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FDI, Size, and Innovation: Influences on Firm-Level Exports in East Asia

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Abstract

Drawing on recent trade and technology theories, this study examines the influence of several factors on the probability of exporting in electronics firms in China, Thailand, and the Philippines. It explores the validity of two alternative proxies for innovation – R&D expenditures and a technology index representing technological capabilities (based on Sanjaya Lall's framework) – as well as control variables. Foreign ownership and acquiring technological capabilities emerge as the key influences on exporting behavior. Firm size also matters in China and the Philippines. While R&D expenditures are not statistically significant, they remain important to future competitiveness in East Asian firms. The technology index is a valuable research tool to study exporting at the firm-level.

JEL Codes: F23, O31, O32, L63, O57

Key words: foreign direct investment, innovation, technological capabilities, R&D, exports, East Asia, China, Thailand and the Philippines.

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1. INTRODUCTION

The roles of foreign direct investment (FDI), size, and innovation in determining exports at the firm-level are widely recognized. Early applied work on international trade and investment highlighted firm-specific advantages in the operation of industry-level determinants of comparative advantage (Glejser *et al.* 1980; Hirsch and Bijaoui, 1985; Wakelin, 1998). The "new new" trade theory focused on firm heterogeneity and its influence on flows of aggregate output and exports (Melitz, 2003; Helpman *et al.*, 2004; and Bernard *et al.*, 2007). The technological capabilities and national innovation systems literature stressed difficult acquisition of capabilities as a source of firm-level export advantage in developing countries (Lall, 1992; Lundvall, ed. 1992; Bell and Pavitt, 1993; Westphal, 2002; UNIDO, 2002/3; Iammarino *et al.*, 2008). Case studies showed that building technological capabilities to absorb imported technologies are more common in developing country firms than R&D activities to create new products and processes often at world frontiers (e.g. Lall, 1987; Hobday, 1995; Pietrobelli, 1987; Mathews and Cho, 2002).

Growing empirical testing using firm-level data from developing countries suggests that the characteristics of firms that export are significantly different from firms that do not. There is some evidence that exporters tend to be larger, have higher foreign equity, be more innovative and more intensive in skill and capital than non-exporters (e.g. Zhao and Li, 1997; Srinivasan and Archana, 2011). A major weakness in existing econometric studies, however, concerns the proxy used for innovation – the ratio of R&D expenditure to sales (hereafter R&D expenditures) – which represents the creation of new products and processes, often at world frontiers. By focusing on R&D expenditure, the bulk of the econometric literature understates the importance of building technological capabilities, which usually forms a large part of firm-level technological activity in developing countries.

This paper contributes to the econometric literature on technological capabilities and firm-level exports using data from electronics firms in three late-industrializing East Asian countries: China, Thailand, and Philippines. Methodological developments on taxonomies of technological capabilities (Lall, 1987 and

1992; Dahlman *et al.* 1987) and a technology index (TI) (Westphal *et al.* 1990) have motivated recent research. A handful of econometric studies have constructed TI that represent expanding technological capabilities in developing countries and explored export determinants, but the findings are somewhat inconclusive. Deraniyagala and Semboja (1999), Rasiah (2003 and 2004), and Wignaraja (2002 and 2008a) have found some evidence of a statistically significant relationship between foreign ownership, technological capabilities, and firm-level export performance in developing countries. However, Deraniyagala and Semboja (1999) and Wignaraja (2002) find no evidence of a statistical link between firm size and exports at the firm-level.

Accordingly, this paper focuses on the influence of foreign ownership, size, and innovation on firm-level export behavior. To the best of our knowledge, this is one of the very few papers to test the validity of alternative proxies of innovation – R&D expenditures and a TI – in export functions in a multi-country setting. The first such study (Rasiah, 2003 and 2004) appears to suffer from some methodological problems (see Section 2). We attempt to improve on previous research by applying the comprehensive Lall (1987 and 1992) taxonomy of technological capabilities to estimate TIs as well as separate firm-level export functions for three East Asian countries using a Probit model. Furthermore, the enterprise sample used here consists of both exporters and non-exporters, and is much larger than previous research on TIs. The availability of a new World Bank Enterprise Surveys database meant that our research covered 784 East Asian firms (524 Chinese firms, 166 Thai firms, and 94 Philippine firms).

The industry and East Asian countries selected are particularly fascinating. The technologically sophisticated electronics industry is one of the East Asia's largest exports and plays a crucial role in the region's industrial development (Mathews and Cho, 2002; Rasiah, 2004). The giant Chinese economy has successfully attracted significant FDI inflows and has rapidly emerged as one of world's largest exporters of electronics. Thailand and the Philippines have also relied on FDI to emerge as notable electronics

exporters. Much remains unknown about the export and technological behaviour of enterprises in these three countries.

The paper is structured as follows. Section 2 undertakes a brief review of the literature on firm-level exports, particularly in developing countries. Section 3 presents the econometric specification and variables. Section 4 presents and evaluates empirical results. Section 5 concludes.

2. A BRIEF REVIEW OF LITERATURE

Approaches to Firm-Level Exports

The analysis of firm-level exporting behavior in this paper draws on two related schools of applied economics: (i) international trade and investment, and (ii) technological capabilities and national innovation systems.

The neo-Hecksher-Ohlin trade model and the neo-technology theories of Posner and Vernon provided early rationale for studies highlighting the importance of firm-specific advantages (i.e., differences in skills, technologies, and tastes) in the operation of industry-level determinants of comparative advantage (Glejser *et al.*, 1980; Hirsch and Bijaoui, 1985; and Wakelin, 1998). Refining these insights, the "new new" trade theory of Melitz (2003) and Helpman *et al.* (2004) emphasized the notion of firm heterogeneity (see also an empirical application to the United States by Bernard *et al.* [2007]). The "new new" trade theory suggests only a few highly productive firms are engaged in exports and local production overseas because they are able to make sufficient profits to cover the large fixed costs required for overseas operations. It follows that almost all the theories of comparative advantage can be firm-specific determining, not only which countries enjoy a comparative advantage in international markets, but also which firms can exploit that comparative advantage better than others. However, most theories of

trade and comparative advantage seem to assume that manufacturing firms in developing countries costlessly and passively absorb technologies in well-functioning markets.

In contrast to trade and investment theories, the literature on technological capabilities and national innovations systems explicitly links efficient capability acquisition to export success at the firm-level in developing countries (Lall, 1992; Bell and Pavitt, 1993; Westphal, 2002; and UNIDO, 2002/3; Iammarino *et al.*, 2008). The underlying evolutionary theory of technical change suggests that difficult firm-specific processes and complex interactions with institutions are required to absorb imported technologies efficiently (Nelson and Winter, 1982; Lundvall, ed. 1992; Nelson, 2008). Technological knowledge has a large tacit element that is difficult to codify in a meaningful way. As a plethora of detailed case studies show (e.g., Lall, 1987; Hobday, 1995; Pietrobelli, 1997; Mathews and Cho, 2002), firms undertake conscious investments in a variety of minor technological activities – technology search, training, engineering, and design – in order to put imported technologies to productive use. Such minor technological activities tends to be more widespread in developing country firms than formal R&D activities aimed at creating new products and processes, often at world frontiers. Furthermore, differences in the efficiency with which mastering technologies is achieved are themselves a major source of differences in comparative advantage between countries. New research on patterns of technological capabilities across countries provides interesting insights on convergence and catching up over the period 1995-2007 (Filippetti and Peyrache, 2011). The empirical findings point to the end of the hegemony of North America, Western Europe and Japan, showing that a process of convergence of technological capabilities has occurred.

Lall's Taxonomy and the TI

The case study research additionally suggests ways of classifying the technical functions performed by manufacturing enterprises to assimilate imported technology. One of the most elaborate taxonomies of technological capabilities is the one proposed by Lall (1987 and 1992), which breaks them down into

investment, production, and linkages. Investment is represented by project execution activities including feasibility studies, equipment search, assessment of equipment, employee training during start-up, and involvement of the firm in detailed engineering. Production is sub-divided into process technology and product technology. Process technology includes quality control, maintenance, plant layout, inventory control, and various improvements in equipment and processes. Product technology covers copying imports (or buyers), improving existing products, introducing new products, and licensing product technology. Linkages are considered under supplier firm linkages, subcontracting linkages, and linkages with institutions that provide trouble-shooting, testing, training, and product design assistance. The advantage of Lall's framework over other approaches[1] is that it provides a clear continuum of technical functions from the time new technology enters a given firm to when it exits to other firms and institutions. Furthermore, as this framework has been successfully used in empirical work[2] it will be used here to examine firm-level exports in the three East Asian countries.

A notable challenge facing research on technological capabilities is how to summarize inter-firm differences in capabilities. The findings from detailed technology case studies are generally based on qualitative evidence. The lack of quantitative measurement and rigorous testing has sometimes exposed this literature to the criticism like "the risk of inappropriate generalizations across different firms, industries, countries and historical periods" (Romijn, 1999, p. 359). It is useful to develop a simplified summary measure that can permit statistical analysis of capability acquisition and exports. As discussed below, some studies have begun to rank firm-level technological capabilities and attempt statistical analysis of determinants of exports.[3] The ranking integrates objective and subjective information into measures of enterprises' capacity to set up, operate, and transfer technology. The typical approach is to highlight the various technical functions performed by enterprises and award a given firm a score for each activity based on the assessed level of competence in that activity. An overall capability score for a firm is obtained by taking an average of the scores for the different technical functions.

This procedure is a simple, practical device for summarizing the evaluation of capabilities. However, it inevitably has subjective elements that can bias the values of the scores. As Westphal *et al.* (1990) explain in the context of their study of Thailand:

> "..the capability scores are biased estimates with respect to the measurement of capabilities cum capacities per se. The degree of bias depends on the respective weights placed on capability and sophistication in the researcher' scoring. Unfortunately, it is not possible to state these weights. However, the bias that is present in the absolute values of the scores does not necessarily affect the relative values obtained when the scores are considered in comparison to one another. Intra-firm comparisons (across capabilities for one firm) and inter-firm comparisons (across firms for one capability) are biased with respect to indicating differences in capabilities cum capacities only to the extent that sophistication levels differ intra and inter-firm respectively. Since most of the analysis is concerned with relative values, it is possible that the bias has minimal consequences for the analysis." (Westphal et al., 1990, pp. 87 and 91)

The subjective element, however, may not matter much for the purpose at hand — inter-firm comparisons of the relative values of the technological capability scores. Note that all the activities are given equal weights by averaging, based on the assumption that they are of similar importance to the capability building process. While this may clearly be mistaken in particular instances, it is difficult to think of a defensible way of assigning different weights across all firms.

Econometric Studies

Most econometric studies of firm-level export determinants in developing countries have included R&D expenditures and standard control variables (like ownership, size, age, skills, and capital). Focusing on the role of transnationals in Brazil's trade, Wilmore (1992) estimated the determinants of exports for 17,053 manufacturing firms. Foreign ownership had a significant and positive effect on export propensities but R&D expenditures were not significant. Zhao and Li (1997) tested the relationship between firm size, R&D expenditures, and exports for 535 manufacturing firms in China. They found that size and R&D expenditures positively affect Chinese exports, but observe that "the model using R&D intensity as the only indicator may not fully capture the impact of technological progress on export performance" (Zhao and Li, 1997, p. 9). Srinivasan and Archana (2011) estimated export functions for separate samples of 800

and 1,365 Indian manufacturing firms. Data limitations, however, meant that both foreign ownership and R&D expenditures could not be tested in the same model. In their main model, R&D expenditures were positive and significant, implying that higher R&D capability contributes to increased export propensity. Firm size was also significant, suggesting that larger firms have more resources to enter export markets (e.g., to overcome initial cost barriers in marketing). In addition, capital intensity, skill intensity, and energy intensity matter. In another model, foreign ownership was positive and significant.

Relying on R&D expenditures as an innovation proxy thus presents two difficulties. One is that small and medium-sized enterprises (SMEs), which lack a separate R&D budget or department but nevertheless innovate, are excluded (Wakelin, 1998). Another is that R&D expenditures are generally low in developing country firms because overall technical change focuses on adaptation and minor changes to products and processes related to imported technologies. By formulating a TI to represent acquiring technological capability, this paper avoids the size bias of R&D expenditures and the bias against developing country firms.

The few TI-based econometric studies of developing countries have produced some interesting results. Using a pooled sample of 75 electronics firms in Malaysia and Thailand, Rasiah (2003) tested both a process TI and R&D expenditures in addition to control variables (e.g., foreign ownership, wages, age, and a country dummy). R&D expenditures (10% level), the process TI (1% level), and foreign ownership (10% level) were positive and significant. Wages, age, and the country dummy were also significant. Enlarging the pooled sample to 98 electronics firms (by including 27 Philippines firms), Rasiah (2004) yielded mixed findings. Foreign ownership (5% level), a process TI (1% level), wages, and a variable representing network cohesion were significant with positive signs. However, R&D expenditures, a human resource capability variable, and the country dummies were not significant. Rasiah (2003 and 2004) was probably the first to test for the influence of both innovation proxies. Nonetheless, a sample bias towards exporters may be an issue since all the surveyed Thai and Philippines firms are exporters.

There is also potential for aggregation bias in cross-country regression analysis relying on pooled enterprise samples and country dummies. Furthermore, the process TI used is oriented towards equipment rather than technical functions performed by firms to absorb imported technologies efficiently.[4]

Other studies have constructed various TIs based on Lall's framework. The content of the TI's used in different studies was determined by data availability on the number of technical functions. The TI in Deraniyagala and Semboja (1999) was made up of 13 technical functions (3 investment and 10 production) to analyze export determinants in 46 engineering firms in Tanzania. Foreign ownership, TI, and a skills index turned out to be significant at the 5% level and positive. Meanwhile, age and firm size were not significant. Analyzing factors affecting exports in 40 clothing firms in Mauritius, Wignaraja (2002) employed a TI consisting of 12 technical functions (10 production and 2 linkages). Foreign ownership and TI were positive and significant (1% level), but firm size and skills were not. Unfortunately, the sample size of the two studies is relatively small (about 40 firms). In probably the first large sample cross-country analysis of 353 clothing firms in China and 205 clothing firms in Sri Lanka, Wignaraja (2008a) formulated a TI comprised of 5 technical functions (1 investment and 4 production). Foreign ownership (1% level), TI (10% level), a variable representing marketing relationships with foreign buyers, and wages are all significant for both countries. Capital was also significant for China. Nonetheless, Wignaraja (2008a) did not explore the influence of alternative innovation proxies on exports.

These studies provide some (qualified) support for the hypothesis that foreign ownership, size, and innovation (both R&D expenditures and building technological capabilities) are positively associated with exporting in developing countries. Skills, capital, and age also show up as important determinants. The remainder of the paper explores the relationship between foreign ownership, size, innovation, and exporting in electronics firms in three East Asian countries (China, Thailand, and the Philippines) using R&D expenditures and TI as alternative innovation proxies.

3. SPECIFICATION AND VARIABLES

The following econometric model is estimated for separate export functions for Chinese, Thai, and Philippine electronics firms:

$$\boldsymbol{Y} = \beta \boldsymbol{X} + \boldsymbol{\varepsilon}, \quad (1)$$

where $\boldsymbol{Y}$ is the vector denoting the probability of exporting at the firm-level, $\boldsymbol{X}$ is the matrix of explanatory variables, β is the matrix of coefficients, and ε is the matrix of error terms. The dependent variable is a binary variable, taking a value of 1 if the firm is an exporter (exports to sales ratio>0) and zero if it is a non-exporter (exports to sales ratio=0). The hypotheses and explanatory variables in $\boldsymbol{X}$ in equation (1) are described below. A description of the variables is provided in Table 1.

Insert Table 1 here.

Foreign ownership, the share of foreign equity (FOR), is expected to have a positive influence on the probability of exporting (Wilmore, 1992; Raisah, 2003). There are two *a priori* reasons. First, access to the marketing connections and know-how of their parent companies, as well as accumulated learning experience of producing for export make foreign affiliates better placed to tap international markets than domestic firms. Second, foreign firms tend to be larger than domestic firms and therefore better placed to reap economies of scale in production, R&D, and marketing. A large firm will be better able to exploit such economies of scale and enjoy greater efficiency in production, enabling it to export more.

Firm size is expected to have a positive sign because large firms are better able to bear the risks and costs of exporting (Zhao and Li, 1997; Srinivasan and Archana, 2011). Exporting is a risky activity and large firms may be at an advantage at collecting market information, launching foreign sales drives, adapting products to export markets, and bearing exchange rate risks (Melitz, 2003). Exporting also allows large

firms to exploit economies of scale in production. A dummy variable (size), which takes a value of 1 when a firm is considered large in terms of employment (more 100 or more employees), is used to represent firm size in order to avoid possible collinearity problems with FOR.

Innovative activity at the firm-level leading to greater cost-efficiency is expected to be positively associated with the probability of exporting. Innovation in developing countries is not just a simple function of years of production experience of conscious investments in building technological capabilities to use imported technologies efficiently, it also involves R&D geared towards new products and processes (Lall, 1992; Zhao and Li, 1997; Westphal, 2002; Rasiah, 2004; Wignaraja, 2008a). Following the empirical literature, two alternative innovation proxies – R&D-to-sales ratio and a firm-level TI – are used (Westphal *et al.,* 1990; Srinivasan and Archana, 2011). The R&D-to-sales ratio captures the firm's expenditures on design and R&D (includes wages of R&D personnel, materials, and training costs). The construction of the TI is discussed below.

Age is represented by the absolute age of the firm (AGE). As firms with experience are regarded as enjoying greater experimental and tacit knowledge, age is considered to be positively associated with the probability of exporting and the building capabilities (Rasiah, 2003).

Human Capital. Within a given activity, a higher level of human capital is expected to have a positive relationship with the probability of exporting (Deraniyagala and Semboja, 1999; Rasiah, 2003; Wignaraja, 2008a). Higher levels of human capital (in terms of a better stock of technically qualified manpower as well as educated and experienced general managers) are associated with more rapid technological learning and development of effective business strategies that are likely to provide a competitive edge at the firm-level. Accordingly, human capital is represented by three variables: (i) the share of technically qualified employees in employment (ETM), (ii) the level of education of the general manager (EDUC), and (iii) years of experience of the general manager (GMEXP).

Capital is represented by the value of production machinery per employee (CAP). Within a given activity, a higher level of physical capital in the form of modern equipment is expected to give a firm a competitive advantage. Thus, CAP is expected to be positively associated with the probability of exporting.

4. DATA AND RESULTS

Firm-Level Dataset

The analysis in this paper uses data from the World Bank's Enterprise Surveys conducted in 2003 for China and the Philippines, and 2004 for Thailand. The Enterprise Surveys covers a representative sample of electronics firms in the three countries. Stratified random sampling with replacement was the sampling methodology used.[5] Face-to-face interviews using a common questionnaire were conducted with business owners and senior managers of electronics firms. This is one of the most detailed and relatively recent firm-level datasets currently available for these countries. The data are not publicly available but it is possible to apply to the World Bank for access for research purposes. The dataset is relatively large, consisting of 524 electronics firms in China, 166 firms in Thailand, and 94 firms in the Philippines. Tables 2 and 3 show the sample profile and descriptive statistics. The sample contains a mix of firms by market orientation, ownership, and size. A minority of Chinese firms export (29%) and have some proportion of foreign equity (22%). Meanwhile, a majority of the Thai and Philippines firms export and are foreign-owned. Furthermore, over 60% of firms in all three countries are large (with over 100 employees).

Insert Tables 2 and 3 here.

Constructing the TI and Comparing with R&D

The TI, which attempts to capture a broader range of technical functions performed by firms, is a variant of the index developed by Wignaraja (1998, 2002, and 2008). The index draws on the Lall (1987 and 1992) taxonomy of technological capabilities (investment, production, and linkages). As Table 1 shows, the largest category, production, is represented by five technical functions (ISO quality certification, process improvement, minor adaptation of products, introduction of new products, and R&D activity). Investment is represented by two functions (upgrading equipment and licensing of technology), and linkages by two function (sub-contracting to other firms and technology linkages with science and technology institutions). Thus, a given firm was ranked out of a total capability score of 9 and the result was normalized to give a value between 0 and 1.[6]

Strikingly, the evidence seem to confirm the argument made by the literature on technological capabilities and national innovation systems about the relative importance of R&D versus other technological activities. Only limited R&D activity seems to be occurring in firms in the East Asian countries while other forms of minor technological activities are more common. Over half the firms do not undertake any R&D expenditure (53% of Chinese firms, 52% of Thai firms, and 68% of Philippine firms). Significant R&D investment (more than 1% of sales) is undertaken by 23% of Chinese firms, 22% of Thai firms, and 11% of Philippine firms. The remaining firms spend up to 1% of sales on R&D activities.[7] In contrast, virtually all the sample firms conduct some type of minor technological activity and a pyramid shape distribution of technical competence is evident. At the top are a handful of firms (2% in China, 2.4% in Thailand, and none in the Philippines) with a high degree of technical competence (TI scores in excess of 0.81). In the middle are some firms (24% of Chinese firms, 34% of Thai firms, and 20% of Philippine firms) with medium to high levels technical competence (TI scores in the range of 0.61 to 0.80). At the bottom are the largest group of firms with limited technical competence (TI scores below 0.60).

Table 4 provides the means for TIs and R&D expenditures, and a breakdown by ownership and size. The data point to three interesting findings on the nature of firm-level innovation in the three East Asian countries. First, in terms of innovation, Chinese firms generally lead those in Thailand and the Philippines. Chinese firms have the highest average TI score (0.52) and are closely followed by Thai firms (0.51). Philippine firms (0.38) lag behind. A much larger R&D expenditure gap is visible where Chinese firms spend an average of 1.45% of sales on R&D activities, compared with only 0.71% in the Philippines and 0.41% in Thailand. Accordingly, Chinese and Thai firms have similar technological competence in using imported technologies efficiently but Chinese firms are ahead in more demanding R&D activities.

Second, in China and Thailand domestic firms spend more than foreign firms on R&D, activities and large firms spend more than SMEs. In the Philippines, large firms outspend SMEs, but foreign firms outspend domestic firms.

Third, the gaps between the TI scores in both ownership and size categories are much narrower in China than the other two countries. For instance, foreign firms have an average TI of 0.54 compared with 0.51 for domestic firms. This seems to suggest that technology spillovers between different types of firms in China occur at a faster rate than in the other two countries. Our preliminary finding seems to support the argument of Wei, Liu, and Wang (2008) that mutual productivity spillovers are taking place between foreign and local firms in China due to diffusion of technology and local learning. More recent work by Fu (forthcoming) suggests that processing trade-FDI has generated significant positive information spillover effects on the export performance of domestic firms in China but limited technology spillover effects. She finds that indigenous innovation, economies of scale and productivity were found to be the key determinants of indigenous firms export performance. Further empirical investigation is needed to verify this interesting finding and the factors underlying it.

Insert Table 4 here.

T-tests between Exporters and Non-Exporters

The sample firms differ in export behavior as measured by the share of exports in total sales. There are 152 exporters in China, 113 in Thailand, and 66 in the Philippines. The samples show some of the stylized facts reported in the literature in the previous section. In particular, exporters have higher levels of innovation, are generally foreign-owned, and are larger than non-exporters. Table 5 shows the mean values of characteristics of exporters and non-exporters, along with the t-values.

Exporters have higher shares of foreign equity than non-exporters. Exporters in the Philippines have the highest average foreign equity share of 84%, compared with 67% in Thailand and 35% in China. These are much higher than the foreign equity shares of non-exporters: 21% in the Philippines, 23% in Thailand, and 6% in China. Underlining the link between foreign ownership and firm size, exporters are also significantly larger (in terms of employment) than non-exporters. On average, exporters in the Philippines (1,400 employees) are the largest and are followed by Thailand, and China (1,171 employees and 865 employees, respectively). Meanwhile, non-exporters have 444 employees in the Philippines, 282 employees in Thailand, and 240 employees in China.

Insert Table 5 here.

There is a significant difference in the acquisition of technological capabilities between exporters and non-exporters in the three countries. Interestingly, a narrower gap is visible in TI scores in China (0.55 for exporters and 0.50 for non-exporters) than in Thailand (0.56 for exporters and 0.39 for non-exporters) and the Philippines (0.45 for exporters and 0.24 for non-exporters). This may indicate that higher technology spillovers have occurred in China compared with the other economies. R&D expenditures, however are not significant in any of the three countries. This seems to suggest that the TI is likely to be a better predictor of the probability of exporting in the econometric analysis than the R&D-to-sales ratio.

There is also a significant difference in the average level of education of the general manager/chief executive officer (CEO) between exporters and non-exporters in all three countries. The other human capital variables (the number of years of experience of the general manager/CEO and the share of technical professionals in employment) are significant in the Philippines but not in the other two countries.

Finally, exporters are significantly younger (measured by number of years in operation) than non-exporters in China and the Philippines. Exporters also have higher capital intensity (in terms of the net value of production machinery) than non-exporters in China and Thailand.

Econometric Results

Analysis of means and t-tests are useful descriptive devices but do not shed much light on causation. Thus, a Probit model was used to estimate the export function specified in Section 3 using the alternative proxies for innovation but the same binary dependent variable and other firm characteristics. Table 6 provides the results of the Probit regressions. Equations 1, 3 and 5 show the complete set of determinants for each country with R&D expenditures as the proxy for innovation. Equations 2, 4 and 6 show the results with TI as the proxy for innovation.

Following testing for multicollinearity,[8] we consider the results. In general, the results are reasonable for this type of cross-section model. The pseudo R^2 for the different regressions are quite high at 0.25 or more. The p-values for the Wald Chi-square test are significant at the 1% level for all the regressions, which indicates that at least one of the predictors' regression coefficients is not equal to zero.

The foreign ownership variable (FOR) positively affects the probability of exporting in all three countries (1% level in both China and Thailand, and 5% level in the Philippines). The presence of several factors – access to marketing connections of parent firms, accumulated learning experience of producing for overseas markets, and larger firm size – combine to give foreign firms an advantage in exports. The

dummy variable for firm size (SIZEDUM) is positively related to exporting in China and the Philippines, which indicates that foreign-owned firms, particularly multinationals, tend to be large. Compared with SMEs, large firms are more able bear the risks and costs of exporting, and can realize economies of scale in production.

The TI as a measure of innovation plays an important role in exporting and a positive relationship is confirmed in all three countries. The TI is significant at the 1% level in the Philippines, 5% level in China, and 10% level in Thailand. The magnitude of the effect of the TI is also more than those of the other explanatory variables in the model. Difficult firm-specific processes are involved in acquiring technological capabilities to use imported technologies efficiently. Conscious firm-level investments in skills and information to operate imported technologies efficiently increase the probability of exporting.

Insert Table 6 here.

In contrast, R&D expenditures as a measure of innovation lack significance in any of the three countries. This seems to suggest that R&D expenditures are an insufficient proxy to fully capture the adaptive and incremental nature of technological activities taking place in the East Asian firms. Another explanation may be that R&D has a dual role at the firm-level. It is both a means of generating new knowledge on products and processes, as well as a means of assimilating and exploiting existing information, new knowledge, and technology (Cohen and Levinthal, 1989). A further explanation is that R&D activities may be largely geared towards supporting production for the domestic market rather than exports. A time lag of 3 years or so may be involved before the benefits of such domestic market-oriented R&D expenditures impact export behavior at the firm-level. However, the World Bank's Enterprise Surveys do not provide information on role of R&D expenditures, the market orientation of R&D expenditures, or past R&D expenditures to investigate these explanations further.

AGE shows significance in Thailand and the Philippines, but with opposite signs. The positive sign and relatively high significance (5% level) suggests that older firms with experience in Thailand do enjoy greater experimental and tacit knowledge, which is linked to the probability of exporting. In the Philippines (with a negative sign and only a 10% level of significance) experience *per se* does not seem to matter much for the probability of exporting. The mixed results for the two countries seems to highlight that age of the firm is at best a crude and very general proxy for learning very broadly defined.

Of the variables representing human capital, only the general manager/CEO's education in China turns in a positive significant sign (10% level) suggesting that well-educated general managers/CEO's influence the probability of exporting. One explanation may be that other types of human capital (e.g., workers skills and the share of tertiary level electronics engineers) or training investments (e.g., training expenditures as a share of sales) are more relevant for creating an export advantage at the firm-level than the characteristics of the general manager/CEO or the share of technically qualified employees. Unfortunately, data on these other forms of human capital were not available from the World Bank's Enterprise Surveys.

Capital is significant in China and the Philippines, but with opposite signs. Accordingly, within a given activity in China, a higher level of physical capital will provide a competitive advantage and increase the probability of exporting. The negative sign on capital in the Philippines seems odd but may be due to measurement error. It is very difficult to accurately measure capital.

5. CONCLUSION

This paper analyzed the role of ownership, size, and innovation in influencing firm-level export behavior in electronics in China, Thailand, and the Philippines. The results indicate that higher levels of foreign equity and technological capabilities increase the probability of exporting in all three countries. Furthermore, the probability of exporting in China is also influenced by firm size as well as higher levels

of managers' education and capital. Firm size and accumulated experience affects Philippine firms' likelihood to export, while accumulated experience matters in Thailand. More generally, the findings suggest that combining trade theories with technological capabilities/national innovation systems approaches provides a useful framework to analyze firm-level exporting in developing countries.

Interestingly, R&D expenditures – the main proxy for innovation in empirical studies – is not significant in any of the three countries. Rather a TI-based on Lall's (1987 and 1992) taxonomy of technological capabilities (which includes R&D as one of several components) emerges as a strong proxy for innovation at the firm-level. This result with a large sample verifies insights from case studies of technological capabilities in developing countries that little R&D at world frontiers is performed in firms and that most of the technological effort involves building technological capabilities. It also validates the argument made by Westphal *et al.* (1990) and others that an innovation measure based on technical functions performed by firms is a robust innovation proxy at the firm-level in developing countries. Furthermore, while R&D expenditures are not statistically significant, such investments remain important to future competitiveness in a world of rapidly changing technologies.

The research suggests that there is a case for policy support to attract export-oriented FDI and acquire technological capabilities. Support for stimulating R&D activity is also warranted. The East Asian experience suggests that the optimal policy framework should include a mix of incentives, human capital investments, technology support, modern infrastructure, and effective policy management.

The availability of a methodology to compute a firm-level TI and the greater availability of survey data makes it easier to understand the process of technology development. Some limitations in the methodology used here needs to be overcome in future research. First, the TI used here was based on a limited number of technical functions (mostly production activities). It was not possible to fully apply the Lall (1987 and 1992) taxonomy of technological capabilities of investment, production, and linkages due

to the lack of information on firm-level technical functions from the World Bank Enterprise Surveys. It would be useful in future work to attempt to collect information on a more complete list of technical functions according to the Lall taxonomy and to tailor the TI to better capture technological change in different industries. Second, the export functions estimated are static as only cross-section data were available. Panel data or time series analysis could not be conducted to analyze changes over time in the determinants of exporting such as ownership and the proxies for innovation. Accordingly, the findings in this paper should be interpreted cautiously. Third, several factors that may also influence export behavior (e.g., trade policies, investment incentives, or the strength of the national innovation system) were not considered in this paper. The inclusion of such factors in the study of firm-level export behavior may produce further interesting results.

It may be appropriate to conclude with insightful comments from a recent survey of science, technology, and innovation indicators by Freeman and Soete (2009):

> "The science-technology-innovation system is one that is continuously and rapidly evolving. …, frontiers and characteristics that were important in the last century may no longer be so relevant today and indeed may even be positively misleading. Research on STI indicators appears today as challenging as ever." (Freeman and Soete, 2009, p. 588).

[1] Several taxonomies exist. For instance, Dahlman *et al.* (1987) categorize technological capabilities into production, investment, and innovation. Romijn (1997) develops a simple classification system based on the complexity of products. Making a distinction between competencies and capabilities, Iammario *et al.* (2008) distinguish two types of technological capabilities – process organization and product centered. Each taxonomy is useful depending on the purpose at hand.

[2] For a selection, see Pietrobelli (1997) on Chile, Wignaraja (1998) on Sri Lanka, Deraniyagala and Semboja (1999) on Tanzania, Wignaraja (2002) on Mauritius, Wignaraja (2008a) on China and Sri Lanka, and Warren-Rodriguez (2010) on Mozambique.

[3] A related strand of econometric literature also uses TIs to explores determinants of firm-level technological capabilities. Examples include Wignaraja (2008b) on Sri Lanka, Iammario *et al.* (2008) on Mexico, and Warren-Rodriguez (2010) on Mozambique.

[4] Rasiah (2003, 2004) employs a simple process capability measure consisting of four items: equipment, machinery, information technology components and quality control instruments. Furthermore, equipment and machinery are measured by logistic variables based on their average age, ICT is measured using a Likert scale of 1 to 5, and quality control by a dummy variable.

[5] This means that all population units are grouped within a homogenous group and simple random samples are selected within each group. This method allows computing estimates for each of the strata with a specific level of precision while population estimates can also be estimated by properly weighting individual observations. The strata for Enterprise Surveys are firm size, business sector, and geographic region within a country. In most developing countries, small and medium-sized enterprises form the bulk of the enterprises. Large firms are oversampled in the firm surveys as they tend to be engines of job creation. For more details of the sampling methodology see www.enterprisesurveys.org/methodology.

[6] Data availability on technical functions performed by firms in the World Bank Enterprise Surveys on China, Thailand, and the Philippines influenced the construction of the TI. The TI is based on the 9 technical functions that were common to all three enterprise samples.

[7] 24% of Chinese firms, 26% of Thai firms, and 21% of Philippines firms.

[8] The correlation matrix (Appendix 1) indicated that there appears to be a significant positive collinearity between TI and FOR in Thailand and the Philippines. The variance-inflation factor and condition indices tests suggest that there is no serious problem of multicollinearity.

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Table 1. Description of Variables

Variable	Description
R&D	Share of total R&D expenditure to total sales, %
TI	The technology scoring scale is based on 9 technical functions, graded according to two levels (0 and 1) to represent different levels of competence. Thus, a given firm is ranked according to a total capability score of 9 and the result is normalized to give a value between 0 and 1. The technical functions are as follows: • Upgrading equipment • Licensing of technology • ISO certification (e.g. ISO 9000, 9002 or 14000) • Process improvement • Upgrade/adaptation of products • Introduces new products • Conducts R&D activity • Subcontracts to other firms • Technology linkages with science and technology institutions
FOR	Share of foreign equity, %
SIZE	Number of permanent employees
SIZEDUM	1 if SIZE>100 employees; 0 otherwise
AGE	Number of years in operation
ETM	Share of technical manpower (with technical and vocational level qualifications) in employment, %
EDUC	Level of education of general manager/chief executive officer: 1 No education 2 Primary school education 3 Secondary education 4 Vocational training/some university training 5 Bachelor degree 6 Graduate degree
GMEXP	Number of years the general manager/chief executive officer has held the position
CAP	Net value of production machinery and equipment per employee, local currency unit
Binary Dependent Variable	1 if exporter (exports to total sales ratio is > 0); 0 otherwise

Table 2. Sample Profile

	All		China		Thailand		Philippines	
	No.	% Dist.	No.	% Dist.	No.	% Dist.	No.	% Dist.
No. of firms	784	100.00	524	66.80 [d]	166	21.20 [d]	94	12.00 [d]
By export orientation [a]								
Exporter	331	42.22	152	29.01	113	68.07	66	70.21
Nonexporter	453	57.78	372	70.99	53	31.93	28	29.79
By ownership structure [b]								
Foreign	284	36.22	113	21.56	99	59.64	72	76.40
Domestic	500	63.78	411	78.44	67	40.36	22	23.40
By size [C]								
Large	510	65.05	319	60.88	117	70.48	74	78.72
SME	274	34.95	205	39.12	49	29.52	20	21.28

Notes: [a] A firm is an exporter if shares of exports to total sales is greater than zero during the sample period; nonexporter otherwise. [b] A firm is foreign if the share of foreign equity is greater than zero; domestic firm otherwise. [c] A firm is large if it has more than 100 employees; small and medium enterprise (SME) otherwise. [d] Percent distribution across countries.
Source: Author's computations.

Table 3. Descriptive Statistics

Firm characteristics	China		Thailand		Philippines	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
R&D	1.45	0.38	0.41	0.13	0.71	0.37
TI	0.52	0.01	0.51	0.02	0.38	0.02
FOR	14.17	1.32	52.78	3.60	64.53	4.94
SIZE	421.33	36.77	888.11	139.25	1115.23	177.07
AGE	14.29	0.57	11.38	0.49	13.92	1.13
ETM	12.24	2.98	6.22	0.67	12.27	1.43
EDUC	4.06	0.02	5.89	0.03	5.06	0.09
GMEXP	5.86	0.20	9.80	0.41	14.90	1.19
CAP (in local currency units)	46.04 (Yuan)	7.39 (Yuan)	353,216.60 (Baht)	83,210.80 (Baht)	464.48 (Peso)	130.68 (Peso)

Note: See Table 1 for definition of variables.
Source: Author's computations.

Table 4. Means of R&D/Sales and TI by Ownership and Size

	China		Thailand		Philippines	
	R&D/Sales, %	TI	R&D/Sales, %	TI	R&D/Sales, %	TI
Mean	1.45	0.52	0.41	0.51	0.71	0.38
By ownership [a]						
Foreign	0.85	0.54	0.18	0.58	0.87	0.41
Domestic	1.61	0.51	0.78	0.40	0.16	0.31
By size [b]						
Large	1.51	0.54	0.50	0.59	0.84	0.42
SME	1.35	0.48	0.19	0.31	0.20	0.27

Notes: [a] A firm is foreign if the share of foreign equity is greater than zero; domestic firm otherwise. [b] A firm is large if it has more than 100 employees; small and medium-sized enterprise (SME) otherwise. The TI scores take a value between 0 and 1.
Source: Author's computations.

Table 5. T-tests of Differences of Means of Exporting and Non exporting Firms

Firm Characteristics	China			Thailand			Philippines		
	Exporter	Non exporter	t-values	Exporter	Non exporter	t-values	Exporter	Non exporter	t-values
R&D	1.08	1.60	-0.61	0.39	0.45	-0.22	0.95	0.12	1.03
TI	0.55	0.50	3.64***	0.56	0.39	5.03***	0.45	0.24	4.77***
FOR	35.34	5.52	11.47***	66.67	23.17	6.24***	83.69	20.62	7.81***
SIZE	865.29	239.93	8.19***	1171.36	282.19	3.04***	1,400.00	444.04	2.54**
AGE	11.85	15.29	-2.77***	11.82	10.43	1.32	12.16	17.96	-2.43**
ETM	18.18	10.34	1.13	5.54	7.66	-1.48	14.21	7.68	2.13**
EDUC	4.16	4.01	2.98***	5.93	5.79	1.98**	5.20	4.75	2.30**
GMEXP	5.56	5.99	-0.98	9.84	9.71	0.16	16.62	11.08	2.22**
CAP	95.55	25.54	4.38***	443,464.70	143,917.80	1.66*	554.23	252.94	1.06

Notes: t-values for two-sample t-test with equal variance: mean(exporter)-mean(nonexporter); *** t-values are significant at 1% level, ** at 5% level, * at 10% level;
See Table 1 for definition of variables
Source: Author's computations.

Table 6. Probit Estimates: Using the R&D/Sales Ratio and Technology Index
Binary Variable: Exporter (1) and Non-exporter (0)

Independent Variables	China		Thailand		Philippines	
	(1)	(2)	(3)	(4)	(5)	(6)
R&D	0.0008		0.2753		0.7718	
	(0.12)		(0.40)		(1.59)	
TI		1.1094		1.2073		5.8068
		(2.13)**		(1.75)*		(4.07)***
FOR	0.0169	0.0173	0.0123	0.0094	0.0135	0.0140
	(5.03)***	(5.12)***	(3.42)***	(3.17)***	(2.49)**	(2.43)**
SIZEDUM	0.8630	0.7388	0.4269	0.4587	2.0918	2.1789
	(4.61)***	(3.89)***	(1.30)	(1.35)	(3.65)***	(4.02)***
AGE	-0.0081	-0.0058	0.0797	0.0774	-0.0192	-0.0373
	(-1.25)	(-0.91)	(2.44)**	(2.47)**	(-0.73)	(-1.72)*
ETM	0.0012	0.0010	0.0051	0.0067	0.0190	0.0166
	(1.26)	(1.06)	(0.34)	(0.43)	(1.50)	(1.00)
EDUC	0.3673	0.3054	0.4419	0.2488	0.2004	-0.2306
	(2.31)**	(1.93)*	(1.37)	(0.93)	(0.56)	(-0.78)
GMEXP	0.0163	0.0184	-0.0489	-0.0299	0.0260	0.0121
	(1.01)	(1.16)	(-1.38)	(-0.90)	(1.15)	(0.47)
CAP	0.0041	0.0044	0.0459	0.0264	-0.0002	-0.0001
	(2.52)**	(2.53)**	(0.66)	(0.83)	(-0.99)	(-1.36)***
Constant	-3.1536	-3.4472	-3.5178	-2.9643	-3.2256	-2.9147
	(-4.39)***	(-4.72)***	(-1.76)*	(-1.79)*	(-1.55)	(-2.06)**
n	358	359	134	156	77	77
Wald χ^2	58.45***	58.93***	38.68***	40.67***	39.06***	53.24***
Pseudo R^2	0.25	0.25	0.26	0.25	0.6	0.7
Log likelihood	-149.36	-149.94	-59.52	-71.77	-19.21	-14.57

Note: z-values are in parenthesis; *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Author's computations.

Appendix 1. Correlation Matrix

China

(obs=359)

	EXPORTER	TI	FOR	SIZEDUM	AGE	ETM	EDUC	GMEXP	CAP
EXPORTER	1.0000								
TI	0.1626	1.0000							
FOR	0.4205	-0.0015	1.0000						
SIZEDUM	0.2533	0.1956	0.0815	1.0000					
AGE	-0.1205	0.0053	-0.2457	0.2070	1.0000				
ETM	0.0564	0.0985	-0.0402	0.0252	-0.0809	1.0000			
EDUC	0.1890	0.1733	0.1358	0.1028	-0.0703	0.0322	1.0000		
GMEXP	-0.0400	-0.0557	-0.1135	-0.0911	0.0613	-0.0492	-0.2741	1.0000	
CAP	0.2871	0.0578	0.1928	0.1077	-0.1314	0.0131	0.1437	-0.0481	1.0000

Source: Author's computations.

Thailand

(obs=156)

	EXPORTER	TI	FOR	SIZEDUM	AGE	ETM	EDUC	GMEXP	CAP
EXPORTER	1.0000								
TI	0.3479	1.0000							
FOR	0.3985	0.3731	1.0000						
SIZEDUM	0.4267	0.5617	0.4527	1.0000					
AGE	0.1136	-0.1296	-0.1439	0.0944	1.0000				
ETM	-0.1135	-0.1014	-0.3085	-0.3321	-0.0017	1.0000			
EDUC	0.1350	0.2324	0.1330	0.1492	-0.1866	-0.0620	1.0000		
GMEXP	0.0201	-0.1064	-0.0989	0.0394	0.6972	-0.1251	-0.1216	1.0000	
CAP	0.1327	-0.0289	0.0614	0.1441	-0.0512	0.0879	0.0707	-0.0037	1.0000

Source: Author's computations.

Philippines

(obs=77)

	EXPORTER	TI	FOR	SIZEDUM	AGE	ETM	EDUC	GMEXP	CAP
EXPORTER	1.0000								
TI	0.6209	1.0000							
FOR	0.6603	0.4322	1.0000						
SIZEDUM	0.7524	0.5240	0.6282	1.0000					
AGE	-0.2573	-0.0508	-0.2846	-0.1787	1.0000				
ETM	0.1775	0.2189	0.2125	0.1589	0.1137	1.0000			
EDUC	0.2562	0.2625	0.2315	0.2972	-0.1045	0.1539	1.0000		
GMEXP	0.2480	0.2917	0.2030	0.2517	-0.0707	-0.0387	0.0099	1.0000	
CAP	0.1208	0.1562	0.1525	0.148	-0.0241	0.1632	0.0404	0.1252	1.0000

Source: Author's computations.