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外銷活動對廠商總要素生產力和技術員工需求之影響

The Impact of Export Activity on Total Factor Productivity and Demand for Skilled Workers

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中文摘要

本研究探討台灣電子業外銷活動與生產力之關係。儘管內銷廠商是電子業廠商輪替的主要來源，外銷廠商佔產業整體產出變化的比重較大。至於持續存活的廠商進出外銷市場的頻率尚稱穩定。

在考慮廠商輪替的選擇偏誤後，長期而言，我們支持自我選擇和外銷學習假說。然而，外銷廠商短期的生產力會受到景氣循環的影響。在景氣衰退階段，持續外銷的廠商生產力成長與持續內銷的廠商差異不大；但在景氣較佳階段，持續外銷的廠商績效表現優於持續內銷的廠商。透過產業總和生產力變動的分解，可發現持續外銷的大型廠商是台灣電子業生產力成長的主力。

關鍵詞：外銷，生產力

Abstract

This paper examines the relationship between exporting and productivity in the Taiwan electronics industry. While local market-oriented plants are the main source of high plant turnover in the electronics industry, exporting plants account for a great amount of change in total output. The degree of transition in and out of the export market for continuing plants is relatively modest.

After accounting for selection bias due to exit, we support the self-selection mechanism and the learning-by-exporting mechanism over a longer time horizon. However, the productivity performance of exporting plants is sensitive to cyclical patterns. While the plants exporting throughout show smaller differences in productivity growth from non-exporters in the downturn period, continuing exporters outperform non-exporters in the upturn period. The decompositions of the change in aggregate productivity show that large continuing exporters contribute the largest fraction of aggregate productivity growth in the Taiwan electronics industry.

Key Words: Export, Productivity

JEL Code: F14, L6

1. Introduction

In recent years, a growing body of research has emerged on the link between exporting and firm performance. Bernard and Jensen (1995, 1999, 2001a,b,c), Clerides et al. (1998), and Aw et al. (2000), among others, have identified characteristics of the behavior and relative performance of exporting firms that hold consistently across a number of countries.[1] The main findings include: (1) successful firms are more likely to export, and (2) firms that export tend to be more successful. With regard to the first point, Aitken et al. (1997) find that plant size, wages, and especially foreign ownership are positively related to export decisions in Mexico. Bernard and Jensen (2001a,b) and Roberts and Tybout (1997) use a dynamic model of export decisions and suggest that sunk costs and plant heterogeneity are important in explaining export status in the U.S., Germany, and Columbia. Bernard and Jensen emphasize that past success is the best indicator of future exporting, and Roberts and Tybout find that prior export experience increases the probability of exporting.

The direction of causality between exporting and productivity has been examined recently using plant- and firm-level panel data. Using manufacturing data for the U.S. and Germany, Bernard and his colleagues find a positive relationship between exporting and productivity, but the causality runs from productivity to exporting rather than the other way (Bernard and Wagner, 1997; Bernard and Jensen, 1999, 2001c). Clerides et al. (1998) and Isgut (2001) have also found strong support for the self-selection mechanism in Columbia, Mexico, and Morocco. Aw et al. (2000) find a different picture of Taiwanese manufacturing plants. They suggest that both self-selection and learning-by-exporting play important roles in explaining the link between exporting and productivity. However, Liu et al. (1999) report little evidence

[1] Tybout (2000) surveys the extensive literature on micro issues in developing countries.

that exporting itself can provide performance gains for Taiwanese electronics plants.

Since most of the research has suggested that exporting confers little benefit in the form of faster productivity growth at the plant level, trade economists have begun to consider not just the within-plant effects of exporting, but also the importance of cross-plant reallocation in improving aggregate productivity growth.[2] Two recent theoretical papers, Bernard et al. (2000) and Melitz (2001) emphasize the importance of trade-driven reallocation effects in aggregate productivity. Bernard et al. (2000) use an extension of the Ricardian model to discuss the enormous plant- and firm-level heterogeneity in exporting and productivity.[3] By relaxing the assumption of perfect competition, they conclude that plants with higher *ex ante* productivity are more likely to export but that exporting does not drive higher productivity. However, reductions in trade barriers and other increases in openness will increase aggregate productivity as more productive plants grow and less productive plants fail. The researchers also attempt to explain the correlations between productivity, exporting, and plant size through the positive association of each with underlying efficiency. Melitz (2001) uses a dynamic model and suggests that an increase in international trade exposure leads to the reallocation of resources towards more productive firms. A subsequent empirical paper by Bernard and Jensen (2001c) confirms the above predictions in the U.S. They report that more than 40 percent of total factor productivity growth in the manufacturing sector comes from changing output shares across plants. The reallocation to more productive plants is mainly towards exporting plants, with higher productivity exporters growing faster than lower productivity non-exporters.

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[2] To understand the effects of trade on micro issues, trade economists have begun to develop models with imperfect competition (Melitz, 2001; Tybout, 2002).

[3] Their model extends basic Ricardian theory to accommodate many countries, geographic barriers, and imperfect competition.

In this paper, we investigate the importance of export activity on plant performance and aggregate productivity growth, using census data from the Taiwan electronics industry from 1986, 1991, and 1996. We address three main issues. First, we describe plant turnover and switching of export status. Second, we test the self-selection and learning-by-exporting hypotheses. Third, using a decomposition method, we evaluate the contributions of within-plant, between-plant, and entry and exit on aggregate productivity growth based on plant export status and plant size.

We find substantial plant turnover in the Taiwan electronics industry. Among the new entrants and departers, local-market-oriented plants are the major source of turnover, while export-market-oriented plants contribute a greater proportion of changes in industry output. The degree of transition of continuing plants in and out of the export market is relatively modest, with entry and exit rates in the export market ranging from 3.5 percent to 6.8 percent per year over the period. Among the survivors, continuing exporters are substantially larger than continuing non-exporters and account for more than half the total output in the industry.

After controlling for selection bias due to exit, our evidence supports the self-selection and learning-by-exporting mechanisms over a longer horizon. Good plants are more likely to become exporters. Plants that export across all three census periods have significantly higher productivity growth than non-exporters. For the five-year periods, the effect of exporting on subsequent productivity is sensitive to cyclical patterns. While the plants exporting throughout show fewer differences in productivity growth than non-exporters in the downturn period, continuing exporters outperform non-exporters in the upturn period.

We decompose the change in aggregate productivity into within-plant and between-plant contributions for continuing plants as well as entry and exit contributions. The decompositions show that exporting plants and large plants account for a great fraction of changes in aggregate productivity growth. The largest contribution comes from large continuing exporters, through the success or failure of their foreign markets. These findings emphasize the important role of large continuing exporters in the Taiwan electronics industry.

The remainder of the paper is organized as follows: Section 2 describes the data, measurement, and descriptive analysis; Section 3 describes plant turnover and switching of export status in the Taiwan electronics industry; Section 4 examines the relationships between export activity, productivity growth, and plant growth. In Section 5, we decompose changes in aggregate productivity for the electronics industry into within-plant effects, between-plant effects, and the effects of entry and exit, and also examine the relative contributions of export status. Conclusions are in Section 6.

2. Data, Measurement, and Descriptive Analysis

The data for this study are drawn from 1986, 1991, and 1996 Taiwanese manufacturing censuses conducted by the Statistical Bureau of Taiwan of Executive Yuan. We restrict our attention to plants in the electrical machinery and electronics industry. The original data sets for the electronics industry consist of 7,530 plants in 1986, 11,686 plants in 1991, and 14,165 plants in 1996. After excluding very small plants (those with two employees or fewer) and plants missing information on key variables (gross output, capital stock, labor, and material expenditures), we have 5,923 plants in 1986, 8,364 plants in 1991, and 9,639 plants in 1996 remaining for analysis. Since we are interested in evaluating the productivity differentials that occur during transition years in and out of exporting, the ID codes of the individual plants have been matched between censuses so that we can create an unbalanced panel across censuses.

The measure of productivity used here is similar to that used by Baily et al. (1992) and Foster et al. (1998). The total factor productivity (TFP) is measured as

$$\ell n\text{TFP}_i = \ell n\text{Q}_i - \alpha_K \text{K}_i - \alpha_L \ell n\text{L}_i - \alpha_M \ell n\text{M}_i \qquad (1)$$

where Q_{it} is real gross output, K_{it} is real capital stock, L_{it}, is labor input, and M_{it} is real value of materials. The α's are the input factor elasticities.

The measure for real gross output is defined as total plant sales deflated by the producer price index in the electronics industry. The measure for capital stock consists of factory buildings, plant equipment, and transportation equipment. It is constructed by subtracting inventories, cash, other short-term liquid investments, land, and other assets from the book value of capital stock and is deflated by the capital goods price deflator for the electronics industry. Labor input is measured as number of workers, including production and non-production workers. Material input includes raw materials, fuel, and electricity expenditures. Raw material expenditures are deflated by a raw material price index. Fuel expenditures are deflated by an energy price index, and electricity expenditures are deflated by an electricity price index.[4]

We assume constant returns to scale, so the sum of factor elasticities equals one.[5] Labor and material input elasticities for each plant are measured as average cost shares in a given year within the same plant-size class in the electronics industry.[6] Thus, factor elasticities of plants are allowed to vary across size classes and over time. Plants are grouped into three size classes according to number of employees: 3-50,

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[4] One potential problem for value-based productivity measures is that they may confound productive efficiency and market power (Bernard et al., 2000). Further, these productivity measures may miss the effect of product quality improvements when technology leads to product innovation rather than process innovation (Kraay et al., 2001).

[5] Huang and Liu (1994) estimate a stochastic frontier production function and find that the electronics industry in Taiwan is close to a constant return to scale.

[6] We also obtain the factor weights from the TFP calculation by regressing Q on K, L, M and impose constant return to scale restraint. The basic estimation results are similar.

51-100, or over 100.

Table 1 presents descriptive statistics of plant characteristics for exporters and non-exporters.[7] We define exporters as plants with positive export sales, and non-exporters as those with exclusively domestic sales. Exporters are found to be substantially larger than non-exporters in size, nearly six times larger in terms of total employment; this is consistent with other empirical evidence. Exporters are also more productive and capital-intensive than non-exporters. On average, TFP is 10 percent greater for exporters in 1991 and 13 percent greater in 1996. Average capital-labor ratios among exporting plants are approximately 1.4 times higher than those of non-exporting plants. In addition, exporters systematically pay higher wages. The average annual wage for exporters per employee is NT$338,520 in 1996, about 19 percent higher than that of non-exporters.[8] The share of non-production workers is 28 percent for exporting plants, somewhat higher than the 24 percent figure for non-exporting plants, suggesting that exporters tend to employ a higher proportion of white-collar workers. The average age of exporting plants is about three years older than that of non-exporting plants. The share of foreign equity participation is 5.3 percent for exporters, much higher than the corresponding figure, 0.5 percent, for non-exporters. Overall, the Student t-test suggests that we can reject the hypothesis that there are no differences in characteristics between exporters and non-exporters.

Taken together, exporters in the Taiwanese electronics industry are larger and older, pay higher wages, and have higher foreign equity participation and degrees of capital intensity and productivity. These findings are consistent with the evidence reported for Taiwan by Aw and Huang (1995) and Liu et al. (1999), and also confirm previous results for the U.S., Germany, and Columbia (Bernard and Jensen, 1995;

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[7] To save the space, we do not report the descriptive statistics for 1986 census.
[8] The 1986 exchange rate is 35.50 New Taiwan Dollars (NT$) per US$.

Bernard and Wagner, 1997; Isgut, 2001).

In Table 2, we further examine the links between plant size, export behavior, and productivity. We classify plants into three categories according to plant size: 3-50, 51-100, or more than 100 employees. There are significant differences in productivity and export activity across size categories. For plants with more than 100 employees, TFP is 0.3 percent, slightly lower than that of plants with fewer than 50 employees in 1991, but more than 9 percent higher than that of plants with fewer than 50 employees in 1996. We also find a positive relationship between export activity and plant size. In 1996, the percentage of exporting plants is between 23 and 80 percent, with large plants more likely to engage in export activity. The percentage of export shipments in total sales is between 25 and 56 percent, with export sales concentrated in the large plants. Exporting plants with more than 100 employees account for 68 percent and 64 percent of export sales in 1991 and 1996, respectively.

3. Plant Turnover and Switching of Export Status

To evaluate the productivity changes that occured during transition years in and out of exporting, we use unbalanced plant-level panel data sets to track the switching of export status over time. In this section, we begin with a description of plant turnover in the industry, then focus on the entry and exit patterns in the export market.

Four entry and exit variables are measured for the electronics industry in each of the time periods. Entry rate is defined as the number of plants that were first observed in operation in the industry at the end of each time period, relative to the total number of plants that were in operation at the end of the time period. Entrants' market share is defined as the entrants' total real output relative to total industry real output at the end of the period. The exit rate (share) expresses the number (output) of plants last observed in operation at the beginning of each time period as a proportion of the total number (output) of plants in operation at the beginning of the period.

Table 3 presents the values of entry and exit variables in each pair of census years. There is substantial entry and exit in Taiwan's electronics industry. For the five-year periods, the entry rate is 69.2 percent in 1986-91 and 52.7 percent in 1991-96 respectively. New entrants account for 39.1 percent and 29 percent of total output during these two periods. The exit rate is 56.5 percent in 1986-91 and 45.5 percent in 1991-96, accounting for 34.7 percent and 28 percent of total industry output, respectively. The degree of turnover is even more significant over a longer horizon. This evidence is consistent with low-threshold entry and exit costs made possible by the presence of a dense network of subcontractors in the Taiwanese manufacturing sector.

To understand more about the entry and exit patterns of the export market, we examine the transitions in and out of exporting for our plant samples. Table 5 reports the fractions of plants that switch their export status across census years. For the five-year census periods, the continuing plants are clustered into four categories: Neither, Thru, Start, and Stop. *Neither* contains plants that did not export during the period; *Thru* contains plants that exported throughout. *Start* holds plants that starting exporting during the period, and *Stop* contains those plants that were exporters but ceased. For the ten-year period, continuing plants are classified into three categories: Never, Always, and Ever. *Never* contains plants that produced solely for the domestic market in all three census periods; *Always* contains plants that exported in all three census periods; and *Ever* contains plants that exported during one or two of the three census periods. The high plant turnover in Taiwan's electronics industry has led us to cluster the entrants and departers into four groups based on their market orientation at the beginning or the end of the period: Local entrant, Export entrant, Local exiter, and

Export exiter. The *Local entrant* category comprises non-exporting entrants and the *Export entrant* category comprises exporting entrants, whereas the *Local exiter* and *Export exiter* categories comprise non-exporting departers and exporting departers, respectively.

As the table shows, the degree of switching is modest for the continuing plants in the Taiwan electronics industry. During the 1986-91 period, 3.5 percent of non-exporters enter the foreign market and 4.5 percent of exporters leave the foreign market, accounting for 3.5 percent and 3.8 percent of total industry output, respectively. The entry and exit rates in the export market rise to 6.2 percent and 6.8 percent during the 1991-96 period. In both five-year periods, plants that exported throughout account for 11 percent of plants and more than half of total output. The average size of continuing exporters is substantially larger than that of continuing non-exporters. Continuing exporters are nearly ten times larger in terms of total employment. Over the longer horizon, the number of continuing exporters and continuing non-exporters relative to the total number of plants is quite similar, about 5.2 percent. However, continuing exporters account for 28.8 percent of output, while continuing non-exporters account for only 1.4 percent of total output.

With respect to the plants that entered or exited the electronics industry, local-market-oriented plants are the main source of plant turnover. Non-exporting entrants and departers account for 40.1 percent and 34.8 percent of plants in the 1991-96 period, while exporting entrants and departers account for only 12.6 percent and 10.7 percent of plants in the same period. Nevertheless, the export-oriented plants contribute heavily to the changes in industry output. The output shares of exporting entrants and departers are both 22 percent, far higher than the corresponding values for non-exporting entrants and departers. This is not surprising since exporting plants are larger than their local counterparts. Among the entrants and departers, the exporting plants are five to six times larger than non-exporting plants in terms of total employment. A similar pattern also exists for the ten-year period.

4. Export Activity, Productivity Growth, and Plant Growth

In this section, we use unbalanced panel data to examine productivity changes in plants after entering or departing the export market. We also investigate the relationship between plant growth, measured alternatively by shipments and employment, and initial export status.

The existing literature suggests two reasons for an improvement in firm performance after beginning to export. First, serving a larger market might allow a firm to take advantage of economies of scale in production or to cushion variations in domestic demand (Feder, 1982). Second, exporting may improve a firm's productivity through the effect of learning-by-exporting (Clerides et al., 1998). Firms that participate in the export market may have better access to technical expertise, including new product designs and production methods, through their foreign buyers or competitors.

Since most studies of the relationship between exporting and productivity growth ignore selection bias arising from balanced panels, we propose the following sample selection model for plant survival and productivity growth:

$$\text{Survival}_i = b_0 + b_1\text{EXPORT}_i + b_2\text{X}_{1i} + \text{u}_{1i} \quad (2)$$

$$\Delta\text{TFP}_i = d_0 + d_1\text{EXPORT}_i + d_2\text{X}_{2i} + d_3\lambda_i + \text{u}_{2i} \quad (3)$$

Equation (2) is a probit regression of the discrete variable Survival, which takes the value one if the plant survives over the 1986-91 or 1991-96 period and zero if it does not, on the initial export dummy (EXPORT) and a vector of initial plant characteristics (X_1), including age, log of total employment, and 9 four-digit industry dummies. Equation (3) describes growth in plant-level productivity from 1986 to

1991 or from 1991 to 1996 as a function of initial export dummy and plant characteristics in 1986 and 1991. The dependent variable is total factor productivity growth (ΔTFP). Among the independent variables, EXPORT is an export dummy and X_2 is a vector of initial plant characteristics, including age, log of total employment, average wages, share of non-production workers, 9 four-digit industry dummies, and 21 city/county dummies. If the coefficient of the export dummy in equation (3) is positive and significant, then exporting does improve plant performance.

Because productivity growth is only observed for surviving plants, a sample selection problem exists. To solve this problem, we include the estimated inverse Mill's ratio λ constructed from the survival regressions as an additional regressor in the productivity growth-rate regressions. White's consistent estimator of the covariance matrix is used to adjust for the heteroskedasticity of the error term.

The results of the productivity growth regressions are reported in Panel A of Table 5. The probit estimates from the survival regressions suggest that younger and smaller plants and plants that did not engage in export activity have higher probabilities of exit.[9] In the regressions for productivity growth, the coefficient of the export dummy variable is insignificantly positive in the 1986-91 downturn period and the 1991-96 upturn period, as well as the longer 1986-96 horizon.[10] On average, exporters have a five-year productivity growth 6.6 percent higher than that of non-exporting plants, after the exporting activity for the 1991-96 period. Over the longer 1986-96 time period, exporters have a ten-year productivity growth 12 percent

[9] To save space, we do not report the estimation results for survival regression in the table.

[10] The aggregate TFP growth in the Taiwan electronics industry for the 1986-91 and 1991-96 periods is -2 percent and 34 percent, respectively. The decrease in TFP growth for the 1986-91 period may have been partly driven by the substantial appreciation of the NT dollar against the US dollar during that period. Between 1986 and 1991, the exchange rate for the NT dollar appreciated by 22 percent against the US dollar. We will discuss decompositions of aggregate TFP growth in Section 5.

higher than that of non-exporting plants. The inverse Mill's ratio (λ) coefficient is significant in each intervals, which indicates that selection bias is not statistically negligible.

To learn more about the nature of the export activity involved, we examine the productivity differentials that occur during transition years in and out of exporting. We re-estimate the productivity-growth-rate regressions as the following:

$$\Delta \mathrm{TFP}_i = d_0 + d_1 \mathrm{START}_i + d_2 \mathrm{THRU}_i + d_3 \mathrm{STOP}_i + d_4 X_{2i} + d_5 \lambda_i + \mathrm{u}_{2i} \qquad (4)$$

where the dummy variables for export status are defined as START = 1 if the plant did not export in the initial year but did after five years, THRU = 1 if the plant exported throughout the period, and STOP = 1 if the plant exported in the initial year but not after five years. The plants that did not export during the period are the reference category.[11] The coefficients d_1, d_2, and d_3 estimate the productivity differentials for the entrants, departers, and survivors in the export market. For the ten-year period, two dummy variables for export status are defined as ALWAYS = 1 if the plant exported in all three census periods, and EVER = 1 if the plant exported at any time during the census periods. The reference category is plants that never exported in any of the three census years. If we support the self-selection hypothesis, then the coefficient of START (or EVER) is positive and significant. If we support the learning-by-exporting hypothesis, then the coefficient of THRU (or ALWAYS) is positive and significant.

The estimation results are presented in Panel A of Table 6. We find, consistently, that plants entering the export market have a substantially higher productivity growth than do continuing non-exporters. On average, plants that enter the export market have a higher productivity growth, by 9.3 to 14.4 percent, than

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[11] The five-year period between censuses makes it impossible to observe plants that re-switched their export status during the period.

continuing non-exporters. While the coefficient of THRU is insignificantly positive for 1986-91, continuing exporters appear to have higher productivity growth than continuing non-exporters in 1991-96. These patterns seem to be consistent with the self-selection hypothesis, but there is mixed evidence for learning-by-exporting.[12] However, the learning-by-exporting mechanism is more significant over a longer horizon. Plants that export in all three census periods and those that become exporters across census years have ten-year productivity growths 13.4 and 9.8 percent higher than plants that never engage in export activity.

Our findings here are generally consistent with the evidence for Taiwan in Aw et al. (2000), but somewhat different from the results for the U.S. reported by Bernard and Jensen (1999, 2001c), for Germany by Bernard and Wagner (1997), and for Columbia, Morocco, and Mexico by Clerides et al. (1998).[13] These studies support the self-selection mechanism but do not support the learning-by-exporting mechanism.[14] It is also worth noting that our results are at odds with those of Aw et al. (2000). Based on 1986 and 1991 census data, they find that electronics plants that exit the export market have 4.4 percent higher productivity than non-exporters.

The evidence presented above suggests that high-productivity plants enter the market, but whether the export activity improves subsequent productivity depends on the time period. Since exporters may contribute to productivity gains in the industry through a combination of higher productivity levels and faster plant growth, we

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12 We cannot examine the causality between exporting and productivity based only on the three censuses reviewed here.

13 Bernard and Jensen (2001c) find that plants entering the export market have significantly faster productivity growth rates than continuing non-exporters, and plants that exit the export market have lower productivity growth rates than continuing non-exporters. However, they also report that continuing exporters underperform continuing exporters in terms of productivity growth, which contrasts with our results here.

14 Using balanced panel data on 875 Taiwanese electronics plants from 1989 to 1993, Liu et al. (1999) find little evidence of learning-by-exporting over a short time period.

further examine the relationship between export status and plant growth. We again estimate a sample selection model of survival and growth, with sales growth and employment growth as the dependent variables in equation (4).

The results of the regressions for shipment growth rate and employment growth rate are given in Panels B and C of Table 5. Unlike the productivity growth rates, the coefficients of export dummy variables are all insignificant but positive in the sales growth rate regressions. However, if we measure plant growth in terms of employment, exporters show higher employment growth rates than non-exporters. To shed light on the changes in export status, we rerun the specification in equation (4) with these two measures of plant growth as the dependent variables. The results are reported in Panel B and C of Table 6. For the five-year periods, plants that export throughout have sales growth 1.7 to 3.8 times faster than continuing non-exporters. New entrants into exporting also have sales growth 2.6 to 3.5 times faster than non-exporters. For the ten-year period, plants that always export and those who ever export show significantly faster growth than plants that never export across the three census periods. Similar estimation results are found in employment growth rate regressions. These results suggest that the reallocation of resources among continuing exporters and new entrants into the export market may be another important source of trade affecting productivity growth.[15]

To summarize, our findings support the self-selection hypothesis and suggest evidence for learning-by-exporting over a longer period. Although there are few differences in productivity growth between continuing exporters and continuing non-exporters in the 1986-91 period, continuing exporters outperform non-exporters in the 1991-96 period. In both periods, continuing exporters have significantly faster

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[15] Since we use three census year data, we cannot perform a direct Granger causality test.

shipment growth and employment growth than non-exporters. These results suggest that the survivors in the export market may play an important role in industry productivity growth over the business cycle.

5. Decomposition of Aggregate Productivity Growth

In this section, we further decompose changes in aggregate productivity growth rates into three components: within-plant, between-plant, and entry and exit effects. We begin by defining the level of industry productivity in year t as the market-share weighted sum of the plant productivity levels.

$$\ell n\mathrm{TFP}_t = \sum_i \theta_{it} \ell n\mathrm{TFP}_{it} \qquad (5)$$

where θ_{it} is the share of the *i*th plant in industry output and $\ell n\mathrm{TFP}_{it}$ is plant total factor productivity calculated as described in Section 2. The growth in TFP between year $(t-\tau)$ and t is then

$$\Delta\mathrm{TFP}_t = \ell n\mathrm{TFP}_t - \ell n\mathrm{TFP}_{t-\tau} \qquad (6)$$

Following Griliches and Regev (1995) and Foster et al. (2001), we can decompose the industry TFP as follows:

$$\Delta\mathrm{TFP}_t = \sum_{i\in C}\left[\left(\frac{\theta_{it}+\theta_{it}}{2}\right)(\ell n\mathrm{TFP}_t - \ell n\mathrm{TFP}_{it-\tau})\right]$$
$$+ \sum_{i\in C}\left[\left(\frac{\ell n\mathrm{TFP}_{it-\tau} + \ell n\mathrm{TFP}_{it}}{2}\right)(\theta_{it}-\theta_{it-\tau})\right]$$
$$+ \left(\frac{\theta_{Et}+\theta_{Xt-\tau}}{2}\right)(\ell n\mathrm{TFP}_{Et} - \ell n\mathrm{TFP}_{Xt-\tau}) + \left(\frac{\ell n\mathrm{TFP}_{Et} + \ell n\mathrm{TFP}_{Xt-\tau}}{2}\right)(\theta_{Et}-\theta_{Xt-\tau}) \qquad (7)$$

where *C, E,* and *X* denote the set of continuing plants, entrants, and departers during the period. The first term represents the within-plant component that comes from the improvements in each continuing plant. The second term represents the between-plant component that results from the changes in output shares among continuing plants.

The last two terms represent the contributions of entrants and departers.[16] The third term is the contribution that comes if the productivity of the entering plants in *t* differs from the period *(t-τ)* productivity of the exiting plants, and the fourth term captures the reallocation of market shares between entrants and departers.[17] This decomposition allows us to quantify the contributions in aggregate productivity growth due to plants becoming more productive or more productive plants growing larger. The within effect is positive if the mean of output weighted within-plant productivity growth is positive, while a positive between effect reflects an increase in output share from plants with higher productivity.

To help understand the sources of these changes, we first perform decompositions based on the export statuses of plants over the five-year intervals. Like the classification of plants in Section 4, the four export categories for continuing plants are Neither, Thru, Start, and Stop. Table 7 reports the results of the decomposition for the 1986-91 and 1991-96 periods. To begin with, the TFP growth fell to slightly below zero during the 1986-91 period (-2.33 percent), but rose to 34.14 percent during the 1991-96 upturn period, which comes to a rate of 6.83 percent per year.

The contribution from the within effect is 20.38 percent during the 1991-96 period, accounting for almost 60 percent of TFP growth. Although the within effect is negative and smaller in magnitude, -6.04 percent, for the 1986-91 period, it is the

[16] Unlike Aw et al. (2001), we combine the last two terms into the entry and exit term following the approach used by Foster et al. (2001). Aw et al. (2001) interpret the third term as the entry and exit effect and combine the second and fourth terms into a single market share reallocation term.

[17] Foster et al. (2001) review several alternative decomposition methods used in empirical studies. They conclude that the decomposition method proposed by Griliches and Regev (1995) is preferable to the others. The advantage of this method is that it is less sensitive to measurement error in outputs and inputs. However, the measured within effect may partially reflect the reallocation effect since it incorporates the share in period t.

dominant source of decline in TFP. The contribution of market share reallocation among continuing plants is relatively small in magnitude for both periods. During the 1991-96 upturn period, the between effect is 3.22 percent, accounting for only 9 percent of TFP growth. In contrast, the effect of entry and exit on aggregate TFP growth is quite large. It is as large as 10.55 percent (2.11 percent per year) during the 1991-96 period, accounting for more than 30 percent of TFP growth during that period. The positive effect of entry and exit also help to offset the productivity decline among continuing plants for the 1986-91 downturn period.

Overall, we find that the productivity growth of continuing plants and the productivity differentials between entering and exiting plants are both major sources of aggregate productivity growth. The relative importance of the entry and exit effect is largely consistent with the evidence found in Chile and Columbia by Liu and Tybout (1996), in Korea by Hahn (2000), and in Taiwan by Aw et al. (2001), but contrasts with the U.S. evidence presented by Baily et al. (1992), Bernard and Jensen (2001c), and Foster et al. (2001). Compared with the cyclical upturn period, the contribution of reallocation to aggregate TFP growth relative to entry and exit tends to be greater during the cyclical downturn period. This result is similar to the evidence found in Korea (Hahn, 2000) and the U.S. (Baily et al., 1992; Foster et al., 2001).[18]

Another major finding from the decompositions is the importance of continuing exporters. The rise/decline in aggregate productivity growth is in large part attributable to the productivity performance of continuing exporters. For the 1991-96 upturn period, the within and between effects for continuing exporters contributing to

[18] Bernard and Jensen (2001c) focus on U.S. continuing plants in their decomposition analysis. They find that entry and exit play only a minor role in productivity growth. Hahn (2000) finds that the relative contribution of the share effect in Korea is smaller than in the United States, although there is also a cyclical pattern that accord well with the U.S. results reported by Baily et al. (1992) and Foster et al. (2001).

overall TFP growth are 57 percent and 11 percent respectively, indicating that 68 percent of overall TFP growth resulted from continuing exporters. Conversely, Starters and Stoppers show small contributions to both within and between effects. Our findings are somewhat at odds with the U.S. evidence reported by Bernard and Jensen (2001c). Although these authors find that continuing exporters account for a greater fraction of aggregate TFP growth, over 87 percent of the overall TFP growth come from the expansion of continuing exporters. Our result also confirms previous findings that there is significantly higher productivity growth of continuing exporters relative to continuing non-exporters during the 1991-96 upturn period.

In order to provide a better estimate of the relative importance of domestic and foreign shipments, we break out the within, between, and entry and exit effects into domestic and foreign components following the approach of Bernard and Jensen (2001c).[19] The results are given in Table 8. The gains or losses in productivity for continuing exporters are mainly attributable to the success or failure of their foreign markets. As the table shows, exports contribute a large amount, about 65 to 77 percent, to the within effect of continuing exporters. We also find a strong positive reallocation contribution for foreign shipments among continuing exporters in both periods, suggesting that these plants are growing faster because of export growth. The within and between effects for continuing exporters attributed to foreign shipments account for almost half of the aggregate TFP growth in 1991-96. Although the positive contribution for domestic shipments among entrants and departers offset some of the decline in overall TFP growth during the 1991-96 downturn period, the foreign shipments of entrants and departers contribute more to the TFP growth during the

[19] The census asks the plants to report the value of products to be shipped directly to foreigners. The products that were shipped for further manufacture or assembly in Taiwan or sold to a trading company were not included in the export values. Therefore, the foreign shipments values presented here may be lower than the actual values.

1991-96 upturn period.

We further decompose the changes in TFP growth into within, between, and entry and exit effects based on export status and size class. We classify plants into six export categories. In addition to the four export categories for continuing plants, we include another two market orientation categories: entrants or departers with export activity (*Export entrant* and *Export exiter*) and entrants or departers producing solely for the local market (*Local entrant* and *Local exiter*) to our analysis. Plants are grouped into three size classes according to the number of employees in the initial year: 3-50, 51-100, and over 100. The results of decompositions are presented in Table 9.[20]

Looking at the interaction of export status and size class of the plant, we find that large exporters throughout show the largest contributions to both within and between plant effects in aggregate TFP growth. For the 1991-96 upturn period, the decomposition shows that over 70 percent of overall TFP growth comes from large continuing exporters with more than 100 employees. By contrast, the small and medium continuing exporters only account for a negligible fraction of the aggregate TFP growth. Since our measure of industry productivity growth is defined as the market-weighted sum of plant productivity levels, it is not surprising that the large continuing exporters made a significant contribution to aggregate productivity growth.

With respect to the entry and exit effect, the net effect of entry and exit for small exporting plants offset part of the strong negative within effects from continuing exporters during the 1986-91 downturn period, whereas the entry and exit effect for large exporters contribute more during the 1991-96 upturn period. Overall, exporting plants and plants with more than 100 employees account for the bulk of both the

[20] To save the space, we do not report the decomposition results for the 1986-91 period.

within-plant and between-plant effects in TFP growth.

6. Conclusions

We find substantial plant turnover in the Taiwan electronics industry. While local market-oriented plants are the major source of the turnover, export-oriented plants contribute more to the changes in industry output. The degree of transition in and out of the export market for continuing plants is relatively modest, with entry and exit rates ranging from 3.5 percent to 6.8 percent over the five-year periods. Among the continuing plants, continuing exporters are substantially larger than continuing non-exporters, accounting for more than half the total output in the industry.

After accounting for selection bias due to exit from the market, our results support the self-selection hypothesis and provide evidence for learning-by-exporting over a longer time period. Good plants become exporters. Productivity growth rates are higher in the years before plants enter the export market. For the ten-year period, plants that export in all three census periods or those that export at any time during the period have significantly higher productivity growth rates than non-exporters. For the five-year periods, productivity performance for continuing exporters is sensitive to cyclical patterns: plants exporting throughout show smaller differences in productivity growth from non-exporters in the 1986-91 downturn period, but outperform non-exporters in the 1991-96 upturn period.

The decompositions indicate that within-plant productivity growth and productivity differentials between entering and exiting plants are the two major sources of changes in aggregate productivity growth. Although reallocation across plants plays only a minor role, the between effect seems to be greater during the cyclical downturn. These results are largely consistent with other evidence from Taiwan (Aw et al., 2001) and Korea (Hahn, 2000).

We find that exporting plants and large plants account for the bulk of both the within and between effects in productivity growth. The largest contribution to both within and between plant changes in productivity growth comes from continuing exporters, especially for those plants with more than 100 employees. The gains or losses of continuing exporters are mainly attributable to the success or failure of their foreign market. These findings suggest that the performance of large continuing exporters plays an important role in the Taiwan electronics industry.

With respect to the entry and exit effect, the positive contribution for domestic shipments among entrants and departers offset some of the decline in overall TFP growth during the downturn period, whereas the foreign shipments of entrants and departers contribute more to the TFP growth during the upturn period. The decomposition shows that the positive net entry effect for the downturn period resulted from the increase in domestic shipments, whereas the positive net entry effect for the upturn period resulted from the increase in foreign shipments. Therefore, further research should link the effects of macroeconomic variables to micro issues such as plant turnover and productivity.

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Table 1 Sample Mean Characteristics of Plants by Market Orientation in the Taiwan Electronics Industry, 1991 and 1996

Variable	Definition	Exporters	Non-exporters	t-statistics
1991				
TFP	Total factor productivity	0.0633 (0.41)	-0.0364 (0.38)	10.55***
WAGE	Average wage (1,000 NT$)	249.80 (110.48)	201.83 (92.19)	19.37***
NPL	Share of nonproduction workers in total employment (%)	28.66 (0.14)	24.16 (0.15)	10.67***
SIZE	Total employment	125.31 (474.10)	19.52 (76.36)	11.36***
EXS	Export sales to total sales (%)	61.42 (34.78)	0.00 (0.00)	90.47***
KL	Capital-labor ratio	424.95 (667.60)	301.69 (442.59)	8.63**
AGE	Age of plants (years)	9.84 (6.94)	7.10 (5.33)	10.67***
N	Number of plants	2624	5740	
1996				
TFP	Total factor productivity	0.072 (0.50)	-0.060 (0.50)	11.73***
WAGE	Average wage (1,000 NT$)	338.52 (127.75)	285.38 (106.87)	19.61***
NPL	Share of nonproduction workers in total employment (%)	27.72 (0.11)	23.65 (0.13)	11.42***
SIZE	Total employment	114.51 (447.26)	19.41 (63.38)	11.37***
EXS	Export sales to total sales (%)	54.61 (34.06)	0.00 (0.00)	86.12***
KL	Capital-labor ratio	883.20 (1292.96)	669.86 (1122.11)	7.71***
AGE	Age of plants (years)	11.59 (7.19)	9.15 (6.10)	15.98***
FOR	Foreign ownership in the firm (%)	5.28 (20.29)	0.53 (6.54)	12.31***
N	Number of plants	2886	6754	

Note: Figures in parentheses are standard deviations. The t statistic tests the null hypothesis of equality between exporters and non-exporters. *** represents statistical significance at 1% level. All values are converted into 1986 NT dollars. The exchange rate was 35.50 NT$/US$ in 1986.

Table 2 Plant Size, Export Behavior, and Productivity

	Size (employees)							
	3-50		51-100		Over 100		Average	
	1991	1996	1991	1996	1991	1996	1991	1996
All Plants:								
TFP	-0.0330	-0.0132	0.0556	0.0852	-0.0230	0.0774	-0.0001	0.0007
% of exporting plants in category	22.95	23.03	65.88	60.63	85.771	79.68	31.38	29.97
% of export sales to total sales in category	26.41	24.83	45.42	39.97	62.37	56.39	54.31	50.72
Exporting Plants:								
TFP	0.1067	0.0846	0.0672	0.1181	-0.0164	0.0846	0.0735	0.0897
% of export sales to total sales in category	61.06	55.34	60.74	56.63	68.12	64.19	66.77	62.97
Non-exporting Plants:								
TFP	-0.0361	-0.0425	0.0333	0.0346	-0.0627	0.0491	-0.0337	-0.0373

Table 3 Entry and Exit Variables for the Taiwan Electronics Industry

	1986-1991	1991-1996	1986-1996
Entry rate (%)	69.2	52.7	78.6
Entrant market share (%)	39.1	29.0	52.5
Exit rate (%)	56.5	45.5	65.1
Exiter market share (%)	34.7	28.0	47.7

Note: The entry rate (share) is defined as the number (real output) of plants that were first observed in operation in the industry at the end of each time period relative to the total number (real output) of plants at the end of the period. The exit rate (share) is defined as the number (output) of plants that were last observed in operation at the beginning of each time period relative to the total number (output) of plants at the beginning of the period.

Table 4 Transitions In and Out of Exporting

Panel A	Continuing plants				Entering and exiting plants			
	Neither	Thru	Start	Stop	Local entrant	Export entrant	Local exiter	Export exiter
1986-1991								
Share of the number of plants (%)	12.1	10.7	3.5	4.5	52.1	17.1	38.8	17.7
Share of output (%)	4.4	49.2	3.5	3.8	10.4	28.7	5.4	29.3
Average size (employees)	20.8	220.9	51.4	42.3	17.3	80.5	17.2	113.2
1991-1996								
Share of the number of plants (%)	23.2	11.2	6.2	6.8	40.1	12.6	34.8	10.7
Share of output (%)	5.1	54.8	4.4	6.6	7.3	21.7	6.0	22.0
Average size (employees)	18.1	199.1	45.5	47.3	15.4	73.2	16.1	103.1

Panel B	Continuing plants				Entering and exiting plants			
	Never	Always	Ever		Local entrant	Export entrant	Local exiter	Export exiter
1986-1996								
Share of the number of plants (%)	5.2	5.2	7.7		68.0	28.6	44.1	21.0
Share of output (%)	1.4	28.8	8.3		6.9	13.1	6.7	39.9
Average size (employees)	20.0	243.4	56.7		15.3	54.4	16.8	119.7

Note: For continuing plants and entering plants, the share of the number of plants (output) is defined as the number (output) of plants that were first observed in operation at the end of each time period relative to the total number (output) of plants in the industry at the end of the period. For the exiting plants, the share of the number of plants (output) is defined as the number (output) of plants that were last observed in operation at the beginning of each time period relative to the total number (output) of plants in the industry at the beginning of the period. Average size is measured as the average of total employment.

Table 5 Export Activity, TFP Growth, and Plant Growth

Panel A	TFP growth		
	1986-1991	1991-1996	1986-1996
EXPORT	0.0425	0.0662	0.1249
	(0.83)	(1.34)	(0.80)
λ	0.6540	1.4358	1.7065
	(1.64)*	(3.02)***	(1.68)*
$\overline{R}^2$	0.050	0.025	0.040
Panel B	**Shipments growth**		
	1986-1991	1991-1996	1986-1996
EXPORT	0.3262	1.5779	1.4445
	(0.49)	(1.44)	(0.91)
λ	7.5276	18.724	16.045
	(1.44)	(1.64)*	(1.50)
$\overline{R}^2$	0.046	0.006	0.081
Panel C	**Employment growth**		
	1986-1991	1991-1996	1986-1996
EXPORT	0.8872	0.6661	1.0919
	(1.83)*	(2.85)***	(1.35)
λ	7.5306	6.9971	8.9837
	(2.05)**	(3.17)***	(1.73)*
$\overline{R}^2$	0.102	0.070	0.141

Note: All regressions include age, log of total employment, average wage, share of non-production workers in total employment, 9 four-digit industry dummies, and 21 city/county dummies. λ is the inverse of Mill's ratio. Figures in parentheses are t-statistics. Regressions ***, **, and * represent statistical significance at 1%, 5%, and 10% level, respectively.

Table 6 Export Status, TFP Growth, and Plant Growth

Panel A	TFP growth		
	1986-1991	1991-1996	1986-1996
THRU	0.0895	0.1470	
	(1.60)	(2.70)***	
START	0.0928	0.1444	
	(3.29)***	(3.95)***	
STOP	0.0620	0.0641	
	(1.05)	(1.12)	
ALWAYS			0.1336
			(1.76)*
EVER			0.0984
			(1.92)*
λ	0.7231	1.4543	1.4642
	(1.70)*	(3.01)***	(2.32)**
$\overline{R^2}$	0.053	0.034	0.014

Panel B	Shipments growth		
	1986-1991	1991-1996	1986-1996
THRU	1.7272	3.7941	
	(2.37)**	(3.09)***	
START	2.6089	3.5233	
	(7.11)***	(3.58)***	
STOP	0.7140	1.1778	
	(0.93)	(0.90)	
ALWAYS			5.2219
			(4.25)***
EVER			3.0778
			(3.71)***
λ	9.2117	18.631	23.385
	(1.67)*	(1.62)	(2.31)**
$\overline{R^2}$	0.065	0.010	0.099

Panel C	Employment growth		
	1986-1991	1991-1996	1986-1996
THRU	1.3030	1.1473	
	(2.55)***	(4.52)***	
START	0.6347	0.7875	
	(2.56)***	(4.70)***	
STOP	0.8231	0.5967	
	(1.53)	(2.24)**	
ALWAYS			1.4149
			(4.54)***
EVER			0.8078
			(3.84)***
λ	7.6867	7.0076	6.1351
	(2.04)**	(3.15)***	(2.35)**
$\overline{R^2}$	0.124	0.097	0.163

Note: See Table 5.

Table 7 Decomposition of TFP Growth in the Taiwan Electronics Industry

Panel A		1986-1991		
Export Status	Within Effect	Between Effect	Entry and Exit	Overall
Neither	0.29	0.05		0.34
	(-12.33)	(-2.20)		(-14.53)
Thru	-6.39	2.01		-4.38
	(274.45)	(-86.23)		(188.22)
Start	0.11	-0.10		0.01
	(-4.87)	(4.37)		(-0.51)
Stop	-0.05	0.09		0.04
	(1.99)	(-3.86)		(-1.87)
Total	-6.04	2.05	1.66	-2.33
	(259.24)	(-87.92)	(-71.31)	(100)

Panel B		1991-1996		
Export Status	Within Effect	Between Effect	Entry and Exit	Overall
Neither	-0.55	-0.32		-0.87
	(-1.61)	(-0.92)		(-2.54)
Thru	19.56	3.64		23.20
	(57.30)	(10.67)		(67.97)
Start	0.38	-0.31		0.08
	(1.12)	(-0.90)		(0.22)
Stop	0.98	0.19		1.18
	(2.88)	(0.57)		(3.45)
Total	20.38	3.22	10.55	34.14
	(59.69)	(9.42)	(30.90)	(100)

Note: Numbers are percentage changes. Numbers in parentheses are relative contributions in terms of percentage.

Table 8 The Contribution of Exports to TFP Growth

Panel A	1986-1991						
Export Status	Within Effect		Between Effect		Entry and Exit		Overall
	Local	Exports	Local	Exports	Local	Exports	
Neither	0.29	0.00	0.05	0.00			0.34
	(-12.33)	(0.00)	(-2.20)	(0.00)			(-14.53)
Thru	-1.46	-4.93	0.58	1.43			-4.38
	(62.83)	(211.62)	(-24.96)	(-61.27)			(188.22)
Start	0.04	0.08	-0.06	-0.04			0.01
	(-1.51)	(-3.36)	(2.63)	(1.73)			(-0.51)
Stop	0.12	-0.17	0.20	-0.11			0.04
	(-5.30)	(7.29)	(-8.59)	(4.72)			(-1.87)
Total	-1.02	-5.02	0.77	1.28	1.96	-0.30	-2.33
	(43.69)	(215.55)	(-33.11)	(-54.81)	(-84.32)	(13.01)	(100)

Panel B	1991-1996						
Export Status	Within Effect		Between Effect		Entry and Exit		Overall
	Local	Exports	Local	Exports	Local	Exports	
Neither	-0.55	0.00	-0.32	0.00			-0.87
	(-1.61)	(0.00)	(-0.92)	(0.00)			(-2.54)
Thru	6.78	12.78	-0.46	4.10			23.20
	(19.87)	(37.43)	(-1.34)	(12.01)			(67.97)
Start	0.17	0.21	-0.36	0.05			0.08
	(0.51)	(0.61)	(-1.05)	(0.15)			(0.22)
Stop	0.76	0.23	1.06	-0.87			1.18
	(2.21)	(0.67)	(3.11)	(-2.55)			(3.45)
Total	7.16	13.21	-0.07	3.28	3.53	7.01	34.14
	(20.98)	(38.71)	(-0.19)	(9.61)	(10.35)	(20.55)	(100)

Note: See Table 7.

Table 9 Decomposition of TFP Growth by Export Status and Plant Size, 1991-96

Export Status	Within Effect			Between Effect			Entry and Exit		
	3-50	51-100	>100	3-50	51-100	>100	3-50	51-100	>100
Neither	-0.32	0.02	-0.25	-0.05	0.02	-0.29			
	(-0.93)	(0.06)	(-0.75)	(-0.13)	(0.07)	(-0.86)			
Thru	-0.12	0.05	19.63	-0.69	-0.12	4.46			
	(-0.35)	(0.16)	(57.49)	(-2.03)	(-0.36)	(13.05)			
Start	0.08	0.08	0.22	-0.03	0.10	-0.38			
	(0.24)	(0.23)	(0.64)	(-0.09)	(0.31)	(-1.11)			
Stop	-0.30	0.07	1.22	-0.20	-0.01	0.39			
	(-0.89)	(0.20)	(3.57)	(-0.57)	(-0.01)	(1.15)			
Local entrant							-0.13	0.06	1.69
& Local exiter							(-0.37)	(0.19)	(4.95)
Export entrant							0.14	0.20	8.59
& Export exiter							(0.40)	(0.57)	(25.15)

Note: See Table 7.