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Productivity and Turnover in the Export Market: Micro-level Evidence from the Republic of Korea and Taiwan (China)

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Widespread empirical evidence indicates that exporting producers have higher productivity than nonexporters, although the reasons why are unclear. Some analysts argue that exporters acquire knowledge of new production methods, inputs, and product designs from their international contacts, and with this knowledge they achieve higher productivity than their more insulated domestic counterparts. Others argue that the higher productivity of exporters reflects the self-selection of more efficient producers into a highly competitive export market. This article analyzes the link between a producer's total factor productivity and its decision to participate in the export market, using manufacturing data from the Republic of Korea and Taiwan (China).

Differences are found between these two economies in the importance of selection and learning. In Taiwan (China) transitions of plants into and out of the export market reflect systematic variations in productivity as predicted by self-selection models. In Korea there are no significant changes in productivity following entry or exit from the export market that are consistent with learning from exporting. A comparison of the two economies suggests that in Korea factors other than production efficiency are more prominent determinants of the export decision.

Over the past three decades the Republic of Korea and Taiwan (China) have achieved high and sustained rates of growth in output and income. Although high savings rates and substantial investments in new capital equipment have contributed to their success, it is impossible to ignore the role of the export market. At a minimum, the ability to export has allowed manufacturers to specialize in a range of products and to increase their output levels far beyond what the size of their domestic market could support. Some economists attribute the success of these economies to the role of exports in serving as a conduit for technology transfer from abroad and in generating technological spillovers to the rest of the economy. Case studies and empirical evidence show that exporting firms or plants

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are more efficient than their counterparts that sell primarily in the domestic market. This belief that export activity generates cumulative productivity benefits is often cited as an argument for the active promotion of exports in many developing countries.

The empirical finding that exporters are more productive than nonexporters is widespread and robust, but only two recent papers have addressed the more complex issue of whether exports play a causal role in generating higher productivity. Clerides, Lach, and Tybout (1998) examine this issue using manufacturing data for Colombia, Mexico, and Morocco. Bernard and Jensen (1999) focus on manufacturers in the United States. Both articles examine two alternative explanations linking productivity and exporting. The first explanation holds that exporters learn from their contacts in the export market, and as a result they adopt better production methods and achieve higher productivity. The second says that the higher productivity of exporting firms may reflect the self-selection of more efficient producers into a highly competitive export market. Both studies find that the self-selection of more efficient producers into the export market is an important part of the story and that there is little evidence of efficiency gains that could reflect the learning that accrues from exporting.

In this article we study the link between a producer's total factor productivity (TFP) and its choice to participate in the export market, using micro-data collected in manufacturing censuses in Korea and Taiwan (China). We specifically focus on the relationship between productivity and the movement of producers into and out of the export market. Productivity differences between producers with different transition patterns, rather than just different exporting status, are crucial to separating the selection and learning explanations. If differences in productivity predate a producer's movement into or out of the export market so that nonexporters with high productivity tend to enter whereas low-productivity exporters tend to exit, then self-selection forces are at work. In contrast, if differences in productivity follow a producer's transition into or out of the export market, then learning-by-doing forces are at work. Producers that enter the export market should subsequently have greater productivity changes than producers who do not enter. Likewise, producers that exit the export market should begin to lag behind their counterparts that remain in.

I. The Relationship between Productivity and Exporting

A large body of empirical evidence demonstrates that firms that participate in the export market perform better than other firms in terms of productivity, size, length of survival, and wages paid.[1] The literature proposes that at least two

1. Several papers examine the export-productivity relationship at the micro-level (see Aw and Hwang 1995; Aw and Batra 1998; Chen and Tang 1987; Haddad 1993; Handoussa, Nishimizu, and Page 1986; and Tybout and Westbrook 1995). Aw and Batra (1999) and Bernard and Jensen (1995) examine the relationships among exports, firm size, and wages. Richardson and Rindal (1995, 1996) summarize the empirical evidence for a wide range of firm characteristics that are correlated with the exporting activity.

mechanisms explain the positive correlation between exporting and productivity. First, the correlation may simply reflect the fact that only the most productive firms survive in the highly competitive export market. If the fixed costs of selling are higher in the export market than in the domestic market or if output prices are lower, only firms with high productivity will find it profitable to enter the export market in the first place. Exporters whose productivity declines will be forced to exit. We refer to this as the self-selection hypothesis.

Second, the correlation may reflect productivity improvements that result from knowledge and expertise that the firm gains as a direct result of its experience in the export market. Some analysts argue that firms that participate in the export market gain access to technical expertise from their buyers, including both new product designs and production methods, that nonexporters do not have. This phenomenon of learning by exporting may be particularly relevant for countries in East Asia.[2]

Both mechanisms are plausible, but their actual importance most likely varies across countries and industries. Different rates of product and process innovation alter the possibilities for learning and the nature of trade policy, which can affect the strength of market selection forces. Clerides, Lach, and Tybout (1998) and Bernard and Jensen (1999) find clear evidence of the importance of self-selection among exporters in the 1980s. Firms that become exporters perform more efficiently prior to entry than their nonexporting counterparts. In addition, both studies find little evidence of efficiency gains that could reflect learning by exporting. Clerides, Lach, and Tybout find that a producer's exporting history does not significantly alter current production costs. Bernard and Jensen find that future productivity growth is not significantly higher for plants that currently export. They do find that employment growth and the probability of survival are higher for exporting plants. This pattern can reflect the same underlying differences in efficiency that lead to self-selection into the export market and does not necessarily reflect improvements that follow as a result of exporting experience. Overall, the evidence weighs heavily on self-selection of the more efficient firms into the export market as the main source of the productivity differences between exporters and nonexporters.

Theoretical Framework

Several recent theoretical models of industry dynamics explain the divergent paths of growth and failure that characterize micro-data on individual producers. All of these models begin with the assumption that producers within the same industry differ in their productive efficiency and are subject to idiosyncratic shocks or uncertainty. Differences in the evolution of their productivity over time, in turn, lead producers to make different decisions regarding entry, growth, and exit. The source of uncertainty differs across models. Jovanovic (1982) empha-

2. See Evenson and Westphal (1995); Grossman and Helpman (1991); Rhee, Ross-Larson, and Pursell (1984); and World Bank (1993) for discussions and evidence on the role of buyers in providing technical expertise.

sizes firms' uncertainty about their own productivity levels, Lambson (1991) focuses on uncertain future market conditions, Hopenhayn (1992) emphasizes randomness in productivity changes over time, and Ericson and Pakes (1995) model uncertainty in the return to firm investments.

To organize our empirical analysis of productivity and the decision to export, we rely on Hopenhayn's (1992) model. Although not specific to the export market, Hopenhayn's model shows how firms with different levels of productivity make different decisions to enter, exit, or remain in a market. It allows us to identify how self-selection will lead to differences in productivity among these three cohorts of firms.

Hopenhayn models a market that is composed of a large number of price-taking firms that produce a homogeneous output. Firms differ in their efficiency, with each firm's output depending on a random productivity shock, θ, which follows a Markov process that is independent across firms. The distribution of future productivity is described by the distribution function $F(\theta_{t+1} \mid \theta_t)$, which is assumed to be strictly decreasing in θ_t. This assumption implies that, relative to a firm with low θ_t, a firm with high productivity in year t has a larger probability of having high productivity in year $t + 1$.

In each period, before the new productivity shock is observed, incumbent firms may choose to exit the market or to remain in the market and pay a fixed cost. Following that decision, they observe their productivity shock and choose their output level for that period. Potential entrants may choose to enter by paying a sunk entry cost, after which they draw their initial productivity level from a common distribution function, $G(\theta)$, and choose their output level. Output prices are determined competitively to equate demand and supply. The model produces two key endogenous variables: the flow of entrants into the market each period and the minimum productivity level needed for an incumbent firm to remain in the market. This productivity level, which we denote X_t, is the lowest level of productivity that will generate positive expected profits for the firm over future periods.

This model makes predictions about differences in the average productivity of entering, exiting, and surviving producers. Hopenhayn demonstrates that firms will exit the market after period t if $\theta_t < X_t$. The current-period productivity, θ_t, which the firm observes, determines the likely future trajectory of productivity through the distribution function $F(\theta_{t+1} \mid \theta_t)$. Firms with $\theta_t < X_t$ expect low future profit streams and exit after period t, while firms with $\theta_t > X_t$ remain in the market. The model implies that exiting firms are concentrated among the least-productive firms. We can test this implication empirically for the export market by examining exporters in period t and looking for systematic differences in productivity between the group that continues exporting in $t + 1$ and the group that exits.

The model allows us to compare the productivity of a cohort of new entrants with the productivity of cohorts of older surviving producers. The distribution function for initial productivity, $G(\theta)$, determines the productivity of the new entrants. The productivity of older cohorts reflects the failure of the least-productive members over time and the random changes in the survivors' productivity over time. Hopenhayn demonstrates that if $F(\theta_{t+1} \mid \theta_t)$ is strictly decreasing in θ_t, then the productivity distribution of any surviving cohort stochastically dominates the productivity distribution of the entering cohort. We can examine this empirically by comparing the productivity of new exporters and incumbent exporters at a point in time.

In the formal model all firms base their entry decision only on knowledge of the distribution of initial productivity $G(\theta)$ and its evolution over time $F(\theta_{t+1} \mid \theta_t)$, and not on information about their own productivity level. Many potential entrants to the export market currently produce in the domestic market and thus have better information on their likely productivity after entry than firms with no prior experience. Therefore, domestic producers with high productivity in year t would be more likely to enter the export market than low-productivity domestic producers. We can examine this empirically by focusing on firms that initially produce only in the domestic market. We ask whether the firms that subsequently enter the export market have higher initial productivity than those that remain specialized in the domestic market.

Although Hopenhayn's model clarifies the important role of firm heterogeneity and self-selection in generating flows of firms into and out of a market, it does not incorporate the idea that productivity may change following entry, as described in the learning-by-exporting hypothesis. Clerides, Lach, and Tybout (1998) include this possibility in a model of a domestic firm's decision to diversify into the export market. The firm makes the decision to enter by comparing expected future profits, which depend on the firm's current and future productivity, with the sunk costs of entry. To incorporate the effect of learning by exporting, Clerides, Lach, and Tybout make a firm's current productivity depend on prior export experience.

Clerides, Lach, and Tybout include a set of simulation results that provide useful insights into how selection and learning interact. They find that firms that enter or remain in the export market always have higher productivity than firms that stop exporting or that remain only in the domestic market. Firms that enter the export market also have higher productivity prior to entry than firms that produce only in the domestic market. Both of these patterns arise because firms self-select into the export market based on their current productivity. Adding learning by exporting to the framework widens the gap between the productivity of firms that enter the export market and those that do not. We can examine this pattern empirically by comparing the pre- and post-entry productivity differentials between entrants and nonentrants.

Empirical Implications in Micro-Data from Korea and Taiwan (China)

We analyze a data set that includes information collected as part of the manufacturing censuses in Korea and Taiwan (China). Appendix A gives a description of the data. In the case of Taiwan (China) observations are at the firm level for the census years 1981, 1986, and 1991. However, for the industries we study, between 80 and 90 percent of all Taiwanese firms are single-plant producers; therefore, the distinction between plant and firm is not as important as it is in many industrial countries. In the case of Korea we have plant-level observations for the years 1983, 1988, and 1993. For simplicity we refer to the data as plant-level for both economies, even though only firm-level information is available for Taiwan (China).

The plant-level observations have been matched over time so that it is possible to identify entering and exiting producers in each census year. In addition, plant-level exports are reported for all three years in Korea and for 1986 and 1991 in Taiwan (China).[3] The data allow us to classify each producer as a nonexporter, an entrant to the export market, an incumbent exporter, or a plant that has exited the export market between each pair of years.

The data set contains information on output and inputs of capital, labor, and raw materials that allows us to construct an index of TFP for each plant. Appendix B gives details on the construction of the productivity index. Although we have time observations for only three years, the fact that the censuses are taken at five-year intervals provides an advantage over a data set with a small number of observations for consecutive years. The longer five-year time period reduces the importance of transitory shocks, cyclical fluctuations, and measurement errors in our productivity comparisons. It also makes it more likely that we will observe long-term changes in productivity than would comparisons based on data of higher frequency.

Given our focus on the role of the export market as a source of knowledge and productivity differentials, we restrict our attention to the five two-digit industries that have a major export role in both Taiwan (China) and Korea—textiles, apparel, plastics, electrical machinery and electronics, and transportation equipment. These industries have the highest export participation rates in the manufacturing sector. (The participation rate is the share of plants that export.) In Taiwan (China) the export participation rate ranges from 26 percent in transportation equipment to 41 percent in electrical machinery and electronics. In Korea the participation rate ranges from 13 percent in apparel to 26 percent in electronics. In both economies the five industries account for more than half of total manufacturing exports in 1986 and 1988, respectively.

To separate the effects of selection and learning, Clerides, Lach, and Tybout (1998) use plant-level panel data with a relatively long time-series component to estimate a two-equation model consisting of the plant's decision to participate in the export market and the plant's cost function. The micro-data for Korea and Taiwan (China) do not have sufficient time-series observations to allow us to use this approach. Our basic empirical strategy, which is similar to that of

3. For Taiwan (China) we observe the level of exports and domestic sales for each firm. For Korea we have the value of plant sales and a set of categorical variables indicating whether the plant's export-sales ratio is high (more than 0.75), moderate (0.25–0.75), low (positive but less than 0.25), or zero.

Bernard and Jensen (1999), is to compare the average productivity of groups of plants that have undergone different transition patterns. As indicated by Hopenhayn's model, self-selection implies that a plant's productivity level in period t should be a determinant of export market participation in year $t + 1$. The learning-by-exporting explanation implies that initial productivity differences between plants that select into the market and those that do not should widen following entry or as firms accumulate more experience in the export market. To isolate this effect, we focus on changes in the differential between periods t and $t + 1$ for exporters and nonexporters.

Aside from learning by exporting, there are several explanations as to why the productivity of exporters changes more than the productivity of nonexporters over time. If entry into the export market allows plants to expand their output and take advantage of economies of scale in production, then exporters will have larger increases in productivity than nonexporters. In general, any factor that results in positive serial correlation in the shocks to plant-level productivity will generate this outcome. Plants experiencing positive productivity shocks are more likely to find it profitable to enter the export market. If these positive shocks continue over time, the productivity of exporters and nonexporters will continue to diverge. With our data we cannot distinguish these alternative explanations. However, the finding that productivity differences between exporters and nonexporters do not diverge following entry would be inconsistent with any of these explanations, including learning by exporting.

To clarify the comparisons, we define four groups of plants based on their participation in the export market in two adjoining years of data (table 1). We make five different comparisons based on these four groups.

In section II we compare the productivity of exporters and nonexporters in each year in order to confirm the positive cross-sectional correlation between exporting and productivity. Then, in section III, we compare the productivity of the four transition groups in the same year in order to see if the decision to participate in the export market reflects plant productivity. In both the first and second comparisons we use all producers operating in the year of interest. Thus we include in comparisons for year t failing plants that exit production entirely after year t, and we include in comparisons for year $t + 1$ new plants that enter production after year t.

In the last three comparisons we use the subset of plants that operate in both years so that we can compare improvements or declines in productivity with

Table 1. *Definitions of Four Groups of Plants Based on Their Participation in the Export Market*

Group	*Plant status*	*Year t*	*Year t + 1*
1	Stay out	Does not export	Does not export
2	Enter	Does not export	Exports
3	Exit	Exports	Does not export
4	Stay in	Exports	Exports

experience in the export market. In section IV we look at nonexporters in year t (groups 1 and 2 in table 1) and compare productivity in years t and $t + 1$. If market selection is important, the productivity of the entrants (group 2) should exceed that of the plants that stay out of the export market (group 1) in year t. Comparing the productivities of the two groups in year $t + 1$ reveals whether the initial differential narrows, widens, or remains unchanged after group 2 has gained some experience in the export market. If learning is important, this differential should widen.

To determine whether or not productivity differentials persist following exit, the fourth comparison, in section V, looks at productivity in years t and $t + 1$ for groups 3 and 4. Plants in these groups begin in the export market and follow different paths over time. If market selection is important, then exit from the export market should be concentrated in plants with lower productivity. If exporting brings additional benefits, then the productivity differential should widen in period $t + 1$ between the group that stays in the export market and the group that exits.

With the fifth comparison, in section VI, we look at whether or not exporters follow different productivity paths than nonexporters over time. We compare the productivity of groups 1 and 4 in years t and $t + 1$. If the export market facilitates the accumulation of knowledge over time, productivity levels between the two groups should increasingly diverge. As a further refinement to this comparison, we look at whether improvements over time accrue to new producers, the group most likely to benefit from learning effects. To do this, we compare productivity in years t and $t + 1$ for the producers in groups 1 and 4 that first begin operating in year t.

II. PRODUCTIVITY DIFFERENTIALS BETWEEN EXPORTING AND NONEXPORTING PLANTS

We begin by summarizing the cross-sectional differences in average productivity between plants that sell in the export market and those that operate solely in the domestic market (table 2). For example, in the textile industry in Taiwan (China) in 1986, exporting plants had 27.6 percent higher TFP levels than nonexporting plants. Across the five industries in Taiwan (China) average TFP levels were higher for exporters than for nonexporters by between 11.8 percent (electrical machinery in 1986) and 27.6 percent (textiles in 1986). All of the differences in means are statistically significant. The data for Korea similarly show higher productivity among exporting plants. The average productivity difference between exporters and nonexporters varies between 3.9 percent (electrical machinery in 1988) and 31.1 percent (textiles in 1983), and all the differences are statistically significant.[4]

4. In both economies these differences are smaller in the newer, higher-technology industries of electronics and transportation. Pack (1992) argues that worker mobility is one way that knowledge gained in the export market can diffuse to other producers. If labor market turnover is higher in industries that use rapidly changing technologies, then the positive spillovers from exporting to nonexporting plants may be higher in these industries. This transmission of knowledge through worker movement would result in smaller average productivity differentials between exporters and nonexporters.

Table 2. *Productivity Differences between Exporters and Nonexporters and the Number of Exporting and Nonexporting Firms in the Republic of Korea and Taiwan (China), 1980s and 1990s*

	Korea			*Taiwan (China)*	
Industry and indicator	*1983*	*1988*	*1993*	*1986*	*1991*
Textiles					
Percentage difference in average productivity[a]	0.311	0.234	0.231	0.276	0.186
	(0.017)	(0.014)	(0.014)	(0.010)	(0.010)
Exporters	510	874	1,163	1,231	946
Nonexporters	1,368	1,767	2,352	2,039	2,589
Apparel					
Percentage difference in average productivity[a]	0.189	0.153	0.199	0.247	0.196
	(0.022)	(0.018)	(0.019)	(0.011)	(0.013)
Exporters	257	499	479	809	571
Nonexporters	1,479	1,852	2,212	1,171	1,465
Plastics					
Percentage difference in average productivity[a]	0.148	0.097	0.071	0.166	0.151
	(0.027)	(0.016)	(0.014)	(0.006)	(0.007)
Exporters	193	481	572	1,806	1,497
Nonexporters	1,171	2,109	3,563	4,811	7,470
Electrical machinery and electronics					
Percentage difference in average productivity[a]	0.068	0.039	0.045	0.118	0.145
	(0.021)	(0.013)	(0.011)	(0.007)	(0.006)
Exporters	385	880	1,149	2,024	2,347
Nonexporters	933	1,917	3,735	3,354	5,703
Transportation equipment					
Percentage difference in average productivity[a]	0.140	0.110	0.094	0.126	0.153
	(0.036)	(0.021)	(0.017)	(0.010)	(0.011)
Exporters	98	248	266	606	678
Nonexporters	507	1,003	2,045	1,751	2,565

a. The values show the percentage by which TFP is higher in exporting than in nonexporting firms. The standard errors of the differences are in parentheses.

Source: Authors' calculations.

The simple comparison of average productivity in table 2 clearly indicates the higher productivity of exporters relative to nonexporters in both countries.[5] The results in table 2 mirror the findings for virtually every other country for which micro-level productivity comparisons have been done. But the underlying causal mechanism is unclear. If the domestic market is limited in size, then firms can benefit from entering the larger export market. However, higher levels of com-

5. See Tybout (1996) for a summary of the empirical literature on productivity differences among firms.

petition in the world market or higher fixed costs associated with selling in the export market mean lower profit streams per unit, so that only the more efficient firms will enter and survive in the export market. Alternatively, if firms already in the export market can take advantage of scale economies or acquire knowledge of new technologies that foster learning, this will be reflected in higher productivity for exporters.

If these externalities from exporting exist, it is very likely that they are higher the greater is the degree of exposure to the export market. Therefore, we look at whether the productivity differential is an increasing function of the share of plant output that is exported and whether the differential is independent of the degree of exposure. Table 3 reports the results of regressions of plant productivity on year and export intensity dummies for each country and industry. The intercept represents the plants that do not export. The remaining coefficients measure the percentage difference in productivity between nonexporters and plants with low export intensity (less than 25 percent of production exported), moderate intensity (25 to 75 percent), and high intensity (more than 75 percent). The positive and significant coefficients on the export intensity dummies for both countries clearly indicate higher levels of productivity for exporting firms relative to nonexporters, as demonstrated in table 2.

The new finding is that differences in average productivity across groups of plants with different export intensities are very small, particularly when compared with the differences between exporters and nonexporters (table 2). The data for Taiwan (China) show that it is not possible to reject the hypothesis that average productivity is the same across all three categories of export intensity for the textile and electrical machinery industries. For the other three industries we cannot reject the hypothesis that two of the three groups have equal average productivity. In addition, there is no consistent movement in the level of average productivity across intensity categories. For two industries productivity falls moving from low to high export intensity; for three industries it increases. Except for the apparel industry, the direction of change within industries is not monotonic across intensity categories.

The data for Korea show similar patterns. For three of the five industries we do not reject the hypothesis that the three export categories have the same average productivity. In the textile and transportation industries the evidence indicates that the plants that export at least 75 percent of their output do have higher productivity. Average productivity among Korean textile plants that export less than one-quarter of their output is 18.8 percent higher than that of nonexporters, and this differential rises to 28.1 percent for plants that export at least three-quarters of their output. In transportation equipment, exporters in the low-intensity category are 9.4 percent more productive than nonexporters, and the differential rises to 20.2 percent for the high-intensity category.

Overall, the cross-sectional results in tables 2 and 3 indicate that being an exporter, per se, signals higher productivity in every case, but the percentage of the plant's output that is exported has little systematic effect on productivity for

Table 3. *The Impact of Export Intensity on Plant Productivity*

Country and industry	*Intercept*	*Export intensity*[a] *Low*	*Medium*	*High*	*Test results*[b]
Korea					
Textiles	−0.118*	0.188*	0.228*	0.281*	2
	(0.009)	(0.018)	(0.014)	(0.011)	
Apparel	−0.068*	0.242*	0.176*	0.173*	1, 2, 3
	(0.009)	(0.037)	(0.030)	(0.013)	
Plastics	−0.067*	0.092*	0.084*	0.111*	1, 2, 3
	(0.009)	(0.014)	(0.016)	(0.020)	
Electrical machinery and electronics	−0.079*	0.058*	0.024*	0.055*	1, 2, 3
	(0.009)	(0.013)	(0.013)	(0.012)	
Transportation equipment	−0.070*	0.094*	0.085*	0.202*	2
	(0.013)	(0.017)	(0.024)	(0.033)	
Taiwan (China)					
Textiles	−0.012*	0.236*	0.212*	0.244*	1, 2
	(0.005)	(0.014)	(0.012)	(0.009)	
Apparel	−0.142*	0.181*	0.193*	0.233*	2
	(0.007)	(0.027)	(0.018)	(0.009)	
Plastics	0.012*	0.145*	0.141*	0.170*	2
	(0.003)	(0.010)	(0.009)	(0.006)	
Electrical machinery and electronics	−0.007	0.145*	0.129*	0.131*	1, 2, 3
	(0.004)	(0.009)	(0.007)	(0.006)	
Transportation equipment	−0.140*	0.179*	0.121*	0.133*	3
	(0.005)	(0.015)	(0.014)	(0.010)	

* Significant at the 5 percent level.

Note: All regressions include year dummy variables. Standard errors are in parentheses.

a. Export intensity is low if the export share is greater than 0 and less than or equal to 0.25, medium if the export share is greater than 0.25 and less than or equal to 0.75, and high if the export share is greater than 0.75.

b. Test results are coded as follows (all are for the 5 percent level of significance): 1, do not reject the equality of all three export intensity coefficients; 2, do not reject the equality of the low and medium export intensity coefficients; and 3, do not reject the equality of the medium and high export intensity coefficients.

Source: Authors' calculations.

most of the industries. That export intensity may not be a good measure of the extent of knowledge that a plant gains from foreign sources could explain this result. An exporter has access to a pool of new ideas that is more likely to be a function of the exporter's number of foreign purchasers or contacts, rather than the percentage of output that it exports. Unfortunately, we do not have any information on the buyers of each plant's output; we can distinguish only whether the plant has some foreign contact or no foreign contact based on its total volume of exports.

III. Productivity Differentials between Transition Groups

To analyze productivity differentials between transition groups, we exploit the time-series aspects of the data and combine information on the transition patterns of plants in the export market with the cross-sectional productivity distribution. Our regression results compare the productivity of all plants in year $t + 1$ based on whether they enter or exit the export market (table 4). The plants that do not export in either year (group 1 in table 1) make up the base category.

For Taiwan (China) there is an identical ranking of categories for all five exporting industries. The group with the lowest average productivity stays out of the export market in both years. Exiting plants have average productivity levels that are 4.4 to 10.3 percent higher than plants that have never exported. Entrants are 13.3 to 18.9 percent more productive than nonexporters. Finally, plants that remain in the export market are 16.7 to 22.3 percent more productive than nonexporters.

Table 4. *The Impact of Transitions into or out of the Export Market on Plant Productivity*

		Differential for plants that[a]		
Country and industry	*Intercept*	*Exit the export market*	*Enter the export market*	*Remain in the export market*
Korea				
Textiles	–0.112*	0.115*	0.240*	0.209*
	(0.008)	(0.032)	(0.012)	(0.017)
Apparel	–0.061*	0.131*	0.186*	0.121*
	(0.008)	(0.048)	(0.015)	(0.030)
Plastics	–0.040*	–0.004	0.077*	0.102*
	(0.006)	(0.028)	(0.012)	(0.022)
Electrical machinery and electronics	–0.025*	–0.032	0.037*	0.056*
	(0.007)	(0.026)	(0.009)	(0.016)
Transportation equipment	–0.022*	–0.018	0.086*	0.149*
	(0.009)	(0.038)	(0.016)	(0.029)
Taiwan (China)				
Textiles	0.150*	0.103*	0.173*	0.223*
	(0.005)	(0.021)	(0.012)	(0.014)
Apparel	–0.018*	0.064*	0.189*	0.219*
	(0.007)	(0.028)	(0.015)	(0.020)
Plastics	0.069*	0.082*	0.138*	0.196*
	(0.003)	(0.014)	(0.008)	(0.012)
Electrical machinery and electronics	0.186*	0.044*	0.138*	0.167*
	(0.003)	(0.014)	(0.007)	(0.009)
Transportation equipment	–0.205*	0.080*	0.133*	0.211*
	(0.005)	(0.023)	(0.013)	(0.018)

*Significant at the 5 percent level.

Note: All regressions include year dummy variables. Standard errors are in parentheses.

a. The percentage difference in average productivity between the given category and firms that do not export (group 1).

Source: Authors' calculations.

Exiting firms are between 11.4 and 15.5 percent less productive than plants that remain in the export market (columns 2 and 4 of table 4). In addition, entrants are between 2.9 and 7.8 percent less productive than experienced exporters (columns 3 and 4 of table 4). Both patterns are consistent with the model of self-selection outlined in section I.

The patterns for Korea differ in some systematic ways from the results for Taiwan (China). First, in three industries—plastics, electrical machinery, and transportation equipment—the average productivity of plants that exit the export market is not significantly different from that of plants with no export market experience. Second, in two cases—textiles and apparel—entrants are more productive than incumbent exporters. Third, in the apparel industry, exiting and surviving plants have nearly the same average productivity (0.131 and 0.121 percent, respectively). All of these patterns indicate that, relative to Taiwan (China), differences in productivity in Korea are not as closely related to transitions into or out of the export market.

An additional refinement we make is to further divide the plants in year $t + 1$ into new plants, those that first appear in production in year $t + 1$, and old plants, those that were present in year t. In Taiwan (China) the differences between the two groups are minimal, with one exception. In the apparel industry, among new plants entering the export market, average productivity is 10 percent higher than that of old plants entering the export market.

In Korea two industries have substantial differences. New plants in textiles are approximately 16 percent more productive than old plants, and this differential holds for both exporters and nonexporters. In apparel new plants that enter the export market are on average 14.3 percent more productive than old plants that begin exporting, but there is no difference between new plants and plants that do not export. The productivity difference between new and old plants can reflect the adoption of different technologies in the new plants. Because this differential is observed for both exporters and nonexporters in Korean textiles, it is unlikely that exporting is the conduit for the improvement in technology. However, for the apparel industries, only new exporting plants have higher productivity. This result raises the possibility that knowledge transfers resulting from contacts with foreign buyers could be the mechanism at work.

Our finding that Taiwanese plants that exit the export market have higher average productivity than nonexporters differs from the findings of Clerides, Lach, and Tybout (1998) and Bernard and Jensen (1999). Both studies find that plants exiting the export market are among the worst performers. One explanation may be that the sunk costs involved in reentering the export market in Taiwan (China) are sufficiently low that plants do not hesitate to exit in the face of low productivity. By contrast, if other countries have higher entry costs, producers may prefer to remain in the export market in the face of low productivity and profits in order to wait and see if productivity improves. When sunk costs are high, firms face a high option value of remaining in operation in order to avoid reentry costs.

Only plants with very low productivity will choose to exit when entry costs are high.[6]

IV. Productivity Differentials between Entrants and Nonentrants

We now focus on entrants and nonentrants to the export market (groups 1 and 2 in table 1), comparing their average productivity in t and $t + 1$ (table 5). In every industry in Taiwan (China) plants that choose to enter the export market have significantly higher average productivity, prior to entry, than plants that choose to stay out. The differential varies from 4.8 percent in electrical machinery to 14.8 percent in apparel. This result is consistent with the self-selection hypothesis. The initial differential between the two groups of plants widens after entry in three of the industries—textiles, plastics, and electrical machinery (column 3 of table 5). The increase in the productivity differential is between 6.0 and 8.3 percent. In the other two industries the change in the differential following entry is not statistically significant. For textiles, plastics, and electrical machinery the widening productivity differential is consistent with the learning-by-exporting hypothesis. However, as noted, this hypothesis cannot be distinguished from other explanations that would generate positive serial correlation in productivity.

Overall, the results for Taiwan (China) indicate that, among continuing plants, productivity differences prior to entry are correlated with the entry decision. In several industries the plants that choose to enter continue to increase their productivity relative to nonentrants in the years following entry. The importance of self-selection into the export market is similar to the findings of Bernard and Jensen (1999) and Clerides, Lach, and Tybout (1998). However, none of the countries they examine shows evidence similar to what we find on the feedback effect on productivity from participating in the export market.

The data for Korea show a different pattern. The positive coefficients for all industries indicate that plants that choose to enter have higher productivity prior to entry than do nonexporters (column 2 of table 5). However, the difference is not statistically significant in two of the five industries. The productivity differential is statistically significant in textiles, where the differential is 17.6 percent; in transportation equipment, where it is 11.5 percent; and in plastics, where the differential is 5.8 percent. In addition, the differential between entrants and nonentrants widens following entry, but the change is not statistically significant in all five industries (column 3 of table 5). Thus the statistical evidence in support of both the self-selection and learning hypoth-

6. Roberts and Tybout (1997) develop the empirical implications of sunk entry costs on plant-level export participation. They find that sunk entry costs are an important determinant of exporting among Colombian manufacturing plants. They cite the absence of a well-developed export trading sector as one source of high entry costs. Campa (1998) finds that sunk exporting costs are also important for firms in the Spanish manufacturing sector. Levy (1991) argues that the well-developed network of trading firms in Taiwan (China) acts to lower the entry costs of new exporters.

Table 5. *Average Productivity Differences between Entrants and Nonentrants to the Export Market*

Country and industry	*Intercept*	*Entering firm differential, pre-entry*	*Change in differential, post-entry*
Korea			
Textiles	-0.143*	0.176*	0.059
	(0.013)	(0.026)	(0.033)
Apparel	0.014	0.036	0.111
	(0.019)	(0.052)	(0.074)
Plastics	-0.024	0.058*	0.008
	(0.014)	(0.027)	(0.038)
Electrical machinery and electronics	-0.006	0.016	0.027
	(0.019)	(0.026)	(0.036)
Transportation equipment	-0.036	0.115*	0.002
	(0.024)	(0.039)	(0.053)
Taiwan (China)			
Textiles	-0.007	0.060*	0.083*
	(0.010)	(0.026)	(0.037)
Apparel	-0.163*	0.148*	-0.026
	(0.013)	(0.044)	(0.062)
Plastics	0.018*	0.076*	0.061*
	(0.005)	(0.015)	(0.021)
Electrical machinery and electronics	0.007	0.048*	0.060*
	(0.008)	(0.016)	(0.023)
Transportation equipment	-0.134*	0.099*	0.025
	(0.010)	(0.028)	(0.039)

*Significant at the 5 percent level.
Note: All regressions include year dummy variables. Standard errors are in parentheses.
Source: Authors' calculations.

eses is much weaker for Korea than for Taiwan (China). The signs of the estimated coefficients are consistent with both effects, but the results are not generally statistically significant.

V. Productivity Differentials between Exiting and Surviving firms

For Taiwan (China) there is a difference in productivity between plants that exit the export market and those that remain (groups 3 and 4 in table 1). Plants that exit the export market after year *t* are less productive (in year *t*) than their counterparts that continue exporting, as indicated by the negative and significant coefficients (column 2 of table 6). The productivity gap varies from 6.2 to 13.1 percent. This result is consistent with the self-selection hypothesis.

Further, in four of the five industries in Taiwan (China), the plants that exit the export market fall further behind the exporting plants in the years following exit, as indicated by the negative regression coefficients (column 3 of table 6). This widening of the productivity differential between exporting and nonexporting

Table 6. *Average Productivity Differences between Plants that Exit the Export Market and Continuing Exporters*

Country and industry	*Intercept*	*Exiting firm differential, pre-exit*	*Change in differential, post-exit*
Korea			
Textiles	0.200*	-0.083*	-0.001
	(0.017)	(0.023)	(0.034)
Apparel	0.125*	0.076	-0.076
	(0.032)	(0.042)	(0.058)
Plastics	0.230*	-0.041	-0.047
	(0.032)	(0.032)	(0.044)
Electrical machinery and electronics	0.068*	-0.090*	0.012
	(0.023)	(0.027)	(0.037)
Transportation equipment	0.153*	-0.053	-0.091
	(0.035)	(0.039)	(0.053)
Taiwan (China)			
Textiles	0.302*	-0.121*	0.001
	(0.012)	(0.022)	(0.031)
Apparel	0.144*	-0.131*	-0.024
	(0.016)	(0.029)	(0.040)
Plastics	0.209*	-0.070*	-0.045*
	(0.010)	(0.016)	(0.022)
Electrical machinery and electronics	0.152*	-0.069*	-0.054*
	(0.007)	(0.014)	(0.019)
Transportation equipment	0.030*	-0.062*	-0.070*
	(0.015)	(0.025)	(0.035)

*Significant at the 5 percent level.
Note: All regressions include year dummy variables. Standard errors are in parentheses.
Source: Authors' calculations.

plants is statistically significant in three industries—plastics, electrical machinery, and transport equipment. Again, this result is consistent with factors that lead to divergent productivity paths for exporting and nonexporting plants, of which learning by exporting is one.

The data for Korea produce a similar pattern, but most of the differentials are not statistically significant. The coefficients in the second column indicate that exiting plants are significantly less productive than continuing exporters in only two of the five industries—textiles and electrical machinery, where the average productivity differential is 8.3 and 9.0 percent, respectively. The widening of the differential continues following exit for all but one industry, as shown in the third column, but this effect is not statistically significant in any of the industries.

Overall, the statistical evidence is stronger for Taiwan (China) than for Korea that exiting plants are less productive than continuing exporters. The evidence is also stronger for Taiwan (China) that the relative position of exporting plants continues to deteriorate after exit. And there is less evidence for Korea than for

Taiwan (China) that either productivity-driven selection or productivity improvement is correlated with export experience.

VI. Productivity Differentials between Long-Term Exporters and Nonexporters

The final comparison we make considers plants that export in both years and plants that never export (groups 4 and 1 in table 1). If the act of exporting results in higher productivity, then we should observe a divergence in the average productivity of these two groups over time. The average productivity differentials in year *t* identify the productivity premium of continuous exporters (column 2 of table 7). These results largely replicate the productivity advantage of plants that remain in the export market, as identified in table 4.

The changes in differentials over time indicate that, for most industries, the productivity of continuous exporters does not improve over time relative to that of nonexporters (column 3 of table 7). In three of the industries in Taiwan (China) and all five industries in Korea, there is no significant change in the productivity

Table 7. *Average Productivity Differences between Continuous Exporters and Continuous Nonexporters*

		Exporting firm differential	
Country and industry	*Intercept*	*Initial year*	*Change in differential over time*
Korea			
Textiles	–0.134*	0.316*	0.013
	(0.011)	(0.017)	(0.025)
Apparel	0.006	0.141*	–0.017
	(0.016)	(0.032)	(0.050)
Plastics	–0.013	0.188*	–0.032
	(0.014)	(0.027)	(0.046)
Electrical machinery and electronics	0.017	0.044	0.017
	(0.019)	(0.024)	(0.035)
Transportation equipment	–0.046	0.167*	0.037
	(0.024)	(0.038)	(0.057)
Taiwan (China)			
Textiles	–0.007	0.309*	–0.094*
	(0.010)	(0.016)	(0.023)
Apparel	–0.163*	0.307*	–0.063*
	(0.013)	(0.021)	(0.030)
Plastics	0.018*	0.191*	–0.002
	(0.005)	(0.012)	(0.017)
Electrical machinery and electronics	0.007	0.145*	0.011
	(0.007)	(0.011)	(0.015)
Transportation equipment	–0.134*	0.165*	0.042
	(0.010)	(0.019)	(0.027)

*Significant at the 5 percent level.
Note: All regressions include year dummy variables. Standard errors are in parentheses.
Source: Authors' calculations.

differential over time. In the two industries in which there is a significant change in the relative productivity of the two groups—the textile and apparel industries in Taiwan (China)—the productivity advantage of the continuous exporters falls over time. Among the group of producers in operation for the two years, there is no evidence that the average productivity of the continuous exporters rises relative to that of the plants with no export experience. There are large initial differences in productivity between the two groups, but there is no evidence that the differential widens with continued export experience. These results are not consistent with a process of ongoing learning by exporting.

A possible reason why productivity differentials between continuous exporters and nonexporters do not widen over time is that both groups are made up of plants of different ages. Learning may be concentrated among young or new plants, with older plants having already fully incorporated the knowledge acquired from past experience. To determine if this is true, we divide the plants in groups 1 and 4 into those that are new in year t and those that were already operating (either in or out of the export market) in the initial census year. We examine the productivity differentials for the new plants. The results, which are not reported here, indicate that in the transportation equipment industry in Taiwan (China), the new plants that are continuous exporters have a productivity differential that widens by 8.1 percent in year $t + 1$ relative to the new plants that have never exported. This is the only industry in Taiwan (China) for which the productivity differential widens over time. Making the same comparison for Korea, we find no industries in which the export differential widens over time. Overall, with the exception of transport equipment in Taiwan (China), this comparison provides no evidence that is consistent with the learning-by-exporting hypothesis.

VII. Summary and Conclusion

The relationships between plant-level TFP and export experience are robust and simple to summarize for the five major exporting industries in Taiwan (China). On average, exporting plants have higher productivity than nonexporters. The transition patterns reflect systematic differences in productivity: average productivity is highest for continuing exporters, followed by entrants, exiting firms, and nonexporters. Plants that diversify into the export market have higher productivity prior to entry than plants that choose not to enter and, in some industries, show evidence of productivity improvements following entry. Plants that exit the export market are less productive than those that remain in the export market. In several industries the relative position of those that exit continues to deteriorate in the years following exit. Finally, there is no evidence that the productivity advantage of continuous exporters over plants that never export increases over time.

These results are consistent with self-selection of higher-productivity plants into the export market. The evidence for several industries indicates that productivity differences between exporters and nonexporters widen as export experience accumulates; however, this tendency is limited to plants that enter or exit the export market, not continuous exporters. This widening productivity gap could reflect direct benefits from exporting, such as knowledge spillovers from buyers, or other factors that lead to positive serial correlation in the shocks to plant productivity. In the latter case the plants with positive (negative) productivity shocks will move into (out of) the export market, and their productivity will continue to diverge from the group of plants that do not make any market transitions. Given the small number of time-series observations in our data, it is impossible to disentangle these two explanations. Nonetheless, the post-entry and post-exit patterns of change in productivity are consistent with efficiency gains that accrue from the exporting process.

Although exporters are on average more productive than nonexporters in Korea and in Taiwan (China), the productivity pattern of the cohorts moving into and out of the export market differs significantly between the two economies. In general, there is less evidence of productivity-based transitions in Korea. Prior to entry, there are no significant differences between entrants and nonentrants for three of the five industries. Following entry, there is no widening of the productivity differential between these two groups in four of the industries. This pattern is also reflected on the exit side. There is no evidence that the productivity gap between plants that exit the export market and those that remain widens after exit. Finally, there is no evidence that the productivity advantage of the group of continuous exporters widens over time relative to producers that never export. Overall, these patterns do not support the learning-by-exporting hypothesis or the self-selection hypothesis.

The lack of any strong evidence of learning by exporting is consistent with the findings of Clerides, Lach, and Tybout (1998) and Bernard and Jensen (1999). Both studies approach the question in a similar way to this article, by asking if the performance (productivity) paths of exporters and nonexporters diverge following a transition from one market to the other. However, our findings are not consistent with the micro-survey evidence reported by several authors. Rhee, Ross-Larson, and Pursell (1984) find that, among Korean firms in 1965–75, a considerable amount of production engineering knowledge came from the purchasers of Korean exporters. Similarly, Keesing and Lall (1992) study five East Asian economies in 1979–80 and find that purchasers often established buying offices in the exporting countries. These offices channeled advice on quality control, design changes, and new technologies to domestic producers. Finally, Egan and Mody (1992) study U.S. imports of bicycles and footwear from East Asian countries in the mid-1980s and find that links between industrial-country buyers and developing-country suppliers acted as conduits for information about marketing and production technologies and provided access to larger industry networks.

There are several possible explanations for the difference in findings between the two groups of studies. First, learning by exporting may have been more important as a source of expertise and knowledge in the early period of expansion of the manufacturing sector, that is, for the 1960s and 1970s in Korea. By the middle and late 1980s, the period covered by our data, much of the knowledge had been acquired and disseminated.

Second, the knowledge gained from exporting diffuses quickly across exporters and nonexporters as a result of labor mobility among firms and other interfirm contacts. Rapid diffusion would make it less likely to observe productivity differences across the groups of exporters and nonexporters examined here. In Korea, in particular, exports expanded primarily through large business groups, rather than through small and medium-size enterprises that dominated the export expansion in Taiwan (China). If the knowledge gained from exporting is transmitted quickly among members within a Korean business group, then individual producers are likely to have incorporated much of this spillover effect prior to entry, leading to less significant productivity improvements after entry. In Taiwan (China) this transmission of knowledge must occur across firms, which is likely to be slower and less complete, leaving more opportunities for individual producers to benefit from their own export experience. This explanation is consistent with our finding of some productivity improvements following entry in four Taiwanese industries.

Third, the time-series improvements in productivity that follow from export-led learning could be small and difficult to detect compared with the cross-sectional differences in TFP. Fourth, despite the fact that all of the studies rely on micro-data, the level of industry aggregation differs significantly. Although specific products may benefit from knowledge gained through exporting, they simply are too small a share of industry production to be detected in our comparisons.

Given these qualifications, our findings suggest that the movements of producers with different levels of productivity into and out of the export market more closely reflect a process of market selection among heterogeneous plants than a process of productivity improvement flowing from export market experience. More generally, our empirical findings suggest that producer productivity is correlated less strongly with export market participation in Korea than in Taiwan (China). Several factors could contribute to this difference.

A plant's long-run expected profits from exporting should guide its export decision. Productivity may serve as a less useful indicator of long-run profits in Korea than in Taiwan (China). Total factor productivity provides a summary index of several production-related factors, including the degree of capital utilization, the importance of returns to scale, and managerial efficiency. The index shows how these factors vary across producers, but it does not provide a perfect measure of long-run expected profits. Factors other than production efficiency may be important determinants of expected profitability. If these other factors differ substantially across producers, they will tend to weaken the correlation between a producer's productivity and its pattern of participation in the export market.

Heterogeneity across producers on the demand side of the market weakens the correlation between profitability and TFP. Hobday (1995) argues that there is little emphasis among Taiwanese manufacturers on brand or product differentiation and little expenditure on advertising or research and development. To the extent that export products are more homogeneous in Taiwan (China) than in Korea, profit differences and export decisions in Taiwan (China) will more closely reflect differences in productive efficiency.

Several institutional factors suggest that determinants of profitability other than productivity may be more important in Korea than in Taiwan (China). Pack (1992), Levy (1991), and Levy and Kuo (1991) argue that the dense network of subcontractors and export traders in Taiwan (China) has lowered the costs of moving into and out of the export market, particularly for small firms. By contrast, the weaker network of subcontractors and traders in Korea implies substantially higher initial investment costs for the producer, which can introduce hysteresis into the export decision. The producer's prior export experience becomes an important determinant of the decision to export and can weaken the link between current productivity and exporting choice. In the 1980s both the extent of subcontracting and entry into exporting increased in Korea, suggesting that entry and exit costs decreased gradually. Investment subsidies also decreased significantly in the 1980s. However, the effects of sunk entry and exit costs as well as of investment subsidies are likely to be long term.

Several researchers, including Pack and Westphal (1986), Westphal (1990), Levy (1991), and Rodrik (1995), have documented the importance of government investment subsidies in Korea. These policies have resulted in the channeling of credit at negative interest rates to Korea's conglomerates and provided them with insurance against business risk, particularly in the export market. In this context Korean producers are less likely to base their decisions on productivity when they consider entering, continuing, or exiting the export market. Their decisions will reflect whether they have access to the necessary finance, contacts, and insurance provided by the government.

Appendix A. Description of the Data

For Taiwan (China) we use a compilation of data from the last three industrial and commercial censuses collected by the Statistical Bureau of Taiwan's Executive Yuan. The censuses cover 1981, 1986, and 1991. The Statistical Bureau collects detailed data on each of the firms operating in the manufacturing sector, which was more than 88,000 firms in 1981 and more than 100,000 firms in 1986 and in 1991. See Aw, Chen, and Roberts (1997) for a more detailed discussion of the Taiwanese data and the construction of inputs and outputs used to measure productivity.

The data for Korea come from the census of manufactures for 1983, 1988, and 1993. The censuses cover all manufacturing plants with more than five employees in each of the 23 industries defined at the two-digit standard industry level. There were approximately 39,022 plants in 1983, 59,732 in 1988, and 88,864 in 1993.

The firm or plant observations for each country not only provide complete cross-sectional coverage of the manufacturing sector but also are matched across the censuses so that analysts can follow individual producers over time and observe entry and exit patterns. The censuses for both countries provide information on the output and input variables that are necessary to measure TFP at the firm or plant level: sales, employment, book value of the capital stock, and expenditures on labor and different types of intermediate inputs. The type of data that are collected in both countries is very similar. Therefore, we discuss the variable construction for both countries at the same time, noting differences where relevant. The type of data collected in the manufacturing census in Taiwan (China) is similar to what is collected in the United States (for its use in productivity measurement, see Baily, Hulten, and Campbell 1992) or in the industrial countries analyzed in Roberts and Tybout (1996).

For Taiwan (China) firm output is defined as total firm sales deflated by a wholesale price index defined at the two-digit industry level. For Korea the value of plant output is measured as the sum of total revenue from sales, repairing and fixing services, and subcontracted work, and the change in the inventory of final goods. It is deflated by a producer price index defined at the two-digit industry level.

We model each producer as using four inputs in production: labor, capital, materials, and subcontracting services. The labor input is measured as the number of production and nonproduction workers. Total payments to labor are measured as total salaries to both groups. The measure of capital input is the book value of the capital stock of the firm or plant. We have adjusted the book values to control for price changes in new capital goods that will cause the book values to change over time with investment in new equipment. The expenditure share on capital is calculated as the residual after subtracting expenditures on labor, material inputs, and subcontracting from the value of output.

The material input is defined to include raw materials, fuel, and electricity. In Taiwan (China) raw material expenditures are deflated by a general producer price index, which covers both manufacturing and nonmanufacturing output in the country. Fuel and electricity expenditures are deflated by an aggregate energy price index. In Korea we use a raw material price index for the manufacturing sector to deflate material expenditures. Fuel expenditures are deflated by an energy producer price index, and electricity expenditures are deflated by an electricity price index.

The final input measures expenditures on subcontracting services. Many producers in both economies hire subcontractors to perform parts of the manufacturing process. Payments to these subcontractors are reported as separate expenditures by the firm or plant in the census data. To construct the subcontracting input, we deflate payments to subcontractors by the output price of the industry in which the firm or plant operates. This is not an ideal price index for deflating subcontracting expenditures. However, the overall inclusion of the subcontracting input is important because it recognizes that the inputs of producers that subcontract some of the production steps need to be increased, and thus their TFP reduced, relative to the producers that do not subcontract.

Appendix B. The Measurement of Plant-Level Total Factor Productivity

Using manufacturing data for Korea and Taiwan (China), we construct an index of TFP for each plant in each year. (See Tybout 1996 for a discussion of alternative productivity measures based on econometric estimation of production functions and a summary of the literature on the sources of productivity differences across producers.) In the case of Taiwan (China) this is done for each of the three census years 1981, 1986, and 1991. For Korea the three census years are 1983, 1988, and 1993.

Caves, Christensen, and Diewert (1982) develop a multilateral index that is useful for measuring TFP in plant- or firm-level panel data sets. They construct the TFP index as the log of the plant's outputs minus a revenue-share-weighted sum of the log of the plant's inputs. In order to guarantee that comparisons between any two plant-year observations are transitive, each plant's inputs and outputs are expressed as deviations from a single reference point. Caves, Christensen, and Diewert's multilateral index uses as the reference point a hypothetical plant with input revenue shares that equal the arithmetic mean of revenue shares over all observations, and output and input levels that equal the geometric mean of output and the inputs over all observations. Each plant's output, inputs, and productivity in each year are measured relative to this hypothetical plant.

Good, Nadiri, and Sickles (1997) discuss an extension of the multilateral index that uses a separate hypothetical-plant reference point for each cross section of observations and then chain-links the reference points together over time in the same way as the conventional Tornqvist index of productivity growth. This productivity index is useful in our application because it provides a consistent way of summarizing the cross-sectional distribution of plant TFP, using only information that is specific to that time period, and describing how the distribution moves over time.

Let each plant f produce a single output Y_{ft} using the set of inputs X_{ift} where $i = 1, 2, \dots n$. The TFP index for plant f in year t is defined as:

$$\text{(B-1)} \qquad \ln TFP_{ft} = \left(\ln Y_{ft} - \overline{\ln Y_t}\right) + \sum_{s=2}^{t}\left(\overline{\ln Y_s} - \overline{\ln Y_{s-1}}\right) - \left[\sum_{i=1}^{n}\frac{1}{2}\left(S_{ift} + \overline{S_{it}}\right)\left(\ln X_{ift} - \overline{\ln X_{it}}\right) + \sum_{s=2}^{t}\sum_{i=1}^{n}\frac{1}{2}\left(\overline{S_{is}} + \overline{S_{is-1}}\right)\left(\overline{\ln X_{is}} - \overline{\ln X_{is-1}}\right)\right].$$

The first line in equation B-1 measures plant output and consists of two parts. The first part expresses the plant's output in year t as a deviation from the reference point, the geometric mean output over all plants in year t. It thus captures information on the cross-sectional distribution in output. The second part sums the change in the output reference point across all years, effectively capturing information on the shift of the output distribution over time by chain-linking the movement in the reference point. Subscript s denotes the reference year. The remaining two lines of the formula perform the same operation for each input X_i. The inputs are then summed using a combination of plant factor shares S_{ift} and average factor shares S_{it} in each year as weights. The index provides a measure of the proportional difference in TFP for plant f in year t relative to the hypothetical plant in the base year. In our application we use 1981 as the base year for Taiwan (China) and 1983 as the base year for Korea.

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