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EXPORTING AND PRODUCTIVITY: A FIRM-LEVEL ANALYSIS OF THE TAIWAN ELECTRONICS INDUSTRY

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Based on the panel data of Taiwanese electronics firms, this paper explores the relationship between exporting and productivity. Contemporaneous levels of exports and productivity are indeed positively correlated. The causality tests show causality from productivity to exporting and vice versa, implying that self-selection and learning-by-exporting effects coexist in the Taiwan electronics industry, while the learning-by-exporting effect is less supported. Exporting also has a positive impact on the productivity growth of firms, while the effect diminishes gradually after entering foreign markets. Decomposing the productivity growth shows that the reallocation effect accounts for only 20 per cent compared to the own-effect share of 80 per cent, which is mostly contributed by firms that continually export.

I. INTRODUCTION

THE role of international trade in economic growth has been widely discussed over the past decades. Literature focusing on the relationship between international trade and economic performance has emphasized that an export-oriented policy usually accompanies higher output growth and many analysts argue that developing countries that pursue export-oriented trade policies generally outperform those embracing import-substitution policies. The study of the East Asian economic miracle by the World Bank (1993) emphasized the role of exporting on promoting economic growth and considered export-oriented growth to be the hallmark of a successful development strategy for developing economies in East Asia.

The role of exporting is actually particularly important for a small open economy, such as Taiwan. During the 1981–2000 period, the magnitude of exports accounted for about 44.90 per cent of GDP. While Taiwan's GDP increased by 7.19 per cent per year from 1981 to 2000, Taiwan's exports increased 9.20 per cent per year over the same period. In addition, exporting also acted as a channel for learning and technological advancement for economic development on the island. Following an OEM (original equipment manufacturer) industry development model,[1] Taiwanese

[1] See Chu (2000).

exporting firms have begun to acquire knowledge and transfer advanced technology from foreign purchasers so as to gradually improve productivity, which in turn generates a technological spillover to the rest of the economy. In other words, exports should be associated with higher productivity and this relationship is relatively well established in the empirical literature.[2]

Why are exporters more productive than non-exporters? Two different mechanisms have been proposed to explain the positive relationship between exporting and productivity. First, it indicates that only the more productive firms can survive in a highly competitive export market. If the fixed costs of selling in a foreign market are higher than that of the domestic market or if output prices are lower, then only high productivity firms will find it profitable to enter the export market. This is called the self-selection hypothesis. Roberts and Tybout (1997) use a dynamic framework to examine the role of sunk cost and plant heterogeneity in the export decision of Colombian manufacturing firms. They find sunk costs to be important in explaining the export decision, implying that it reflects the self-selective entry of more efficient producers into the more competitive export market.

Competition and exposure to a superior foreign market can also speed up technological acquisition and thus lead to promoting technological capability. Therefore, exporters are more likely to have contracts abroad, and could have higher rates of productivity growth than those selling in the domestic market. This is known as the learning-by-exporting hypothesis. Clerides, Lach, and Tybout (1998) examine this issue using manufacturing data for Colombia, Mexico, and Morocco. The estimates show that relatively highly efficient firms become exporters, but their unit costs are not affected by previous export market participation. Exports, on the one hand, do not help these producers become more efficient.

Both mechanisms stated above are plausible, but the literature discussing the causality of an exporting-productivity relationship is limited. Bernard and Jensen (1999a, 1999b) find that firms with high productivity levels have a higher propensity to export, but they do not have superior productivity growth in the case of the United States. In addition, their actual importance is likely to vary across countries and industries.

An export-oriented policy indeed is a key factor to economic growth in Taiwan.[3] The question is whether it is adequate for a government to devote most of its resources to promote exports depending on the direction of the causality between exporting and productivity. Therefore, this issue is particularly important for a small open economy like Taiwan.

Liu, Tsou, and Hummitt (1999) find that the self-selective entry of more efficient

[2] See, for example, Aw and Batra (1998), Aw and Huang (1995), Bernard and Jensen (1995), Bernard and Wagner (1997), and Tybout and Westbrook (1995).

[3] The World Bank (1993) and Page (1994) emphasize that productivity growth has played a crucial role in the successful experience of Taiwan's economic development.

producers into the export market is an important part of the exporting decision for Taiwanese electronics plants. Aw, Chung, and Roberts (2000) find that the transition of firms in and out of the export market reflects systematic variations in productivity as predicted by the self-selection hypothesis. However, is the learning effect really unworkable? Taiwanese electronics firms have succeeded in both productivity enhancement and export expansion via the OEM mode of development, implying that the learning-by-exporting effect should also play some role in stimulating productivity growth. Thus, I attempt to reexamine the direction of causality by using more longitudinal and comprehensive data to investigate whether there is any evidence that firms learn to be more efficient by becoming exporters.

Although the role of trade in promoting a firm's productivity has been addressed in the literature, the interaction between exporting and long-run productivity movement is less understood. Recent works in economic growth literature have outlined some mechanisms. The possibility that trade facilitates the transfer of technology and knowledge across countries could be the major mechanism (Ben-David and Loewy 1998; Feeney 1999; and Grossman and Helpman 1991).

Several recent studies have analyzed the role of trade in stimulating economic growth with aggregate cross-country or cross-industry data.[4] However, studies conducted at the firm level that focus on the issue are very limited. Bernard and Jensen (1999b) examine the role of exporting in increasing productivity growth in U.S. manufacturing, finding no evidence that exporting increases productivity growth rates of manufacturing plants. In addition, they decompose productivity growth into own and reallocation effects, showing that exporting is associated with the reallocation of resources from less efficient to more efficient plants.

This paper uses more comprehensive firm-level panel data on the Taiwan electronics industry, to explore the implications implied in the relationship between exporting and productivity. By testing the causality of exporting and productivity, the influences of self-selection and learning-by-exporting effects can be identified clearly. In addition, I ask whether exports lead to faster productivity growth and decompose the change in the productivity growth rate of the electronics industry to explore the dynamics of resources reallocation. These estimates can provide evidence (based on firm-level data) of how trade, in the form of exports, might be related to the aggregate productivity growth rate.[5] While there is a considerable amount of literature debating the magnitude and sources of productivity growth in Taiwan based on aggregate or sector data, this study provides the first evidence on the role of micro-level reallocation as a determinant of productivity change.

The paper proceeds as follows: first I briefly introduce Taiwan's electronics in-

[4] For example, Ben-David (1993) and Proudman and Redding (1998).

[5] Due to the lack of data, I cannot consider the influence of imports on productivity. The importance of omitting imports is hard to judge. If the effect of imports is similar as argued by Lawrence and Weinstein (1999), then this study may be overstating the importance of exports.

dustry and describe the data. In Section III I present the difference in productivity between exporters and non-exporters. Section IV tests the causality of exporting and productivity in both aggregate and firm-level data. Whether exporting plays an important role in productivity growth is explored in Section V. In Section VI I decompose the change in aggregate productivity in the electronics industry into components due to increased productivity within firms and the reallocation of resources across firms. Conclusions and policy implications follow in Section VII.

II. THE DEVELOPMENT OF THE TAIWAN ELECTRONICS INDUSTRY AND DATA STATISTICS

The development of the island's electronics industry began with the exporting of labor-intensive consumer electronics during the 1960s and 1970s. At that time, this industry was designated as a "strategic industry" for economic development and became a beneficiary of tax relief and tariff reduction, low-interest loans, assistance in technical and operation management, and so on. Since the 1980s, enormous changes in the industrial environment of Taiwan have occurred. Many issues such as environmental protection, increases in the cost of land and labor, and a large fluctuation in the local currency's exchange rate have emerged.

In order to move the industry from being labor-intensive to technology- as well as capital-intensive, the government established the Science-Based Industrial Park in Hsinchu to attract high-technology industrial companies concerned with both research and manufacturing. The government promoted this through three measures, namely, tax incentives, financial assistance, and R&D grants to encourage investment; and it has devoted large amounts publicly funded R&D to support the technical needs of the industry. Thus, the exports of electronics firms, which had been concentrated in consumer electronics, shifted to advanced electronics goods, such as personal computers, notebook computers, computer peripherals, semiconductors, opto-electronics, and telecommunications. The development of the electronics industry has been rapid and successful.

The magnitude of output and export share of the electronics industry has grown gradually and is now the most important exporting industry of Taiwan outweighing that of the textile industry.[6] The dense network of subcontractors and export traders in Taiwan has helped to lower the costs of entry into and exit from the export market (Levy 1991). This implies that the turnover rate is rather high in the electronics industry.

In contrast with the large size of firms at the international level, most Taiwanese electronics firms are small and medium-sized enterprises (SMEs). Despite this fact,

[6] In the recent three census years, the electronics industry has led the manufacturing sector in terms of its contribution to exports at 12.85 per cent in 1986, 36.10 per cent in 1991, and 33.93 per cent in 1996.

Taiwan in the late 1990s is clearly a major producer of information technology products in the world. Several key commodity categories have obtained a leading share in the global market. In 1998 the cumulative global market share of Taiwanese firms was 58% in computer monitors, nearly 40% in notebook PCs, 61% in motherboards, 69% in desktop scanners, 65% in computer keyboards, and 60% in mouses.[7] This also reflects the strong export orientation of Taiwan's electronics industry.

The micro data are drawn from the census surveys conducted by the Directorate-General of Budget, Accounting and Statistics (DGBAS), Executive Yuan in 1986, 1991, and 1996. The electronics industry that I selected is the two-digit SIC industry, "electrical machinery and electronics industry" (31). This industry comprises nine three-digit SIC industries: electrical machinery, apparatuses, appliances, and suppliers (311); electrical appliances and housewares (312); lighting equipment manufacturing (313); data storage media processing equipment (314); video and radio electronics products (315); communication equipment and apparatuses (316); electronics parts and components (317); batteries (318); and other electrical and electronic machinery and equipment (319). The ID codes of individual firms have been matched to provide balanced panel data. The sample consists of 1,750 firms in each year.

There are several prominent advantages of the data over alternative sources. First, this census survey is a unique official survey containing information on exports, productivity, and producer characteristics in each survey period. Secondly, the longer time periods of this data can help to reduce the role of transitory shocks, cyclical fluctuations, and measurement errors that can affect productivity comparison based on a higher frequency of data. In addition, focusing on the same industry can also reduce the influences of macro factors on the exporting structure. However, the drawback of the balanced panel data is that it omits firms that enter and exit the market during the period. As a result, this sample-selection bias is not accounted for in my analysis.[8]

Table I presents the percentage of exporting firms, share of exports in terms of shipments, and average firm size of exporters and non-exporters by the three-digit industry in the three census periods. The bottom of column 3 indicates a declining trend from 52.69 per cent in 1986 to 44.74 per cent in 1996. The average export ratio appears to show a similar trend, about 32.87 per cent and 20.95 per cent in 1986 and 1996, respectively. The statistics seem to contradict the fact that Taiwan has been a major electronics product exporter in the global market ever since the late 1980s. This may have been caused by the wave of outward foreign direct investment from Taiwan since the late 1980s, including electronics firms. Therefore, many operation lines have moved to foreign subsidiaries.

[7] See Chung (1997, pp.180–83).

[8] Aw, Chen, and Roberts (2001) argue that the productivity differentials among entry, survival, and exit firms are also one source contributing to productivity growth in Taiwanese manufacturing.

TABLE I

INDUSTRY CHARACTERISTICS, 1986, 1991, AND 1996

3-Digit Industries (SIC Code)	Firms (No.)	Firm Exporting (%)	Export Share of Total Sales (%)	Employees	
				Exporters (No. of Persons)	Non-exporters (No. of Persons)
Electrical machinery, apparatuses, appliances, and suppliers (311)	296	29.61 30.92 29.61	20.92 9.57 15.30	170.27 102.08 107.59	11.07 19.70 19.08
Electrical appliances and housewares (312)	143	51.05 53.85 39.86	33.94 13.69 5.25	141.62 119.10 50.71	26.54 19.16 80.07
Lighting equipment manufacturing (313)	184	51.63 39.67 34.78	18.06 13.74 6.88	67.91 36.51 24.86	15.34 16.44 11.10
Data storage media processing equipment (314)	57	73.68 71.93 57.89	26.26 5.23 16.49	107.83 261.17 290.45	16.00 14.75 48.08
Video and radio electronics products (315)	201	63.68 64.18 55.72	28.94 45.90 55.80	226.00 169.53 151.88	23.11 47.11 35.62
Communication equipment and apparatuses (316)	69	73.91 65.22 40.58	42.05 27.49 65.33	223.18 144.20 165.50	45.06 66.83 36.22
Electronics parts and components (317)	509	57.76 57.56 53.04	46.82 26.50 22.45	207.88 202.74 203.61	32.96 25.91 45.98
Batteries (318)	18	88.89 72.22 72.22	39.62 23.56 31.31	115.63 175.77 184.31	11.50 43.00 20.40
Other electrical and electronic machinery and equipment (319)	273	42.49 39.19 37.36	21.80 10.86 10.08	62.48 49.71 42.89	11.12 15.64 16.11
Total	1,750	52.69 50.91 44.74	32.87 17.35 20.95	157.74 144.83 139.32	22.74 23.66 16.11

Source: Calculated based on DGBAS (1986, 1991, and 1996 editions).
Note: The three lines of figures shown for each industry indicate the statistics in 1986, 1991, and 1996, respectively.

In the case of subsectors (315) and (316), entrants into the electronics industry have raised some market share in exporting. In addition, exporting firms are most heavily concentrated in: data storage media processing equipment (314), video and radio electronics products (315), communication equipment and apparatuses (316), and electronics parts and components (317). As for the scale of firms, exporters are substantially larger than non-exporters, employing about seven times as many people on average.

III. PRODUCTIVITY DIFFERENTIALS BETWEEN EXPORTERS AND NON-EXPORTERS

Before moving into an econometric analysis of the causality and the impact of exporting on productivity growth, I need to find out if there are significant differences in productivity levels between exporter and non-exporter groups. My measurement of productivity is total factor productivity (TFP). Following Griliches and Regev (1995), each firm's TFP is calculated as real output less raw materials, fuel and electricity, salaries, and capital inputs, with weights given by the share of these inputs to total sales. Real output is defined as sales deflated by a three-digit product-price deflator. Raw materials are deflated by a two-digit material-price deflator. Fuel and electricity expenditures are deflated by an aggregate energy-price deflator. Total payments to workers are deflated by a salary-price deflator. The measure of capital input is the book value of a firm's capital stock. In order to guarantee the comparisons between any two firms across years, all these calculations are deflated relative to 1986 as the base year. In addition, the share expended on capital is calculated as the residual, after subtracting the expenditures on material inputs, labor, and energy inputs from the value of output.

I examine the contemporaneous differences in productivity between exporters and non-exporters in Table II. Exporters differ substantially from non-exporters in terms of productivity in all periods and most of the *t*-ratios are statistically significant at 1 per cent. This suggests that an export advantage exists and exporters have a higher productivity level than non-exporters. In addition, all electronics firms, including exporters and non-exporters, show an increasing trend of real productivity during the 1986–96 period. In particular, data storage media processing equipment (314) and communication equipment and apparatuses (316) manifested an extremely high rate of productivity growth, and this shows why some Taiwanese electronics products have dominated the global market since the late 1980s.

Other firm characteristics may account for the preponderance of these differences. To examine this possibility, I control these factors and estimate the productivity differentials as the following regression form:

$$\ln (Y_{it}) = b_0 + b_1 \ln (KL_{it}) + b_2 EXP_{it} + b_3 Z_{it} + u_{it}, \quad (1)$$

TABLE II

DIFFERENCE IN TFP BETWEEN EXPORTERS AND NON-EXPORTERS

(NT$ million)

SIC Code	1986			1991			1996		
	Exporters	Non-exporters	*t*-Value	Exporters	Non-exporters	*t*-Value	Exporters	Non-exporters	*t*-Value
311	141.887 (452.224) [107]	10.931 (20.915) [189]	3.314***	329.294 (1,099.16) [113]	31.805 (48.465) [183]	3.113***	462.356 (1,365.97) [104]	38.799 (69.568) [192]	3.380***
312	189.594 (965.458) [73]	5.939 (13.879) [70]	1.941*	391.284 (1,940.30) [77]	25.893 (66.950) [66]	1.965**	259.474 (1,037.10) [57]	254.492 (1,950.50) [86]	0.689
313	38.245 (112.402) [95]	6.23 (4.917) [89]	2.978***	60.002 (196.465) [73]	15.144 (15.928) [111]	2.219**	62.995 (253.383) [64]	15.787 (20.128) [120]	1.817*
314	147.650 (282.626) [42]	6.731 (6.355) [15]	3.407***	894.909 (1,418.59) [41]	14.84 (9.728) [16]	4.079***	2,250.280 (5,712.63) [33]	202.676 (458.344) [24]	2.581***
315	183.917 (794.271) [128]	24.861 (157.720) [73]	2.453***	313.657 (1,390.80) [129]	113.631 (558.88) [72]	1.784*	618.713 (3,928.41) [112]	59.408 (229.842) [89]	1.836*
316	198.427 (336.944) [51]	22.177 (51.805) [18]	3.792***	467.723 (1,007.59) [45]	246.371 (883.43) [24]	1.371	1,462.720 (4,769.03) [28]	113.545 (284.575) [41]	1.819*
317	139.974 (363.622) [294]	11.658 (23.797) [215]	6.039***	309.832 (789.596) [293]	29.519 (53.705) [216]	6.074***	642.300 (2,105.54) [270]	208.996 (1,228.22) [239]	3.088***
318& 319	44.001 (76.018) [132]	7.134 (9.929) [159]	5.533***	87.470 (164.199) [120]	19.061 (32.327) [171]	4.563***	120.354 (259.624) [115]	29.609 (64.470) [176]	3.800***
Total	129.721 (490.131) [922]	10.851 (50.325) [828]	7.318***	304.374 (1,064.45) [891]	38.624 (224.61) [859]	36.460***	572.536 (2,535.69) [783]	105.095 (854.096) [967]	4.939***

Notes: 1. The batteries (318) and other electrical and electronic machinery and equipment (319) are merged as a whole due to few firms being in the batteries industry.
2. Figures in parentheses and brackets are standard errors and the number of firms, respectively.
3. ***, **, and * represent statistical significance at 1, 5, and 10 per cent, respectively.

where the dependent variable ln(*Y*) is the logarithm of TFP. In addition, another indicator of productivity, value added per employee (VAE), is also considered.

Labor productivity is not really a true measure of TFP, but after it has been purged of its correlation with capital stocks, it embodies the concept of TFP. It may also have the advantage of lowering the bias due to the difficulty of getting the capital price. The estimates of VAE equation can be used as an alternative to indicate the relationship between exports and productivity when errors in the measurement of capital usage and capital price appear. However, one should be cautious about drawing strong conclusions from the results obtained using labor productivity alone.

Among the independent variables, ln(*KL*) is the log of the capital-labor ratio, while *EXP* is a dummy variable of export status. In an alternative specification, I use the share of exports in total sales, *EXS*, to replace *EXP*. If the coefficients of *EXP* and *EXS* are positive and significant, then this implies that an export premium exists (Bernard and Jensen 2001). Other firm and industry characteristics are considered in the *Z* vector, including firm size (*S*), the ratio of subcontracting expenditures to total sales (*SUB*),[9] and three-digit industry dummy variables.

Since the data cover the time frame of 1986, 1991, and 1996, a panel data model is used to estimate equation (1). To account for unobserved heterogeneity, both a random-effects and fixed-effects model can be used for estimation. I show the results of the fixed-effects model in Table III.[10]

Models (1) and (2) represent export status using a zero-one dummy while models

TABLE III

EXPORTING AND PRODUCTIVITY

	(1) ln*TFP*	(2) ln*VAE*	(3) ln*TFP*	(4) ln*VAE*
ln(*KL*)	0.128***	0.246***	0.128***	0.256***
	(0.014)	(0.011)	(0.014)	(0.011)
EXP	0.284***	0.225***		
	(0.042)	(0.023)		
EXS			0.280E–02***	0.225E–02***
			(0.577E–03)	(0.293E–03)
S	0.134E–02***	0.115E–03***	0.135E–02***	0.124E–03***
	(0.109E–03)	(0.203E–04)	(0.110E–03)	(0.205E–04)
SUB	0.048***	0.034***	0.049***	0.036***
	(0.363E–02)	(0.301E–02)	(0.363E–02)	(0.303E–02)
R^2	0.828	0.615	0.827	0.615

Notes: 1. Numbers in parentheses are standard errors.
2. *** represents statistical significance at 1 per cent.

[9] Many producers in the Taiwan electronics industry hire subcontractors to perform portions of the manufacturing process that are less competitive.

[10] The Hausman statistics show that the fixed-effect is a more appropriate specification.

(3) and (4) use the export share variable. Consistent with previous comparisons, the coefficients of *EXP* and *EXS* are positive and statistically significant at 1 per cent in all cases, implying that exporters have a productivity advantage over non-exporters. From the results of models (1) and (2), the two productivity measures, total factor productivity (ln*TFP*) and labor productivity (ln*VAE*), are about 28 per cent and 22 per cent higher for exporters than non-exporters after controlling for firm characteristics and unobserved heterogeneity. The relationships are similar for the export share variable in models (3) and (4). Exporting firms have an advantage in productivity over non-exporting firms as the share of exports rises. These findings are largely consistent with previous studies on Taiwan by Aw and Hwang (1995), Liu, Tsou, and Hammitt (1999), and Aw, Chung, and Roberts (2000). The cross-section analysis reported in Table II and panel data analysis reported in Table III verify that there exists a substantial difference in productivity between exporters and non-exporters in the Taiwan electronics industry during the 1986–96 period.

IV. SELF-SELECTION AND LEARNING-BY-EXPORTING

Contemporaneous levels of exporting and productivity are indeed positively correlated. What is the direction of causality between exporting and productivity? As discussed above, both self-selection and learning-by-exporting can be used to explain the positive relationship between exporting and productivity.

Although recent plant-level studies have suggested that exporting confers little or no benefit in the form of faster productivity growth (Clerides, Lach, and Tybout 1998; Bernard and Jensen 1999b), the effect of learning-by-exporting may be particularly relevant for Taiwan's electronics industry, because it functions as a subcontractor for international high-tech industries.

To separate the selection and learning effects, I run a simple Granger-causality test. Both industry-level data and firm-level data are used in this study to investigate the direction of causality between exporting and productivity. These different dimensional views can help to enhance the robustness of the estimates. First, using annual industry-level data from 1978 to 2000 on labor productivity, TFP, and exports, I estimate the following two separate vector autoregressions (VARs) with two lags each of productivity (*prod*) and exports (*export*).[11]

$$\ln export_t = \sum_{j=1}^{2} \beta_j^1 \ln prod_{t-j} + \sum_{j=1}^{2} \alpha_j^1 \ln export_{t-j} + \varepsilon_t^1, \quad (2)$$

$$\ln prod_t = \sum_{j=1}^{2} \beta_j^2 \ln prod_{t-j} + \sum_{j=1}^{2} \alpha_j^2 \ln export_{t-j} + \varepsilon_t^2, \quad (3)$$

[11] The time span for the electronics industry data was as long as I could get. Therefore, I have used only two lags due to the short time span.

TABLE IV

TESTING THE CAUSALITY OF EXPORTING AND PRODUCTIVITY: THE TAIWAN ELECTRONICS INDUSTRY, 1978–2000

	ln *export*		ln*TFP*	
ln*TFP*	1.258*	(0.734)	1.727***	(0.419)
ln*TFP*	–1.243	(0.789)	–1.074**	(0.398)
ln(*export, t*–1)	0.735*	(0.412)	–0.257	(0.201)
ln(*export, t*–2)	0.278	(0.378)	0.413**	(0.184)
	ln *export*		ln(labor productivity)	
ln(labor productivity, *t*–1)	1.443*	(0.761)	0.76*	(0.375)
ln(labor productivity, *t*–2)	–1.155	(0.723)	0.008	(0.322)
ln(*export*, *t*–1)	1.010**	(0.378)	–0.005	(0.080)
ln(*export*, *t*–2)	–0.127	(0.398)	0.115	(0.085)

Notes: 1. Numbers in parentheses are standard errors.
2. *** ,**, and * represent statistical significance at 1, 5, and 10 per cent, respectively.

On the export regressions in Table IV, the coefficients of one-lagged productivity variable, including labor productivity and TFP, are positive and significant at the 10 per cent statistical level. This means that higher productivity in the previous periods tends to induce more exports, reflecting the self-selection effect.

On the other hand, the sum of coefficients on exports is slightly larger than zero and the impacts are negative and positive on the lag 1 and lag 2 periods, while a significantly positive impact exists only for TFP. This evidence supports the learning-by-exporting hypothesis which claims that experience exporting can help promote the productivity level, although it is less supported than the self-selection hypothesis. Although the results highlight the argument that the effects of both self-selection and learning-by-exporting may exist contemporaneously in the Taiwan electronics industry, there seems to be a strong causal relationship of productivity spurring exports.

Although the evidence from the industrial data tends to support the coexistence of self-selection and learning-by-exporting, I also use the more detailed firm-level data to investigate the direction of causality by estimating the following two separate VARs.

$$\ln EXP_{it} = \beta_j^1 \ln Y_{i,t\text{-}1} + \alpha_j^1 \ln EXP_{i,t\text{-}1} + \gamma_j^1 Z_{it} + \varepsilon_{it}^1 , \quad (4)$$

$$\ln Y_{it} = \beta_j^2 \ln Y_{i,t\text{-}1} + \alpha_j^2 \ln EXP_{i,t\text{-}1} + \gamma_j^2 Z_{it} + \varepsilon_{it}^2 , \quad (5)$$

where dependent variable Y is productivity measured as TFP and VAE. Only one period lag is considered in the independent variables due to the census data covering only three periods and each period is five years. Thus, I can estimate two separate VARs for the 1986–91 and 1991–96 periods. In addition, firm size (S) and the ratio

TABLE V

TESTING THE CAUSALITY OF EXPORTING AND PRODUCTIVITY:
THE TAIWAN ELECTRONICS FIRMS

	1986–91				1991–96			
	ln*EXP*	ln*TFP*	ln*EXP*	ln*VAE*	ln*EXP*	ln*TFP*	ln*EXP*	ln*VAE*
Constant	4.271***	2.061	3.451***	2.984***	4.381***	2.094***	3.608***	2.966***
	(0.238)	(0.076)	(0.642)	(0.080)	(0.230)	(0.073)	(0.634)	(0.080)
ln*EXP*(–1)	–0.021	0.012	0.063**	0.612E–02**	–0.020	0.012	0.060**	0.549E–02**
	(0.032)	(0.010)	(0.025)	(0.310E–02)	(0.032)	(0.010)	(0.025)	(0.312E–02)
ln*TFP*(–1)	0.457***	0.141***			0.434***	0.133***		
	(0.102)	(0.032)			(0.101)	(0.032)		
ln*VAE*(–1)			0.464 **	0.076***			0.437**	0.080***
			(0.198)	(0.025)			(0.197)	(0.025)
S	0.151E–03	0.185E–04	0.161E–03	0.367E–04	0.651E–03**	0.312E–03***	0.688E–03**	0.565E–04
	(0.292E–03)	(0.928E–04)	(0.293E–03)	(0.368E–04)	(0.279E–03)	(0.882E–04)	(0.280E–03)	(0.351E–04)
SUB	0.035	0.683E–02	0.034	–0.005	–0.017	–0.013*	–0.017	–0.001
	(0.027)	(0.871E–02)	(0.028)	(0.003)	(0.022)	(0.007)	(0.022)	(0.003)
R^2	0.029	0.018	0.010	0.012	0.020	0.037	0.013	0.012

Notes: 1. Numbers in parentheses are standard errors.
2. ***, **, and * represent statistical significance at 1, 5, and 10 per cent, respectively.

of subcontracting expenditures to total sales (*SUB*) also can be considered in the *Z* vector to control for the effects of firm characteristics.

The coefficient of lagged productivity is positive and significant at the 1 per cent or 5 per cent statistical levels in all specifications (see Table V). The evidence indicates that the higher productivity of exporters in Taiwan's electronics industry reflects the self-selection effect of more efficient firms entering the more competitive global market.

Does the existence of the self-selection effect mean that the possibility of learning-by-exporting is quite limited? My view is that the relationship of the two effects is not one of exclusion but of contemporaneousness. Is there any evidence that a firm learns to be more efficient by becoming an exporter? Table V shows that the coefficients of lagged exports are positive and significant at the 5 per cent statistical level in the labor productivity regressions, while these effects are not so significant in the TFP regressions. One explanation is that exporting actually stimulates higher labor productivity, but the higher labor productivity may arise from more capital or machinery inputs. When capital usage is less efficient than labor, it may lower the learning effect on TFP. Therefore, the learning-by-exporting effect also seems to play a part in the Taiwan electronics firms, although this hypothesis is less supported.

Liu, Tsou, and Hammitt (1999) and Aw, Chung, and Roberts (2000) both conduct a similar test on Taiwan. Liu, Tsou, and Hammitt's (1999) results challenge the learning-by-exporting mechanism, while Aw, Chung, and Roberts (2000) find that there is evidence of productivity improvement in several industries, including the electronics industry, following entry into the export market. My empirical results seem to support the findings of Aw, Chung, and Roberts (2000).

In attempting to sort out the direction of causality, the industry- and firm-level data analyses show that both the self-selection and learning-by-exporting effects do exist contemporaneously for the Taiwan electronics industry, even though the latter is less supported. This reflects the fact that the more efficient firms select to enter the export market, while the exporting experience also results in a higher productivity level for the electronics industry.

V. EXPORTING AND PRODUCTIVITY GROWTH

Despite exporters outperforming non-exporters in terms of productivity, does exporting lead to faster productivity growth? This section focuses on the role of exporting in increasing productivity growth, because the learning mechanism is an important part of the story in the Taiwan electronics industry. The learning effect can facilitate higher productivity, while it can also promote the productivity of non-exporters if the spillover of the learning effect to the rest of the economy is quick. The difference in the productivity growth rate for exporters and non-exporters will then be quite limited.

To investigate the relationship between exporting and productivity growth, my empirical strategy, which is similar to the approach of Aw, Chung, and Roberts (2000), distinguishes groups of firms that have undergone different transition patterns and then to evaluates the productivity growth differentials arising from the transition in and out of exporting. This approach can reduce the bias due to the high turnover rate of transitions in or out of an export market for the island's electronics industry.

In order to isolate this in and out effect, I define four export types based on a firm's export market participation in two adjoining census years:

Firm Status	Year t	Year $t+1$	Symbol
1. Stay Out	No exports	No exports	(0, 0)
2. Entrant	No exports	Exports	(0, 1)
3. Exit	Exports	No exports	(1, 0)
4. Stay In	Exports	Exports	(1, 1)

In the sample, 208 firms had not exported in 1986, but had entered the export market by 1991, 239 firms were in export market in 1986, but had exited by 1991, 620 firms were non-exporters in both years, and 683 firms remained in the export market. Thus, the turnover rate of transition in or out of the export market is 27.26.[12] Based on the "stay out" type, three dummy variables, *ENTRT*, *EXIT*, and *CONT*, are used to proxy the export status. I estimate the following regression:

$$\Delta \ln (Y_{i,\,t+1}) = b_0 + b_1 ENTRY_{it} + b_2 EXIT_{it} + b_3 CONT_{it} + b_4 D_i + b_5 Z_{it} + u_{it}, \quad (6)$$

where the dependent variable $\Delta \ln (Y)$ is one of two measures for productivity growth rate and D is an industry characteristic vector that includes eight three-digit industry dummies based on "electrical machinery, apparatuses, appliances, and suppliers" (311). The Z vector includes S and SUB. Due to the calculation of the growth rate, the data set reduces to a two-period panel.

Table VI reports the results estimated using a random-effect model. The first two columns represent the other variables that are not controlled. I compare here increases or declines in productivity in the four transition groups. Equations (iii) and (iv) include eight three-digit industry dummies and additional firm characteristics are added in the estimates of equations (v) and (vi).

The results show that productivity growth differentials actually exist across the four transition groups, and the estimates are quite similar in all specifications. For the TFP growth rate, the entrants have a substantially higher growth of 39 per cent, relative to firms that remain non-exporters during the five-year period. In labor pro-

[12] The turnover rate of transition in or out of an export market is defined as the share of the number of entrants and exits compared with all sample firms. The turnover rate is 29.03 per cent in the 1991–96 period.

TABLE VI

EXPORTING AND PRODUCTIVITY GROWTH BASED ON TRANSITIONS: IN OR OUT OF THE EXPORT MARKET

Variable	(i) ln*TFP*	(ii) ln*VAE*	(iii) ln*TFP*	(iv) ln*VAE*	(v) ln*TFP*	(vi) ln*VAE*
ENTRY	0.399***	0.140***	0.395***	0.139***	0.396***	0.112***
	(0.065)	(0.047)	(0.065)	(0.042)	(0.065)	(0.038)
EXIT	−0.292***	−0.070*	−0.291***	−0.028	−0.283***	−6.58E–02
	(0.058)	(0.043)	(0.059)	(0.037)	(0.059)	(0.035)
CONT	0.087*	0.035	0.062	0.030	0.072	6.14E–02
	(0.052)	(0.023)	(0.053)	(0.032)	(0.053)	(0.031)
D	×	×	v	v	v	v
Z	×	×	×	×	v	v
R^2	0.026	0.007	0.039	0.007	0.041	0.128

Notes: 1. Numbers in parentheses are standard errors.
2. ***, **, and * represent statistical significance at 1, 5, and 10 per cent, respectively.
3. v and × represent the "including" and "non-including" vector variables, respectively.

ductivity growth entrants also outperform those that remain non-exporters by a rate of 11.2 to 14 per cent. In fact, the firms that are labeled *ENTRY* have entered foreign markets during the past five years. The positive effect of *ENTRY* on productivity growth implies that the more rapid productivity growth than for non-exporters takes place after the firm starts exporting. This reflects the learning-by-exporting hypothesis that exports act as a channel for learning and technological acquisition. At the same time, competition and exposure to more competitive foreign markets can also stimulate and speed up technological advancement.

The coefficients of *CONT* are all positive and not so significant relative to non-exporters. Is the learning effect not important for survivors in an export market? My viewpoint is that the learning effect actually plays an important role for exporters, with the effect lasting for some time and then gradually declining. When the learning effect spills over to the rest of the economy, the result is a substantial lowering of the impact on the productivity growth of firms continuing to export. Therefore, it is positive and significant for new entrants during the first five years after entrance. It also indicates the possibility that only a quite limited number of exporters continuing to see a higher growth rate for a long period of time.

All the coefficients of *EXIT* are conversely negative and significant at the 1 per cent statistical level in the TFP regressions. This indicates that exiting firms encounter bad outcomes, with about a 29 per cent decline in TFP growth and a 8 per cent decline in labor productivity growth. The phenomenon reflects that the more efficient exporters choose to exit the export market due to some disadvantage in production, such that the exit groups show a bad performance in productivity growth.

VI. REALLOCATION OF RESOURCES WITHIN THE ELECTRONICS INDUSTRY

In this section I seek to quantify the aggregate impact of the rapid expansion of exporting firms.[13] To understand the dynamic patterns of the electronics industry's productivity growth, I decompose five years of change in the industry's total factor productivity into between-firm (reallocation) and within-firm (own) effects following Bernard and Jensen (1999b).

$$\Delta PR_{ELEC} = \sum_{i=1}^{I} \Delta (PR_i \cdot SH_i) = \sum_{i=1}^{I} \Delta SH_i \cdot \overline{PR_i} + \sum_{i=1}^{I} \Delta PR_i \cdot \overline{SH_i}, \tag{7}$$

where PR_{ELEC} is the productivity of the electronics industry, PR_i is the productivity of an individual firm, and SH_i is the share of total sales of an individual firm. The first term of decomposition is the reallocation effect. It is equal to the product of the change in the sales share from period $t-1$ to t at the individual firm, ΔSH_i, and the average TFP in period $t-1$ to t, $\overline{PR_i}$. The second term is the own-productivity effect that is measured as the product of the change in total factor productivity from period $t-1$ to t, ΔPR_i, and the average sales share in period $t-1$ to t, $\overline{SH_i}$.

This decomposition enables us to quantify the contributions of the reallocation effect arising from more productive firms that are growing and the own effect showing that firms are growing more productive. When there is an increasing portion of the total share for firms with a higher than average productivity, the share effect is positive and results in a positive reallocation effect. On the other hand, the own effect will be positive when the mean of sale-weighted within-firm productivity growth is positive.[14]

We now take the transitions in and out of exporting into account and rewrite equation (7) as follows:

$$\Delta PR_{ELEC} = \sum_{j=1}^{J} \sum_{i=1}^{I} \Delta SH_i \cdot \overline{PR_i} + \sum_{j=1}^{J} \sum_{i=1}^{I} \Delta PR_i \cdot \overline{SH_i}, \tag{8}$$

where j represents the exporting group for firm i. I classify firms into four groups according to the exporting status in period $t-1$ to t. As defined in Section V, the four groups are composed of non-exporters (*NOEXP*), entrants (*ENTRY*), firms that exit the export market (*EXIT*), and continuing exporters (*CONT*). In the decomposition, we can separate the fractions of industry growth into that arising from the growth of

[13] Exports also have a positive impact on the growth of firms in terms of the percentage change in sales and employment, although these estimates are not reported here.

[14] The components of this decomposition are largely determined by firms with relatively large productivity changes in levels and/or by large firms with positive productivity growth. See Bernard and Jensen (1999b). In addition, the panel data used in this paper exclude new births and failures, which may induce an upward bias for own-effect and the magnitude of bias is hard to judge.

firms in each category and that due to within-firm productivity growth in each category.

Table VII shows the calculated fractions of aggregate productivity growth for each of the exporting groups during the 1986–91 and 1991–96 periods. In the decomposition for 1986–91, the overall TFP growth and VAE growth are 27.83 per cent and 15.53 per cent, respectively. While the reallocation effect accounts for a lower share of industry productivity as predicted, only 2.73 per cent of TFP growth and 17.83 per cent of VAE growth are contributed by an increase in the share of sales for the more productive firms. By contrast, the dominant source of overall productivity growth is the own effect, accounting for 97.27 per cent of TFP growth and 82.17 per cent of labor productivity growth, a surprisingly large part of overall growth. This tells us that the mean of sale-weighted within-firm productivity growth is the most important part of industry productivity growth. These findings are consistent with the prediction by Aw, Chung, and Roberts (2000) that the reallocation

TABLE VII

DECOMPOSITION OF ELECTRONICS TFP GROWTH BY FIRM TYPE

(%)

	Export Status	Reallocation Effect	Own Effect	Overall
A.	TFP growth (1986–91)			
	NOEXP(0,0)	0.49	1.29	1.78
	ENTRY(0,1)	0.07	0.18	0.25
	EXIT(1,0)	1.36	2.03	3.39
	CONT(1,1)	0.81	93.78	94.59
	All	2.73	97.27	100.00
B.	VAE growth (1986–91)			
	NOEXP(0,0)	1.56	5.29	6.85
	ENTRY(0,1)	0.97	1.90	2.87
	EXIT(1,0)	3.50	5.74	9.24
	*CON*T(1,1)	11.80	69.24	81.03
	All	17.83	82.17	100.00
C.	TFP growth (1991–96)			
	NOEXP(0,0)	−0.41	−0.46	−0.87
	ENTRY(0,1)	−0.43	−0.09	−0.52
	EXIT(1,0)	1.11	5.49	6.60
	CONT(1,1)	25.76	69.03	94.79
	All	26.04	73.96	100.00
D.	VAE growth (1991–96)			
	NOEXP(0,0)	−1.85	0	−1.85
	ENTRY(0,1)	−0.04	2.05	2.01
	EXIT(1,0)	1.73	9.43	11.16
	CONT(1,1)	21.02	67.67	88.09
	All	20.86	79.14	100.00

effect makes only a minor contribution to industry productivity growth in Taiwan.[15]

The results so far have suggested that entrant firms exhibit substantially faster growth and thus should account for a preponderant share of reallocation, while the results indicate that only less than 1 per cent of productivity growth arises from entrants. One possible explanation is that the share of entering firms to total firms accounts for only 11.89 per cent, and these entrants are much smaller in scale.

The dominant source of own-productivity growth comes from the firms that continue to export. They are responsible for a surprisingly larger share of the industry's productivity growth, accounting for 93.78 per cent of TFP growth and 69.24 per cent of labor productivity growth. This may seem surprising after the results show no relatively significant productivity growth and firm growth advantages for exporters. However, continuing exporters do account for 39.03 per cent of the sampled firms, and they are significantly larger in size and more productive. A combination of these factors may contribute disproportionately to overall productivity growth than for firms with a smaller scale and low productivity levels, even if they have the same growth rates. In addition, the results of Table VII would imply that a learning effect arising from a firm's exporting experience plays a key role in the productivity growth of Taiwan's highly export-intensive electronics industry. Non-exporters have a larger own effect than reallocation effect, and it may be due to the spillover of learning to other firms in the electronics industry.

Turning to the decomposition for the period 1991–96, these components show a similar although somewhat different pattern.[16] Compared to the previous period, the portion for the reallocation effect rises, while the importance of the own effect falls. I find once again that firms which continue to export are by far the most important group.

In Table VIII I decompose a longer time period, 1986–96, of aggregate productivity growth. This decomposition shows that the contributing fraction of each component of TFP growth approaches the same level of VAE growth in the long run. The reallocation effect due to more competitive firms growing is about 20 per cent, and the own-productivity effect is nearly 80 per cent. The groups of continuing exporters still play a very important role in aggregate growth, contributing 66–71 per cent of own-productivity effect.

In summary, the continuing exporting firms comprise the major groups that contribute to the growth of the electronics industry, and this result provides evidence for the experience of Taiwan's economic development. Because the domestic market is so much smaller than the global market, the island's government has supported the

[15] Using a similar method, Bailey, Hulten, and Campbell (1992) estimate reallocation effects of 31 per cent for U.S. manufacturing during 1972–87. Bernard and Jensen (1999b) find that the reallocation effect accounts for 41.9 per cent in the United States for the period 1983–92.

[16] The difference may result from enormous changes in the industrial environments of Taiwan since the late 1980s. Many less competitive firms are devoting themselves to outward foreign direct investment.

TABLE VIII

DECOMPOSITION OF ELECTRONICS TFP GROWTH BY FIRM TYPE, 1986–96

(%)

Export Status	Reallocation Effect	Own Effect	Overall
A. TFP growth			
NOEXP(0,0)	−0.01	0.07	0.06
ENTRY(0,1)	0.02	0.13	0.15
EXIT(1,0)	0.94	8.46	9.40
CONT(1,1)	19.14	71.25	90.39
All	20.09	79.91	100.00
B. VAE growth			
NOEXP(0,0)	−0.18	0.93	0.76
ENTRY(0,1)	0.33	3.06	3.39
EXIT(1,0)	0.85	9.81	10.66
CONT(1,1)	19.15	66.04	85.19
All	20.15	79.85	100.00

development of a strategic exporting industry since the 1960s. Ever since the 1980s, the electronics industry has become the most important exporting industry in Taiwan, and the electronics industry has played a dominant manufacturing role in global high-tech products. The OEM development mode has exposed exporting electronics firms to a highly competitive global market and enabled them to gain access to advanced management, designs, and production technologies from big foreign buyers. In this way Taiwan's electronics firms have gradually enhanced their technology and productivity which has made them highly competitive in the world.[17]

VII. CONCLUSION AND POLICY IMPLICATION

Previous empirical studies have shown that there is a strong, widespread correlation between exporting and productivity, but there have been few studies that have addressed the more complex issue of the direction of causality and whether exporting plays a causal role in generating higher productivity growth. The interplay between productivity and international trade on long-run growth has been discussed before, while various fields of economics have produced both cross-country and cross-industry studies. However, firm-level studies are quite limited.

This paper uses 1986–96 panel data for Taiwan electronics firms to investigate the relationship between exporting and productivity. Simple statistics show exporters to be larger and substantially more productive than non-exporters in each of

[17] The factors stimulating overall productivity growth include the R&D effort, and the inflow of overseas Taiwanese. These influences are not discussed in this paper. For the influence of R&D and technology importing on the productivity of Taiwan manufacturing, see Yang, Chen, and Branstetter (2001).

the three-digit industries examined. Consistent with other literature, the regression results indicate that exporting actually has a positive impact on productivity level.

To evaluate the importance of the self-selection and learning-by-exporting mechanisms, this study used both aggregate and firm-level data to explore the issue. The Granger-causality tests show that self-selection and learning-by-exporting coexist in the Taiwan electronics industry, and the former seems to be more significant. Good firms become exporters and exporting offers access to foreign advanced technology, thus enhancing productivity.

The panel data also show how the link between export and productivity growth between exporters and non-exporters changes over time. This study found evidence that exporting per se is associated with faster productivity growth, and this can be used to support the learning-by-exporting hypothesis, while the effect seems to decay as time passes. The productivity path for a firm switching from being a non-exporter to an exporter shows a faster rise in productivity growth and a flat trajectory that is somewhat higher relative to non-exporters when the firm continues as an exporter for the next five years.

Decomposing the productivity growth of the electronics industry shows that the magnitude of reallocation effect due to changes in market share is not the most important part, accounting for only 2.73–26.04 per cent in different measures of productivity growth and 20 per cent in the long-run analysis for 1986–96. In contrast, the dominant source of aggregate growth comes from the own-productivity effect, and it is largely contributed by continuing exporters, accounting for a surprisingly larger share of about 70 per cent of the industry's productivity growth.

Regarding policy implication, the export-orientation strategy has been used successfully to develop Taiwan's economy. The government has taken many measures, including the establishment of a science-based park and providing tax incentives, financial assistance, and R&D grants, to encourage and support the development of its electronics industry. The development of the electronics industry has been rapid and successful and it is now the most important industry in terms of the share of exports and GDP in Taiwan. It also is a major player in the global high-tech products market.

Whether the government's policy of pumping most of its resources into export-oriented firms and/or industries is appropriate should be examined more carefully. The performance difference between the two groups of firms (exporters and non-exporters) may be evidence of this policy. This study's findings indicate that exporters actually outperform non-exporters in productivity. The OEM operation mode has enabled Taiwan's exporting electronics firms to adopt and learn advanced technology and then improve their productivity. Therefore, switching from being a non-exporter to an exporter allows a firm to have faster productivity firm growth.

The results of this study also provide firm-level evidence that exports and export policies play a crucial role in stimulating growth. Generally speaking, broad gov-

ernment support for exports has been a successful and highly effective way to enhance the absorption of foreign advanced technology, thus boosting productivity and output growth in Taiwan.

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