and Helpman, 1991; Barro and Sala-i-Martin, 1995 and references therein). Therefore, increasing returns to scale in manufacturing industry might be a prominent factor for industrialization and economic growth. However, Blomstrom and Wolff (1993) indicated that the new growth literature has largely neglected the discussion of the transformation and the technology diffusion within countries and industries. Using Mexican manufacturing data, they found that most of the variation in labour productivity across plant class sizes can be attributed to differences in capital intensity and that the variation in TFP levels across size classes tends to be small. This result corresponds to Meller (1976) and Ramaswamy's (1994) findings of no systematic differences in technical efficiency between large and small establishments for Chilean establishments and Indian industry, respectively.

In this study, we estimate the returns to scale and examine size-efficiency relations of the manufacturing sector by using Taiwan's firm data. We find weak increasing returns at the

0003–6846 © *1999 Routledge*

aggregate manufacturing level. Comparing exporting versus nonexporting firms, we find that exporting firms in aggregate generally exhibit stronger increasing returns and a higher capital intensity than nonexporting firms. In a two-digit industry level, however, significant variable returns to scale can only be found in some industries: namely, food, textiles, chemicals, chemical products, plastic products, and basic metal industries. By using our efficiency measure, we find that 12 out of 20 industries have a small optimal firm size for the exporting firms. Such evidence should perhaps come as little surprise, given that SME's predominate in Taiwan's for-export markets.

The rest of the paper is organized as follows. Section II provides a brief description of the Taiwanese economy; Section III presents the empirical model; Section IV discusses data and the estimation method employed; Section V summarizes the estimation results for aggregate manufacturing and two-digit industries. Concluding remarks are finally made in Section VI.

II. THE TAIWANESE ECONOMY

Since the end of World War II, Taiwan's economy has grown by leaps and bounds, and has successfully transformed from an agriculturally-oriented economy to an industrially-oriented one, with a subsequent rise of the advanced service industry appearing still more recent. From 1953 to 1993, the annual average economic growth rate in Taiwan measured an impressive 8.7% (6.3% for per capita GNP). The share of agriculture in GDP was 34.45% in 1953, and has declined steadily over time to reach 3.46% by 1993. The share of industry was only 19.39% in 1953, and then increased annually, surpassing agriculture in 1962. It reached its highest value of 47.64% in 1986 and then slightly declined beginning in the late 1980s. Production structure has changed dramatically as well, as evident in the shift of the leading industry from food to textiles, and then to electrical and electronic machinery. Obviously, Taiwan's rapid economic growth is synonymous with its successful industrialization process.

As the government policy passed from import substitution in the early 1950s, through export-promotion beginning in the late 1950s, and then onto more aggressive trade liberalization in the 1980s, the dependence of Taiwan's economy on foreign trade has increased tremendously. From 1960 to 1993, the average annual growth rate of real exports was 15.4% (13.7% for real imports). The trade structure also changed enormously. The share of industrial products was only 8.1% in 1952, but later surged to 46% in 1965 and 78.6% in 1970; thereafter, following a moderate increasing trend, it reached 96% in 1993. As for Taiwan imports, during 1952–93, over 60% of all imports were agricultural and industrial raw materials due to the scarcity of natural resources. The share of capital goods in total annual imports increased from 14.2% in 1952 to 29.3% in 1965, hovered above 30% until 1975, and then gradually declined to 15.45% in 1993.

As the economy matured and expanded outwardly, private savings also increased. The savings rate (i.e., gross national savings divided by GDP) increased from 15.3% in 1952 to 32.1% in 1972 and then remained stable at approximately 33% through 1990. It was the increase in domestic savings which really enabled the economy to finance its accumulation of physical capital. Since the mid 1970s, however, domestic savings has outpaced domestic investment, reflecting the sustained trade surplus in Taiwan's current account.

Investment in human capital accumulation was also remarkable. The distribution of employed workers having completed primary, secondary, and tertiary schooling was 54.95%, 14.87%, and 3.93%, respectively, in 1964. However, the same figures in 1993 registered 26.09%, 51.80%, and 18.04%, respectively, indicating an unequivocal upward shift in the quality of the labour force.

In sum, Taiwan's economic growth over the past four decades has been characterized by successful industrialization, heavy dependence on international trade, and persistent accumulation of capital and improvement in human resources. Hence, Taiwan is definitely a qualified candidate for investigation as a case-study in this paper.

III. THE EMPIRICAL MODEL

In this study, a Solow-type production function, augmented to include embodied technical change, is adopted to estimate returns to scale. Moreover, we allow the latter to vary as a function of firm size. As indicated in Szpiro and Cette (1994), the Solow production function can be generalized in the following manner:

$$Y_i = A_j \cdot \exp\{\lambda_j (ETC_i)\}\, S_i^{f_j(s_i)} \qquad (1)$$

where indices i and j denote the individual firm and sector, respectively; $S_i = K_i^{\alpha_j} L_i^{1-\alpha_j}$ is an index of firm size for firm i in sector j, and $s_i = \alpha_j k_i + (1-\alpha_j) l_i$ is the logarithm of S_i;[1] Y, K, L are the volumes of value added, capital, and labour in production, respectively; ETC represents the embodied technical change, and λ_j reflects the effect of the embodied technical change; $f_j(s_i)$ is a sector-specific polynomial function of variable s_i, and captures the possibility of variable returns to scale for each industry j. Taking the logarithm, Equation 1 becomes

$$y_i = a_j + \lambda_j (ETC_i) + g_j(s_i) \qquad \text{with } g_j(s_i) = s_i \cdot f_j(s_i) \quad (2)$$

[1] Hereafter lower case letters denote the logarithm form of the capital letters' variables.

Notably, if $f_j(s_i)$ is a polynomial of order n then Equation 2 can be further simplified to

$$y_i = a_j + \lambda_j(ETC_i) + \sum_{\rho=1}^{n+1} \tau_{\rho i} s_i^{\rho} \tag{3}$$

If $\tau_{\rho i} \neq 0$ for all $\rho > 2$, then variable returns to scale cannot be rejected. However, if $\tau_{1i} \neq 0$ but $\tau_{\rho i} = 0$ for all $\rho > 2$, then the production function has the fixed returns' property and, in fact, the constant returns to scale provided that $\tau_{1i} = 1$. We define returns to scale as the elasticity of output with respect to firm size, i.e.,

$$R_i(s) \equiv \frac{\partial y_i}{\partial s_i} = \sum_{\rho=1}^{n+1} \rho \cdot \tau_{\rho i} s_i^{\rho-1} \tag{4}$$

our measure of variable returns for each industry is, $R_i(s)$, thus only constrained to be some polynomial of order n.

Using the concept of total factor productivity and eliminating the effect of the embodied technical change, we examine size-efficiency relations by constructing an efficiency index defined as

$$EFF_i \equiv y_i - \lambda_j(ETC_i) - s_i \tag{5}$$

Each sector's optimal firm size can thus be determined by comparing the *EFF* indices between different size classes of firms. Thus, in this paper the optimal firm size is defined as the one with the highest *EFF* index. Equations 3, 4 and 5 are the basic equations used for our empirical estimations in Section V.

IV. DATA AND THE ESTIMATION METHOD

Data

The data used herein originated from The Report on 1991 Industrial and Commercial Census for Taiwan-Fukien Area published by Directorate-General of Budget, Accounting and Statistics, Executive Yuan, The Republic of China. The definitions of variables are found in the Appendix. The census has been conducted every five years since 1954, the most recent issue available covering 1991. However, due to data limitations for the measure of embodied technology change, we look only at data for manufacturing establishments in 1991. For that year, the census documents 146 086 manufacturing establishments, comparing 2 622 934 employees and a total output value of NT$1610 (US$62) billion. Measuring by establishment unit, the mean value of total output is NT$5 155 000, while the average size is 18 employees. Gross value added per person is NT$287 000, and the net value of assets in operation per person is NT$1 390 000 with an average rate of automation at 38%. Value added per dollar sale is 0.15, and the average share of exports in firm's total sales is 28%. In general, the size of Taiwan's manufacturing firms (in conventional terms of the number of employees) is rather small. Approximately 90% of establishments employ fewer than 30 persons, and 97.88% have less than 100 employees.

As for two-digit industries, 22 classifications are in the report. For our purposes herein we omit tobacco manufacturing and petroleum and coal products industries from our sample since those industries are public-owned enterprises and enjoy a monopolistic position.[2] Table 1 lists the sample mean values by establishments for the two-digit industries. For these two-digit industries, electrical and electronic machinery, leather and fur products, and transport equipment have the largest share in gross value added. Chemicals, electrical and electronic machinery, and leather and fur products have the largest scale in terms of employed workers. Basic metals, machinery and equipment, fabricated metal products, and printing processing have the highest labour productivity. Chemical, basic metals, and food industry have the greatest capital labour ratio. Printing processing, fabricated metal products, and furniture and fixtures have the highest value added per dollar of sale. Precision instruments, furniture and fixtures, leather and fur products, wearing apparel, and electrical and electronic products have export shares exceeding 50% of total production. Finally, textile mill products, basic metals, pulp and paper products, and chemicals show the greatest degree of automation.

Estimation method

For estimation purpose, the embodied technical change described in Equation 1 is further decomposed into two components: the effects of vintage capital and accumulated learning by doing. The vintage capital effect is captured by using dummy variable of automation ($AUTO = 1$ if automation machinery is used or $AUTO = 0$ otherwise). The effect of accumulated learning by doing from operating machinery is captured by the ratio of accumulative depreciation to total value of the machinery ($ACCU$). The larger the value implies the longer the machine is used and, hence, the greater effect on learning by doing is expected to obtain. Both variables are expected to have a positive sign.

In this paper the firm size is defined as a weighted combination of labour and capital. In estimating Equation 3, the weight parameter α_j, a value between zero and one, is estimated by a nonlinear least squares method using the Marquardt iterative method.[3] The order of polynomial of

[2] The twenty two-digit industries are food, textile mill products, wearing apparel and accessories, leather and fur products, wood and bamboo products, furniture and fixtures, pulp, paper and paper products, printing processing, chemicals, chemical products, rubber products, plastic products, non-metallic mineral products, basic metals, fabricated metal products, machinery and equipment, electric and electronic machinery, transport equipment, precision instruments, and miscellaneous manufactured products industries.
[3] The convergence criterion is set that the changes in loss function satisfied $(LOSS^{i-1} - LOSS^{i})/(LOSS^{i} + 10^{-6}) < 10^{-8}$.

Table 1. *Mean values of statistics*

Sector	GDP NT$1000	Labour person	Labour productivity NT$1000/person	Capital intensity NT$1000/person	Share of VA (%)	Share of export (%)	Automation %	Observations establishment
Manufacturing	5155	18	287	1390	14.78	28.01	37.77	146 086
Food	4069	17	240	1999	7.62	15.22	46.40	7742
Textile mill products	6269	26	240	1452	11.66	29.34	67.46	8364
Wearing apparel and accessories	6023	27	225	509	26.71	58.76	13.27	3899
Leather and fur products	10 147	36	285	831	22.22	59.16	18.14	1408
Wood and bamboo products	3064	10	297	1319	29.87	28.29	14.43	5325
Furniture and fixtures	4542	16	292	886	33.70	65.87	23.11	4145
Pulp, paper and paper products	4352	17	254	1181	7.31	5.92	61.27	4044
Printing processings	2412	7	327	1044	48.83	4.84	28.94	7799
Chemicals	7732	49	158	3388	2.80	18.23	54.16	1374
Chemical products	6012	22	272	1648	14.69	16.11	19.13	2547
Rubber products	5559	24	228	858	21.47	49.73	29.05	2105
Plastic products	4642	17	277	1201	23.73	37.99	22.18	13 544
Nonmetallic mineral products	6140	23	273	1393	15.79	9.98	44.10	4808
Basic metals	8699	22	389	2264	9.23	7.67	63.16	5070
Fabricated metal products	2817	9	331	1015	37.29	28.83	26.10	31 104
Machinery and equipments	3718	11	334	1184	27.34	29.39	23.96	15 509
Electrical and electronic machinery	10 689	37	287	1535	15.38	56.60	36.05	12 496
Transport equipments	10 088	27	378	1366	16.28	19.05	45.25	5660
Precision instruments	6918	23	303	780	31.23	72.51	22.75	1935
Misc. manufactured products	4809	19	254	680	33.85	77.18	22.42	7025

Source: The Report on 1991 Industrial and Commercial Cences Taiwan-Fukien Area, The Republic of China, Directorate-General of Budget, Accounting and Statistics, Executive Yuan, 1993.

variable returns (n) is determined by finding the order form specification that has the minimum residual sum of squares or the contribution of reducing sum of square is less than 10^{-8} by adding one higher order (the initial value for n is zero). For those variable returns' cases, an order of three or below can generally be found. Hence, the returns to scale measure $R(s)$ are generally a polynomial of order two of the firm size, that is, it is either a concave or a convex curve.

V. ESTIMATION RESULTS

Aggregate manufacturing level

As expected, Table 2 reveals that the coefficients of both variables of embodied technical change show positive signs and statistically significant ($AUTO = 0.1273$, SE $= 0.0047$; $ACCU = 0.2918$, SE $= 0.0065$). This finding implies that significant embodied technological change has occurred in Taiwan's manufacturing industry. Tests of null hypothesis of constant returns by using Cobb–Douglas production function or variable return's formulation are all rejected whether or not we consider embodied technical change (Regressions 1 and 2). Nonlinear estimates of variable returns indicate that the returns to scale are a polynomial function of firm size with an order of three (Regression 3).

If we further run regressions for nonexporting and exporting firms separately (Regressions 4 and 5), we find that value of α for exporting firms is nearly twice than that for nonexporting firms. However, the effect of embodied technical change (measured by $AUTO$ and $ACCU$) is lower for exporting firms than for nonexporting firms, and the effect of accumulated learning for nonexporting firms is around three times that of exporting firms. Those results imply that production technology is quite different between exporting and nonexporting firms.

Tests of constant returns to scale for the two types of firm are still rejected. Variable returns with order three in firm size are also found for the two types of firm. Figure 1 depicts the measure of variable returns to scale, $R(s)$, as defined in Equation 4. A U-shaped curve of $R(s)$ is found in which exporting firms have a higher magnitude than nonexporting firms everywhere except in the middle range of firm size where constant returns are prevailed. We further confined our sample to exporting firms only. By adding variable of export share to total output (EX) (Regression 6) we find a negative and significant effect for the export share variable (-0.0354, SE $= 0.0175$). This is certainly puzzling, given the conventional wisdom that exporting goods abroad should have a positive effect on productivity. Nevertheless, if we add an interaction term between export share and our index of firm size (denoted by s), a weighted combination of labour and capital, for the interaction term, then the coefficient of export share is positive (0.1836, SE $= 0.0779$) and that of the interaction term is negative (-0.0428,

Table 2. *Regression results for aggregate manufacturing industry*

Dep. var.	(1) *LNY*	(2) *LNY*	(3) *LNY*	(4) *LNY*	(5) *LNY*	(6) *LNY*	(7) *LNY*
Constant	4.3994* (0.0190)	4.4013* (0.0101)	4.3271* (0.0210)	4.393* (0.0224)	3.7236* (0.2285)	3.9553* (0.0465)	3.8438* (0.0606)
AUTO		0.1273* (0.0047)	0.1274* (0.0047)	0.1223* (0.0052)	0.1078* (0.0133)	0.1096* (0.0133)	0.1098* (0.0133)
ACCU		0.2918* (0.0065)	0.2922* (0.0065)	0.3082* (0.0052)	0.0872* (0.0269)	0.0863* (0.0271)	0.0896* (0.0271)
LNK	0.1919* (0.0014)	–	–	–	–	–	–
LNL	0.8536* (0.0017)	–	–	–	–	–	–
LNS	–	1.0188* (0.0021)	1.0930* (0.0169)	1.0981* (0.0201)	1.1952+ (0.1288)	1.0066 (0.0053)	1.0297# (0.0136)
*LNS*²	–	–	− 0.0215* (0.0047)	− 0.0236* (− 0.0061)	− 0.0468# (0.0241)	–	–
*LNS*³	–	–	0.0019* (0.0004)	0.0017* (0.0006)	0.0035# (0.0015)	–	–
EX	–	–	–	–	–	− 0.0354# (0.0175)	0.1836* (0.0779)
EXLNS	–	–	–	–	–	–	− 0.0408* (0.0148)
α	–	0.1836* (0.0016)	0.1833* (0.0016)	0.173* (0.0017)	0.2813* (0.0082)	0.2827* (0.0063)	0.2815* (0.0083)
No. of Obs.	135 646	135 306	135 306	121 059	8593	8550	8550

Notes: Numbers in the parentheses are standard deviation.
For *LNS* variable, the null hypothesis is that the estimated parameter equals to one.
*, #, and + indicate statistical significance at 1%, 5%, and 10% levels, respectively.

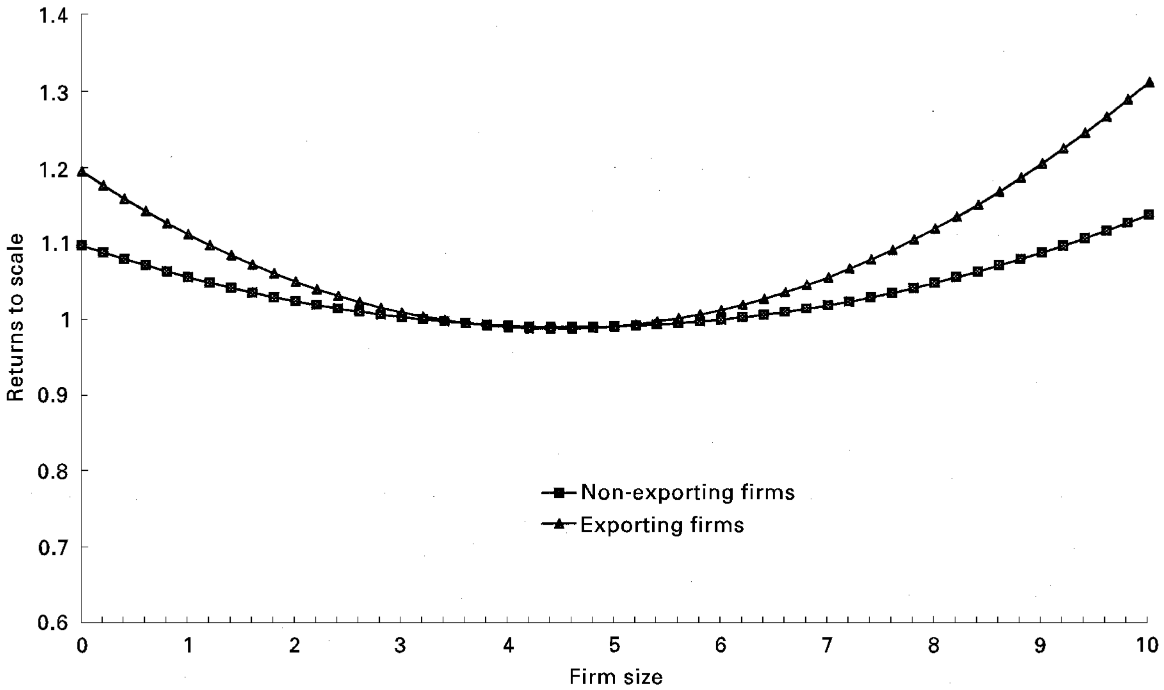

Fig. 1. *Variable returns to scale*

SE = 0.0148) (Regression 7). Therefore, the firm size cannot be too large to guarantee a positive effect from exporting. The estimated ceiling for the firm size is $\mathrm{Ln}S = 4.3$, *smaller* than the median value of firm size for the sample of 4.6.

This result suggests that in order for trade to have a positive effect on firm's production, the firm should be small in terms of our weighted Cobb–Douglas measure. Most importantly, this measure also allows different combinations of capital and labour that satisfy the required standard for positive trade effect. For instance, for a firm with a median value of capital, the minimum required number of worker falls to less than ten employees. Meanwhile, for a firm with median value of labour the required value for capital is less that NT$1 164 000.

Two-digit industry

Our study includes 20 industries in the two-digit industrial classification. Table 3 summarizes the estimation results at this level. Tests of constant returns are not rejected for most two-digit industries, the exceptions being food, textiles, chemicals, plastic products, and basic metals industries. Estimates based upon the variable returns specification also confirm this finding. Among the six increasing returns industries, a polynomial of order three in firm size is found for food textiles, chemicals, and basic metals industries and an order of four is found for chemical products and plastic products industries.

Firms found to be subject to increasing returns are generally noted to have higher α values (i.e., are more capital intensive than firms subject to constant returns). The only exceptional case of the constant returns' industries is the electrical and electronic machinery which has a α value of 0.2247 comparable to that of the increasing returns industries. As for embodied technical change measured by *AUTO* and *ACCU*, the vintage capital effect is highest for chemicals, food, nonmetallic minerals, leather, machinery, and electrical and electronic machinery industries; in turn the effect of embodied learning by doing is highest for printing processing, paper and paper products, leather, fabricated metal products, plastic products, rubber products, textiles, and chemicals industries.

According to previous estimates obtained for aggregate manufacturing, production technologies may be different for exporting and nonexporting firms. If we distinguish between exporting and nonexporting firms and run regressions for each type of firm, as in the aggregate level from Tables 4 and 5, nonexporting firms are generally found to have greater embodied technical change, except for chemicals and chemical products industries where the effect of accumulated learning by doing for exporting firms is four times that for nonexporting firms. However, α values are higher for exporting firms in all industries, i.e., for the same firm size exporting firms tend to be relatively more capital intensive. For exporting firms in all except for the food

Table 3. *Returns to scale for two-digit manufacturing industries*

Sector	*COBB*(a)	*COBB*(b)	*AUTO*	*ACCU*	α	μ_1	μ_2	μ_3	μ_4	No. of obs.
Food	406.0972*	195.6075*	0.1986*	0.2745*	0.2224*	1.7472*	− 0.1725*	0.0138*	–	6893
Textile mill products	96.9960*	27.9626*	0.0863*	0.2961*	0.1962*	1.1618*	− 0.041#	0.0038*	–	7363
Wearing apparel and accessories	0.1820	3.1301+	0.0823*	0.2322*	0.1672*	0.9851	–	–	–	3494
Leather and fur products	8.1651*	0.2204	0.1541*	0.3310*	0.2025*	1.0059	–	–	–	1269
Wood and bamboo products	19.2645*	4.8419#	0.0768*	0.1516*	0.1336*	1.0169	–	–	–	5098
Furniture and fixtures	17.5042*	2.4988	0.0936*	0.1956*	0.1439*	1.0136	–	–	–	3856
Pulp, paper and paper products	24.7193*	3.9029#	0.0945*	0.3419*	0.1817*	1.0184	–	–	–	3727
Printing processing	5.3514#	2.4845	0.1028*	0.3723*	0.1579*	0.9882	–	–	–	7635
Chemicals	78.5788*	38.4016*	0.2082*	0.2997*	0.2261*	0.8417*	0.0443	− 0.0017	–	981
Chemical products	84.8425*	46.0110*	0.0935*	0.1820*	0.1934*	2.6230*	− 0.6261*	0.1049#	− 0.0062#	1948
Rubber products	13.6009*	2.9586+	0.0716+	0.3062*	0.1906*	1.0191	–	–	–	1935
Plastic products	84.7175*	12.6628*	0.1134*	0.3162*	0.2032*	1.3281*	− 0.1517+	0.0296#	− 0.0020#	12 776
Nonmetallic mineral products	88.1552*	35.7860*	0.1982*	0.0909*	0.1921*	0.9652*	0.0112#	–	–	4202
Basic metals	136.2944*	73.1809*	0.0986*	0.2318*	0.2278*	0.8237*	0.0465+	− 0.0025	–	4608
Fabricated metal products	89.2903*	0.3061	0.1115*	0.3323*	0.1718*	1.0020	–	–	–	30 217
Machinery and equipments	53.6845*	2.1162	0.1385*	0.2321*	0.1774*	1.0063	–	–	–	14 669
Electrical and electronic machinery	61.4089*	2.3098	0.1396*	0.2795*	0.2247*	1.0077	–	–	–	10 980
Transport equipments	28.0206*	4.0995#	0.1004*	0.2336*	0.1739*	1.0129	–	–	–	5300
Precision instruments	19.4589*	4.3811#	0.04875*	0.2236*	0.1970*	1.0240	–	–	–	1725
Misc. manufactured products	2.6201	2.1064	0.1115*	0.2496*	0.1742*	0.9900	–	–	–	6511

Notes: (a) F test of constant returns based on Cobb-Douglas production without embodied technical change; (b) with embodied technical change. See notes in Table 2.

Table 4. *Two-digit manufacturing industries – nonexporting firms*

Sector	*COBB*(a)	*COBB*(b)	*Constant*	*ACCU*	*AUTO*	α	μ_1	μ_2	μ_3	μ_4	*N*
Food	17.5444	59.2619	3.0024*	0.3043*	0.2107*	0.2204*	1.7263*	− 0.1727*	0.0141*	–	6521
Textile mill products	47.6828*	12.5291*	4.3727*	0.3192*	0.0827*	0.1808*	1.0232	–	–	–	6530
Wearing apparel and accessories	8.4858*	18.8313*	4.7595*	0.2817*	0.0531	0.1484*	0.9551	–	–	–	2929
Leather and fur products	0.2500	0.7708	4.4079*	0.3233*	0.2256*	0.1881*	0.9848	–	–	–	969
Wood and bamboo products	8.3304*	1.5983	4.6951*	0.1535*	0.0576	0.1342*	1.0107	–	–	–	4538
Furniture and fixtures	0.9297	0.6989	4.7404*	0.241*	0.0606	0.1384*	0.9917	–	–	–	3356
Pulp, paper and paper products	13.0042*	0.8028	4.4388*	0.3481*	0.092	0.1764*	1.0089	–	–	–	3551
Printing processing	1.9224	5.3191*	4.7101*	0.3751*	0.0999*	0.1539*	0.9823	–	–	–	7525
Chemicals	34.6266*	20.5111*	4.0517*	0.1909*	0.1788*	0.2059*	1.0911	–	–	–	835
Chemical products	46.7119*	25.5154*	3.4191*	0.1002*	0.1326*	0.1838*	1.8156*	− 0.2169*	0.0195*	–	1683
Rubber products	2.0807*	0.1318	4.4701*	0.3297*	− 0.0136	0.1799*	1.0048	–	–	–	1606
Plastic products	10.1373*	0.6291	3.9444*	0.3227*	0.1019*	0.1883*	1.602*	− 0.2947*	0.0603*	− 0.0044*	11 335
Nonmetallic mineral products	69.3303*	27.7969*	4.2425*	0.1135*	0.1892*	0.1837*	1.0463	–	–	–	3508
Basic metals	78.8593*	38.7119*	4.1382*	0.2566*	0.1158*	0.221*	1.0490	–	–	–	4315
Fabricated metal products	20.0462*	6.3163$^{\#}$	4.6238*	0.3391*	0.1002*	0.1655*	0.9912	–	–	–	28 672
Machinery and equipments	4.8698$^{\#}$	4.2967$^{\#}$	4.6465*	0.2464*	0.1395*	0.1674*	0.9897	–	–	–	13 254
Electrical and electronic machinery	1.3927	7.0092$^{\#}$	4.3946*	0.2893*	0.1529*	0.2055*	0.9831	–	–	–	8797
Transport equipments	1.7640	0.2744	4.6950*	0.2164*	0.0678*	0.1606*	0.9951	–	–	–	4649
Precision instruments	3.2016^{+}	0.0137	4.4896*	0.289*	0.0733	0.1703*	1.0019	–	–	–	1337
Misc. manufactured products	22.3953*	46.1703*	4.7723*	0.3028*	0.116*	0.1486*	0.9427	–	–	–	5075

Notes: See notes in Tables 2 and 3.

Table 5. *Two-digit manufacturing industries – exporting firms*

Sector	*COBB*(a)	*COBB*(b)	*Constant*	*ACCU*	*AUTO*	α	μ_1	μ_2	μ_3	*N*
Food	12.7201*	10.1684*	3.1415*	− 0.2290*	0.0686	0.2855*	1.4623*	− 0.1120	0.0093	373
Textile mill products	3.3644^{+}	0.5037	3.6709*	0.0434	0.0803	0.3178*	1.0071	–	–	833
Wearing apparel and accessories	0.1739	0.0937	4.4812*	0.0056	0.1377	0.2132*	0.9859	–	–	564
Leather and fur products	0.1001	0.6604	4.5090*	0.2195	0.0144	0.2382*	0.9509	–	–	300
Wood and bamboo products	0.3944	0.0458	4.9100*	0.1384	0.1387	0.1309*	0.9820	–	–	560
Furniture and fixtures	0.0856	0.3065	4.8617*	− 0.1851	0.1391*	0.1499*	1.0070	–	–	500
Pulp, paper and paper products	0.1057	0.0017	3.9585*	0.1071	0.0967	0.2809*	1.0069	–	–	176
Printing processing	0.1223	0.1271	4.0388*	− 0.0054	0.0773	0.3080*	0.9731	–	–	110
Chemicals	2.1081	0.9076	2.8688*	0.8397*	0.1992*	0.3578*	1.0651	–	–	146
Chemical products	0.6552	0.0479	4.0680*	0.5797*	0.0376	0.2371*	1.0246	–	–	265
Rubber products	0.0028	0.5548	4.4079*	0.1282	0.1919*	0.2235*	0.9874	–	–	329
Plastic products	3.3470^{+}	0.5548	3.8414*	0.1799*	0.1086*	0.2912*	1.0066	–	–	1441
Nonmetallic mineral products	6.9154*	4.6203$^{\#}$	3.8931*	− 0.1030	0.2017*	0.2607*	1.0354	–	–	694
Basic metals	4.0172$^{\#}$	4.3384$^{\#}$	3.2466*	− 0.2189	− 0.1124	0.3525*	1.0805	–	–	293
Fabricated metal products	0.1478	0.1940	4.2995*	0.0828	0.0796*	0.2516*	0.9846	–	–	1545
Machinery and equipments	0.0750	1.2045	4.3850*	− 0.0142	0.0771*	0.2450*	0.9841	–	–	1415
Electrical and electronic machinery	0.1300	0.3858	4.0172*	0.1270*	0.0703*	0.2884*	0.9911	–	–	2183
Transport equipments	1.9728	0.0758	4.0558*	0.3070*	0.1290*	0.2552*	1.0107	–	–	651
Precision instruments	4.4410$^{\#}$	2.3001	4.0443*	− 0.0378	− 0.0139	0.2794*	0.9966	–	–	388
Misc. manufactured products	0.0011	0.0253	4.4072*	− 0.0567	0.0626	0.2258*	0.9952	–	–	1436

Notes: See notes in Tables 2 and 3.

industry, constant returns to scale cannot be rejected, while for nonexporting firms food, chemical, and plastic products industries are still found to exhibit increasing returns. These findings in two-digit industry level in contrast to what we have found in aggregate manufacturing level in the previous section where the magnitude of returns to scale measure is higher for exporting firms as shown in Fig. 1.

Existence of industry-wide technology spillovers

In light of this clear contrast, we briefly return to aggregate analysis. These results apparently suggest that a certain form of technology spillover effects may exist among exporting firms in the same industry. Chuang (1996) estimated that approximately 40% of output growth of Taiwan's manufacturing during 1975–90 has due to trade-induced learning by doing. By using the volume of exports (*LNE*) and total volume of other firms' exports of the industry (*SPOR*) as an additional variable capturing spillover effects across exporting firms within the same industry, for the entire manufacturing industry, we find that

$$LNY = \underset{(0.0935)}{3.2512} + \underset{(0.0128)}{0.1135}\,AUTO + \underset{(0.0260)}{0.0972}\,ACCU$$

$$+ \underset{(0.0109)}{0.9073}\,LNS + \underset{(0.0040)}{0.0990}\,LNE + \underset{(0.0048)}{0.0160}\,SPOR$$

$$\alpha = 0.2843,\ N = 8593,\ R^2 = 0.9970$$

Both firm-specific learning and industry-wide spillover effects are positive and significant. Moreover, industry-wide spillover effect across firms within the same industry is approximately one-sixth of the firm-specific export-induced learning effect. Notably, by including the effect of export-induced learning, increasing returns disappears in aggregate manufacturing data as well.

Productive efficiency and optimal firm size

This subsection further examines the relations between productive efficiency and optimal firm size for each two-digit industry. Firms are first divided and ranked from one to ten according to firm size, *s*.[4] An index of productive efficiency is calculated according to Equation 5 for each firm and the mean values of the productive efficiency of each class are presented in Table 6. In particular, optimal firm size appears large for food, textile products, furniture and fixtures, printing processing, chemicals, nonmetallic mineral products, and transport equipment, while small optimal size is found only in the wearing apparel industry.

Earlier results from Tables 4 and 5 reveal that the effects of embodied technical change and returns to scale are quite different for exporting and nonexporting firms. If we further decompose the two-digit industry classification (as before at the aggregate level) sample into exporting firms and nonexporting firms, optimal firm sizes are rather different for the two types of firm (see Tables 7 and 8). Although the mean value of firm size is relatively larger for exporting firms than for nonexporting firms, interesting comparisons arise between the two groups. For food, textiles, chemicals, and chemical products industries, optimal firm size is small for exporting firms but is large for nonexporting firms. For machinery, electrical and electronic machinery, transport equipment, and precision instrument industries, optimal firm size is found to be small for both types of firm. As a whole, our estimations clearly indicate that for exporting firms, small firm size has an efficiency advantage over a large one. This may account for why small- and medium-size enterprises take a majority share in Taiwan's total exports and they are the major contributions to Taiwan's economic growth. Our findings also suggest that a large technology spillover effect among firms and across industries is the most likely reason for efficiency in small-scale production.

VI. CONCLUDING REMARKS

Taiwan's firm data reveal that weak increasing returns exist for aggregate manufacturing industry. Returns to scale are a U-shaped curve with respect to firm size, and their magnitude is higher for exporting firms than for nonexporting ones. Moreover, export is beneficial only if the firm remains small. In contrast, for the two-digit industry constant returns to scale prevail for most of the industries particularly for the case of exporting firms. This evidence, as the finding from time series data (see, for example, Chuang, 1996), suggests that certain form of technology spillovers exists among firms and across industries. We find that industry-wide spillover effect across firms is approximately one-sixth of the firm-specific export-induced learning effect. These findings correspond to the hypothesis of endogenous growth models posting 'constant returns learning spillover technology' (see, for example, Stokey, 1988; Young, 1991; and Lucas, 1993).

As for size-efficiency relations, evidence clearly indicates that optimal firm size for exporting firms is small in most industries, particularly the highly export-oriented ones. Electrical and electronic machinery, precision instruments, machinery and equipment, rubber products, food, leather and fur products, and textiles industries are prime examples. This finding helps account for why small- and medium-sized

[4] In the sample, our measure of firm size (*s*) has a correlation coefficient of 0.9714 with the conventional proxy of the number of employees. There are eleven instead of ten classes for exporting firms.

Table 6. *Productive efficiency and optimal firm size*

Sector	Class of firm size 1	2	3	4	5	6	7	8	9	10	Optimal firm size
Food	81	80	83	86	85	87	90	100	94	–	big
	(7)	(1195)	(3078)	(1628)	(605)	(253)	(96)	(27)	(2)	–	
Textile mill products	94	86	87	87	88	88	91	95	100	84	big
	(10)	(620)	(2537)	(2338)	(1233)	(467)	(131)	(21)	(4)	(1)	
Wearing apparel and accessories	100	90	90	91	90	90	86	91	85	–	small
	(14)	(362)	(1091)	(1124)	(617)	(238)	(37)	(9)	(2)	–	
Leather and fur products	100	98	97	97	97	98	100	96	62	–	Intermediate
	(1)	(79)	(380)	(400)	(214)	(116)	(58)	(19)	(2)	–	
Wood and bamboo products	96	95	96	96	97	97	98	100	–	–	big
	(270)	(1333)	(2123)	(952)	(325)	(79)	(12)	(1)	–		
Furniture and fixtures	94	93	95	94	95	94	98	99	100	–	big
	(60)	(813)	(1552)	(913)	(378)	(115)	(19)	(4)	(1)	–	
Pulp, paper and paper products	92	83	84	84	84	85	85	95	100	–	big
	(3)	(331)	(1434)	(1340)	(460)	(124)	(32)	(1)	(1)	–	
Printing processings	93	91	92	90	91	91	99	100	–	–	big
	(110)	(1984)	(3782)	(1406)	(296)	(45)	(9)	(1)	–	–	
Chemicals	–	85	87	88	90	92	99	100	–	–	big
	–	(29)	(211)	(314)	(281)	(113)	(29)	(4)	–	–	
Chemical Products	–	89	92	93	94	97	100	99	–	–	big
	–	(157)	(584)	(631)	(380)	(154)	(36)	(4)	–	–	
Rubber products	100	96	96	97	97	98	100	98	–	–	Intermediate
	(2)	(129)	(635)	(646)	(381)	(119)	(22)	(1)	–	–	
Plastic products	97	98	97	98	98	99	100	95	67	–	Intermediate
	(1)	(841)	(4639)	(4463)	(2038)	(629)	(148)	(12)	(2)	–	
Nonmetallic mineral products	80	86	85	87	87	88	91	100	97	–	big
	(7)	(363)	(1177)	(1236)	(971)	(380)	(62)	(4)	(1)	–	
Basic metals	100	81	82	82	84	86	87	92	87	–	Intermediate
	(2)	(248)	(1244)	(1599)	(949)	(396)	(135)	(29)	(6)	–	
Fabricated metal products	96	93	94	94	94	95	97	100	98	–	big
	(229)	(7491)	(13489)	(6569)	(1963)	(408)	(52)	(7)	(2)	–	
Machinery and equipments	100	96	96	97	96	97	97	98	96	–	Intermediate
	(62)	(2657)	(6012)	(4077)	(1472)	(320)	(52)	(8)	(4)	–	
Electrical and electronic machinery	100	94	94	95	94	95	94	96	98	99	Intermediate
		(417)	(2493)	(3974)	(2656)	(1045)	(329)	(110)	(40)	(8)	
Transport equipments	74	70	70	70	70	71	73	76	85	100	big
	(25)	(754)	(1817)	(1516)	(773)	(306)	(80)	(22)	(2)	(1)	
Precision instruments	95	91	94	94	94	94	97	92	100	–	Intermediate
	(1)	(104)	(527)	(573)	(355)	(118)	(38)	(8)	(1)	–	
Misc. manufactured products	99	98	100	100	99	99	96	89	39	–	Intermediate
	(26)	(903)	(2341)	(1970)	(914)	(269)	(68)	(14)	(3)	–	

Notes: Ten class sizes have been defined from 1 to 10 by breaking down the logarithms of size (S).
In each sector, the table supplies the mean value of productive efficiency measure for the class, the index 100 referring to the class in which it is highest.
Numbers in the parentheses are numbers of establishment.

Table 7. *Optimal firm size – nonexporting firms*

Sector	Class of firm size 1	2	3	4	5	6	7	8	9	10	Optimal firm size
Food	82	81	83	87	85	88	93	100	87	–	Big
	(7)	(1188)	(3047)	(1559)	(489)	(173)	(46)	(8)	(1)	–	
Textile mill products	96	89	90	90	91	91	94	100	–	–	Big
	(14)	(864)	(2487)	(2017)	(880)	(231)	(32)	(4)	–	–	
Wearing apparel and accessories	100	95	95	95	92	91	87	95	–	–	Small
	(23)	(440)	(1046)	(939)	(384)	(89)	(7)	(1)	–	–	
Leather and fur products	99	93	93	93	92	94	100	87	23	–	Intermediate
	(2)	(99)	(370)	(330)	(124)	(31)	(10)	(2)	(1)	–	
Wood and bamboo products	97	96	97	97	97	97	100	–	–	–	Big
	(257)	(1290)	(1938)	(784)	(214)	(45)	(7)	–	–	–	
Furniture and fixtures	96	97	98	97	96	97	100	–	–	–	Big
	(81)	(822)	(1458)	(728)	(227)	(36)	(3)	–	–	–	
Pulp, paper and paper products	99	86	88	88	88	89	85	100	–	–	Intermediate
	(4)	(366)	(1437)	(1244)	(399)	(79)	(20)	(1)	–	–	
Printing processings	95	94	95	93	94	93	100	–	–	–	Intermediate
	(135)	(2057)	(3715)	(1321)	(263)	(26)	(7)	–	–	–	
Chemicals	97	83	84	85	88	87	96	100	–	–	Big
	(1)	(43)	(227)	(316)	(196)	(41)	(10)	(1)	–	–	
Chemical Products	–	86	89	90	90	92	100	98	–	–	Big
	(2)	(178)	(575)	(555)	(270)	(83)	(15)	(3)	–	–	
Rubber products	100	96	97	97	97	98	99	–	–	–	Intermediate
	(2)	(169)	(611)	(541)	(243)	(34)	(6)	–	–	–	
Plastic products	100	96	95	95	95	95	98	74	31	–	Small
	(10)	(1127)	(4728)	(3804)	(1397)	(235)	(27)	(3)	(1)	–	
Nonmetallic mineral products	87	92	92	93	93	96	100	–	–	–	Big
	(7)	(422)	(1093)	(982)	(724)	(246)	(33)	–	–	–	
Basic metals	100	85	85	86	87	88	89	90	90	–	Intermediate
	(3)	(270)	(1294)	(1530)	(848)	(283)	(71)	(13)	(3)	–	
Fabricated metal products	100	97	98	97	96	98	100	–	–	–	Intermediate
	(293)	(8139)	(12 806)	(5794)	(1438)	(180)	(15)	–	–	–	
Machinery and Equipments	100	96	96	96	95	95	94	–	–	–	Small
	(104)	(3075)	(5675)	(3360)	(905)	(121)	(9)	–	–	–	
Electrical and electronic machinery	100	93	92	92	91	92	87	92	87	98	Small
	(5)	(542)	(2669)	(3372)	(1733)	(389)	(67)	(12)	(3)	(1)	
Transport equipments	72	70	70	70	69	70	74	79	–	100	Intermediate
	(43)	(870)	(1773)	(1301)	(506)	(121)	(23)	(7)	–	(1)	
Precision instruments	100	94	97	96	96	95	92	–	–	–	Small
	(3)	(173)	(515)	(446)	(173)	(24)	(3)	–	–	–	
Misc. manufactured products	100	97	99	97	95	92	78	42	39	–	Small
	(86)	(1094)	(2102)	(1322)	(387)	(66)	(9)	(3)	(3)	–	

Notes: See notes in Table 6.

Table 8. *Optimal firm size – exporting firms*

Sector	1	2	3	4	5	6	7	8	9	10	11	Optimal firm size
	Class of firm size											
Food	–	–	100	93	86	81	76	78	88	82	–	Small
	–	–	(6)	(31)	(61)	(75)	(63)	(27)	(15)	(1)	–	
Textile mill products	–	–	100	85	86	80	75	74	77	66	70	Small
	–	–	(3)	(40)	(108)	(157)	(135)	(77)	(33)	(7)	(3)	
Wearing apparel and accessories	–	85	95	100	100	99	92	94	93	–	–	Intermediate
	–	(3)	(15)	(63)	(84)	(89)	(33)	(5)	(4)	–	–	
Leather and fur products	–	100	84	88	83	81	80	82	87	–	–	Small
	–	(1)	(7)	(31)	(49)	(52)	(27)	(23)	(2)	–	–	
Wood and bamboo products	100	87	92	89	91	90	89	–	–	–	–	Intermediate
	(2)	(10)	(46)	(67)	(49)	(17)	(4)	–	–	–	–	
Furniture and fixtures	–	98	99	98	97	95	99	96	100	–	–	Intermediate
	–	(4)	(25)	(65)	(66)	(41)	(6)	(1)	(1)	–	–	
Pulp, paper and paper products	–	–	85	93	89	84	81	84	100	–	87	Intermediate
	–	–	(2)	(37)	(37)	(36)	(31)	(9)	(1)	–	(1)	
Printing processings	–	–	100	84	77	77	74	73	90	75	–	Small
	–	–	(2)	(9)	(16)	(20)	(17)	(4)	(1)	(1)	–	
Chemicals	–	–	–	–	100	92	90	82	75	83	–	Small
	–	–	–	–	(15)	(27)	(51)	(38)	(8)	(2)	–	
Chemical products	–	–	100	94	91	91	92	77	–	–	–	Small
	–	–	(11)	(32)	(76)	(69)	(25)	(8)	–	–	–	
Rubber products	–	100	98	92	92	89	90	89	87	–	–	Small
	–	(1)	(9)	(43)	(80)	(68)	(13)	(5)	(1)	–	–	
Plastic products	–	–	95	92	90	88	85	83	85	100	–	Intermediate
	–	–	(14)	(105)	(223)	(294)	(181)	(61)	(6)	(1)	–	
Nonmetallic mineral products	–	–	89	85	87	88	86	91	100	93	–	Big
	–	–	(8)	(23)	(78)	(62)	(40)	(9)	(2)	(1)	–	
Basic metals	–	–	72	93	89	90	92	94	100	95	–	Big
	–	–	(1)	(11)	(37)	(71)	(81)	(53)	(15)	(2)	–	
Fabricated metal products	–	100	90	84	80	74	72	63	67	–	–	Small
	–	(4)	(43)	(203)	(274)	(229)	(100)	(18)	(3)	–	–	
Machinery and equipments	–	100	91	91	90	86	86	83	80	74	–	Small
	–	(2)	(44)	(243)	(431)	(301)	(104)	(22)	(6)	(2)	–	
Electrical and electronic machinery	–	–	100	100	99	96	93	91	90	94	89	Small
	–	–	(18)	(134)	(358)	(461)	(310)	(142)	(47)	(18)	(3)	
Transport equipments	–	–	98	93	90	87	88	86	86	100	–	Intermediate
	–	–	(6)	(49)	(93)	(123)	(85)	(40)	(11)	(2)	–	
Precision instruments	–	–	–	100	93	88	83	85	82	–	–	Small
	–	–	–	(21)	(57)	(67)	(40)	(15)	(1)	–	–	
Misc. manufactured products	–	94	100	96	96	96	93	88	–	–	–	Small
	–	(4)	(39)	(134)	(197)	(111)	(51)	(4)	–	–	–	

Notes: See notes in Table 6.

enterprises comprise over 90% in Taiwan's manufacturing industry.

In sum, the findings in this study provide valuable insight into Taiwan's economic development which is remarkable but not unique. The estimated U-shaped curve of returns to scale suggested that another development path may exist wherein optimal firm size is larger, and in which trade may or may not be good for economic development. However, evidence from Taiwan's development experience provides a good example for developing countries: initial conditions such as small firm size and production of labour intensive goods need not be anti-thetical to growth; by contrast they, along with policies to open trade to international markets, may serve as keystones in development strategies leading to a successful process of industrialization and sustainable economic growth. As our measure of firm size allows different combinations of capital and labour that satisfy the required standard for positive trade effect, there may exist significant variations for the values of required capital and labour. Therefore, a close investigation of these values and the regimes in which most Taiwanese firms appear to have operated, are surely areas for future study.

ACKNOWLEDGEMENTS

I am grateful to an anonymous referee for very helpful comments and to the National Science Council of Taiwan for Financial support (NCS85-2415-H-004-002).

REFERENCES

Barro, R. and Sala-i-Martin, X. (1995) *Economic Growth*, McGraw Hill, New York.

Blomstrom, M. and Wolff, E. N. (1993) Growth in a dual economy, NBER Working Paper no. 4433.

Chuang, Y.-C. (1996) Identifying the sources of growth in Taiwan's manufacturing industry, *Journal of Development Studies*, **32**, 445–63.

Grossman, G. M. and Helpman, E. *Innovation and Growth in the Global Economy*, MIT Press, Cambridge MA.

Lucas, R. E., Jr. (1993) Making a miracle, *Econometrica*, **61**, 251–72.

Meller, P. (1976) Efficiency frontiers for industrial establishments of different sizes, *Explorations in Economic Research*, **3**, 379–407.

Ramaswamy, K. V. (1994) Technical efficiency in modern small scale firms in Indian industry: applications of stochastic production frontiers, *Journal of Quantitative Economics*, **10**, 309–24.

Romer, P. M. (1986) Increasing returns and long run growth, *Journal of Political Economy*, **94**, 1002–37.

Stokey, N. L. (1988) Learning by doing and the introduction of new goods, *Journal of Political Economy*, **58**, 701–17.

Szpiro, D. and Cette, G. (1994) Returns to scale in the French manufacturing industry, *European Economic Review*, **38**, 1493–504.

Young, A. (1991) Learning by doing and the dynamic effects of international trade, *Quarterly Journal of Economics*, **106**, 369–405.

APPENDIX: DEFINITIONS OF VARIABLES

ACCU	Accumulated depreciation as the share of machinery.
AUTO	1 for using automation machinery, 0 for not using automation machinery.
DUMEX	1 for exporting firms, 0 for nonexporting firms.
EX	Share of exports to total production.
EXLNS	Product of *EX* and *LNS*.
EFEF	An index of productive efficiency.
LNY	Logarithm form of value-added.
LNK	Logarithm form of net asset.
LNL	Logarithm form of workers employed.
LNS	Logarithm form of firm size, where $LNS = \alpha LNK + (1 - \alpha) LNL$.
LNE	Logarithm form of value of exports.
SPOR	Logarithm form of total value of other firm's exports within the same industry.

Source: The Report on 1991 Industrial and Commercial Census for Taiwan-Fukien Area, Directorate-General of Budget, Accounting and Statistics, Executive Yuan, The Republic of China.