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Production Networks, Profits, and Innovative Activity: Evidence from Malaysia and Thailand

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Abstract

Cross-border production networks have been playing an increasingly important role in the Association of Southeast Asian Nations (ASEAN) countries' trade in recent years, but micro-level studies are rare. This paper uses firm-level data from the two most active ASEAN countries in production networks (Thailand and Malaysia) and examines the effect of participating in production networks on profits and technological capabilities of firms. The empirical results show that participating in production networks raises profits. The evidence further suggests that participation in production networks is also positively correlated with technology upgrading, measured by a technological capabilities index.

JEL Classification: F10, F23, O14

Contents

1. INTRODUCTION

There is little doubt that production fragmentation, first identified by Jones and Kierzkowski (1990), has transformed the global and Asian trade landscape in recent decades.[1] It is associated with the emergence of the global factory in Asia, the industrial success of the People's Republic of China (PRC), and unprecedented prosperity in the region (Baldwin 2011). The slicing of production and relocation of activities across geographical space in Asia was fostered by many influences including rising factor costs in home production bases, a reduction of trade barriers, rapid advancements in production technology, and a decrease in transport and communication costs.

Numerous studies have examined the impact of production fragmentation on trade flows and trade patterns (see, for instance, Yeats 2001; Ng and Yeats 2003; Yi 2003, 2010; Grossman and Rossi-Hansberg 2008). The fact that trade in production networks has grown faster than manufacturing trade underlies the importance of production network trade (Athukorala 2011). While there is a body of such macro-level work on production networks and trade, micro-level research on the workings of firms in production networks is largely absent. Despite the growing importance of production networks in ASEAN countries, little work has been conducted to examine the effects of production networks on firms and innovative activities or technology capabilities at firm-level.

This paper undertakes a micro-level econometric study of enterprise behavior in production networks in Malaysia and Thailand. First, by way of background, it updates the macro-level findings of Athukorala (2011) and uses trade in parts and components in selected categories as a proxy for trade caused by the emergence of production networks. The results show that global trade in production networks more than tripled between 1992 and 2011. Furthermore, the share of Asian countries—led by the People's Republic of China (PRC) and the Association of Southeast Asian Nations (ASEAN) countries—has risen significantly since 1992. By 2011, the PRC accounted for 20% of global production networks trade and ASEAN countries for 9%.

Second, the paper attempts to narrow the research gap on micro-level work, by using firm-level data from Malaysia and Thailand which collectively account for more than 40% of ASEAN's trade in production networks and have been playing a notable role in the region's electronics and automobile industries. Using a sample of over 2,000 firms, the paper examines the effects of participation on the global production network (proxied by sourcing materials abroad and also exporting) on value-added and technology upgrading measured using a technological capabilities index (TI). The research on Malaysian and Thai firms was inspired by different theoretical insights and empirical contributions. These include: theoretical work by Glass and Saggi (2001) on the links between participation in production networks, profits, and technology upgrading; empirical work by Görg and Hanley (2011) on outsourcing and research and development (R&D) activities in Irish firms; and the literature on technological capabilities in developing countries conceptualized by Lall (1987 and 1992) with empirical work on a TI by James and Romijn (1997), Wignaraja (2002, 2008, and 2012a), Rasiah (2003), and Iammarino et al. (2008).

The econometric results show that participating in production networks raises profits in firms in Malaysia and Thailand. The evidence also suggests that participation in production networks is positively correlated with technology upgrading, measured by a technological capabilities index (TI).

The remainder of the paper is organized as follows. Section 2 provides a brief literature review on outsourcing and the effects on firm performance and technology upgrading.

[1] The term fragmentation is often attributed to pioneering work by Jones and Kierzkowski (1990). Production sharing (Drucker 1977), vertical specialization (Hummels et al. 2001), outsourcing (Grossman and Helpman 2005), and global value chains (Gereffi, Humphrey, and Sturgeon 2005) refer to a similar phenomenon.

Section 3 maps the spread of production networks. Section 4 test the hypotheses derived from the literature review empirically. Section 5 concludes.

2. LITERATURE REVIEW

2.1 A new trend in trade—production network trade

Reductions of trade barriers, rapid advancements in production technology, and a decrease in transport and communication costs in the last decade enabled firms to exploit differences in factor prices around the world (Blinder 2006; Baldwin 2011). Globally-acting firms exploited these price differences (for instance for inputs or low-skilled labor) by splitting up the production process into different stages that can be performed anywhere in the world. This phenomenon has been described by various terms in the economic literature: slicing up the value chain (Krugman et al. 1995), fragmentation (Deardorff 2001)[2], or vertical specialization (Hummels et al. 2001) all refer to the same phenomenon. The remainder of the paper will use the term "participants in production network" to describe firms that import a certain part of their inputs from abroad and also export. The results are also checked for variations of this definition.

These definitions were chosen based on the development of global production networks. The first sectors to participate in production fragmentation were the electronics sector and the clothing sector. Semi-Conductors are amongst the earliest examples of a production network. Semi-conductors which have a high value were designed and fabricated in the United States (US), air-freighted to Asia for assembly, and then returned to the US for final testing and shipment to the customer. Subsequently, final testing facilities were established in Asia which is the final destination of some of the products anyhow. Hence, Asia's share of semi-conductor sales has almost doubled between 1984 and 2004 (Brown and Linden 2005).

Over time, the global production network deepened and spread also into other sectors such as automobiles, televisions, and cameras. This deepening of the production networks also meant that countries specialized in certain steps of the production and hence more and more countries participated in the production of one final good.[3] The deepening of the production networks also means that some firms decided to re-locate also the final assembly in order to exploit cost differences and/or to be close to the final customer. One example of such a deep production network are Japanese car manufacturers such as Honda and Toyota that located entire assembly plants in low cost countries like Thailand and sourced inputs from neighboring countries (Techakanont 2008; Athukorala 2011). Major Japanese auto parts suppliers (like Denso) also set up plants in Thailand, following car manufacturers.

2.2 How to quantify the trade in production networks

Several studies show that this trend of deepening production networks has changed the trade landscape considerably, especially in Asia (Ando and Kimura 2005). The measurement of production network trade is not straightforward. Earlier studies rely on data from Organisation for Economic Co-operation and Development (OECD) countries and are focused on the European Union (EU) and the US (Görg 2000; Feenstra 1998). These studies use data from outward processing trade (OPT). Under a special customs scheme goods can be exported from the EU territory for processing and resulting final goods can be released for free circulation within the EU. However, not all products are covered under the OPT scheme and the product coverage varies over time. Also, the importance of such tariff concessions

[2] Production fragmentation can occur within and across countries (Deardorff 2001).

[3] An illustrative example is a Barbie Doll described by Feenstra (1998) who quotes Tempest (1996). The producing firm sources raw materials from Taipei,China and Japan, produces the dolls in Indonesia and Malaysia, using doll clothing from the PRC and paints from the US.

may be somewhat reduced due to unilateral trade and investment liberalization. Furthermore, one has to treat the EU as one block as the final destination of the goods is unclear.

Another way is to use input-output tables to compute the level of vertical integration (e.g., Hummels et al. 2001). A variant also using input-output tables traces value-added in production networks and suggests that value-added seems a more accurate means of capturing production network activity than trade data (e.g., WTO IDE-JETRO 2011). The measuring trade in value added approach is attracting increasing interest in academic circles. Nonetheless, it remains a work in progress as far as empirical application is concerned in most developing countries. Since input-output tables are not available over the past years for Malaysia, Thailand, and other ASEAN countries it was not possible to use this methodology in this paper.

An alternative and convenient way of measuring production network trade is to use data from the United Nations (UN)-COMTRADE database. Yeats (2001) describes how one can derive proxies for production network trade from the UN database. This methodology has been adopted by Ng and Yeats (2003), and Ando and Kimura (2005), among others. The disadvantage of this method is that trade data are less accurate than value-added data to represent detailed production network activities particularly between countries. However, the main advantage is is that the trade data set is comprehensive and covers most countries for a vast range of years. Accordingly, it can be readily applied to show trends in production networks for ASEAN countries as useful background for this research.

A recent example of this approach is Athukorala (2011) who uses data from firm surveys in Malaysia and Thailand to identify product groups of production network trade. The author identifies the following categories according to the US Standard International Trade Classification (SITC) in which production networks trade is heavily concentrated: office machines and automatic data processing machines (SITC 75), telecommunication and sound recording equipment (SITC 76), electrical machinery (SITC 77), road vehicles (SITC 78), professional and scientific equipment (SITC 87), and photographic apparatus (SITC 88). Using this definition the study confirms the sharp increase in production network trade in the world with production network trade. According to Athukorala (2011), global production network trade flows grew from about US$1 billion in 1992–93 (about 23.8% of total exports) to more than US$4.5 billion (45.5%) in 2006–07. The share of developing countries in total world production networks exports increased from 22 to 45%. This trend was mostly driven by rise of the PRC, but also the share of ASEAN countries grew faster than the regional average reflecting the vital role of ASEAN countries.

2.3 Effect on wages and employment—concerns in the developed world

Given the enormous growth of production network trade in past decades, it not surprising that the trend of outsourcing of both goods and services and the subsequent trade within production networks has received a lot of attention from the public and academia in the developed world.[4] These concerns are based on the economic intuition that firms that participate in production networks have access to cheaper inputs and the countries will specialize in certain production steps. For developed countries this implies a change towards more skill-intensive activities. This argument is in line with a Heckscher-Ohlin model of trade. In the developed country there will be a change from low-skill to high-skill intensive sectors. This means that jobs may be lost in the low-skill intensive industries and these workers might not be able to find work in the high-skill intensive sectors due to market imperfections (Davidson and Matusz 2000; Feenstra and Hanson 1996). Some empirical findings, however, cast doubt on the argument that outsourcing has overall negative effects on the countries in terms of wages and employment (Geishecker and Görg 2008; Amiti and Wei 2005).

[4] See Feenstra (2008) for an overview of the academic debate.

2.4 Links between outsourcing and innovation in firms

This paper focuses on the effects of participating in production networks on firms. The research was inspired by Görg and Hanley (2011). The authors use Irish firm-level panel data and find a positive relationship between service outsourcing and R&D activities measured by the R&D over sales ratio. This is true for international as well as domestic outsourcing of services though the magnitude of this effect is smaller for domestic service outsourcing. The authors also find a positive relationship between international service outsourcing and profitability of firms. This effect is insignificant for domestic service outsourcing. The study by Görg and Hanley (2011) as well as this study is based on the theoretical work by Glass and Saggi (2001) who develop a dynamic theoretical model on the effects of outsourcing on wages. In their two country model (a developed North and a developing South) they argue that access to the low-wage workforce of the South increases profits of the outsourcing firms in the North. Glass and Saggi (2001) argue that these excess profits create an incentive for the Northern firms to improve products through costly innovations. These positive effects of outsourcing via innovative activities may actually offset the potential negative effects on the wages for low-skilled workers in the North.

2.5 Building technological capabilities at firm-level

It is important to clarify the concept of innovation in the context of developing countries like Malaysia and Thailand for the purposes of this paper. R&D in the sense of creating entirely new products and processes at world technological frontiers—more typically found in firms in advanced countries with well-developed national innovation systems—is limited in Malaysia and Thailand. The existing theoretical literature recognizes the role of innovation and learning for exporting manufactures, especially in developing countries. Innovation and learning at the firm-level in developing countries is often defined as the acquisition of technological capabilities, i.e., the skills and information needed to use imported technologies efficiently (Lall 1987 and 1992; Bell and Pavitt 1993; Westphal 2002). This typically spans a wide spectrum of technological activities including acquisition, use, modification, improvement, and creation of technology. Firms in developing countries generally lack domestic capabilities and rely instead on a range of mechanisms to import technology, including technology transfer by multinational corporations (MNCs) and foreign buyers of output. The evolutionary theory of technical change emphasizes that difficult firm-specific processes are involved in building technological capabilities as well as complex interactions between firms, institutions, and incentives (Nelson and Winter 1982; Nelson 2008). Differences in the efficiency with which capabilities are created are themselves a major source of competitiveness between countries. Innovative activity in this paper is thus viewed in terms of acquisition of technological capabilities at firm-level rather than R&D *per se*. Firms in production networks are likely to have invested in acquiring technological capabilities and exhibit higher levels of technological capabilities than firms outsideproduction networks.

The Lall (1987 and 1992) taxonomy of technological capabilities provides a comprehensive matrix of technical functions required for firms in developing countries to set up, operate, and transfer imported technology efficiently. Lall groups these functions under three sets of capabilities: investment, production, and linkages. The Lall taxonomy of technological capabilities has been successfully used in case study research to assess firm-level technological development in developing countries and also in the formulation of a technological capabilities index in studies of firm-level exports (for a survey, see Wignaraja 2012a).

2.6 Research gap

Despite the important role of production networks for developing countries and especially for Asian economies, only few studies have looked at the relationship between participating in production networks and innovative activity at micro-level (Kimura and Obashi 2010).

One example from a developed country in Asia is the study by Hijzen et al. (2010) who use Japanese data from 1994–2000. The study finds that intra-firm offshoring (sourcing of intermediate inputs to foreign affiliates within a firm) has a positive effect on productivity though this effect is not confirmed if a firm sources from an unaffiliated foreign firm. However, intra-firm offshoring is not the phenomenon that we would like to investigate here. This paper will focus on a production network of individual firms that participate in global production networks.

Paul and Yasar (2009) use Turkish plant level data from 1990 to 1996 and show that in textile and apparel firms labor productivity is 64% higher in firms that engage in input sub-contracting compared with firms which do not. The authors find that more productive plants initiate outsourcing and also increase their productivity after they started outsourcing.

Havie, Narjoko, and Oum (2010) use firm-level data from a pooled sample of ASEAN countries (Thailand, Indonesia, Malaysia, Philippines, Viet Nam, Cambodia, and Lao PDR) to explore factors affecting participation of small and medium enterprises (SMEs) in production networks. They find that foreign ownership, labour productivity, and technological capability are positive and significant. Using a larger pooled sample of ASEAN firms, Wignaraja (2012b) tests the hypothesis that firm size, technological capabilities, human capital, and various control variables (e.g., foreign ownership or access to credit) influence participation of SMEs in production networks. He finds that size, ownership, and technological capabilities are positive and significant. The focus of these two studies is on SMEs and separate dummy variables are used to represent technological capabilities (e.g., ISO 9000, patenting activity, and foreign technology licenses). The present study expands on the methodology of these studies by examining influences of firms of different size classes in production networks, employing a composite technological capabilities index and estimating separate models for value-added and technological capabilities.

Given the scarce empirical evidence on the effects of outsourcing and innovation, this paper will further narrow the research gap on the correlation between participating in production networks, profits, and innovative activities. In our definition, a firm participates in the production network if a firm procures materials by a firm or source abroad and also exports. All remaining firms form our control group.

2.7 Hypotheses

Based on the theoretical model by Glass and Saggi (2001), this paper will test the following hypotheses in the context of Southeast Asia:

- Firms that participate in production networks show higher profits compared with firms that do not participate;
- Firms that participate in production networks are more innovative measured by a technology index based on the taxonomy of technological capabilities developed by Lall (1987 and 1992).

3. MAPPING PRODUCTION NETWORKS

To measure the magnitude of trade caused by production networks, the definition of production networks trade by Athukorala (2011) is applied in this paper and the numbers updated up until 2011. Using data from the UN-COMTRADE database, we define production network trade as the sum of trade exports in parts and components in the following five-digit product groups from SITC, Rev. 3: office machines and automatic data processing machines (SITC 75), telecommunication and sound recording equipment (SITC 76), electrical machinery (SITC 77), road vehicles (SITC 78), professional and scientific equipment (SITC 87), and photographic apparatus (SITC 88). The results are shown in Table 1.

Table 1: Evolution of Production Network Exports 1992–2011

	Total manufacturing (% of total manufacturing trade)			Total production network trade (% of total production network trade)		
	1992–93	2006–07	**2011**	1992–93	2006–07	**2011**
East Asia	28.3	34	**35.6**	32.2	40.3	**51.3**
Japan	12.3	7.2	**6.6**	18.4	9.5	**8.0**
Developing East Asia	16	26.8	**29.0**	13.8	30.9	**43.3**
PRC	4.5	14.3	**16.8**	2.1	14.5	**18.9**
Hong Kong, China	1.8	0.7	**0.1**	1.3	0.7	**6.2**
Taipei,China	2.9	2.5	**2.7**	2.7	3.2	**4.0**
Republic of Korea	2.3	3.4	**4.4**	2.1	4.7	**5.7**
ASEAN	4.5	6	**5.1**	5.6	7.8	**8.6**
Indonesia	0.6	0.6	**0.7**	0.1	0.5	**0.4**
Malaysia	1.2	1.7	**1.3**	1.8	2.6	**2.1**
Philippines	0.3	0.7	**0.3**	0.4	1.2	**0.5**
Singapore	1.5	1.4	**2.6**	2.5	1.9	**3.9**
Thailand	0.8	1.3	**1.5**	0.8	1.6	**1.7**
Viet Nam	0	0.3	**0.0**	0	0.1	**0.0**
South Asia	0.9	1.3	**2.0**	0.1	0.3	**0.6**
India	0.6	1	**1.8**	0.1	0.3	**0.6**
North American Free Trade Area (NAFTA)	17.2	14	**11.8**	22.6	16.4	**15.3**
Mexico	1.2	2.2	**2.4**	2	3.3	**4.0**
EU15	41.3	35.4	**34.9**	37	30.3	**24.9**
World	100	100	**100.0**	100	100	**100**
Total exports in billion US$	2,651	8,892	**10,339**	1,207	4,525	**4,168**

Notes: South Asia: India, Pakistan (Bangladesh not available for 2011). Developing East Asia: ASEAN; PRC; Republic of Korea; Hong Kong, China; Taipei,China. East Asia: Developing East Asia plus Japan. EU15: no data available for Spain and Italy. ASEAN: no data available for Brunei Darussalam, Cambodia, Lao PDR, Myanmar, and Viet Nam in 2011.

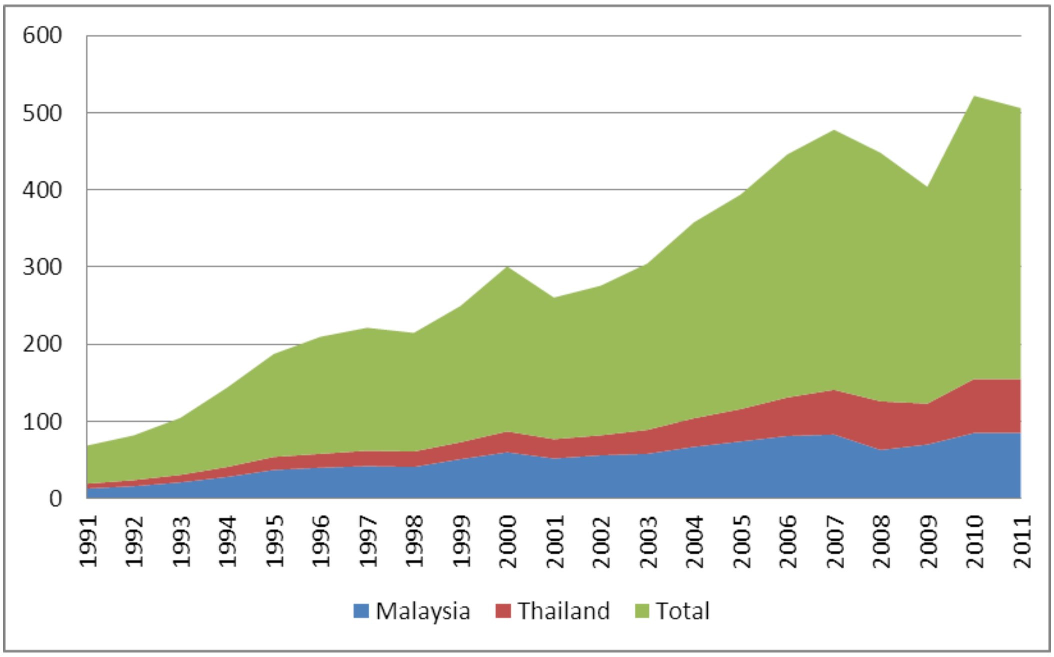
Source: Athukorala (2011). Data for 2011: author's computations based on UN COMTRADE. Source for Taipei,China: Council for Economic Planning and Development, Taipei.

Worldwide the trade in production networks more than tripled between 1992 and 2011. The share of developing East Asia in production networks trade rose from 14% in 1992–93 to about 43% in 2011. The major Asian players are the PRC and the ASEAN countries which accounted for about 30% of worldwide production network trade in 2011. The analysis in this paper will focus on Thailand and Malaysia, which are the main ASEAN economies in production networks in 2011.

Looking at the detailed composition of exports confirms the strong role of these countries in production network trade. In addition to natural resources (oil/gas and palm oil), the top exports of Malaysia are electronics and machinery. These four categories made up about 65% (electronics and machinery 38%; oil/gas and palm oil 27%) of Malaysia's total exports in 2011. Analyzing the export profile of Thailand yields similar results. Machinery and electronics were Thailand's top exports in 2011, followed by rubber products and vehicles. These four product categories accounted for about 45% of Thailand's exports in 2011.

Figure 1 shows that production network trade in ASEAN[5] has risen dramatically in the last decade. Since 2000, ASEAN countries have experienced a boom in production network trade that peaked in 2008 and recovered fairly quickly after the financial crisis. Figure 1 also shows that Thailand and Malaysia have been the most important countries in ASEAN in terms of production network trade in the past decade as they account for the bulk of ASEAN's production network trade. The statistics in Figure 1 and the statistics of production network trade worldwide confirm that Thailand and Malaysia are indeed interesting case studies for establishing the relationship between participating production networks, enterprise profits, and innovative activities of firms.

Figure 1: Total Production Network Trade Exports, US$ billion, 1991–2011



Note: We use the definition by Athukorala (2011) and define production network trade as exports of selected five-digit products from SITC, Rev. 3, 7 (Machinery and Transport Equipment) and SITC, Rev. 3, 8 (Miscellaneous Manufacturing).

Source: Authors computation based on UN-COMTRADE data.

[5] The ASEAN countries are: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

4. EVIDENCE FROM FIRM-LEVEL DATA

4.1 Dataset

The empirical analysis uses firm level data from the productivity and investment climate surveys in Malaysia and Thailand collected by the World Bank in 2007. The surveys provide cross-sectional, firm-level information on sales, production costs, employment, ownership, human capital, technology, access to credit, and aspects of the policy regime. The data from both countries is representative for the respective country.[6] Stratified random sampling with replacement was the sampling methodology used. Face-to-face interviews using a common questionnaire were conducted with senior management of firms.

The raw data contain 1,115 firms in Malaysia and 1,043 firms in Thailand, which results in a pooled sample size of 2,158 firms. Deleting firms with inconsistent or missing data leaves us with 2,057 observations for the empirical analysis.

Table 2 shows means and median values of basic firm characteristics by country and for the entire sample. Value-added is defined as total revenue less total expenses (excluding wages and interest fees). The overall mean value is about US$11 million in purchasing power parity (PPP) terms. The median values, however, are much lower and relatively similar in Malaysia and Thailand, which shows that the mean is driven by few firms with extremely high value-added. About every third firm in our sample participates in production networks. In Malaysia this number is about 10% higher than in Thailand. Firms in Thailand are considerably bigger (237 employees on average) than in Malaysia (141 employees on average). Similar to value-added, the distribution of firm size is skewed as the low median values show. Roughly every second firm both in Malaysia and Thailand participates in the export market.[7] The distributions of the expertise of the general manager in years and the firm age are neither skewed nor do they differ substantially across countries. On average, a general manager has about 10 years of experience and the average firm is about 16 years old.

4.2 Key variables

Table 3 shows the key variables for the empirical investigation by sector. Firms that source material abroad and also export are defined as participants in production networks. The first column of Table 3 shows the percentage of firms per sector that participate in production networks in Malaysia and Thailand. On average 36% of the firms participate in production networks. Auto parts, electronics, chemicals, and garments are the sectors that are most involved in production networks, with more than half of the firms on average sourcing materials from abroad and exporting. Generally, the values for Thailand and Malaysia do not vary substantially. If anything, the values for participation rates in production networks are slightly higher in Malaysia.[8]

[6] The information stems from a note about the sampling methodology are from the Thailand Investment Climate Update 2008 of the World Bank.

[7] The training dummy takes the value 1 if the firm provides training programs for production workers.

[8] The detailed statistics by country are available from the authors upon request.

Table 2: Basic Enterprise Characteristics by Country

		Mean	Median	N
Thailand	Value-added	6,303,012	1,216,559	1025
	Participates in production network	31.22%	0	1025
	Firm size	237.38	76.00	1025
	Technology Index	0.43	0.40	1025
	Export dummy	52.29%	100.00%	1025
	Training dummy	64.00%	100.00%	1025
	GM expertise in years	10.99	10.00	1025
	Firm age	14.44	13.00	1025
Malaysia	Value-added	16,400,000	1,544,372	1032
	Participates in production network	40.60%	1	1032
	Firm size	141.75	43.00	1032
	Technology Index	0.29	0.30	1032
	Export dummy	59.21%	1	1032
	Training dummy	88.76%	1	1032
	GM expertise in years	10.22	7.00	1032
	Firm age	19.15	17.50	1032
Total	Value-added	11,400,000	1,375,888	2057
	Participates in production network	44.77%	0	2057
	Firm size	189.40	58.00	2057
	Technology Index	0.36	0.40	2057
	Export dummy	55.76%	1	2057
	Training dummy	76.42%	1	2057
	GM expertise in years	10.60	9.00	2057
	Firm age	16.80	15.00	2057

Source: Author's computations based on World Bank enterprise data.

Table 3: Production Network Participation, TI, and R&D / sales by sector

	Participating in Production network	Technology Index	R&D / sales
Processing Food	26.11%	0.328	0.021
N	337	337	337
Auto Parts	45.71%	0.489	0.021
N	140	140	140
Electronics	62.70%	0.466	0.036
N	185	185	185
Rubber and Plastic	31.27%	0.358	0.023
N	518	518	518
Furniture	25.00%	0.351	0.037
N	200	200	200
Machinery/Equipment	42.60%	0.343	0.033
N	169	169	169
Wood products	10.71%	0.175	0.000
N	28	28	28
Textile/Garment	51.49%	0.351	0.012
N	402	402	402
Chemicals	55.13%	0.356	0.034
N	78	78	78
Total	35.93%	0.361	0.024
	2057	2057	2057

Source: Author's computations based on World Bank enterprise data.

Columns 2 and 3 report the mean values by sector of two measures for the innovative activity of firms. The technology index (TI) reported in column 2 is an index based on the taxonomy of technological capabilities by Lall (1987, 1992). This paper applies the modification that has been used in Wignaraja (2008 and 2012a). It consists of eight components from the following areas: firms' competence in the following areas: (i) upgrading equipment, (ii) licensing technology, (iii) International Organization for Standardization (ISO) quality certification, (iv) process improvement, (v) minor adaptation of products, (vi) introduction of new products, (vii) research and development (R&D) activity, and (viii) technology linkages. A firm can score either 1 or 0 and each of the components is weighted equally which results in a TI between 1 and 0.[9]

The results reported in Table 3 show that the average score of the TI is about 0.36. Auto parts and electronics typical industries of the new production networks show the highest score of the TI. The results from using the R&D ratio as a proxy for innovative activity of a firm are slightly different. Firstly, the variation of the indicator is smaller compared with the variation of the TI index. Secondly, besides typical production networks sectors such as machinery or auto parts which have a high R&D ratio, the furniture sector also has a high R&D over sales ratio. Given the higher plausibility of the TI in the data set, we will primarily use the TI as a measure for innovative activities.

After having established sectoral differences we now turn to differences between companies that participate in production networks and companies that do not. The results are reported in Table 4.

[9] Details about the composition of the TI are included in the Appendix.

Overall, the means of all indicators chosen in Table 4 differ significantly between firms that participate in production networks and firms that do not. In line with the hypothesis by Glass and Saggi (2001), firms in production network have a higher value-added per worker compared with firms that do not participate.[10]

Also, firms in production networks are on average more than three times bigger (419 employees) than firms that do not participate. The causality for this effect runs in both directions. It could be that a certain investment in market research is necessary before entering a production network and therefore smaller firms do not have access to sufficient funds and therefore bigger firms self-select themselves into the production network. On the other hand, it could also be that firms who enter the production network can exploit international cost differences and hence start to grow.

Both indicators used here to measure innovative activity (Technology Index and R&D intensity) show that firms in production networks report more innovative activities than firms outside production networks.

The magnitude of the significant differences for the variables representing firm age and the expertise of the general manager (measured in years) is not large. Therefore, the findings of other studies that most of the firms that participate in production networks are recently established and led by relatively young general managers cannot be confirmed. Also, the research does not detect any gender imbalances as more than half of the enterprises' owners are female both inside and outside production networks.

4.3 Econometric analysis

We now turn to a more formal analysis of the relation between value-added and participating in international production networks. In particular, the following equation is estimated:

$$lnY_i = \beta_1 pn\_dummy_i + \beta_2 Z_i + \varepsilon_i \qquad (1)$$

In (1) Y_i stands for the value-added of firm i. Value-added is defined as ln of total revenue less total expenses (excluding wages and interest fees). pn_dummy is a dummy variable that takes the value 1 if a firm participates in the international production network, meaning the firm imports inputs and also exports. Vector Z_i represents a number of control variables. These control variables include a dummy that takes the value 1 if the firm provides in-house training for production workers, the expertise of the general manager measured by years of work experience, the age of a firm in years since establishment, and a dummy that takes the value 1 if the general manager has a college degree. Furthermore, we control for differences in value-added caused by differences by inputs by including the logarithm of the capital stock (measured by the replacement value of all machinery and equipment), and the logarithm of labor inputs (number of full-time employees). Finally, a full set of sector dummies are included to control for sectoral heterogeneity. ε_i represents a random error term.

[10] We find that the variances between the groups differ. Hence, a test is used that assumes unequal variances.

Table 4: Enterprise Characteristics by Participation in Production Networks

	Value-added per worker (US$, PPP)	Firm size	Technology Index	R&D / intensity	Firm Age	Expertise of GM in years	% of female owners
Not participating in production network	43,498	124.080	0.311	0.015	16.346	10.005	60.24%
	1,318	1,318	1,318	1,318	1,318	1,318	1318
Participating in production network	70,860	419.939	0.451	0.039	17.618	11.663	65.49%
	739	739	739	739	739	739	739
T test	**	***	***	***	***	***	***
Total	53,338	230.37	0.361	0.024	16.80	10.60	62.13%
	2,057	2,057	2,057	2,057	2,057	2,057	2057

Note: * p<0.10, ** p<0.05, *** p<0.01 are p-values from a T test testing the hypothesis that the mean values differ in the categories.
Firm size: number of full-time employees in the past year; Technology Index: (see Appendix) R&D intensity, expenditure on R&D/sales.

Source: Authors' computations based on World Bank enterprise data.

Table 5: OLS Regression: Dependent Variable: ln Value Added

	(1) Pooled	(2) Pooled	(3) Thailand	(4) Malaysia	(5) Pooled
Ln capital	0.1328***	0.5626***	0.3236***	0.6121***	0.1413***
	(0.0176)	(0.0938)	(0.1122)	(0.1727)	(0.0177)
Ln labor	0.8847***	0.7140***	0.6912***	0.7255**	0.6926***
	(0.0266)	(0.1051)	(0.1109)	(0.3168)	(0.0306)
Participation in production networks		0.3680***	0.4552***	0.2503**	0.5462***
		(0.0641)	(0.0670)	(0.1181)	(0.0681)
Training		0.3070***	0.4294***	0.1284	0.5804***
		(0.0672)	(0.0794)	(0.1408)	(0.0691)
GM expertise		0.0029	0.0004	0.0085	-0.0003
		(0.0038)	(0.0051)	(0.0056)	(0.0040)
GM has college degree		0.2020***	0.0659	0.3257**	0.1109*
		(0.0632)	(0.0692)	(0.1266)	(0.0641)
Firm Age		0.0001	-0.0014	0.0031	0.0076**
		(0.0032)	(0.0044)	(0.0050)	(0.0034)
Constant		8.0967***	8.4525***	8.4903***	8.5358***
		(0.2051)	(0.2384)	(0.3696)	(0.2104)
Country dummies	yes	yes	no	no	no
Sector dummies	yes	yes	yes	yes	no
Country dummy significant	yes	yes			
P value joint significance sector dummies	0.000	0.000	0.000	0.000	
N	1683	1683	1005	678	1683
Adjusted R-squared	0.6334	0.6485	0.7089	0.5881	0.5970
F statistics constant returns to scale	0.6271	10.0047	14.2071	1.5722	33.9546
P value constant returns to scale	0.4285	0.0016	0.0002	0.2103	0.0000

Robust standard errors parentheses
* p<0.10, ** p<0.05, *** p<0.01

Source: Author's computations based on World Bank enterprise data.

The estimation results could be influenced by a number of biases. Reverse causality between participating in production networks and value-added might be an issue. In our case this means that we assume that firms that plug into production networks are able to increase value-added due to, for instance, cheaper inputs or the economies of scale that they can exploit. However, it is not implausible that firms are able to export because of a rise in value-added that enables them to pay potential costs of exporting (e.g., search for potential clients). Despite the cross-sectional character of our data set we have the information in which year a firm started exporting. The majority of firms for which we have data report to have started exporting in the same year the enterprise was set up. This lends support to the view that reverse causality is not an issue for our estimation. Even though there is some data to control for reverse causality, we cannot control for the fact that firms might export for an unobserved reason that is correlated with value-added For instance, more motivated enterprise owners could be more likely to seek out export opportunities and hence their firms could earn higher value-added than firms with less motivated owners. Also, even though we can rule out reverse causality between high value-added and participating in production networks, we cannot control for reverse causality between low value-added and not participating in production networks.[11] Tests for heteroscedasticity were also conducted using visual inspection and a Breusch Pagan test. The tests do not lend support to the hypothesis that heteroscedasticity is an issue for the estimation results. The correlation matrix in the Appendix and the fact that most of the coefficients are significant when all controls are included confirm that multicollinearity does not seem to be an issue either.

Furthermore, the data set does allow controlling for indirect participation in production networks. (e.g., a local enterprise that interacts with a firm that participates in production networks). Such effects imply a potential downward bias on our results because the comparison group may include some firms that are indirectly involved in production networks. Also, measurement error might bias the estimation results downwards.

Table 5 reports the results from estimating (1) using ordinary least squares (OLS). All of the specifications show that participating in production networks has a positive effect on value-added. The coefficients of the other control variables have the expected signs. Providing in-house training and the general manager having a college have significant and positive signs in most specifications.

Since a Cobb-Douglas production function is assumed, the F-statistic and p-values of an F-test for constant returns to scale are reported. The F tests in models 1 and 4 show that coefficients of labor and capital add up to 1. This cannot be found in models 2 and 3. However, the sum of the coefficients in models 2 and 3 is close to 1 and also the hypothesis that the coefficients are unequal to 1 can only just be rejected.[12] In column 5, the results are reported without sector and country dummies. The main findings are not altered. Also, results from a joint F test on the joint significance of the sector dummies shows that the dummies are jointly significantly different from zero. Overall, the results from Table 5 confirm the hypothesis that firms that participate in production networks have higher value-added compared with firms that do not. These findings are robust in variations of the definition of participation in production networks and across countries.[13]

In a second step, we now analyze the correlation between the technological capabilities of firms and the participation in production networks using the following specification:

$$TI = \beta_1 X_i + \beta_2 pn_{dummy} + \varepsilon_i \quad (2)$$

Technological capabilities of firms are measured using the technology index (TI) (for details about its composition see the Appendix) that ranges from 0 to 1 and has been used in numerous other studies. The vector X represents control variables such as industry and country dummies, firm age, the experience of the manager, and dummies that take the value of 1 if the general manger has a college degree or the firm provides in-house training.[14] ε_i represents a random error term.

[11] One way of solving the issue of reverse causality would be to use an instrumental variable. Our data set does not contain a suitable instrument variable, however.

[12] We also estimated a constant elasticity of substitution production function. The main results did not change..

[13] The questionnaires in Malaysia do not ask directly for profit or value added of the enterprises. Therefore, we cannot test the robustness of our results to using reported gross profit as dependent variable.

[14] We also included firm size to control for the fact that it might be that only bigger firms find it profitable to invest in innovation. The coefficient was highly significant but very small in magnitude.

Table 6: Dependent Variable: Technology Index, OLS and Tobit Estimations

	(1) Pooled OLS	(2) Pooled Tobit	(3) Thailand OLS	(4) Malaysia OLS
Participation in production networks	0.1055***	0.1125***	0.0727***	0.1242***
	(0.0102)	(0.0108)	(0.0142)	(0.0126)
Training	0.0550***	0.0546***	0.1082***	-0.0090
	(0.0106)	(0.0113)	(0.0127)	(0.0175)
College	0.0566***	0.0619***	0.0395***	0.0607***
	(0.0094)	(0.0102)	(0.0126)	(0.0124)
Size	0.0001***	0.0001***	0.0000***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
GM expertise	0.0015***	0.0018***	0.0012	0.0015**
	(0.0005)	(0.0006)	(0.0009)	(0.0006)
Firm age	-0.0013***	-0.0016***	-0.0012	-0.0010*
	(0.0004)	(0.0005)	(0.0007)	(0.0005)
Constant	0.2523***	0.2429***	0.2523***	0.1649***
	0.0136)	(0.0148)	(0.0169)	(0.0237)
Country dummies	yes	yes	no	no
Sector dummies	yes	yes	yes	yes
N	2057	2057	1025	1032
Log pseudolikelihood		152.0325		
Adjusted R-squared	0.270		0.231	0.239

Robust standard errors parentheses
* p<0.10, ** p<0.05, *** p<0.01

Source: Author's computations based on World Bank enterprise data

The results from estimating (2) are presented in Table 6. Again, we are unable to rule out the endogeneity between the TI and participating in production networks due to the lack of a suitable instrument. The results are shown using OLS and Tobit estimates. Just about 10% of the sample are censored and hence it is not surprising that the results using OLS or Tobit do not differ substantially. Again, we could not detect any evidence that heteroscedasticity or multicollinearity are an issue for the estimates. The results using the pooled sample of Malaysia and Thailand are presented in column 1. The findings reveal that training activities, the experience of the general manager, and the college dummy have a significant and positive impact on the TI, which is in line with expectations. Also, participating in production networks significantly increases the technology index. There is also some evidence that younger firms have a slightly higher TI and that bigger firms have a higher TI. In columns 3 and 4 we present the findings of individual country regressions. In both country regressions the participation in production networks dummy remains highly significant and positive. In the Thailand regression, the expertise of the general manager and firm age have the same sign but become insignificant compared with the pooled sample. In the Malaysia regression, the training dummy and firm age are no longer significant. These changes are most likely due to measurement errors.

To sum up, the analysis showed that participating in production networks has a positive effect on value-added of firms. Despite the cross-sectional nature of our data set, there is some evidence that exporting causes higher value-added and not vice versa. Hence, the findings show that participating in production networks leads to higher value-added that in turn is positively correlated to technological upgrading.

5. CONCLUSIONS

This paper focuses on micro-level factors associated with the participation of firms in production networks in Malaysia and Thailand—a hitherto under-explored area in the literature on fragmentation and production networks. It updates previous research by Athokorala (2011) on trends in global production networks trade using parts and components trade data. Then, using firm-level data, it attempts to test the theoretical insight by Glass and Saggi (2001) that firms in production networks are different from firms outside production networks. In particular, firms which participate in international production networks are able to exploit international cost differences and therefore realize higher profits. These profits in turn are re-invested in technology upgrading. To explore this, econometric models of value-added and technological capabilities were estimated for Thai and Malaysian firms. The empirical analysis of technology upgrading applies concepts from the literature on technological capabilities in developing countries including a taxonomy of technological capabilities by Lall (1987 and 1992) and a technological capabilities index used in subsequent research.

The paper finds that global production network trade has increased significantly since 1992, driven partly by rising shares of the PRC along with ASEAN economies like Malaysia and Thailand. Using data from the World Bank enterprise surveys, the firm-level econometric analysis of production networks in Malaysia and Thailand shows two other interesting results. First, there is indeed a significantly positive association between enterprise profits and participating in production networks. Second, participating in production networks significantly increases value-added and participation in production networks is also positively correlated with technological upgrading, proxied by an index of technological capabilities.

The econometric results indicate that micro-level investigation of production networks based on firm survey data is a fruitful endeavour which usefully complements macro-level analysis using trade data. Further work might usefully refine and extend the analysis in this paper in several directions. One could be to explore factors affecting the participation of firms in less developed ASEAN economies (such as Cambodia, Lao PDR, and Myanmar) which may face higher initial barriers to entry and policy-induced distortions to participating in production networks. Another might be to use panel data estimation test the robustness of cross-section estimation, providing the requisite firm-level data are available from the World Bank or other surveys. Finally, it would be interesting to examine the influence of national and regional policy level factors on firm-level participation in production networks including trade policy, free trade agreements, cross-border infrastructure, and trade facilitation.

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APPENDIX

Detailed composition of the Technology Index (TI)

The technology index is composed of 8 of the following questions that we evaluate with either 0 or 1.

1) Upgrading equipment
    a. 1 if the value of new investment on production machinery and equipment > industry average in 2006, 0 otherwise
2) Licensing and Technology
    a. 1 if the firm obtained a new licensing agreement in the past 2 years, 0 otherwise
3) Licensing and technology
    a. 1 if the firm received any ISO (e.g. 9000, 9002 or 14,000) certification, 0 otherwise
4) Process improvement
    a. 1 if the firm upgraded equipment and machinery within last 2 years (since 2004), 0 otherwise
    b. 1 if the firm increased capacity utilization in the past 2 years (since 2004), 0 otherwise
5) Minor adaptation of products
    a. 1 if the firm upgraded an existing product line, 0 otherwise
6) Introduction of new products
    a. 1 if the firm developed a new product line in 2006, 0 otherwise
7) Research and development (R&D) activity
    a. 1 if the firm's spending on R&D was bigger than the industry average in 2006, 0 otherwise
8) Technology linkages
    a. 1 if the firm uses marketing tools (web & e-mail), 0 otherwise

Correlation matrixes for variables included in Tables 5 and 6

	ln value-added	Participation in production network	ln capital	Ln labor	Training	GM expertise	College	Firm age
ln value-added	1							
Participation in production network	0.4303	1						
ln capital	0.5368	0.2692	1					
Ln labor	0.7251	0.3779	0.5476	1				
Training	0.3622	0.2503	0.156	0.2906	1			
GM expertise	0.1239	0.0759	0.1042	0.1646	0.0009	1		
College	0.2616	0.1832	0.2718	0.2875	0.0597	-0.039	1	
Firm age	0.1388	0.0615	0.0867	0.1014	0.1579	0.2792	-0.0255	1

	Technology Index	Participation in production network	Training	College	Firm size	GM expertise	Firm age
TI2	1						
Participation in production network	0.3018	1					
Training	0.1004	0.2011	1				
College	0.299	0.1928	0.0359	1			
Firm size	0.3026	0.2574	0.1494	0.1716	1		
Training	0.1073	0.0909	0.0038	-0.0161	0.1435	1	
Firm age	-0.0718	0.0603	0.1491	-0.0102	0.1126	0.2421	1