Technology and Export Decision

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ABSTRACT. Taiwan has played an important role in international trade in the world and its manufacturing industries are dominantly composed of SMEs, yet little is known about the export decision of Taiwanese SMEs, especially the role of technology. This paper aims to explore the role of technology on the export decision of Taiwanese SMEs. In addition, whether there are differences in the determinants of the export decision for different groups of SMEs classified by size is also discussed. The empirical results show that the technological capability embodied in firms, measured by R&D, technology import, and training investment, do increase the probability of exporting. There does exist some variations in the determinants of exports between SMEs of different sizes. The impact of R&D is significantly positive on export propensity in all SMEs, while the role of technology imports and training investment are evidenced for only small firms, implying that external technological sources and other R&D-related activities are particularly important on the formation of technological capability for small firms.

1. Introduction

International markets are generally very attractive for firms as they represent significant opportunities for growth, especially for those located in small open economies. In the past two decades, Taiwan increased its exports of manufacturing at a fairly high rate during the period from 1981 to 2000. While output rose from $48.2 billion to $301.1 billion with a 7.19% growth rate per year, exports also rose from $22.6 billion to $148.3 billion, an average increase of 9.20% per year over the same period. At the same time, the share of exports in GDP hovered around 44.90%. The increased exports to international markets accounted for all the increase in aggregate output and this exporting performance has contributed greatly to Taiwan's economic growth. The value of foreign trade by Taiwan ranked 14th in the world in 2000.

Reviewing the history of Taiwan's exporting activities, two predominant phenomena are worth emphasizing. First, the export structure moved from labor-intensive products toward technology-intensive products, which focuses on the two major categories of Taiwan's exports, textile and electronics products. Figure 1 displays the time trend of their export share during the period 1987–2000. Before the early 1980s, textile products accounted the largest share of Taiwan's exports and they hovered around 30%.

From the 1980s onwards, enormous changes in Taiwan's industrial environments have occurred. Many issues such as environmental protection, increases in cost of land and labor, and large fluctuations in the foreign exchange rate have emerged. Although the magnitude of these changes is in part determined by the ability to absorb the cost or exiting from the existing export market, the alternative mechanism for firms to respond to the shock is to promote technological capability in order to improve their competitiveness. Since the early 1980s when the share of textile products in exports had been outweighted by electronic products, textile exports fell steadily from 16.88% in 1987 to 10.26% in 2000.

In order to move the industry from labor-intensive to technology-intensive as well as capital-intensive, the government established the Science-Based Industrial Park to attract high-technology industrial companies concerned with both

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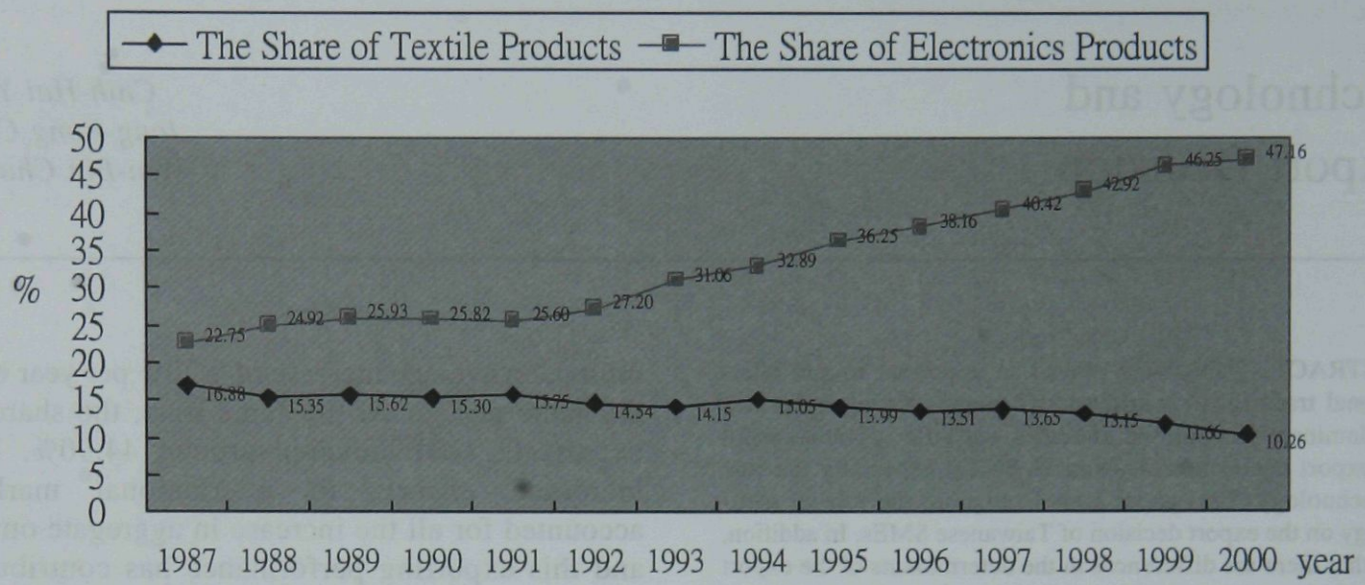

Source: Ministry of Economic Affair, Taiwan.

Figure 1. The export share of textile and electronic products of Taiwan, 1987–2000.

research and manufacturing. The government initiated three measures namely tax incentives, financial assistance, and R&D grants to encourage investment, devoting large publicly-funded R&D to support the technical needs of the industry. Thus, the exports of electronics firms have concentrated on consumer electronics toward advanced electronics goods, such as personal computers, notebook computers, computer peripherals, semiconductors, opto-electronics, and telecommunications. During the period 1987–2000, the export share of the electronics industry grew gradually from 22.7% to 47.16%. Hence, technological capability embodied in firms should play an important role on the exporting decision of Taiwanese firms in the 1990s, which is very little understood in the literature.

Secondly, a dominant share of Taiwan's manufacturing structure, about 97%, is composed of small and medium-sized enterprises (SMEs). This is a unique feature of the island's market structure and is well known for most industrial economists. In fact, SMEs actually have played an important role in promoting trade under the support of government policies in the past decades.

An import protection policy was imposed by Taiwan's government for the purpose of saving foreign exchange in the early 1950s. As the balance of payments later improved, the objective of import controls shifted to protection. However, it is obvious that both tariff and non-tariff restrictions on imported goods impede the promotion of an export expansion policy. The government thus adopted another compensatory package of export incentives. This is called an offsetting trade policy package by Chou (1985), which consists of import controls cum tax rebates and bureaucratic red-tape cum export facilities. The latter includes, among others, the establishment of export processing zones as well as export loans. As a result, exporting firms can use imported materials and equipment with nearly no tariff costs through tax rebates and benefit from various bureaucracy-skirting measures. This situation is described as "domestic sales subsidizing export sales."

A cheap costing, but good quality, labor force also provides comparative advantages for labor-intensive industries to export. Together with low labor cost, the offsetting policy package facilitates the expansion of simple processing industries, leading to low entry barrier for small firms to enter the export market. At the same time, the maintenance of conservative measures prevents import competition and induces protective monopoly in the domestic market. Therefore, small firms in export-oriented industries can export their labor-intensive products at very competitive prices in the world market. On the contrary, domestic-market-oriented firms are protected by regulations, high tariffs, and taxes imposed by the government.

As a result of the policies, export-oriented industries tend to be more competitive and have lower levels of market concentration, while domestic-market-oriented industries tend to be more monopolistic. This is referred to as a "dichotomous market structure" in Chou (1988). It is also verified in Chen and Yang (1997) for a longer 1976–1991 panel of data. Combined with these two phenomena, one interesting and important issue arises. What role does technology play on the exporting decision for Taiwan's manufacturing SMEs in the 1990s?

Recent theoretical and empirical literature on international trade have emphasized the contribution of technology and skills to a country's relative competitiveness. The neo-technology theory highlights the role of technology gap in determining a country's international trade pattern (Posner, 1961; Vernon, 1966). Dosi et al. (1990) also proposed that the absolute differences in technology are considered to be more important than an endowment-based comparative advantage in explaining a trade pattern. A large body of empirical literature has analyzed the relationship between technological change and international trade at a macro-economic level (Soete, 1981, 1987; Sveikauskus, 1983; van Hulst et al., 1991; Cotsomitis et al., 1991; Verspagen and Wakelin, 1997).[1]

A similar conclusion also emerges from micro-economic studies, because technological knowledge is embodied in firms, and it is at a firm level that the decision to perform innovative activities is taken and the gains from innovation are collected (Wakelin, 1997). In fact, the many studies carried out at firm level, such as Greenhalgh (1990), Buxton et al (1991), Willmore (1992), Lefebvre et al (1998), Wakelin (1997), Bernard and Wagner (1998), and Sterlacchini (1999), have generally confirmed a positive and significant relationship between innovations and export decision in industrialized countries.

In the case of developing countries, the neo-technology models have had a limited success in explaining export behaviors.[2] Furthermore, this relationship appears weak when innovation is measured exclusively by means of R&D indicators. This may be because the measure usually used, namely R&D as a percentage of sales, remains too limited to provide any significant discriminatory power. In fact, in order to promote technological capability, technology can be developed internally and/or acquired externally (such as a technology import) for a non-developed country.

Yang et al. (2001) discovered that acquiring technology directly from abroad is also an important way in promoting productivity level and growth in Taiwan. In addition, SMEs usually lack the ability to endure the risk of R&D, even though theory offers ambiguous predictions on size-innovation relationship.[3] Himmelberg and Petersen (1994) also indicated that capital constraints appear to limit R&D expenditures, especially in smaller firms. The popular operation mode of OEM for Taiwanese firms means that firms should do not shoulder the burden of high marketing and R&D expenses, particularly for SMEs. Therefore, not only R&D, but R&D-related efforts, should also be taken in account, especially when in fact R&D expenditure data for SMEs are not usually useful. This paper argues that the technology factor, measured by multiple indicators, could be important for explaining the export decision of Taiwanese manufacturing SMEs.

Many studies carried out at firm level have discussed the determinants of exports for SMEs, but whether the impacts of determinants vary between smaller and larger firms is discussed less often. With the potential heterogeneity among firms due to firm size controlled, the determinants influencing the probability of exporting are also analyzed.

Using a more recent firm-level sample survey data in 1996, this paper aims to examine the role of technology, measured by R&D, technology purchase, and training investment, as the determinant of entering a foreign market for Taiwanese manufacturing SMEs. In addition, the impact of determinants for different groups of SMEs is compared. The empirical results show that technological capability embodied in firms, measured by R&D, technology import, and training investment, increase the likelihood and propensity of exporting. The industry's innovative environment, its R&D intensity, also has a positive and significant impact on SMEs' export decision.

Consistent with previous works, we also find evidence that firm size has a positive influence on firms' export decision, and the size-export relationship shows an inverted U-shape, implying that SMEs may be at a disadvantage on exporting

compared to larger firms, even though SMEs account for 97% in the composition of Taiwanese manufacturing industries. Other firm characteristics and industry-level variables, such as skill intensity, productivity, and industry R&D intensity, all have positive impacts on export. The share of subcontracting revenue to sales and industrial market size exerts a negative influence on SMEs' exporting decision. Furthermore, the effects of these determinants are different among groups classified by firm size. Particularly, the role of technology importing and training investment are evidenced for only small firms, implying that external technological sources and other R&D-related activities would be more important on the formation of technological capability for small firms.

The rest of this paper is organized as follows. In Section 2 we discuss the technology-export relationship in newly-industrialized countries (NICs). Section 3 describes the data we used. Section 4 presents the empirical model and the variables. In Section 5 the empirical results and analysis are reported. Conclusions and policy implications follow in Section 6.

2. Technology and export policy of firms in NICs

It is commonly recognized that firms cannot escape today's technology-oriented competition. According to the neo-technology theory, countries where innovation is intensive enjoy a certain degree of market power by offering proprietary products of which they are the sole producers and the competitive advantage in this case is independent of factor intensities. According to the product cycle model (Vernon, 1966), an increase in total sales in the introductory stage is less than that when the product reaches maturity. Owing to their leadership in technology, industrialized countries can earn a higher margin when introducing a new product. During the growth stage, demand expands and is accompanied with a decreasing margin. Thus, the production of a new product may be relocated to newly-industrialized countries, which embody a certain degree of technological capability to reduce production costs.

Given the phase of the cycle, innovative firms located in a small country tend to export a higher share of their output. Krugman (1979) established a technology gap model to explain the North-South trade. Under the assumptions of the existence of a certain imitative, adaptive capability in the South, which allows for diffusion of technological innovations, he argued that new technology is primarily created in the North and then is diffused to the South. The gap between such creation and diffusion creates the possibility of trade.

Does the neo-technology theory imply that non-industrialized countries are likely to be in an apparently disadvantageous position in the export of high-tech products? In fact, NICs also have advantages on technology competition although the R&D activity is adaptive in nature. In the supply chain of international vertical disintegration, the firms from NICs specialize in a specific stage of the production process. Thus, they can play an important role as the subcontractor for high technology goods in international markets.

North firms commercialize new inventions and get a high margin at the introduction phase of the new product, whereas the profit decays at the growth stage while the market is expanding. At the same time, the new technology is diffused to the South and NICs' firms improve their production process and lower production costs via conducting R&D or transferring technology from foreign firms. Owing to short product life cycles, NICs' firms, especially those operating on the mode of OEM or ODM, can also export high technology products.

A good example is Taiwan's PC industry, which has been the most important global supplier of PC products since the late 1980s. It is of keen interest to explore how the firms of labor-intensive industries maintain competitiveness after the comparative advantage of low-cost labor vanishes. A common strategy of responding to these changes is direct foreign investment in developing countries. Moreover, increasing the value-added of products is also a feasible method for labor-intensive firms. It has been verified that innovative activities have a significant positive impact on firms' productivity for non-industrialized countries.[4] This implies that the process of technology innovation differentiates innovating firms from non-innovating firms in terms of export activity.

To sum up the above discussion, NICs' enter-

prises are likely to achieve competitive advantage on the basis of their own technological activities. Innovation is considered as a characteristic that fundamentally changes the firm and its performance, including the firm's export behavior. In fact, earlier studies have found a positive and significant relationship between R&D and export propensity at the firm level.[5] However, the innovative activity consists not only of R&D expenditures from the viewpoint of NICs.

Pavitt (1982) showed that innovative activities such as design work and engineering development are frequently neglected. Thus, other innovative inputs must be taken into account besides R&D. Dasgupta and Siddharthan (1985), Lall (1986), and Kumar and Siddharthan (1994) have all considered the effect of technology importing on the similar issue for the case of India's enterprises. Lefebvre et al. (1998) and Wakelin (1998) constructed several R&D indices to explore the role of R&D on export for SMEs, and Sterlacchini (1999) also focused on the role of technology importing on the export decision.

Technological capability of course plays an important role in international competition. In order to promote technological capability, non-developed countries can develop technology internally or acquire it externally.[6] Internal technological sources include in-house R&D activities and technology diffusion, while external sources include either technology transferred from foreign direct investment (FDI) or technology imported directly from foreign firms. In addition, higher quality labor through on-job training or technology instruction can also promote firms' technological capability.

Even though the innovative activities are emergent for aggregate data in Taiwan,[7] whether the technological capability embodied in SMEs can stimulate their export activity is of concern. In order to give new evidence for the role of technology on exports, this paper aims to explore the contribution of technology, measuring not only the R&D indicator, but also the purchase of foreign technology, the viewpoint of human resources, and the expenditure of on-job training to Taiwanese manufacturing SMEs' export decision. In addition, we also aim to examine whether the role of technology varies among firms of different size.

3. Data and descriptive analysis

The data used in this study are drawn from the 1996 Taiwan manufacturing sample surveys conducted by the Statistical Bureau of Taiwan. This survey is a supplement to the 1996 manufacturing census. A total of 7,794 firms were included in that survey. According to the official definition, small firms are defined as enterprises with less than 200 employees in the manufacturing industry. In addition, firms employees less than 400 are usually regarded as medium-size firms according to the international standard. Under the classification, there are 6,849 small firms and 485 medium firms in our sample. That is, SMEs are 7,334 in total and account for 94.11% in our data.[8]

Table I presents the descriptive statistics of firm characteristics for an R&D-firm and non-R&D-firm. The criterion used here to differentiate is the R&D expenditure, as used in most of earlier studies. Thus, R&D-firms are those with positive R&D expenditures and non-R&D-firms are those not engaging in R&D.[9]

During the high technology era of the 1990s, it is generally believed that technological development was among the most formidable challenges confronting countries in their efforts to meet global competition. This implies that the role of technology is becoming more important. An important point to note from Table I is that the R&D-firms have a higher propensity to export than non-R&D firms.

The propensity to export for R&D-firms was 78.3% in 1996 and was 40.8 percent higher than that of non-R&D SMEs; the difference is quite large and is statistically significant. This implies that R&D firms may have a positive impact on the export decision. This is consistent with the comparison made in Hirsch and Bijaoui (1985) and Wakelin (1997).

As mentioned above, technology can be developed internally or acquired externally and the relationship between R&D and technology import is usually complementary in literature findings.[10] Our measure of technological capability seems to evidence this relationship. R&D firms systematically expend more on technology imports and training investment (TI) over time. Even though the variance of TI is high, the average annual expenditure on technology imports of R&D firms

TABLE I
Sample mean characteristics of firms by R&D in Taiwanese manufacturing SMEs, 1996

Variable	Definition	R&D firm	Non-R&D firm	*t*-statistics
EX	Propensity to export	0.783 (0.412)	0.375 (0.484)	6.890***
TI	Technology imports (1,000NT$)	1,130.671 (5,849.086)	56.678 (1,319.779)	5.783***
TRAIN	Training investment (1,000NT$)	453.785 (1,139.83)	28.768 (159.048)	5.398***
EMP	Total employment	136.209 (100.786)	45.075 (58.902)	27.853***
SALE	Sales (million NT$)	575.724 (773.785)	156.468 (367.117)	16.637***
CAP	Physical capital (million NT$)	289.391 (547.686)	69.971 (329.684)	12.322***
N	Number of firms	999	6335	

Note:
1. Figures in parentheses are standard deviations.
2. The *t* statistic tests the null hypothesis of equality between an R&D firm and a non-R&D firm.
3. *** represents statistical significance at 1%.

is found to be about 20 times higher than that of non-R&D SMEs in 1996. A similar pattern of R&D firms/non-R&D firms' training investment disparity is also observed. R&D firms invested an average of NT$454,000 in 1996, which was more than 15 times higher than that of non-R&D SMEs.

R&D firms also have a larger firm size than non-R&D firms. In 1996 the average number of employees was 136.209 for R&D firms and 45.075 for non-R&D firms. This disparity on employees is more than three-fold and thus is statistically significant. Similar patterns are also shown when we use sales and physical capital as a proxy to represent the firm size. The average sale of R&D firms was NT$575.724 million, about 3.68 times higher than that of non-R&D firms. The R&D firms invested more on physical capital than non-R&D firms and the *t* tests for CAP is significant at the 1% level.

Although the difference of firm size we discussed is classified by whether the firm engages in R&D, we find that R&D firms tend to have a higher propensity to export and they are larger. This statistical description seems to imply that large firms also tend to have a higher probability to export. We are interested to see whether there is a difference in establishing technological capability among firms. Thus, we proceed to examine the linkage between firm size and technology and between export activity and technology.

Before plunging into the analysis of the determinants of exporting for different groups of firms, we differentiate the firms into three groups: 1–99, 100–199, and 200–399 employees,[11] and then show some descriptive statistics of firm characteristics in Table II.

We observe significant differences in firm size and export activity. There is an increasing relationship between export propensity and firm size in Taiwanese SMEs, whereby the percentage of exporting firms is between 36 and 84 percent with medium-sized firms being more likely to engage in exporting. The data also show that there are significant differences in technological activity and firm size. For firms with less than 100 employees, the average R&D intensity is as low as 0.35% as compared to 1.10% for medium-sized firms with 200–399 employees.

Even though the R&D may not be the major source for small firms to acquire technology, the ratios of firms importing technology or investing on training for small firms are also lower than that for larger firms. This paper will explore whether

TABLE II
Firm size, technology and market orientation

	Size (employees)		
	1–99	100–199	200–399
All SMEs			
Export propensity (%)	35.85	72.74	83.92
R&D intensity (%)	0.35	1.08	1.10
Technology import propensity (%)	1.70	11.65	13.81
Training investment propensity (%)	9.25	37.55	52.99
Number of firms	6042	807	485
Exporting firms			
R&D intensity (%)	0.69	1.27	1.23
Technology import propensity (%)	3.46	12.78	14.99
Training investment propensity (%)	15.84	40.55	52.09
Number of firms	2166	587	407
Non-exporting firms			
R&D intensity (%)	0.17	0.58	0.40
Technology import propensity (%)	0.72	8.64	7.69
Training investment propensity (%)	5.57	29.55	57.69
Number of firms	3876	220	78

Note: Technology import propensity and training investment propensity are defined as the share of firms with positive expenditures on technology import and training investment to all firms, respectively.

the impacts of technological activities on the export decision are different for SMEs of different sizes. In addition, the technological activity disparity between exporting and non-exporting firms is not invariant, but decreases with respect to size. This phenomenon also implies that larger firms devote more effort to technological activity, thus influencing export activity.

4. The empirical framework and the variables

In this section we propose an empirical model and describe the variables we used to estimate the export determinants of manufacturing SMEs in Taiwan. The present study emphasizes the idea that technological capability measures other than R&D should also be employed in explaining the export decision and the role of firm size should also be re-examined.

As for the empirical model, the Probit model is employed due to the dependent variable Y being a dichotomous variable that takes the value of 1 if a firm exports, and zero otherwise. The Probit model can be stated as:

$$y_i^* = \beta' X_i + \gamma' Z_i + e_i, \quad e_i \sim N(0, \sigma^2) \tag{1}$$

where y_i^* is the probability of being an exporter for firm X_i; X_i denotes the technological capability embodied in firms; β are the parameters we are interested in; Z includes other firm characteristics and industry variables; and e is a "white noise" error term.

As emphasized before, R&D is not the only choice for SMEs to promote technological capability. Thus, the innovative activity is set as a function of multiple technology measures, including R&D expenditure (RD), the purchase of foreign technology (TI), and the expenditure of on-job training (TR). Firms usually consider the internal source, RD, and external source, TI, simultaneously and training investment can be regarded as an innovative-related exogenous variable.[12] Hence, we can write the expression for X_i as follows:

$$X_i = f(\mathrm{RD}_i, \mathrm{TI}_i) + \ln \mathrm{TR}_i. \tag{2}$$

Assume the technology sourcing function takes the Generalized Leontief-linear functional form. In order to include interactive relationships between them, it can be written as follows:[13]

$$X_i = \beta_1 \sqrt{\mathrm{RD}_i} + \beta_2 \sqrt{\mathrm{TI}_i} + \beta_3 \sqrt{\mathrm{RD}_i}\sqrt{\mathrm{TI}_i} + \beta_4 \ln \mathrm{TR}_i. \tag{3}$$

Substitute Equation (3) into Equation (1) and include other explanatory variables. The specifications of the empirical model are then given as:[14]

$$EX_{it} = \alpha + \beta_1\sqrt{RD_i} + \beta_2\sqrt{TI_i} + \beta_3\sqrt{RD_i}\sqrt{TI_i} + \beta_4 \ln TR_i + \beta_5 SIZE_i + \beta_6 SIZE_i^2 + \beta_7 KL_i + \beta_8 SKIL_i + \beta_9 PROD_i + \beta_{10} ADS_i + \beta_{11} SUB_i + \beta_{12} INDS_i + \beta_{12} INDRD_i + \varepsilon_i \quad (4)$$

where EX = 1 if an SME exports and EX = 0 if the exports are zero, and EXP is the export intensity measured by the share of exports to sale.

Different measures for R&D and technology importing are also necessary for precisely investigating the role of technology on SMEs' export decision, due to the variance of these expenditures being very large. Therefore, R&D expenditure to sale share (RDS), technology import to sale share (TIR), dummy variables for R&D status (RDD), and technology import status (TID) are employed to construct the technology-sourcing function.

The explanatory variables include technological capability and firm size. Some other firm and sector characteristics are also employed. Three technology variables at the firm level are included: the chi-square of RD, TI, and TR are as defined earlier. In addition, their interactive effects (INTER) are also included due to the fact that these activities may be simultaneous and interactive in the formation of SMEs' technology capability. As discussed above, technological capability is an indicator of a firm's competitiveness and it gives firms an advantage over their competitors in international markets. This is expected to be an important factor in explaining inter-firm variation in export behavior for the case of Taiwanese SMEs. Technology factor will be captured not only by in-house R&D activity, but also by technology import (TI), because Taiwanese SMEs have learned and adopted foreign technology as a strategy to improve technological capabilities gradually.

Technology import also plays a role in strengthening export competitiveness. Kumar and Siddharthan (1994) found that technology importing has a positive impact on firms' export performance for the case of India. We expect the effect of technology imports to be positive in explaining the propensity of exports for Taiwanese SMEs. In fact, technological capability embodied in firms can be partly attributed to the people who work for them. On-the-job training is usually used as a way to improve the work skill of employees and to meet the need of advanced technologies. Other things being equal, labor of higher quality implies higher productivity, thus strengthening the competitiveness of a firm in international markets. Therefore, it is necessary to quantify the effect of the technology variable, TR, from the viewpoint of manpower, and we would expect it to have a positive impact on export decision.

SIZE stands for the size of a firm and we use the number of employees to represent firm size. Even though Chou (1988) argued that small firms tend to export, which favored with the government's trade policy in the 1970s, larger firms seem to be more export-oriented as shown in Tables I and II. Thus, we argue that firm size should be a positive impact on the export decision, even though the sample we discussed are SMEs. In addition, it is possible that a minimum size is required to overcome the sunk cost of exporting, beyond which increases in size have no impact on export behavior; that is, the size-export relationship is non-linear. Thus, a square term of SIZE is included in the regression to test whether the size-export relationship is an inverted U-shape as with the findings in Wilmore (1992), Kumar and Siddharthan (1994), and Wakelin (1997, 1998).

Some firm characteristics are used to indicate the attributes and the level of competitiveness of the firm. The capital intensity, KL, indicates the ratio of firm assets that include building and machinery to employees. Capital embodied in past innovations and influences the marginal cost of output of the firm (Walelin, 1997). However, a higher capital intensity is unlikely to give the firm a competitive advantage in a developing country with abundant labor (Kumar and Siddharthan, 1994). In the case of Taiwan, the advantage of high-quality, low-cost labor for labor-intensive industries has diminished since the late 1980s. The turnover rate of SMEs is pretty high in Taiwan and thus whether capital really indicates SMEs' past innovations and higher capital intensity would give SMEs a competitive advantage is indeed worth exploring.

A labor-cost variable, SKIL, is also considered to represent the skill intensity. It is measured by the ratio of salary of skilled labors to total labor

cost.[15] The skill intensity of operations may indicate the potential of informal innovations and there is considerable evidence supporting the importance of skills in determining the export performance of developed countries (Oulton, 1996). We expect a positive relationship between SKIL and expert decision, because the industries in Taiwan have developed to become more skill-intensive since the late 1980s.

The variable PROD is the ratio of value-added to employees, representing a firm's productivity and it is also a measure of the firm's success. The positive relationship between productivity and exporting is well established in empirical studies by Aw and Hwang (1995) and Aw et al. (2000) for the case of Taiwan.[16] Clerides et al (1998) examined the direction of the causality for exporting and productivity and reinforced the idea that it is higher-productivity firms that enter the export market. Hence, the coefficient of PROD is expected to be positive.

The variable ADS stands for advertising intensity. In spite of the fact that Taiwanese firms become conscious of the need to maintain quality in the process of spending on advertisement to build brands or trade names, Taiwanese enterprises compete in international markets on the basis of price-cutting or operate as subcontractors of multinational groups, particularly for SMEs. Thus, firms that spend more advertising may be domestic market-oriented. Hence, the relationship between ADS and export decision is an empirical issue for SMEs.

SUB is the share of sales due to the productive decentralization of other firms. A higher value of SUB identifies the nature of whether the firms are subcontractors. "Central-Satellite System" is the unique production network practiced in Taiwan, where many small firms act as subcontractors of other domestic firms. That is, a higher SUB implies that a firm is less likely to be an exporter.

In addition to the firm's characteristics, two industrial characteristics (four-digit SIC codes) are also included to account for the environment within which the firms operate. INDS is industry sales and it represents the domestic market size. When domestic markets are large enough, firms are less likely to export. Taiwan is a small open economy, and a reasonably large domestic market is usually not available; thus, the export propensity of the manufacturing sector is quite high. Even so, we would expect a large domestic market to be negatively related to export behaviors.

Industrial R&D intensity, INDRD, is also considered. It is an indicator of the technological opportunity available in the sector, and the innovation potential, including the spillovers effect, will have an important impact on the firm's competitiveness to export. Hence, a positive coefficient would be expected to indicate the importance of the innovative environment in influencing the firms' export decision. The definitions of variables stated above are shown in Appendix 1.

Using the technique of maximum likelihood to maximize the log-likelihood function, the model of equations (4) can be estimated.

5. Empirical findings

Table III presents the parameters estimated for the Probit model of several specifications. In all specifications, the impacts of determinants are quite similar, and the values of log-likelihood and fraction of correct predictions show that the fitness is near the same.

At first we look at the role of technology that we are concerned about. Do the innovative activities affect the probability of being an exporter for SMEs? The main variable capturing the technology factor, R&D, is statistically significant with a positive sign in each regression. This result is consistent with previous works, such as Lefebvre et al. (1998) and Wakelin (1998). The import technology, TI, is also positive and significant in each regression except model (1), which may due to the high variation of TI and higher correlation between RD and TI. Even though the coefficient of technology importing is less significant than that of R&D, it shows that external technology sources, technology importing, also have a positive effect on the probability of exporting.

As mentioned above, Taiwanese firms have learned and adopted foreign technology to improve technological capabilities following an industry development mode of OEM model; hence, the external technology source also plays an important role in improving technological capability. Therefore, the firms acquiring technology from developed countries can strengthen their

TABLE III
The determinants of export activity in Taiwanese SMEs

Variable	(1)	(2)	(3)	(4)
C	–0.660***	–0.672***	–0.678***	–0.662***
	(0.210)	(0.210)	(0.210)	(0.210)
$\sqrt{RD}$	0.462E-02***			
	(0.826E-03)			
$\sqrt{TI}$	–0.583E-03			
	(0.160E-02)			
$\sqrt{RDR}$		0.182E-03***		0.182E-03***
		(0.300E-04)		(0.311E-04)
$\sqrt{TIR}$		0.109E*		
		(0.069)		
$\sqrt{RDD}$			0.441***	
			(0.063)	
$\sqrt{TID}$			0.307*	0.184*
			(0.181)	(0.105)
INTER	0.720E-04	–0.164E-04	–0.247	–0.656E-08
	(0.680E-04)	(0.198E-04)	(0.216)	(0.117E-07)
lnTR	0.020*	0.020*	0.018*	0.019*
	(0.011)	(0.011)	(0.011)	(0.011)
EMP	0.016***	0.016***	0.016***	0.016***
	(0.671E-03)	(0.669E-03)	(0.671E-03)	(0.669E-03)
EMP2	–0.352E-04***	–0.343E-04***	–0.344E-04***	–0.344E-04***
	(0.221E-05)	(0.219E-05)	(0.219E-05)	(0.219E-05)
KL	–0.014	–0.015	–0.015	–0.015
	(0.013)	(0.013)	(0.013)	(0.013)
SKIL	0.712E-02***	0.723E-02***	0.689E-02***	0.718E-02***
	(0.101E-02)	(0.101E-02)	(0.101E-02)	(0.101E-02)
PROD	0.239E-07**	0.275E-07***	0.224E-07**	0.280E-07***
	(0.105E-07)	(0.104E-07)	(0.104E-07)	(0.104E-07)
ADS	–0.017**	–0.020**	–0.020**	–0.020**
	(0.791E-02)	(0.795E-02)	(0.799E-02)	(0.795E-02)
SUB	–0.140E-02**	–0.152E-02**	–0.141E-02**	–0.152E-02**
	(0.609E-03)	(0.636E-03)	(0.588E-03)	(0.635E-03)
INDS	–0.030**	–0.029**	–0.027**	–0.030**
	(0.014)	(0.014)	(0.014)	(0.014)
INDRD	0.071***	0.071***	0.071***	0.070***
	(0.012)	(0.012)	(0.012)	(0.012)
Log-likelihood	–4163.68	–4164.80	–4158.09	–4163.99
Fraction of correct prediction	70.56%	70.79%	70.89%	70.77%

Note:
1. Figures in parentheses are standard deviations.
2. * significant at 10%, ** significant at 5%, *** at 1%.

export competitiveness. This finding supports previous works for developing countries, like India (Dasgupta and Siddharthan, 1985; Lall, 1986; Kumar and Siddharthan, 1994).

The interactive effect of R&D and technology seems to be minor. The other technology measure, logarithm of training investment (ln TR), also exerts a favorable and statistically significant

influence on SMEs' export decision. Generally, technological capability embodied in firms can be partly attributed to the people who work for them. How to call in the best overseas brains is regarded as an important strategy of the technological development for developing countries.

Training investment is another channel to raise the technological capability embodied in human resources. Thus, engaging in training investments increases the likelihood of exporting. To sum up, the technological activities of firms is important in explaining the export decision for Taiwanese manufacturing SMEs. Innovative activities such as technology importing and training investment should not be neglected, and that R&D statistics may be misleading in the SMEs, which often do not have formal R&D units and R&D financial reports. Furthermore, our findings can also give evidence of the neo-technology models for NICs.

The coefficient of SIZE, one of the variables of interest, is positive and significant in each regression. It suggests that firm size has a positive effect on the export decision over the relevant range of firm size. The coefficient of $SIZE^2$ is significantly negative, indicating that the relationship between firm size and the probability of exporting is inverted U-shaped. This result confirms the findings in most studies; however, it contradicts the dichotomous market structure of Taiwan's manufacturing industries proposed in Chou (1988). This unique feature is a reasonable result of economic development. Export-oriented industries shifted from being labor-intensive in the 1970s and 1980s to technology-intensive in the 1990s. Thus, larger firms usually benefit from economies of scale and own more resources to venture in foreign markets, especially in the high-tech products' market. Therefore, we argue that the dichotomy feature of Taiwan's manufacturing industries has been gradually disappearing since the 1990s.

As for the firm's characteristics, the measure of capital intensity, KL, is not significant with the hypothesized positive sign in each regression. One reason is that a higher capital intensity may not give the firms, especially SMEs, a competitive advantage in Taiwan. However, the skill intensity, SKIL, is significant with the hypothesized positive sign related to export propensity in all specifications. This is directly due to the evolution of industry distribution toward skill-intensive, and it also confirms the importance of firm-level competitive advantage embodied in the skills of the workforce in influencing a firm's competitiveness in international markets. Another measure of firm-level competitiveness, PROD, also exerts a significant positive impact on SMEs' export decision. This result is consistent with the findings in earlier studies of Aw and Hwang (1995) and Liu et al. (1999) for the case of Taiwan.

A firm's advertising intensity is found to be exerting a surprising negative and statistically significant influence on SMEs' export decision. Generally, the process of spending on advertisement is beneficial for building brands or trade names. One possible explanation for this result could be that exporters from NICs like Taiwan usually serve as subcontractors of multinational groups; high advertising intensity is not so necessary for the production mode of OME or ODM. In contrast, advertising and establishing goodwill for their brand is more important for domestic-oriented firms. The coefficient of SUB is significant with a hypothesized negative sign, indicating a subcontractor is less likely to be an exporter and this result is consistent with the case of Italian SMEs studied by Sterlacchini (1999).

Regarding industry-level variables, the coefficient of INDS is significant at the 5% level with the hypothesized positive sign related to export propensity in all specifications. A large domestic market actually lowers the probability of exporting. Even though the domestic market of Taiwan is very large, it is still large enough to accommodate SMEs to survive and grow. The sector's innovative environment, INDRD, has a significant coefficient with a positive sign in all estimates, implying that the technological opportunity available in the sector and the innovation potential also have important impacts on SMEs' competitiveness to export.

Now we consider the variations across the different groups of firms. Table II shows that there exist significant differences on innovative activities among different size groups. It is interesting to take a more homogeneous subsample of firms and then consider the determinants of the export decision for them alone, especially the role of technological activities. As discussed in Scherer and Ross (1990), several disadvantages emerge

from R&D investment for small firms. This may imply that other innovative activities such as technology importing and training investment should be more important for small firms relative to larger firms.

Interesting results emerge when we separate SMEs into two groups according to firm size with employee less than 100 and 100–399.[17] Comparing the analyses presented in Table IV with those displayed in Table III suggests that the potential heterogeneity embodied in firms changes fundamentally the determinants of exports of Taiwanese SMEs, and these variations have several facets.

First and the most important implication worth emphasizing is that all of the estimates on innovative variables are positive and significant on the probability of exporting for small firms and the impacts of technology importing and training investment are more significant relative to the estimates using all sample; however, only the impact of R&D is positive with a statistical level for larger SMEs. This would suggest that the technology strategy on strengthening firms' export competitiveness is different for SMEs.

Small firms are generally constrained in acquiring external finance and are less likely to endure the risk and uncertainty of R&D outcome. Potential small exporters should be particularly concerned as to how to engage in technological activities to promote their technological capability so as to meet the tough competition in the international market. Therefore, R&D-related efforts, including in-house R&D, technology imported directly from foreign firms, and training investment, can all be used to enhance small firms' technological capability and then raise the propensity to export.

The negative coefficient of INTER in model (5) implies that the relationship between R&D and technology importing tends to be substantial from the viewpoint of small firms. It can be attributed to the fact that limited financial ability enforces small firms to choose rather than combine the internal and external technological sources. However, the insignificant impact of technology importing and training investment in specifications (7) and (8) do not imply that these R&D-related activities can be neglected.

Why are they less influential on the exporting decision for larger firms? As seen in Table II, the ratio of engaging technology importing and on-job training is higher for firms with employees more than 99. This implies that these activities would be pervasive among larger firms and R&D should play the dominant role in enhancing their technological capability.

The second facet is that the size-export relationship is still characterized by an inverted U-shape, and the size effect is decreasing as the firm size increase. Thus, reaching a minimum efficient size seems to be an inescapable condition for SMEs to enter foreign markets. In addition, it appears to contradict the argument of a dichotomous market structure found in Chou (1988).

The effects of a firm's characteristics result in important differences between groups. Capital intensity, KL, appears to be insignificantly related to the probability of exporting for firms with less than 100 employees, as well as negatively and significantly related to the probability of exporting for SMEs with more than 100 employees. SKIL and PROD have a positive sign and achieve statistical significance in all estimates, indicating the importance of the potential of informal innovations in determining the export behavior.

Our SMEs' estimates also support the arguments of the self-selection effect in Aw and Hwang (1995) and Aw et al. (2000) for the case of Taiwan. The coefficient of ADS and SUB vary between different groups, and their effects are negative in all estimates, but significant for firms with more than 99 employees. The differences in impact of advertising intensity and intensity of subcontracting revenue could be because of the fact that the small firms are more domestic market-oriented, resulting in that the influences of ADS and SUB are minor on the exporting decision.

As seen in Table III, the coefficients of the sector size variable, INDS, are significant with a hypothesized negative sign in all full-sample estimates. It seems surprising that the impact is significant only on the estimates of the subsample with employees less than 100. The domestic market can accommodate less large firms, other things be equal. Why is the impact of INDS not significant for larger SMEs? One possible reason is that the larger SMEs are more foreign-domestic oriented as shown in Table II, and result in the market size effect being diminished. In the same

TABLE IV
The determinants of export decision for different groups of firms

Variable	(5) 1–99	(6) 1–99	(7) 100–399	(8) 100–399
C	–1.235***	–1.223***	–1.330*	–1.330*
	(0.230)	(0.230)	(0.704)	(0.703)
$\sqrt{RDR}$	0.173E-03***	0.169E-03***	0.193E-03***	0.190E-03***
	(0.345E-04)	(0.353E-04)	(0.707E-04)	(0.714E-04)
$\sqrt{TIR}$	0.289**		–0.057	
	(0.133)		(0.157)	
$\sqrt{TID}$		0.390***		0.066
		(0.153)		(0.156)
INTER	–0.830E-04*	–0.207E-07	0.103E-03	0.304E-07
	(0.432E-04)	(0.148E-07)	(0.137E-03)	(0.510E-07)
lnTR	0.039***	0.037**	0.880E-02	0.664E-02
	(0.015)	(0.015)	(0.016)	(0.016)
EMP	0.042***	0.042***	0.984E-02***	0.993E-02***
	(0.251E-02)	(0.251E-02)	(0.313E-02)	(0.313E-02)
EMP2	–0.290E-03***	–0.290E-03***	–0.156E-04**	–0.158E-04**
	(0.277E-04)	(0.277E-04)	(0.685E-05)	(0.694E-05)
KL	0.645E-02	0.613E-02	–0.126***	–0.126***
	(0.014)	(0.014)	(0.039)	(0.039)
SKIL	0.673E-02***	0.668E-02***	0.368E-02*	0.356E-02*
	(0.113E-02)	(0.113E-02)	(0.213E-02)	(0.213E-02)
PROD	0.247E-07**	0.244E-07**	0.717E-07**	0.715E-07**
	(0.110E-07)	(0.111E-07)	(0.322E-07)	(0.321E-07)
ADS	–0.703E-02	–0.734E-02	–0.073***	–0.072***
	(0.886E-02)	(0.887E-02)	(0.018)	(0.017)
SUB	–0.998E-03	–0.994E-03	–0.254E-02*	–0.249E-02*
	(0.667E-03)	(0.665E-03)	(0.147E-02)	(0.146E-02)
INDS	–0.038***	–0.039***	–0.035	–0.034
	(0.015)	(0.015)	(0.039)	(0.038)
INDRD	0.071***	0.071***	0.042	0.040
	(0.013)	(0.013)	(0.028)	(0.028)
Log-likelihood	–3423.08	–3422.17	–645.315	–645.182
Fraction of correct prediction	70.32%	70.29%	77.63%	77.63%

Note:
1. Figures in parentheses are standard deviations.
2. * significant at 10%, ** significant at 5%, *** at 1%.

logic, the effect of RDR is diminished for larger SMEs, because they are more R&D intensive relative to smaller SMEs.

6. Conclusion and policy implication

Taiwan has increased its exports at a fairly high rate in the past two decades, and the share of electronics products at the same time has risen considerably in the composition of output exported. However, the interfirm variation in the export decision of Taiwanese SMEs remains unclear. Using the neo-technology theories, this paper explores the role of technology on the SMEs' export decision; we also reexamine the role of firm size on exports of Taiwanese SMEs to test the dichotomous market structure proposed in Chou (1988). In addition, whether the determi-

nants influencing the probability of exporting vary with firm size is also analyzed. This investigation reveals some interesting results and the implications for government policy are considerable.

First, the estimates uphold our prediction that SMEs' technological activities influence favorably their export decision in NICs such as Taiwan. The R&D as well as the technology importing and training investments all have positive effects on influencing the possibility of exports for Taiwanese SMEs. These effects of technology variables do vary between different groups of SMEs and the R&D-related activities do appear to provide a competitive advantage to smaller SMEs. This implies that the government's efforts to stimulate innovation could improve the export activity for a small open economy. Policies, such as tax incentives, financial assistance, R&D grants, and other measures used to promote R&D spending by the government, should also be considered when aiming to encourage importing advanced technology and investing in on-the-job-training, particularly for small firms.

Second, the size-export relationship is consistent with the results found in the literature, revealing an inverted U-shape, which is also consistent in all estimates according to firm size. This hypothesis of dichotomous market structure proposed in Chou (1988), whereby small firms tend to be exporters due to government support, disappears gradually following economic development. From a policy perspective, the sunk cost of entering foreign markets has a disincentive for SMEs. Therefore, gathering information, tax incentives, and other export promotion efforts for SMEs are considerable policies for Taiwan, which is a small open economy with the market structure of a high ratio of SME.

Firm-specific characteristics are also important determinants on firms' export activity. Given Taiwan's factor endowments, a higher degree of capital intensity does not provide a competitive advantage for SMEs to export; on the other hand, skills appear to be a much more important determinant of the export decision for all groups of SMEs. Maintaining an adequate level of productivity is also beneficial for exporting. Advertising intensity has a surprising negative effect on the probability and propensity of export. A possible explanation is that domestic-oriented SMEs tend to spend a higher ratio of advertising, and exporting firms in Taiwan usually operate as subcontractors of multinational groups, making their advertising intensity less when compared with that of firms focusing on domestic markets. SMEs that operate as subcontractors for other domestic firms are less likely to export.

As for sector characteristics, the domestic market size measured by industry sales exerts a negative effect on export decision for SMEs, implying that SMEs tend to export when the domestic market is not large enough to accommodate all output of the firms located in that sector. In addition, a more innovative environment can improve SMEs' competitiveness in the international market, indicating that there are spillovers from innovation to the export behavior. Government policies to stimulate innovation should consider not only the firm level, but also the industry level.

Appendix 1. Measurements of variables

(i) EX: a dichotomous variable that takes the value of 1 if a firm exports, and zero otherwise
(ii) SIZE: the numbers of employees
(iii) RD: R&D expenditure (NT$ thousand)
(iv) TI: expenditure of technology import (NT$ thousand)
(v) RDR: R&D expenditure to sales ratio (%)
(vi) TIR: technology imports to sale ratio (%)
(vii) RDD: a dummy variable that is equal to 1 if a firm has positive R&D expenditure, and zero otherwise
(viii) TI: a dummy variable that is equal to 1 if a firm has technology imports, and zero otherwise
(ix) TR: on-the-job training investment (NT$ thousand)
(x) KL: the logarithm of physical capital to employee ratio
(xi) SKIL: the salary of non-production employees to total salary ratio (%)
(xii) PROD: value-added to employee ratio (NT$ million/person)
(xiii) ADS: advertisement expenditure to sales ratio (%)
(xiv) SUB: subcontracting revenue to sales ratio (%)
(xv) INDS: the logarithm of industry sales
(xvi) INDRD: industry R&D expenditure to industry sales ratio (%)

Notes

[1] For a recent survey of the studies on innovation and trade on the macro level, see Wakelin (1997).

[2] Dasgupta and Siddharthan (1985), Lall (1986), Kumar (1990), and Kumar and Siddharthan (1994) all examined the role of technology on export for India. Willmore (1992) studied the Brazil case.

[3] Acs and Audretsch (1987) found that small firms had higher

innovation-per-employee ratios than their larger counterparts in four-digit industries with high innovation rates.

[4] For example, Bassant and Fikkert (1996) studied the case of India and Yang et al. (2001) explored a similar issue for Taiwan.

[5] See Dasgupta and Siddharthan (1985), Kumar (1990), Greenhalgh and Buxton et al. (1991), Willmore (1992), and Bernard and Wagner (1998).

[6] See Zahra and Covin (1994) for related issues.

[7] See Yang et al. (2001).

[8] If we add the deleted observations that the number of employee is zero, then the share of SMEs is near 95%. According to the chi-square test the size distribution is an insignificant difference with that of the population data in both clean and raw data.

[9] As mentioned above, the innovative activities of SMEs include more than just R&D, while R&D expenditure is usually used as the standard to differentiate innovators and non-innovators.

[10] See Basant and Fikkert (1996) and Katrak (1997).

[11] The official definition of small firms proposed by the Ministry of Economic Affairs was enterprises with less than 100 employees in 1992. This classification was redefined in 1999 that small firms are defined as enterprises with less than 200 employees.

[12] For the relationship between R&D and technology import, see Yang et al. (2001) for a short review.

[13] See Fuss et al. (1978) for a discussion of the functional form.

[14] To consider the potential endogeneity problem of technology choice, we also use the instrument variables' (IV) approach to estimate. Let the first stage IV equations for technology choice be estimated as:

$$RD_i = b_0 + b_1\, TI_i + b_2 \ln TR_i + b_3\, EMP_i + b_4\, KL_i + b_5\, SKIL_i + b_6\, SUB_i + b_7\, INDRD_i + e_i$$

$$TI_i = b_0 + b_1\, RD_i + b_2 \ln TR_i + b_3\, EMP_i + b_4\, KL_i + b_5\, SKIL_i + b_6\, SUB_i + b_7\, INDRD_i + e_i$$

By comparing the log likelihood of the IV approach and the specification of equation (4), the LR statistics are statistically insignificant at all specifications. Therefore, we adopt equation (4) as our regression equation. One advantage of this specification is to include the interactive effect between R&D and technology import.

[15] Following the definition used in Berman et al. (1994), we classify non-production workers as skilled labor. This classification is imperfect (Leamer, 1994), but has successfully tracked employment and wage by skill category (Berman et al., 1994; Sachs and Shatz, 1994).

[16] Aw and Huang (1995) and Aw et al. (2000) found firm's productivity and export participation to be interrelated, and it seems to support the self-selection hypothesis that more efficient firms choose to enter foreign market, while the role of technology is not discussed in their works.

[17] We also separate firms into three groups, 1–99, 100–199, and 200–399, and then estimate the determinants of export, respectively. Because small firms are defined as enterprises with less than 100 employees before 1999 and the estimates of groups two and three are quite similar, we merge sample firms with employees between 100 and 399 into a group and show the regression result.

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