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**Understanding Innovation in
Production Networks in East Asia**

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**Abstract**

This paper explores the "black box" of innovation in the electronics production network in East Asia through a mapping exercise of technological capabilities and an econometric analysis of exporting in the People's Republic of China (PRC), Thailand, and the Philippines. Technology-based approaches to trade offer a plausible explanation for firm-level exporting behavior and complement the literature on production networks. The econometric results confirm the importance of foreign ownership and innovation in increasing the probability of exporting in electronics. Higher levels of skills, managers' education, and capital also matter in the PRC as well as accumulated experience in Thailand. Furthermore, a technology index composed of technical functions performed by firms (to represent technological capabilities) emerges as a more robust indicator of innovation than the research and development (R&D) to sales ratio. Accordingly, technological effort in electronics in these countries mostly focuses on assimilating and using imported technologies rather than formal R&D by specialized engineers.

**JEL Classification:** F23, O31, O32, L63, O57

# **Contents**

# 1. INTRODUCTION

A growing body of work has focused on the role of global production networks in East Asia's economic development. The region's emergence as the global factory and unprecedented prosperity is attributed to entry into global production networks (Baldwin 2008). Large multinational corporations (MNCs) that use East Asia as a global production base have driven production fragmentation (Hiratsuka and Uchida, eds. 2010). Production processes are sliced into smaller steps, with each located in the most cost-effective economy, thereby further improving efficiency (Ando and Kimura 2005; Kuroiwa and Heng, eds. 2008). East Asian economies are linked by a dense network of parts and components trade (Athukorala 2011). Fragmentation has been facilitated by rising costs in home production bases, reductions in transport and communication costs, advances in production technology, and falling tariffs.

Electronics—with one of the world's most technologically sophisticated production networks—is East Asia's leading global export (Sturgeon and Kawakami 2010). The initial hub of the electronics production network were economies like Thailand and the Philippines, but relocation to the PRC occurred due to locational advantages (competitive wages, high worker productivity, and a large domestic market). The PRC attracted significant foreign direct investment (FDI) inflows since economic liberalization and is one of the largest electronics exporters (Wignaraja 2011; Tung and Wan 2013). Electronics parts and components trade between the PRC and the Association of Southeast Asian Nations (ASEAN) economies has also grown.

The literature sheds valuable light on a wide range of important issues concerning East Asia including the dynamics of fragmentation in electronics and other industries, the measurement of production network trade, the business and sourcing strategies of MNCs, the complex network structures in which there are intricate links (horizontal, diagonal, and vertical) between firms, and governance arrangements for production networks. Nonetheless, arguably the key driver of production networks in East Asia—innovation—appears somewhat neglected in the literature. Case studies of innovation in single firms or electronics sub-sectors do exist (e.g. Hobday 2001; Mathews and Cho 2002; Dedrick, Kraemer, and Linden 2010; Tung and Wan 2013) but few attempts have been made to generalize from the results of case studies. In particular, there is an absence of cross-country, cross-firm studies that can systematically open up the "black box" of innovation in electronics production networks and try to disentangle the links between FDI and innovation as drivers of export behavior in East Asia.

This paper explores the nature of innovation in the electronics production network in East Asia through a firm-level, cross-country econometric study of the PRC, Thailand, and the Philippines. Using recent developments in applied international trade and innovation and learning, it argues that innovation in a developing country context means building technological capabilities to use imported technology efficiently. The conducting of various technological activities at firm-level to unbundle tacit elements in imported technology can affect participation in production networks via exporting. The paper attempts two related tasks: (i) it maps firm-level innovation in the three countries to highlight whether levels of innovation in PRC firms are higher than those in Thailand and the Philippines; and (ii) it conducts econometric analysis of the links between exporting, ownership and innovation in the three countries. (i) is effectively a simple benchmarking exercise using a technology index made of technical functions performed by firms in using imported technology efficiently (to represent technological capabilities). For (ii), a comprehensive firm-level export function was estimated (which includes foreign ownership, innovation, and other control variables) using a Probit model. This is one of a handful of firm-level cross-country econometric studies on these issues using a common framework.[1] The dataset used in this

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[1] Others include: Rasiah (2003) on Malaysia and Thailand, and Wignaraja (2008a) on the PRC and Sri Lanka.

paper is a relatively large one, covering 524 firms in the PRC, 166 firms in Thailand, and 117 firms in the Philippines.

An important qualification to the research should be made upfront. Firm-level participation in production networks can be defined in terms of three kinds of activities: direct exporting or importing (which is usually the most frequent), indirect exporting as subcontracting to large firms or input suppliers (which is somewhat common), and FDI in overseas locations (which is more risky than home market production or trade). This research focusses only on direct exporting behavior in firms in the PRC, Thailand, and the Philippines due to a lack of data on indirect exporting and foreign investment.

Section 2 reviews recent theoretical and empirical literature on firm-level exporting, FDI, and innovation. Section 3 presents a mapping of innovation at firm-level in the PRC, Thailand, and the Philippines using a technology index while section 4 presents econometric results. Section 5 concludes.

# 2.  THEORETICAL AND EMPIRICAL LITERATURE

## 2.1  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 rationales 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; Wignaraja 1998; 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 research and development (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.

## 2.2  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[2] 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[3] 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 criticism, for example that it carries "the risk of inappropriate generalizations across different firms, industries, countries and historical periods" (Romijn 1999: 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.[4] 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

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[2] 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.

[3] 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 the PRC and Sri Lanka, and Warren-Rodriguez (2010) on Mozambique.

[4] A related strand of econometric literature also uses TIs to explore 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.

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's 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: 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.

## 2.3 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 propensies 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 the PRC. They found that size and R&D expenditures positively affect PRC 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: 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 technology index (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.[5]

Other studies have constructed various TIs based on Lall's framework. The content of the TIs 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 the PRC 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 the PRC. 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 (the PRC, 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 PRC, Thai, and Philippine electronics firms:

$$Y = \beta X + \varepsilon , \tag{1}$$

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[5] 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.

where **Y** is the vector denoting the probability of exporting at the firm-level, **X** is the matrix of explanatory variables, $\beta$ is the matrix of coefficients, and $\varepsilon$ 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 **X** in equation (1) are described below. A description of the variables is provided in Table 1.

**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:<br>• Upgrading equipment<br>• Licensing of technology<br>• ISO certification (e.g. ISO 9000, 9002 or 14000)<br>• Process improvement<br>• Upgrade/adaptation of products<br>• Introduces new products<br>• Conducts R&D activity<br>• Subcontracts to other firms<br>• 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:<br>1   No education<br>2   Primary school education<br>3   Secondary education<br>4   Vocational training/some university training<br>5   Bachelor degree<br>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 |

**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 of 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

## 4.1  Firm-Level Dataset

The analysis in this paper uses data from the World Bank's Enterprise Surveys conducted in 2003 for the PRC 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.[6] 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 the PRC, 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 PRC 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).

**Table 2: Sample Profile**

|  | All | | PRC | | 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.

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[6] 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.

**Table 3: Descriptive Statistics**

| Firm characteristics | PRC | | 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.

## 4.2  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, 2008, and 2012). 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.[7]

Strikingly, the evidence seems 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 PRC firms, 52% of Thai firms, and 68% of Philippine firms). Significant R&D investment (more than 1% of sales) is undertaken by 23% of PRC firms, 22% of Thai firms, and 11% of Philippine firms. The remaining firms spend up to 1% of sales on R&D activities.[8] 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 the PRC, 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 PRC firms, 34% of Thai firms, and 20% of Philippine firms) with medium to high levels of technical competence (TI scores in the range of 0.61 to 0.80). At the bottom is the largest group of firms with limited technical competence (TI scores below 0.60).

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[7] Data availability on technical functions performed by firms in the World Bank Enterprise Surveys on the PRC, 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.

[8] 24% of PRC firms, 26% of Thai firms, and 21% of Philippines firms.

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, PRC firms generally lead those in Thailand and the Philippines. PRC 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 PRC 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, PRC and Thai firms have similar technological competence in using imported technologies efficiently but PRC firms are ahead in more demanding R&D activities.

Second, in the PRC 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 the PRC 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 the PRC 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 the PRC 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 the PRC 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.

## 4.3   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 the PRC, 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 the PRC. These are much higher than the foreign equity shares of non-exporters: 21% in the Philippines, 23% in Thailand, and 6% in the PRC. 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 the PRC (1,171 employees and 865 employees, respectively). Meanwhile, non-exporters have 444 employees in the Philippines, 282 employees in Thailand, and 240 employees in the PRC.

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 the PRC (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 the PRC 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.

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

| | PRC | | 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 | PRC | | | 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.

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 the PRC and the Philippines. Exporters also have higher capital intensity (in terms of the net value of production machinery) than non-exporters in the PRC and Thailand.

## 4.4  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,[9] 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 the PRC 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 the PRC and the Philippines, which indicates that foreign-owned firms, particularly multinationals, tend to be large. Compared with SMEs, large firms are more able to 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 the PRC, and 10% level in Thailand. The magnitude of the effect of the TI is also greater 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.

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

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[9] 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.

## Table 6: Probit Estimates: Using the R&D/Sales Ratio and Technology Index

Binary Variable: Exporter (1) and Non-exporter (0)

| Independent Variables | PRC | | 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 $\chi^2$ | 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.

Surveys do not provide information on the 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/CEOs education in the PRC turns in a positive significant sign (10% level) suggesting that well-educated general managers/CEOs 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 the PRC and the Philippines, but with opposite signs. Accordingly, within a given activity in the PRC, 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. CONCLUSIONS

This paper explores the complex issue of innovation in production networks in East Asia through a cross-enterprise, cross-country study of electronics firms in the PRC, Thailand, and the Philippines. The mapping of innovation in electronics using a technology index (to represent technological capabilities) suggests that that PRC firms have higher levels of innovation than those in Thailand or the Philippines, which partly explains the relocation of production networks to this giant economy. The econometric results further indicate that higher levels of foreign equity and technological capabilities increase export propensity of firms in all three countries. Furthermore, in the case of the PRC, the probability of exporting is influenced by higher levels of skills, managers' education, and capital. Accumulated experience affects Thai firms' likelihood to export. More generally, the findings suggest that technology-based approaches to trade offer a plausible explanation for firm-level exporting in developing countries.

Interestingly, the R&D to sales ratio—the dominant proxy for innovation in most empirical studies—is not significant in any of the three countries in the reduced form regressions. Rather, an alternative broad based technology index (which includes R&D as one of eight components) emerges as a strong indicator of innovation at the firm-level. This result confirms the argument made by Westphal et al. (1990), Guan and Ma (2003), and Bhadhuri and Ray (2004) that an innovation measure based on a range of technical functions performed by firms is a robust proxy for innovation at the firm-level in late industrializing East Asian countries. Typically, little R&D is performed at the firm-level in such economies (particularly towards the development of new products and processes at the frontiers of technology) and most of the technological effort is directed towards learning to use imported technologies efficiently.

The availability of a methodology to compute a firm-level technology index and the greater availability of survey data makes it easier to develop micro-level innovation indicators to study enterprises in production networks particularly in developing countries. Further work is

needed to refine this useful innovation tool for wider applicability in studies of innovation in production networks. In this vein, tailoring the technology index to better capture the technical functions performed in different industries and different processes within production networks, application of more complex econometric estimation methods (e.g., panel data estimation), and improved data availability and quality would be useful ways forward. In addition, expansion of the analysis to study the innovation behavior of other actors in the production networks—particularly subcontractors and outward investors—would be a fruitful empirical exercise.

# REFERENCES

Ando, M., and Kimura, F. 2005. The Formation of International Production and Distribution Networks in East Asia. In: International Trade in East Asia, NBER-East Asia Seminar on Economics, Volume 14, NBER Chapters (S. 177–216). National Bureau of Economic Research.

Athukorala, P. 2011. Production Networks and Trade Patterns in East Asia: Regionalization or globalization? *Asian Economic Papers* 10(1): 65–95.

Auquier, A. 1980. Sizes of Firms and Exporting Behaviour, and the Structure of French Industry. *The Journal of Industrial Economics* XXIX(2): 203–218.

Baldwin, R.E. 2008. Managing the Noodle Bowl: The Fragility of East Asian Regionalism. *Singapore Economic Review* 53(3): 449–478.

Barrios, S., H. Gorg, and E. Strobl. 2003. Explaining Firms' Export Behaviour: R&D, Spillovers and the Destination Market. *Oxford Bulletin of Economics and Statistics* 65(4): 475–496.

Bell, M., and K. Pavitt. 1993. Technological Accumulation and Industrial Growth. *Industrial and Corporate Change* 2(2): 157–209.

Bhaduri, S., and A. Ray. 2004. Exporting through Technological Capability: Econometric Evidence from India's Pharmaceutical and Electrical/Electronics Firms. *Oxford Development Studies* 32(1): 87–100.

Bleaney, M., and K. Wakelin. 2002. Efficiency, Innovation and Exports. *Oxford Bulletin of Economics and Statistics* 64(3): 3–15.

Correa, P., M. Dayoub, and M. Francisco. 2007. Identifying Supply-Side Constraints to Export Performance in Ecuador: An Exercise with Investment Climate Survey Data. *World Bank Policy Research Working Paper* 4179, March.

Deardoff, A. 2005. How Robust is Comparative Advantage. *Review of International Economics* 13(5): 1004–1016.

Dedrick, J., K.L. Kraemer,, G. Linden. 2010. Who Profits from Innovation in Global Value Chains? A Study of the iPod and notebook PCs. *Industrial and Corporate Change* 19 (1): 81–116

Dominguez, L., and F. Brown. 2004. Measuring Technological Capabilities in Mexican Industry. *CEPAL Review* 83(August): 129–144.

Dosi, G., C. Freeman, R. Nelson, A. Silverborg, and L. Soete 1988. *Technical Change and Economic Theory.* London: Pinter.

Du, J., and S. Girma. 2007. Finance and Firm Export in China. *Kyklos* 60(1): 37–54.

Dunning, J.H. 1993. *Multinational Enterprises and the Global Economy.* Wokingham, United Kingdom: Addison-Wesley.

Filippetti, A., and A. Peyrache. 2011. The Patterns of Technological Capabilities of Countries: A Dual Approach using Composite Indicators and Data Envelopment Analysis. *World Development* 39(7): 1108–1121.

Fu, X. (forthcoming). Processing Trade, FDI and the Exports of Indigenous Firms: Firm-Level Evidence from Technology-Intensive Industries in China. *Oxford Bulletin of Economics and Statistics.*

Ernst, D, T. Ganiatsos, and L. Mytelka, eds. 1998. *Technological Capabilities and Export Success in Asia.* London: Routledge.

Hobday, M. 2001. The Electronics Industries of the Asia-Pacific: Explaining International Production Networks for Economic Development. *Asia-Pacific Economic Literature* 15(1): 13–29.

Grossman, G., and E. Helpman. 1994. Technology and Trade. *NBER Working Paper* No. W4926.

Glejser, H.A., A. Jaquemin, and J. Petit. 1980. Exports in an Imperfect Competition Framework: An Analysis of 1446 Exporters. *Quarterly Journal of Economics* XCIV: 507—524.

Guan, J., and N. Ma. 2003. Innovative Capability and Export Performance of Chinese firms. *Technovation* 23(9): 737–747.

Hiratsuka, D., and Y. Uchida, eds. 2010. *Input Trade and Production Networks in East Asia*. Cheltenham, United Kingdom: Edward Elgar.

Hirsch, S., and Z. Adar. 1974. Firm Size and Export Performance. *World Development* 2(7): 41–46.

Iammarino, S., R. Padilla-Perez, and N. von Tunzelmann. 2008. Technological Capabilities and Global-Local Interactions: The Electronics Industry in Two Mexican Regions. *World Development* 36(10): 1980–2003.

Ito, K., and V. Pucik. 1993. R&D Spending, Domestic Competition and Export Performance of Japanese Manufacturing Firms. *Strategic Management Journal* 14: 61–75.

Kumar, N., and N.S. Siddharthan. 1994. Technology, Firm Size and Export Behaviour in Developing Countries: The Case of Indian Enterprises. *Journal of Development Studies* 31(2): 289–309.

Kuroiwa, I., and T.M. Heng, eds. 2008. *Production Networks and Industrial Clusters: Integrating Economies in Southeast Asia*, Singapore: Institute of Southeast Asian Studies and Tokyo: Institute of Developing Economies, Japan External Trade Organization.

Lall, S. 1986. Technological Development and Export Performance in LDCs: Leading Engineering and Chemical Firms in India. *Weltwirtschaftliches Archiv* 122 (1): 80–91.

Lall, S. 1987. *Learning to Industrialize*. Basingstoke, United Kingdom: Macmillan Press.

Lall, S. 1992. Technological Capabilities and Industrialization. *World Development* 20: 165–86.

Lall, S., G. Barba-Navaretti, S. Teitel, and G. Wignaraja. 1984. *Technology and Enterprise Development: Ghana Under Structural Adjustment*. Basingstoke, United Kingdom: Macmillan Press.

Lundvall, B.A., ed. 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

Mathews, J.A, and D. Cho. 2002. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia*. Cambridge: Cambridge University Press.

Metcalfe, S.J. 1998. *Evolutionary Economics and Creative Destruction*. London: Routledge

Nelson, R.R., and S.G. Winter.1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap-Harvard University Press.

Nelson, R.R. 2008. Economic Development from the Perspective of Evolutionary Economic Theory. *Oxford Development Studies* 36(1): 9–21.

Rasiah, R. 2003. .Foreign Ownership, Technology and Electronics Exports from Malaysia and Thailand. *Journal of Asian Economics* 14: 785–811.

Rasiah, R. 2004. *Foreign Firms, Technological Intensities and Economic Performance, Evidence from Africa, Asia and Latin America*. Cheltenham, UK: Edward Elgar.

Romjin, H. 1997. Acquisition of Technological Capability in Development: A Quantitative Case Study of Pakistan's Capital Goods Sector. *World Development* 25(3): 359–377.

Srinivasan, T.N., and V. Archana. 2011. Determinants of Export Decision of Firms. *Economic and Political Weekly* 46(7): 49–58.

Sturgeon, T., and M. Kawakami. 2010. Global Value Chains in the Electronics Industry: Was the Crisis A Window of Opportunity for Developing Countries. In: *Global Value Chains in a Postcrisis World*, edited by O. Cattaneo, G. Gereffi, and C. Staritz. Washington, DC: World Bank.

Tung, A., and H. Wan Jr. 2013. Chinese Electronics Export—The Win-Win Outcome Along the Evolving Global Value Chain. *The World Economy.* Doi. 10.111/twec.12045.

Van Dijk, M. 2002. The Determinants of Export Performance in Developing Countries: The Case of Indonesian Manufacturing. *Eindhoven Centre for Innovation Studies Working Paper* 02.01.

Warren-Rodriguez, A. 2010. Uncovering Trends in the Accumulation of Technological Capabilities and Skills in the Mozambican Manufacturing Sector. *Oxford Development Studies 38(2)*: 171–198.

Westphal, L.E., K. Kritayakirana, K. Petchsuwan, H. Sutabutr, and Y. Yuthavong. 1990. The Development of Technological Capability in Manufacturing: A Macroscopic Approach to Policy Research. In: *Science and Technology: Lessons for Development Policy,* edited by R.E. Evenson and G. Rani. London: Intermediate Technology Publications.

Wignaraja, G. 1998. *Trade Liberalization in Sri Lanka: Exports, Technology and Industrial Policy.* London: Macmillan Press and New York: St. Martins Press.

Wignaraja, G. 2002. Firm Size, Technological Capabilities and Market-Oriented Policies in Mauritius. *Oxford Development Studies* 30(1): 87–104.

Wignaraja, G. 2008a. Ownership, Technology and Buyers: Explaining Exporting in China and Sri Lanka. *Transnational Corporations* 17(2) (August): 1–15.

Wignaraja, G. 2008b. Foreign Ownership, Technological Capabilities and Clothing Exports in Sri Lanka. *Journal of Asian Economics* 19(1): 29-39.

Wignaraja, G. 2011. Economic Reforms, Regionalism and Exports: Comparing China and India. *East West Center Policy Studies* No. 60. Honolulu: East West Center.

Wignaraja, G. 2012. Innovation, learning and exporting in China: Does R&D or a Technology Index matter? *Journal of Asian Economics* 23(3): 224–233

Wilmore, L. 1992. Transnationals and Foreign Trade: Evidence from Brazil. *Journal of Development Studies* 28(2): 314–335.

Wei, Y, X. Liu, and C. Wang. 2008.Mutual Productivity Spillovers between Foreign and Local Firms in China. *Cambridge Journal of Economics* 32(4): 609–631.

World Bank. 2008. *Enterprise Surveys.* Available: http://www.enterprisesurveys.org.

Zhao, H., and H. Li 1997. R&D and Exports: An Empirical Analysis of Chinese Manufacturing Firms. *The Journal of High Technology Management Research* 8(1): 89–105.