LABOR PRODUCTIVITY OF SMALL AND LARGE MANUFACTURING FIRMS: THE CASE OF TAIWAN

MEI HSU and BEEN-LON CHEN*

This work studies the factors influencing the labor productivity of small and medium-sized enterprises (SMEs) and large firms using Taiwan as a case study. A special emphasis is placed on two possible international channels: exports and foreign direct investment (FDI). Different from conventional studies, we employ the two-stage switching regressions to correct the firm-size effect on labor productivity and estimate labor productivity for SMEs and large firms. The main findings are as follows. First, the estimates of the selectivity variable are statistically significant for both SMEs and large firms, supporting the hypothesis of correcting the effect of firm-size truncation. Second, while a larger trade intensity significantly increases the labor productivity of SMEs, it deteriorates significantly that of large firms. Third, FDI enhances the labor productivity of SMEs internally, whereas it has a negative spillover on that of other small and large firms in the industry. While the first outcome lends supports to the role of self-selection, the remaining stands in sharp contrast to conventional wisdom. (*JEL* F1, L1, L6)

I. INTRODUCTION

This article studies the determinants of labor productivity, stressing in particular two possible channels of international technology adoption. Technology adopting of developing economies in theoretical models has been pioneered by Findlay (1978), and its importance has recently been further underscored in economic growth models by Romer (1994) and Chen and Shimomura (1998). There is thus little doubt concerning the role of technology adoption for a developing economy. A more relevant issue is the manner in which technology is adopted, as there are various channels and some of them are more effective than others. Existing studies, however, have not yet offered clear answers.

Many existing works contend multinationals to be vital instruments in adopting technology. Wang and Blomstrom (1992), for example, have asserted that multinationals have become the most important actors in the generation and transfer of modern technology. Building on the models of Caves (1974), several studies have documented the existence of an intra-industry spillover of foreign direct investment (FDI) in manufacturing in many countries. These studies support the hypothesis that multinationals can enhance the labor productivity of host countries. However, the multinationals may also reduce labor productivity of host countries, as Rodriguez-Clare (1996) and others have recently argued. Their reasons are that multinationals affect the host country through the generation of backward and forward linkages and other effects. The net impact of multinationals on the host country depends on the linkages they generate compared to those that would be generated by domes-

ABBREVIATIONS

FDI: Foreign Direct Investment
NIEs: Newly Industrialized Economies
NT$: New Taiwan Dollars
OLS: Ordinary Least Squares
SMEs: Small and Medium-Sized Enterprises

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Hsu: Associate Professor, Department of Economics, National Taipei University, Taiwan, Email mhsu@cc.nchulc.edu.tw

Chen: Research Fellow, Institute of Economics, Academia Sinica, Taiwan, Phone 886-2-27822791, ext. 309, Fax 886-2-27853946, Email bchen@ieas.econ.sinica.edu.tw

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tic firms they displace. To the extent that the multinationals have fewer linkages than domestic firms, increasing FDI reduces rather than raises the labor productivity of domestic firms.

Another channel that may affect labor productivity is via international trade, in particular, exports. Conventional wisdom holds that countries with superior export performance have better growth accomplishment (e.g., World Bank, 1993). Nevertheless, some researchers (e.g., Young, 1991) have contended that a more freely trading regime retards the productivity upgrading of developing countries as a result of international comparative advantage, under which developing economies specialize in producing goods with exhausted learning by doing. Therefore, the effects of exports may be ambiguous for developing countries.

Although export performance may effect technology adoption, the existing empirical works documenting the positive spillover of FDI do not examine whether export performance is positively correlated with the labor productivity of private plants. This omission could be due to a lack of data in exports or inward orientation in these countries in the years under concern. In this work we conduct an empirical study of the relationship between the labor productivity and both the aforementioned channels of technology adoption while controlling for other factors of labor productivity. A consideration of these two competing channels is important as they have been and remain employed in an important manner by successful developing countries, especially East Asian newly industrialized economies (NIEs). We use Taiwan as a case study to see whether Taiwan's labor productivity in manufacturing is more FDI led or more export-performance promoted.

One particular feature in Taiwan is the pivotal role of small and medium-sized enterprises (SMEs). Taiwan's SMEs are nimble and responsive to profit opportunities, making them competitive in the world market (Wade, 1990; Levy, 1991). This led some to conclude the SMEs are one of the pillars of Taiwan's economic success (Amsden, 1991). The role that the SMEs play in Taiwan may provide valuable experiences to the developing world. Existing SMEs works using Taiwan's data mainly concern the evolution and change of the market structure (Amsden, 1991). Since the effects of productivity determinants are likely to be different between SMEs and large firms, but no existing works explore them separately, this article investigates and compares them separately. The existing works distinguish SMEs from large firms in a way implicitly treating the size distribution of SMEs as the whole population, albeit the size distribution of SMEs is in effect truncated. One of the features differentiating our study from existing works of SMEs is correcting the effect of the sample selection problem as the sample under study is divided into SMEs and large firms. A variant of the two-stage technique can be used to tackle the problem of this kind, but surprisingly existing works of SMEs do not apply it. This study explicitly admits the size distribution nature and takes this into account in estimation.

The main findings are as follows. First, the estimates of the selectivity variable are statistically significant for both SMEs and large firms, supporting the hypothesis of correcting the effect of firm-size truncation. Second, a larger trade intensity significantly increases the labor productivity of SMEs, whereas it deteriorates significantly the labor productivity of large firms. Third, while an SME's own FDI enhances its labor productivity, FDI has a negative spillover on the labor productivity of other small and large firms in the industry.

II. PRODUCTIVITY ANALYSIS: ECONOMETRIC MODEL

This section sets up an econometric model for the labor productivity analysis. The model described here is a two-stage switching regression model (Greene, 1997, pp. 974–984). This approach was originally used in the area with a clear-cut discrete regime, for example, to join the union or not (Lee, 1978) and to have college education or not (Willis and Rosen, 1979). Recently, there are applications to the area where the choice variable is continuous and the choice set is ordered. Examples in this regard include college schooling and returns where the schooling variable is continuous (Garen, 1984), and part-time and full-time wage differentials where the working hours of a part-time job are continuous (Hotchkiss, 1991). The idea for this extension is simple. As Garen (1984, p. 1217) noted, as long as the return on labor

productivity to each size choice is affected by a different disturbance, the disturbance in part determines which choice is made. This choice, in turn, influences the disturbances of equations, which determine the return to the choice.

Our model consists of an equation describing the dichotomous firm size and two labor productivity equations. The formulation is employed in order to take into account the relationship between firm size and labor productivity determination. Consistent estimators of the determinants of labor productivity can be obtained only after correcting for the potential size effect. The observations of firm size may be thought of as falling into one of two mutually exclusive regimes.

Consider a random sample of N firms in which M firms are large and the remaining are SMEs. Since the population and thus the sample of firms combine both large and small firms, we define firm size for a firm $i = 1, 2, \ldots, N$ to be a dichotomous outcome I_i, which is given by

$$(1) \qquad I_i = \begin{cases} 1 & \text{if the number of} \\ & \quad \text{employees } \geq H_i^*, \\ 0 & \text{otherwise.} \end{cases}$$

Since our purpose is to compare the difference in the determinants of the labor productivity of large firms and SMEs, we specify the equations for firm i's labor productivity to be[1]

$$(2) \quad \begin{cases} Y_i|_{I_i=1} = X_{L_i}\beta_L + \varepsilon_{L_i}, \\ \qquad i = 1, 2, \ldots, M, \\ Y_i|_{I_i=0} = X_{S_i}\beta_S + \varepsilon_{S_i}, \\ \qquad i = M+1, M+2, \ldots, N, \end{cases}$$

where $Y_i|_{I_i=1}$ and $Y_i|_{I_i=0}$ are, respectively, the labor productivity of large firms i (i.e., $I_i = 1$) and SMEs i (i.e., $I_i = 0$), and for convenience we denote them respectively as Y_{L_i} and Y_{S_i}. The explanatory variables X_{ji} are a $1 \times k$ vector in which $j = L$ indicates a large firm and $j = S$ a SME, β_j is a $k \times 1$ vector of parameters, and ε_{ji} is an error term, which is assumed to be normally distributed with

$$(3) \quad E(\varepsilon_{ji}) = 0, \quad E(\varepsilon_{ji}\varepsilon_{j'i'}) = \sigma_{jj'} \ \text{if } i = i', \quad = 0 \ \text{if } i \neq i.$$

If we use the ordinary least squares (OLS) method to estimate the coefficients for large firms and SMEs in equation (2), the estimated coefficients are unbiased but inconsistent. This is because the separation of small and large firms renders both the distribution of small firms and that of large firms truncated, and therefore the OLS method generates a sample selection problem. To control for this effect, we employ a variant of the two-stage estimation method, after Heckman (1979), by treating the sample truncation, or sample selection, bias as a specification error. Specifically, we add a third equation of firm-size determination and then append into each equation in equation (2) an omitted variable summarizing the size determination calculated from the third equation. The idea is that the firm size is determined by the difference between the benefits and costs of becoming a particular size. These gains and costs, however, may not be observable by econometricians, although the size is. The benefits and costs are nevertheless affected by a vector of observable variables and unobservable variables. Firm size can thus be formulated as

$$(4) \qquad H_i^* = W_i\gamma + u_i,$$

in which W_i is a $1 \times m$ vector of observable explanatory variables, γ is a $m \times 1$ vector of parameters, and the error term u_i summarizes unobservable variables affecting the benefits and costs and is assumed to be normally distributed with zero mean and common variance. We assume further that the bivariate normally distributed Y_{ji} and I_i are correlated and denote the correlation coefficient as ρ_j, $j = L$ and S. This formulation gives rise to the following Probit model:

$$(5) \quad \begin{cases} \text{Prob}(I_i = 1) = \int_{-\infty}^{W_i\gamma} \phi(t)\,dt \\ \qquad\qquad = \Phi(W_i\gamma), \\ \text{Prob}(I_i = 0) = \int_{W_i\gamma}^{\infty} \phi(t)\,dt \\ \qquad\qquad = 1 - \Phi(W_i\gamma), \end{cases}$$

where Φ is the cumulative function of the standard normal distribution and Φ is its density function. The estimation is proceeded

1. If we pool the data of large and small firms and introduce a firm-size variable, we cannot distinguish the effects of other explanatory variables for large firms and SMEs, respectively.

in two steps. First, the probit equation in equation (5) can be estimated by employing the maximum likelihood estimation to obtain estimates of γ. We then compute the consistent estimators of inverse of Mill's ratio for each observation i in the sample, namely,

$$(6)\quad \begin{cases} \hat{\lambda}_{L_i} = \dfrac{\phi(W_i\hat{\gamma})}{\Phi(W_i\hat{\gamma})} & \text{for large firms,} \\ \hat{\lambda}_{S_i} = \dfrac{\phi(W_i\hat{\gamma})}{[1-\Phi(W_i\hat{\gamma})]} & \text{for SMEs.} \end{cases}$$

In the second stage, we add the variable $\hat{\lambda}_{L_i}(\hat{\lambda}_{S_i})$ as a regressor into the original labor productivity equation for large firms (SMEs). The modified models become

$$(7)\quad \begin{cases} Y_{L_i} = X_{L_i}\beta'_L + \beta_{L\lambda}\hat{\lambda_{L_i}} + \nu_{L_i}, \\ \qquad i = 1, 2, \ldots, M, \\ Y_{S_i} = X_{S_i}\beta'_S + \beta_{S\lambda}\hat{\lambda_{S_i}} + \nu_{S_i}, \\ \qquad i = M+1, M+2, \ldots, N, \end{cases}$$

where $\beta_{j\lambda}, j = L, S$, is a parameter and $\nu_{ji}, j = L, S$, is assumed to be normally distributed with zero mean and common variance and serially uncorrelated. The estimated $\beta_{j\lambda}$ captures the effect of firm-size correction on labor productivity, which equals the product of ρ_j and the standard deviation of ε_j. Equations (7) can be estimated using OLS. With the correction of the firm-size effect, the resulting estimated coefficients of X_{ji} become consistent.

To separate large firms from SMEs, a threshold must be introduced in the data. The same method has been used in other kinds of research, for example, the firm-size wage differentials in Garen (1985) and part-time and full-time wage differentials in Hotchkiss (1991). Although the threshold is unknown, we will not follow the method proposed by Hotchkiss (1991) to find the threshold. To do that, we need to estimate the Probit equation and the productivity equations of both large firms and SMEs under all possible thresholds, and then choose the threshold with the highest likelihood function. The number of possible thresholds could be more than 100, not around 30 as in Hotchkiss. Our concern is not to detect the threshold. Rather, our study stresses and compares the different effects of international technology adoption channels on the labor productivity. The threshold number H^* is set at 100 because this critical point has been used by many other researchers (e.g., Storey, 1982). By doing so, our starting point is compatible and our results can be compared to existing wisdom. To avoid the result of relying on a single threshold, we also conduct the estimation with 150 as a threshold and with and without industry effects. As we will show below, the results are the same, implying the robustness of our results for a range of thresholds.[2] Even if we follow the method of Hotchkiss (1991) and find a threshold different from 100 and 150, either between or outside them, we expect the effect of FDI and international trade on the labor productivity of SMEs and large firms to be robust. We thus do not follow the method in Hotchkiss.

We must point out that the distribution is skewed in the probit or tobit models, as the number of observations in one of the groups is typically much smaller than the other. Nevertheless, the skewed distribution usually only changes the constant term and does not affect the slope coefficients in the logit and probit models (as noted in, e.g., Maddala, 1992, pp. 330–332). Moreover, as the numbers of observations on either group is large, the distribution approaches normal according to the central limit theorem. When the threshold of firm size is 100 and 150, there are respectively 1,832 and 1,169 large firms and 8,596 and 9,259 SMEs. The sample size seems to be large enough.

III. EXPLANATORY VARIABLES AND SAMPLE DESCRIPTION

We now discuss the explanatory factors influencing the labor productivity, that is, the vector X_L and X_S in equation (7). A large number of works has investigated the determinants of labor productivity. We follow the works by Caves (1974), Blomstrom and Persson (1983), and Haddad and Harrison (1993) in documenting the labor productivity, although their main concern was the spillover of multinationals. This facilitates comparisons of the effects of FDI with theirs, while holding under control a set of other variables. To make comparisons between SMEs

2. When we conduct the estimation using 200 workers as a threshold (data not reported), the results change, indicating that the threshold separating SMEs from large firms in Taiwan is about 100–150 employees.

and large firms, we employ the same variables for X_L and X_S to control the same set of variables. In general, the labor productivity of both a small and a large firm depends on the quantity and quality of inputs, the efforts to improve the levels of human capital and technology, and domestic and international factors influencing the markets. We illustrate these factors as follows.

A. The Quantity and Quality of Inputs

Capital and labor are two major inputs. What matters for the labor productivity per employee is the capital intensity (denoted K/L). Since capital and labor are in general complements, a larger amount of capital intensity is expected to raise the labor productivity per capita, other things being equal. Capital of different vintages and laborers of dissimilar qualities have distinct productivity. Although there is a lack of data on capital vintages, there are data capturing the quality of labor. Intuitively, a laborer with a larger human capital stock has a better quality and a firm with labor of better quality is more productive. Therefore, higher labor quality (denoted *QUA*) should be more productive, other things being equal.

B. The Effort to Improve the Levels of Human Capital and Technology

A firm can potentially improve its labor quality and technology level by investing in training programs (denoted *TR*) and in welfare programs (denoted *WEL*). Intuitively, a better welfare attracts the entry of laborers with a higher quality, whereas a training program improves the quality of workers already hired. While both these factors tend to increase the labor productivity, the effect of the investment in a training program may be lagging, rendering its effects ambiguous in the short run. Another factor that potentially improves the technology level and thus enhances labor productivity is the investment in research and development (denoted *RD*). While the effect of research and development tends to advance the technology level in the long run, its effect in the short run is usually ambiguous. There is a lagged effect of R&D investment.

C. The Domestic and International Factors Influencing the Markets

The most important domestic market factor is monopolistic power in the industry (denoted *MONO*) to which a firm belongs. Intuitively, a firm in an industry can generate a larger value added per employee than an otherwise identical firm in different industries simply because of the monopoly power in the industry. Moreover, monopoly rents may give a firm a larger ability to do investment. For international openness factors, the two aforementioned elements are significant in Taiwan. We denote exports and FDI of a firm as X as FDI_i respectively. As FDI of a firm may generate an spillover effect on other firms in the industry, we introduce this external effect and denote it as FDI_e. Existing wisdom has argued opposite spillover effects for FDI.

To recapitulate the explanatory factors of labor productivity, nine variables are included. A list summarizing the definitions of variables is illustrated in Table 1. We should point out that there may be omitted variables. For example, a firm may have a higher labor productivity because of higher quality of management and other factors. Because of the availability of data, however, only these nine variables are included.

Since our estimation of labor productivity differentiates small from large firms, we need to specify the variables determining the firm size. In estimating the probit model of firm-size determination, we include all the nine variables of labor productivity except for K/L and FDI_e. The variable FDI_e is not included because it is an external factor outside a firm, whereas the variable K/L is excluded because the probit regression turns out to be singular if it is included. We expect that higher TR, WEL, and RD are likely to be associated with larger firms, as a larger expenditure of these items implies a higher entry barrier for new firms (Tan and Batra, 1997). An industry with a larger concentration ratio (*MONO*) is expected to generate more large firms (Storey, 1982), whereas the multinationals (FDI_i) usually like to do a joint venture with large firms, thereby contributing to the formation of large firms. We expect *QUA* to negatively affect the size as skillful workers or managers are more likely to start their own business. The remaining variable, X, is expected to have ambiguous effects because

both small and large firms can be inward or outward oriented.

Our data are from the *1991 Manufacturing Survey in Taiwan*. In the data set, there are 13,330 firms classified into 243 four-digit industries in which six industries have no data. There are 567 firms owned by multinationals (to be defined) and some domestic firms have either no capital or no labor inputs. We therefore obtain 10,428 domestic firms belonging to 237 four-digit industries, of which 1,832 firms have employees larger than or equal to 100, and 1,169 firms have employees larger than or equal to 150 (hence are large firms respectively under different thresholds).

We are now ready to construct the variables. As one of the variables under concern is the spillover effect of FDI, we start by differentiating the multinationals from local firms. In usual practice, a firm is referred to as foreign if foreigners possess 50% or more of its capital share because foreigners therefore control the firm completely. In contrast, it may be contended that a very small fraction of foreign capital shares is enough to generate a spillover since foreign skills and managerial practices may be then transferred via original equipment manufacturing and other courses. Following Blomstrom and Persson (1983) and others, we define the multinationals as those firms with at least 15% of foreign capital shares.[3] There are 567 multinationals under this definition.

We follow Caves (1974) and his followers by constructing the labor productivity (Y) as the ratio of total value added per employee (thousands of New Taiwan dollars, NT$)[4]. Labor quality ($QUA$) is better measured as the level of educational attainment or years of working experience, but there are no such data in the survey. We use as a proxy the ratio of staff to workers.[5] Staff either work at managerial or administrative posts or have higher skills, whereas workers take part in assembling or manufacturing. The monopoly power of an industry ($MONO$) is represented by the Herfindahl index, which has been shown to be the best measure among 11 market concentration measures (Vanlommel et al. 1977). We use the employment share to construct the Herfindahl index.[6] The internal effect of FDI (FDI_i) is constructed as a dummy variable, specifying 1 if there is foreign capital in the firm and 0 otherwise, whereas the external effect of FDI (FDI_e) is defined as the employment share of foreign firms in a four-digit industry.

The way to construct other variables, including the capital intensity (K/L) and the investment in training programs (TR), in welfare programs (WEL), and in research and development (RD), and the export intensity (X) is summarized in Table 1. The mean and variance of each variable when the threshold separating firm size is 100 employees are reported in Table 1 for SMEs and large firms, respectively. Some observations from the means are in order. First, value added per employee for large firms is on average 50% higher than that for SMEs. This is reasonable as large firms on average have a larger capital intensity. Second, large firms on average have a larger expenditure per employee in training, welfare, and R&D. Third, large firms' average export share in sales is more than twice that of SMEs. This property is shared with the positive relation between export participation and firm size in West Germany and in U.S. manufacturing (Bernard and Jensen, 1995), but differs from the finding in Taiwan's manufacturing that small firms are export-oriented while large firms are domestic-oriented in the 1970s and the early 1980s (e.g., Chou, 1986). Fourth, large firms possess more foreign capital shares than SMEs.

IV. RESULTS OF ESTIMATION

The estimation is conducted in two stages. We start by estimating the probit model of size determination in equation (5). Maximum likelihood estimates of this equation are presented in Table 2. Two columns are reported for different thresholds separating SMEs from large firms. The threshold is 100

3. The result is insensitive to the critical point chosen. See Chen et al. (1999) for test of robustness by varying the critical point.

4. For reference, US$1 exchanges into NT$25.7475 in December 1991 (source: *Taiwan Statistical Data Book*).

5. According to the survey, staff includes managers, engineers, technicians, and accountants, whereas workers consist of mechanics, assembly-line workers, drivers, and coolies.

6. We use (labor) input rather than output value to construct *MONO* because the dependent variable is measured using output value added. The same reason applies for FDI_e below.

TABLE 1
Definitions and Constructions of Variables, and Summary Statistics[a]

Variables	Meanings	Construction of the Variables	Mean (Variance)
Y (1000 NT$)	Labor productivity	The ratio of value added to total number of employees in a firm	1.[b] 613.48 (541.66) 2.[c] 403.84 (331.04)
K/L (1000 NT$)	Capital intensity	The ratio of book value assets to total number of employees in a firm	1. 810.26 (1282.00) 2. 707.44 (1316.44)
QUA (%)	Quality of labor	The ratio of staff to workers in a firm	1. 0.4354 (0.5477) 2. 0.4953 (0.5433)
TR (1000 NT$)	Training expenditure	Training expenditure per employee	1. 1.2087 (8.5644) 2. 0.233 (2.451)
WEL (1000 NT$)	Welfare expenditure	Welfare expenditure per employee	1. 15.72 (17.633) 2. 13.85 (17.38)
RD (1000 NT$)	Research and development	R&D expenditure per employee	1. 15.3879 (51.05) 2. 1.7997 (14.99)
$MONO$ (%)	Monopoly power	Herfindahl index: $\sum_{i=0}^{n}(l_i/l)^2$, where l_i is the employment of the ith firm and l is total employment of a four-digit industry	1. 0.1059 (0.1238) 2. 0.1040 (0.1178)
X (%)	Exports intensity	The ratio of exports to sales	1. 0.4458 (0.4045) 2. 0.2090 (0.3583)
FDI_i (dummy)	Foreign direct investment in a firm	1 if there is foreign capital shares, 0 otherwise	1. 0.0235 (0.1514) 2. 0.0034 (0.0580)
FDI_e (%)	Foreign direct investment in an industry	The ratio of the number of employees in foreign plants of a four-digit industry	1. 0.1317 (0.1484) 2. 0.1152 (0.1352)

Sources: Manufacturing Survey of the 1991 Industrial and Commercial Census in Taiwan, Directorate-General of Budget, Accounting and Statistics.

[a]Total number of observations is 10,428.

[b]Means and variances for large firms with the number of employees larger than or equal to 100. There are 1,832 large firms.

[c]Means and variances for small firms with the number of employees less than 100. There are 8,596 SMEs.

in column (1), whereas it is 150 in column (2). The results are the same. Examination of the results reveals that the signs of parameter estimates generally conform to a priori expectations. The probability of becoming a large firm significantly increases with the investments in training, welfare and R&D, export intensity, and foreign share; it also increases with the market power although less significantly. The latter result is likely to reflect the competitive market structure characteristics in Taiwan (Wade, 1990). The estimated coefficient of labor quality is negative, indicating that a firm using more skilled labor tends to be a small firm. The product of -2 and the log-likelihood ratio is distributed as χ^2 with 7 degrees of freedom, where the restricted form of the likelihood function contains all coefficients to zero. These large values certify the overall explanatory power of the size-determination equations.

The fitted values of the probit model are then used to construct the selectivity variables for large firms and SMEs, respectively, using equation (6). When each of these variables is added to the corresponding labor productivity equations, the resulting regressions may be estimated by using the OLS method. Both OLS regressions for SMEs and large firms, however, are found to have the problem of heteroschedasticity using the Breusch-Pagan/Godfrey test (Greene, 1997, pp. 352–353). To correct the problem, we use the two-step generalized least square following Greene (1997, pp. 558–562) to infer the forms of heteroskedasticity and correct the problem accordingly. The resulting estimates of labor productivity are demonstrated in

TABLE 2
Probit and Productivity Estimation

Variables	(1) Probit	(2) Probit	(3) SMEs	(4) Large Firms	(5) SMEs	(6) Large Firms
Constant	−1.2083***	−1.4970	419.21***	623.97***	372.63***	1474.7***
	(0.030)	(0.033)	(36.10)	(102.05)	(42.59)	(331.61)
X	0.8218***	0.7273***	289.94***	−176.61***	187.83**	−507.31***
	(0.036)	(0.040)	(56.937)	(40.308)	(73.119)	(109.01)
FDI_i	0.8702***	0.8497***	471.28***	14.753	645.23***	−59.62
	(0.055)	(0.055)	(123.49)	(80.784)	(132.83)	(205.11)
FDI_e	—	—	−59.723***	−127.04***	−26.058	−223.02***
			(19.058)	(34.12)	(29.088)	(76.348)
K/L	—	—	0.1032***	0.2871***	0.059***	0.2043***
			(0.0042)	(0.0125)	(0.0092)	(0.0381)
QUA_L	−0.2126***	−0.1682***	−10.168	75.964***	12.503	93.346***
	(0.033)	(0.0346)	(11.717)	(16.424)	(13.254)	(29.936)
TR	0.0213***	0.0230***	14.406***	−1.0413	12.879***	−3.7556
	(0.004)	(0.004)	(2.8146)	(1.0094)	(4.0591)	(1.0453)
WEL	0.0025***	0.0025***	5.6266***	3.7422***	5.5474***	3.5110***
	(0.0008)	(0.0008)	(0.2789)	(0.4989)	(0.3924)	(0.9533)
RD	0.0087***	0.0060***	5.7950***	−0.1482	3.9977***	−0.8381
	(0.0006)	(0.0005)	(0.8862)	(0.1054)	(0.8467)	(0.4576)
$MONO$	0.1382	0.2195*	21.316	317.59***	72.526**	727.93***
	(0.121)	(0.133)	(23.477)	(72.383)	(31.574)	(293.54)
$\hat{\lambda}$	—	—	817.35***	−201.94***	745.30**	−557.99***
			(167.79)	(59.496)	(307.74)	(169.34)
No. observations	10,995	10,995	8596	1832	9259	1169
No. large firms	2155	1423	—	1832	—	1169
No. small firms	8840	9572	8596	—	9259	—
−2(log-likehood ratio)	1408.946	1057.489	—	—	—	—
Adj R^2	—	—	0.136	0.386	0.182	0.400

Notes: The multinationals are included in the estimation of the Probit equations (1) and (2). The dependent variables in (1) and (2) are a dummy, specifying its value as 1 if the number of employees of a firm is larger than or equal to 100 and 150, respectively, and 0 otherwise. The dependent variables for (3)–(6) are value added per employee in thousands of NT$. The threshold separating SMEs from large firms in (3) and (4) is 100, and (5) and (6) is 150. All regressions use the two-step estimation to correct heteroskedasticity. Standard deviations are given in parentheses. The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

columns (3)–(6) in Table 2.[7] The estimates for SMEs in columns (3) and (5) are very consistent even though the thresholds are different, and so are those for large firms in columns (4) and (6). Of interest are the coefficients of the selectivity variable ($\hat{\lambda}$), which reflect the variation of labor productivity and the correlation between labor productivity and firm size. The coefficients are significantly positive in the SMEs' equations but negative in the large firms'. They imply negative correlation between labor productivity and firm size. These results lend support to the hypothesis of correcting firm-size effects. It is thus necessary to control for the size effect when studying the SMEs' labor productivity, which have been neglected in existing works.

In analyzing other estimates, three variables are of particular concern. First, while a larger export intensity (X) significantly increases the labor productivity of SMEs in columns (3) and (5), it deteriorates significantly the labor productivity of large firms in

7. The estimation is conducted for linear form and log-linear form. For the log-linear form, logarithmic value is taken for Y, X, K/L, TR, WEL, and RD. As the results are the same using both functional forms, we report only those of the linear form.

columns (4) and (6). Using columns (3) and (4) as examples, the estimates indicate that, if the export intensity is increased by one standard deviation (see the standard deviation values in Table 1), real value added per employee is on average increased by NT$103,900 for an SME while decreased by NT$71,400 for a large firm. Second, introducing FDI to a firm (FDI_i) enlarges the labor productivity statistically significantly only for SMEs, not for large firms. Using again columns (3) and (4) for illustration, the estimated coefficients indicate that by introducing FDI a small firm generates value added per employee at an extra NT$471,000 as compared to large firms and those of small firms that do not introduce FDI. Third, the spillover of FDI in other firms of an industry (FDI_e) on the labor productivity is negative for both small firms and large firms in this industry. The negative spillover of FDI is statistically significant for large firms. For small firms, the results are mixed as the thresholds change.

Other results of estimates are as follows. First, the capital input per capita (K/L) significantly improves the labor productivity of both small and large firms, but the effect for large firms is at least twice as much as that for small firms. Second, labor quality (QUA) raises the labor productivity for large firms, but not for small firms. Third, all forms of investment expenditure aiming to improve either human capital or technological level (TR, WEL, and RD) raise the labor productivity for small firms, but except for the welfare programs, not for large firms. While the first two results (K/L and QUA) indicate that large firms utilize inputs of both quantity and quality more efficiently than small firms, the third results (TR, WEL, and RD) suggest that the small firms manage to enhance their technology level more competently. Finally, market concentration of an industry ($MONO$) statistically significantly increases only the labor productivity of large firms in that industry. The last result seems to signify that large firms are able to make good use of market power.

The negative effect of export intensity on the labor productivity of large firms is surprising given that conventional wisdom advocates exports as a critical source of the engine of economic growth in Taiwan (e.g., World Bank, 1993). As evidenced by our data that large firms on average have a share of exports in sales more than twice as large as that of SMEs (see Table 1), our estimates then suggest that extra exports of large exporters have a damaging effect on their labor productivity, other things being equal. This result sheds light on the finding of Aw and Hwang (1995), which used firm-level data of electronics industry in Taiwan in 1980 and found that the technical efficiency of exporters is larger than that of nonexporters. Our result suggests that the contribution of exports to technical efficiency is not monotonic; it increases with export intensity when the intensity is smaller, and decreases when the intensity is larger.

Some possible explanations for the different effect of export intensity for SMEs vis-à-vis large firms follow. SMEs in Taiwan are nimble and are always ready for competition in international markets (e.g., Wade, 1990; Levy, 1991), giving them pressure and incentives to improve technology and find niche markets when they want to export more. Large firms, on the other hand, generally tend to use technology that renders large-scale production and exports possible. The technology may be simply copied from multinationals or from domestic partners. Technology of this kind, however, is usually more standard and mature, and the effect of learning by doing is more exhausting, giving firms less incentive to improve it when they produce and export. A simple experiment may partially verify the reliance on capital of large firms by using the estimates in columns (3) and (4) of Table 2. Excluding the effect of firm size, we increase all determinants by one standard deviation (see the standard deviation values in Table 1). By doing so, the labor productivity of large firms is on average enlarged by NT$417,239, in which 88.21% is contributed by capital per capita, whereas that of SMEs is on average raised by NT$451,350, in which only 30.10% is contributed by capital per capita. Including the effect of the selectivity variable,[8] the contribution of capital per capita to labor productivity is even larger for large firms and smaller for SMEs, as a large-firm size has a harmful effect on productivity.

The negative spillover result of FDI is nonconventional. The result stands in sharp

8. Standard deviation of selectivity variables is 0.352 and 0.160 for large firms and SMEs, respectively.

contrast to the conventional finding documenting a positive spillover for manufacturing at (1) the aggregate (industry) level in Australia (Caves, 1974), Canada (Globerman, 1979), and Mexico (Blomstrom and Persson, 1983), and (2) the firm level in Morocco (Haddad and Harrison, 1993). Nevertheless, our result is consistent with the negative effect on economic growth across (1) 75 developing countries (Saltz, 1992) and (2) the 141 four-digit manufacturing industries in Taiwan (Chen et al., 1999). This outcome is generated possibly because the backward and forward linkages that the multinationals generate are smaller than those of the local firms replaced by them (Rodriguez-Clare, 1996). In general, the multinationals in Taiwan have a large ratio of intrafirm transactions and a low share of local procurement according to the Investment Commission (1993), indicating fewer backward linkages with domestic firms.[9] Moreover, many multinationals retard the inflows of technology using various methods.[10] Furthermore, the effect of foreign subsidiaries may be purely to inject additional competition into the domestic market, destroying rents that would otherwise count in domestic firms' productivity levels. All these factors make possible the negative spillovers of FDI.

V. INDUSTRY EFFECTS: TESTS OF ROBUSTNESS

Our estimation above finds the effects of exports on labor productivity for large firms and the spillover of FDI for both small and large firms to be contrary to conventional wisdom. These results are obtained by confining the same effect for all manufacturing industries. It may be argued that the effects may change for specific industries. Given this consideration, we investigate in this section the robustness of these results for industries at the two-digit level.

There are 20 two-digit manufacturing industries. We proceed the estimation in the following way. Under controlling the same set of other explanatory variables, we replace in regressions the export variable X by X_j, $j = 1, 2, \ldots, 20$, of the 20 two-digit industries.[11] The variable X_j is constructed as the interaction of X and a dummy variable, specifying the value 1 for this dummy variable if the firm belongs to the jth industry and 0 otherwise. Alternatively, while controlling the same set of other variables, we replace in the regressions the external FDI (FDI_e) by FDI_{ej}, $j = 1, 2, \ldots, 20$. The way to construct FDI_{ej} is the same as that of X_j. By doing so, we get the specific effect of X_j and FDI_{ej} on labor productivity for each industry. To save space, summary statistics for the number of firms, the share of exports in sales, and external FDI are not reported.

The industry effects of export performance for SMEs and large firms are reported in Table 3. The results in columns (1) and (2) are for the threshold 100, whereas those in columns (3) and (4) are for the threshold 150. All regressions control K/L, TR, WEL, RD, $MONO$, and $\hat{\lambda}$ and include an intercept, but they are not reported in Table 3. The effects of internal and external FDI (FDI_i and FDI_e) are also controlled. The effects of these variables are the same as those in Table 2 in terms of both quantity and significance. For the industry effects of export intensity, it is obvious to see that they are positive for SMEs in all industries and are statistically significant in all but the categories printing and related industry (X_8) and precision product industry (X_{19}) when the threshold is 150 employees. For large firms, the effects are positive and statistically significant only for the gasoline and coal product industry (X_{10}) in both columns (2) and (4), whereas 17 out of 20 industries in column (2) and 18 out of 20 industries in column (4) have negative effects and most of them are statistically significant. In particular, export intensity of large firms in the

9. Evidence can be found in a survey conducted by the Investment Commission (1993) in Taiwan which reveals that foreign subsidiaries have on average 60% of imports in materials.

10. For example, in a work studying Japanese foreign direct investment in the Taiwanese electronic industry, Liu (1987) found that the inflow of technology with Japanese multinationals was usually accompanied by restrictions on key components or product market constraints in order to hinder the dissemination of their technologies.

11. These industries are 1, food, beverage, and tobacco; 2, textiles; 3, leather; 4, apparel; 5, wood; 6, furniture; 7, pulp and paper; 8, printing and related; 9, chemical material and products; 10, gasoline and coal; 11, rubber products; 12, plastic products; 13, nonmetallic mineral products; 14, basic metal; 15, metallic products; 16, machinery; 17, electric and electronic products; 18, transportation; 19, precision products; and 20, miscellaneous.

TABLE 3
Industry Effect of Export Performance

Variables	(1) SMEs	(2) Large Firms	(3) SMEs	(4) Large Firms	Variables	(1) SMEs	(2) Large Firms	(3) SMEs	(4) Large Firms
FDI_i	529.17**	17.630	611.64***	−38.976	X_{10}	1664.0*	93970***	1180.0***	81149***
	(220.17)	(193.45)	(132.99)	(208.79)		(853.20)	(5625.6)	(346.78)	(6778.4)
FDI_e	−35.984Δ	−83.410*	−17.755	−194.52**	X_{11}	384.90***	−206.02**	171.59**	−652.17**
	(22.203)	(48.901)	(30.271)	(89.928)		(113.24)	(92.006)	(86.659)	(121.88)
X_1	292.60***	−110.72	135.50*	−326.99***	X_{12}	337.97***	−217.89***	178.09**	−567.62***
	(104.23)	(91.442)	(75.920)	(117.64)		(104.68)	(84.012)	(76.464)	(109.21)
X_2	329.12***	−147.78*	195.50***	−433.12***	X_{13}	342.24***	−189.44*	189.70**	−398.97**
	(102.36)	(84.759)	(73.644)	(114.59)		(112.32)	(105.85)	(86.951)	(197.94)
X_3	357.77***	−233.51***	159.48**	−538.68***	X_{14}	582.85***	292.66	450.16***	380.73
	(104.93)	(85.489)	(76.361)	(108.00)		(145.25)	(316.76)	(109.31)	(383.56)
X_4	335.63***	−204.17**	168.27*	−520.59***	X_{15}	333.63***	−144.43*	173.57**	−425.59***
	(112.59)	(86.084)	(86.946)	(108.57)		(102.60)	(84.057)	(74.003)	(120.65)
X_5	332.20***	−267.59***	166.64**	−595.18***	X_{16}	364.38***	−195.71**	180.24**	−576.14***
	(108.90)	(87.284)	(84.313)	(124.00)		(100.63)	(88.422)	(73.375)	(145.83)
X_6	312.19***	−192.73**	148.85*	−500.73***	X_{17}	316.64***	−169.21**	120.03Δ	−525.74***
	(106.34)	(82.759)	(77.786)	(111.34)		(101.63)	(85.735)	(76.260)	(118.44)
X_7	302.65***	−185.58	128.59Δ	−71.363	X_{18}	392.36***	−72.493	230.45***	−517.76***
	(107.04)	(202.03)	(81.037)	(575.52)		(107.07)	(90.514)	(77.535)	(132.36)
X_8	198.76*	664.00	158.96	−2549.7***	X_{19}	270.92***	−260.01***	77.232	−606.94***
	(106.21)	(1115.6)	(192.61)	(245.92)		(102.57)	(84.832)	(75.316)	(113.52)
X_9	609.92***	−179.52	414.85***	−137.23	X_{20}	315.79***	−221.99***	159.06**	−533.02***
	(156.56)	(127.52)	(104.84)	(212.18)		(102.27)	(85.619)	(75.248)	(108.22)
Adj R^2	0.135	0.394	0.186	0.418	Adj R^2	0.135	0.394	0.186	0.418

Notes: Dependent variables are value added per employee in thousands of NT$. The threshold separating SMEs from large firms is 100 for columns (1) and (2) and 150 for columns (3) and (4). Both equations control K/L, QUA_L, *TR*, *WEL*, *RD*, *MONO*, and $\hat{\lambda}$ and include an intercept. Both regressions use the two-step estimation to correct heterskedasticity. Standard deviations are in parentheses. ***, **, *, and Δ represent statistical significance at the 1%, 5%, 10%, and 15% level, respectively.

eight industries with the largest export shares show the strongest negative effect on labor productivity,[12] whereas the only estimate with a significant positive effect is associated with the industry with the smallest export intensity (X_{10}). This evidence confirms the fact that the relation between export intensity and labor productivity is an inverse U.

The industry effects of external FDI are given in Table 4. When the threshold is 100, only four industries in SMEs in column (1) show significantly positive effects; 12 out of 20 industries have negative signs for both SMEs and large firms, and eight of them in SMEs and eight in large firms are statistically significant. The results are similar when the threshold is 150. We point out an interesting result for the four industries with the largest share of FDI.[13] Three of these have significant negative effects for both SMEs and large firms, and only the chemical material and product industry has a significant positive effect for SMEs. It is interesting to point out that the electric and electronic industry (FDI_{e17}) and the chemical material and product industry (FDI_{e9}) had the largest fraction of FDI, which have been the two most important industries in Taiwan since the 1980s. The spillover of FDI in these two industries, however, are opposite.

12. The eight industries are apparel (X_3), leather (X_4), furniture (X_6), rubber products (X_{11}), plastic products (X_{12}), electric and electronic products (X_{17}), precision products (X_{19}), and miscellaneous products (X_{20}), each of which has export intensity greater than 50%.

13. These industries are leather (FDI_{e4}), chemical material and products (FDI_{e9}), electric and electronic products (FDI_{e17}), and precision (FDI_{e19}) industries, each of them having a share larger than or around 20%.

TABLE 4
Industry Effect of External Foreign Investment

Variables	(1) SMEs	(2) Large Firms	(3) SMEs	(4) Large Firms	Variables	(1) SMEs	(2) Large Firms	(3) SMEs	(4) Large Firms
FDI_i	566.75***	−24.231	606.31***	−76.429	FDI_{e10}	147340*	1981800	117360*	1835400*
	(214.60)	(141.69)	(131.62)	(178.56)		(87495)	(7534500)	(60534)	(943890)
X	371.07***	−172.10**	178.60**	−451.19***	FDI_{e11}	−161.74	−56.866	−387.39**	−787.24Δ
	(104.42)	(86.258)	(73.424)	(106.83)		(138.59)	(414.67)	(160.85)	(487.44)
FDI_{e1}	117.30	14.433	211.47*	−310.06	FDI_{e12}	58.329	−438.23Δ	−54.054	−1397.7**
	(112.22)	(437.59)	(108.22)	(682.15)		(160.73)	(296.66)	(171.77)	(590.17)
FDI_{e2}	47.632	221.47	242.72*	55.376	FDI_{e13}	−169.58	−838.89*	−377.62**	−531.30
	(144.00)	(252.44)	(142.55)	(358.62)		(127.00)	(437.53)	(167.77)	(1950.4)
FDI_{e3}	−118.73***	−261.18***	−253.18***	−840.33***	FDI_{e14}	616.09***	261.60	622.91***	136.65
	(41.537)	(55.756)	(57.264)	(213.03)		(188.80)	(635.81)	(150.06)	(669.31)
FDI_{e4}	−65.960	−199.65***	−99.374	−371.91***	FDI_{e15}	−120.22**	−36.210	−152.00**	226.57
	(105.49)	(71.183)	(129.55)	(106.74)		(60.265)	(153.67)	(77.128)	(385.47)
FDI_{e5}	−2859.9	−9067.2**	−4151.3Δ	−22904**	FDI_{e16}	−104.43***	−59.369	−119.37***	−342.85*
	(2307.5)	(4539.9)	(2663.8)	(7686.3)		(24.231)	(79.437)	(34.269)	(189.73)
FDI_{e6}	−174.80*	−233.65**	−227.13**	−411.79*	FDI_{e17}	−84.116***	−78.475*	−116.33***	−309.86***
	(96.410)	(105.22)	(107.29)	(230.74)		(23.451)	(44.253)	(32.381)	(72.385)
FDI_{e7}	−145.36	−99.658	−62.048	−708.91Δ	FDI_{e18}	164.75*	208.16	93.667	395.85
	(91.875)	(243.63)	(104.42)	(477.05)		(84.463)	(303.32)	(73.915)	(350.26)
FDI_{e8}	−514.29***	2051.6	−504.37*	−313.63	FDI_{e19}	−145.30***	−428.52***	−233.68***	−510.71***
	(188.47)	(1839.9)	(273.13)	(1090.6)		(46.645)	(69.086)	(61.795)	(94.954)
FDI_{e9}	111.49*	122.33	167.72***	180.37	FDI_{e20}	−175.02**	−215.58***	−109.14	−343.74*
	(60.130)	(188.60)	(49.038)	(226.54)		(84.576)	(76.418)	(213.89)	(194.22)
Adj R^2	0.138	0.423	0.188	0.423	Adj R^2	0.138	0.423	0.188	0.423

Notes: Dependent variables are value added per employee in thousands of NT$. In this table the threshold separating SMEs from large firms is 100 for columns (1) and (2) and 150 for columns (3) and (4). Both equations control K/L, QUA_L, TR, WEL, RD, $MONO$, and $\hat{\lambda}$ and include an intercept. Both regressions use the two-step estimation to correct heterskedasticity. Standard deviations are in parentheses. ***, **, *, and Δ represent statistical significance at the 1%, 5%, 10%, and 15% level, respectively.

We also conduct an estimation by replacing both X with X_j and FDI_e with FDI_{ej}, $j = 1, 2, \ldots, 20$ at the same time. The results are similar to those in Tables 3 and 4.[14] Unlike Table 3, however, none of the coefficients of X_js are significantly positive for large firms. Moreover, there are no significantly positive effects of FDI_{ej}s for both SMEs and large firms. Therefore, in contrast to conventional wisdom, most of the effects of exports are negative for large firms at a two-digit industry level, and so are spillover effects of FDI for SMEs and large firms.

VI. CONCLUDING REMARKS

In this article we have investigated the determinants of the technical efficiency in Taiwan. An emphasis is placed on two channels of international technology adoption: exports and FDI. We estimate the determinants for SMEs and large firms separately because the effects of the two channels of technology adoption are very likely to be different. Our estimation method differs from existing works of SMEs by using two-stage switching regressions to correct the firm-size effect.

The main results are as follows. First, the estimates of the selectivity variable are statistically significant for SMEs and large firms, supporting the hypothesis of correcting the firm-size effect. Second, while a larger trade intensity increases the labor productivity of SMEs, it deteriorates that of large firms. Third, an SME's own FDI enhances its labor productivity, whereas FDI into large and small firms has a negative spillover on labor productivity of other firms in the industry.

14. The estimated coefficients are not reported here and are available upon request.

These results have implications for policy in the developing world. To the extent that the market structure of a developing country involves a large share of SMEs, as is evidenced by the trend in the post-oil-shock era, our results suggest that exports are a significant channel that boosts labor productivity. Since exports and imports are complements, this implication corroborates the recent call for international trade liberalization advocated by Sachs and Warner (1995). Introducing FDI to an SME is an alternative way to enhance the firm's labor productivity. By doing so, however, the cost is its detrimental spillover. There is thus a trade-off in introducing FDI. Our results nevertheless indicate that the positive effect of FDI dominates the negative spillovers for SMEs. In light of this, the trade-off seems to be worthwhile.

The negative spillovers of FDI for both large and small firms and the negative effect of exports for large firms are nonconventional. These results are obtained using as measures the labor share of foreign firms and the exports, respectively. These measures may not be the best. Moreover, our spillover is in terms of intra-industries at the four-digit level. We wonder if the negative spillover remains for interindustries or at a more aggregated level.[15] More research should be done to assess the substance of these results. This suggests avenues for further research. In the meanwhile, given our findings, the traditional theory linking exports and FDI to the level of productivity may be revised. It has been a practice in theoretical models to impose a positive spillover of FDI on local firms' productivity (e.g., Ethier and Markusen, 1996), and so there are existing models of trade that assume a positive relation between exports and productivity (e.g., Grossman and Helpman, 1991). Our findings, however, imply a possibility of negative relations. Little existing theoretical work has been devoted to investigating the possibility. This calls for more careful theoretical explanation of the relations. The effects of exports on labor productivity are positive for SMEs but negative for large firms. In addition to the reasons mentioned in section V, the negative relations could be because small Taiwanese firms are more competitive than large firms in the international market due to product characteristics or other market features.[16] Our data, however, do not permit a deeper investigation in this direction. We do not follow the method proposed by Hotchkiss (1991) to find the unknown threshold because the results should be similar. Nevertheless, detecting the threshold separating SMEs from large firms itself is an important issue. All these point out avenues for further research.

15. The existence of an interindustry spillover at a two-digit level in Taiwan has been documented by Chan et al. (1995).

16. Thanks to an anonymous referee for pointing out this possible direction.

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