THESIS PROPOSAL

Laos' integration into the international economy: The role of production networks, technology and SMEs

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Contents

1 The issues

The emergence of production networks has shifted the centre of gravity of production and trade towards the Association of Southeast Asian Nations (ASEAN). Production networks are the breakup of production processes into fragments with each located in different economies (Jones & Kierzkowski 2005; Athukorala 2013), which is also known as slicing up the value chain (Krugman et al. 1995), international fragmentation (Deardorff 2001), and vertical specialisation (Hummels et al. 2001). The process has initially started in the electronics and garment sectors then gradually spread into such diverse industries as automobiles, televisions and radio receivers, office equipment, power and machine tools, cameras and watches, and printing and publishing (Athukorala 2011). Enhancement in production and communication technologies enables multinational corporations (MNCs) to decentralise their operations in order to take locational advantage, allowing for finer division of labour and greater efficiency gains (Kimura & Ando 2005). Wage differences and ASEAN efforts in lowering trade and investment barriers, upgrading technology, and building strong connections with the world market have contributed to their success in integrating into the global production sharing (Wignaraja et al. 2013).

Production networks (network trade), measured by the exports of parts and components, and assembled products, made up 65 per cent of ASEAN manufacturing exports in 2013.[1] Singapore specialises in high-tech network trade including medical equipment, and research and development (R&D), whereas new ASEAN members (Cambodia and Laos) produce low-tech products such as garments. In the middle, there are Malaysia, Indonesia, the Philippines, and Thailand engaging in the electronics and automotive sectors, among others. Despite being the biggest economy in Southeast Asia, Indonesia still lags behind in integration into production networks, with only 14.5 per cent of its firms participating compared to one-third in Vietnam (Athukorala & Kohpaiboon 2013). While labour cost

[1] Calculated from Comtrade's mirrored statistics of exports in 4 sectors: electrical appliances, information and communication technology, automotives, and textiles and clothing. See section on 'Measuring production networks and technology' for detailed classification. Athukorala & Kohpaiboon (2013) reported that ASEAN production networks accounted for 85.5 per cent of its manufacturing exports in 2009-10 compared to 40 per cent in 1992-93.

matters, other factors such as technological capabilities, infrastructure and business environment often influence locational decisions of MNCs (Kadarusman & Nadvi 2013).

The engagement of ASEAN in production networks varies by countries, reflecting not only their levels of development but also differences in endowments, innovative capacity, and institutional quality (Yusuf et al. 2004). Singapore has the highest R&D expenditure over GDP (2 per cent) in 2012 equivalent to that of developed countries, while the ratio ranges between 0.05 and 0.2 per cent in other ASEAN members (OECD 2013). The private sector dominates the performers of R&D in Singapore, Malaysia and the Philippines, while the public sector plays a leading role in the rest of ASEAN (OECD 2013). Even though large firms tend to dominate production sharing in Southeast Asia, small and medium enterprises (SMEs) have also increased their engagements, with the participation rate of 46.2 and 30 per cent in Malaysia and Thailand, respectively (Wignaraja 2012). The higher participation reflects their higher industrial development, resulting from more foreign direct investment and earlier exposure to the global production sharing (Harvie 2009). In Laos, 20.4 per cent of firms participate in production networks (World Bank enterprise surveys). The participation is largely concentrated on the garment sector and gradually expanding into other industries, including wood processing, electrical appliances, and automotives (Vilavong et al. forthcoming).

Motivations and rationale

It is the emergence and the diverse positions of ASEAN members in production networks that set the stage for this research. It seeks to understand what are the contributing factors, and whether does technology play a significant role in driving such process? While there exist studies that examine this in a cross-country context (Athukorala 2013; Harvie et al. 2010; Wignaraja 2013), this research will explore the determinants of production network participation in Laos focusing on the roles of technology and SMEs. It is interesting to see how has its integration effort been translated into a growth dynamic and whether there remain challenges to be addressed? Laos has sustained a robust economic growth averaging 7 per cent over the two decades, and managed to halve the share of its population below the poverty line (US$1.25 a day) to only 28 per cent in 2008 (MOIC 2012). Such achievements are largely attributed to economic reforms undertaken under its integration into ASEAN and accession to the World Trade Organisation (WTO). Nevertheless, it has experienced no observable growth in labour productivity in spite of a rise in wages by 70 per cent between 2009 and 2012 (Record et al. 2014).[2] This raises a concern about whether its economic growth is running out steam, and what has to be done to sustain it.

This research is significant for three reasons. First, the focus on production networks is important given the country's proximity to ASEAN and China, the two dynamic hubs of the global production sharing. Participation in network trade eliminates the need for Laos to gain competency in the entire production systems, focusing only a particular segment that commensurate with its resources and national capacity. Apart from productivity stagnation, its exports are concentrated on resource-based products, with mining and electricity accounting for 60 per cent of the total exports in 2013 (Vilavong 2015). It is likely that Laos may remain stuck in a development model that could not sustain growth if no efforts are put in place to reverse this. The over-reliance on the resource sectors can make Laos vulnerable to external shocks such as commodity price fluctuations and a Dutch disease symptom. This underlines the need for Laos to manage and insulate itself from these vulnerabilities while trying to diversify its economy away from resource dependency. It is interesting to explore whether tapping into production networks would provide a viable option?

Second, the emphasis on technology is important as it underpins productivity and hence long term growth. This is a key motivation of this research. Technology differences shape the patterns of trade as predicted by the classical Ricardian model that productivity determines comparative advantage, which can also be explained by the models of technology gap (Krugman 1986) and product life cycle (Helpman 1993), i.e. more technologically-advanced economies exporting more high-tech products. In the context of developing countries, technological capabilities encompass an ability to adopt imported technologies and to assimilate them into productive use rather investing in costly R&D (Almeida & Fernandes 2008). It is the upgrading within the world technological frontier rather than pushing off the boundary. It is interesting to explore how has technology

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[2] Labour productivity is measured by the real value of firms' sales over full-time workers.

influenced the patterns of the global production sharing?

Third, the focus on SMEs is motivated by the fact that they are the backbone of the Lao economy. SMEs make up 97 per cent of all the companies registered in Laos and employ around 81 per cent of the workforce (GIZ 2014; ERIA 2014). What motivates this study to focus on SMEs not only stems from their dominant role but also the need to understand more about their behaviours in international trade and the constraints that they face. Exporting involves high sunk costs whereby only highly productive firms can exploit the economy of scale and self select to export (Melitz 2003). This implies that SMEs are at disadvantage compared to larger firms, e.g. in terms of size, access to resources, and innovative capabilities (Harvie et al. 2010; Oum et al. 2014).

In the context of Laos, a firm survey (GIZ 2014) reveals that SMEs are most concerned about low levels of technology and high wages while larger corporations consider the shortage of labour (both skilled and unskilled) as their problems. In addition, SMEs report that they are more sensitive to shocks and experience greater volatility in turnovers and profit than large corporations. This underlines the importance of a greater understanding of the constraints facing SMEs and the magnitude of impacts on them so that the private sector in Laos can be supported if it wishes to benefit from the shifting of gravity into the region. Evidence suggests that greater SME participation in production networks through closer linkages with MNCs have been viewed as an effective means of accelerating technology transfer, spillovers, and economic development (Lim & Kimura 2010; Wignaraja 2012).

Research questions

The research seeks to understand how technology influences the participation in production networks. A greater understanding is needed with respect to the factors and mechanisms that underpin such linkage. Specifically, it will address three questions. First, what are the extent and depth of Laos and its firms integrating into regional production sharing? In this light, there is a need to know how production networks are defined and measured. Second, what are the factors that affect the participation in production networks at both the country and firm levels? Third, how significant is the effect of technology on such participation, and whether the significance differs across sectors?

Measuring production networks and technology

Before delving into further analysis, it is necessary to be clear how production networks and technology are measured. As for the former, there are two approaches: value adding and trade-based. The first method uses an input-output table to capture value adding in vertical integration (Hummels et al. 2001). Alternatively, a trade measure can be constructed by exploiting the notion of production networks that involves cross-border transactions of parts and components, and assembled products, as adopted by Athukorala (2011), Athukorala & Nasir (2012), and Wignaraja et al. (2013). This study opts for the second approach. Even though this may be less accurate than the value-added approach (e.g. possible double counting from re-export), the trade measure can be easily constructed from the UN Comtrade and data is available for all the ASEAN members.[3] For the firm level, production network participation can be captured from the concept that firms source foreign inputs and export. The World Bank's enterprise surveys contain data series which can be used to construct a dummy variable representing firms' production network participation.[4]

Now we turn to measuring technology. Given its multi-dimensionality and no universally accepted definition, this research will focus only on technological capabilities to represent an ability to adopt and adapt technologies. At the country level, there are some candidates to be considered: an input measure which represents resources devoted to developing technological capabilities (e.g. expenditure or the number of researchers in R&D), and an output measure to gauge the outcomes of innovation (e.g. patents, scientific journals). Note that R&D activities are important for generating new technologies but they do not necessarily lead to successful technology upgrading (Almeida & Fernandes 2008). Likewise, the outcome measures such as patents may underrepresent technological capabilities in developing countries given their relatively small number of patent holdings. Therefore, this research will use human capital (proxied by school enrolment) in addition to

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[3] Specifically, production networks are measured by the exports of parts and components, and assembled products in the following categories: ICT (SITC 75+76+772+776), electrical appliances (SITC 77-772-776), automotives (SITC 78), textiles and clothing (SITC 84+65+724). The list of parts and components is provided in Athukolara (2011).

[4] This is adopted in Wignaraja et al. (2013) while some other studies use only a firm's exporter status without combining with input importing.

R&D expenditure to represent technological capabilities for macro analysis. Human capital is not only a critical factor in creating the ability to absorb, assimilate and diffuse imported technologies but also to innovate on the basis of these imports (Yusuf et al. 2004).[5] For the firm-level analysis, technological capabilities will be measured by a combined index representing technical functions performed by firms.[6] The World Bank's enterprise surveys report several data series including firms having technology licensing or internationally-recognised quality certification, which can be used to construct such an index.

Expected contribution

In tackling research questions, the study will explore whether a gravity model can be employed to examine the influence of technology or technological capabilities on a country's participation in production networks at the regional level while controlling for other determinants. The gravity model has been used widely to evaluate the determinants of bilateral trade, among other areas, with a recent application in trade in intermediate goods (Kimura et al. 2008; Baldwin & Taglioni 2011). To better appreciate the significance of technology across industries, case studies will be conducted for selected sectors relevant to Laos: textiles and clothing, and automotives. In addition, this study will assess the significance of technological capabilities on firms' participation in production networks in Laos to supplement the macro analysis on a cross-country basis. By working on these empirical testings, this research is intended contribute to a better understanding of the theories of international trade and investment, organisation of international production, and technology.

Structure of the proposal

The remainder of this proposal is structured as follows. Section 2 gives an overview of Laos as regards participation in production networks, characteristics of SMEs and their

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[5] It has to be noted that at early stages of development, mass literacy and universal primary education deserve priority while the upgrading at middle incomes paying more attention to higher education or institutional quality.

[6] These functions are investment, production and linkages according to a taxonomy developed by Lall (1992). See Wignaraja (2013) for a review of other taxonomies.

constraints, and innovation and technology. Section 3 develops theoretical framework and research methodology for analysing the determinants of production network participation at both the macro and firm levels. Section 4 explains data sources while Section 5 outlines the possible structure of the thesis.

2 An overview of Laos

Laos has enjoyed a strong and sustained economic growth at 7 per cent on average since the mid-1990s (Record et al. 2014). In 2011, it was upgraded in classification from a low-income to a lower middle-income economy by the World Bank.[7] The country has also made significant progress in poverty reduction, with the proportion of those living below the poverty line falling from 39 per cent of the population in 1992 to 27.6 per cent in 2008 (MOIC 2012). These are considered impressive for such a landlocked and agrarian country like Laos. Such achievements are largely attributed to economic reforms carried out under the New Economic Mechanism (NEM) being introduced in the 1980s. The reforms are essentially centered on the integration of Laos into the regional and international trading system. Over 90 laws and regulations governing economic activities were enacted or revised during the fifteen years leading up to its membership in the WTO in 2013 (Pholsena & Vilavong forthcoming). The country is on track in implementing its ASEAN commitments. A trade portal has been established as an online platform to boost transparency on trade-related regulations forming part of an ASEAN trade repository. This also paves the way for its future implementation of the WTO Trade Facilitation Agreement (Vilavong 2015).

Despite such progress, Laos is still among the group of least developed countries (LDCs) classified by the United Nations, whereby the criteria based on per capita incomes, human assets and economic vulnerabilities (including export concentration). Its exports are confined to a very limited number of products that are resource-based. Mining and electricity made up over 60 per cent of its total exports in 2013 (Vilavong 2015). Such

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[7] Lower-middle-income economies are those with average gross national income (GNI) per capita of US$1,006 to US$3,975. Using the Atlas method, the GNI per capita of Laos was US$1,010 in 2011.

export concentration highlights a critical need for the country to manage and insulate itself from external vulnerabilities including commodity price shocks in the short run while in the longer term it has to find ways to diversify its export basket. Would integrating into the regional production sharing provide a viable means?

There are signs that subsidiaries of MNCs with production base in China and Thailand planning to diversity some of their operations to other ASEAN countries. One factor is rising wages and rental costs in China (Athukorala & Kohpaiboon 2013). Ongoing political unrest in Thailand since 2008 also prompts Japanese investors to consider the possibility of relocating some labour-intensive segments to neighbouring countries such as Cambodia, Laos and Myanmar, under a Thailand-plus one model (Chachavalpongpun 2014). A question is how can Laos offer a connecting link and benefit from this? What policies should the country pay attention on including education and skill development, infrastructure, business environment?

2.1 Laos' participation in production networks

This section gives an overview of Laos' network trade in four sectors: ICT, electrical appliances, automotives, and textiles and clothing. In terms of exports, production networks accounted for 23.7 per cent of the country's total exports in 2014 compared to around 30 per cent in 1990. In 2014, automative exports (including motorcycles and parts) took up the highest proportion (13.9 per cent), followed by ICT (5.2 per cent) while electrical appliances, and textiles & clothing made up around 2 per cent each. The share of textile and clothing exports was declining from the peak of 10.8 per cent in 2000. Even though its export value was growing but at a slower rate given the rising share of resource-based product exports. The share of production networks in manufacturing exports was relatively higher as shown in the lower panel of Table 2.1.

<Table 2.1 is about here>

In terms of imports, ICT products (parts & components and final assembly) accounted for 8.1 per cent of the total imports of Laos in 2014, followed by 6.7 per cent for textiles & clothing. Table 2.2 reveals some striking feature about the textile and clothing industry. It accounted for 70 per cent of manufacturing imports in 2011. This reflects a lack of upstream linkage with most materials and machinery being sourced from overseas (Douangboupha et al. 2007).

<Table 2.2 is about here>

2.2 Firm characteristics and PN participation

It is worth exploring some key characteristics of firms in Laos in comparison with other countries. One key feature as shown in Table 2.3 is that most of the firms are owned by domestic private investors (91.8 per cent) compared to 88 per cent on average for economies in East Asia and the Pacific (EAP). However, firm size and age are relatively comparable. In terms of performance, Lao firms have slightly lower capacity utilization than their EAP counterparts, 75.7 per cent compared to 79.4 per cent.[8] Around 28 per cent of firms in Laos are exporting (directly or indirectly), while 45.7 per cent source their inputs from overseas, averaging 13.1 and 55.4 per cent respectively, for EAP average. The human resource indicators (management experience, ratio of unskilled staff) are more or less comparable.

<Table 2.3 is about here>

Out of the manufacturing firms surveyed in 2012, 20.4 per cent participated in production networks, of which the majority (84.2 per cent) were large, followed by medium and small firms (10.5 per cent and 5.3 per cent, respectively) as shown in Table 2.4.[9] On the contrary, out of non-participating firms, small and medium businesses made up of 43.2 per cent and 44.6 per cent, respectively. The difference can also be seen from foreign ventures. Foreign invested companies accounted for 31.6 per cent of the participating firms as compared to only 12.2 per cent for the non-participating firms. Similarly, the proportion of firms accredited with international standards (e.g. ISO) was higher among those that participate in

[8] Comparison of the current output with the maximum output possible using all the resources available.

[9] Participation in production networks is defined as firms that export directly and source inputs from overseas.

production networks, 21.1 per cent comparing with 12.5 per cent for non-participating firms. However, there appears to be no significant difference regarding firm age. In short, firms that are larger and in joint venture with foreign investors tend to participate more in production networks.

2.3 SMEs and their constraints

SMEs are the backbone of the Lao economy, accounting for 97 per cent of all the companies, of which 84.6 per cent are small businesses with less than 20 staff, and 12.3 per cent are medium enterprises with 20-99 staff (GIZ 2014). In terms of employment, SMEs took up around 81 per cent of the total workforce (ERIA 2014). This is not an isolated case of Laos as the dominant role of SMEs has also been observed in most Southeast Asian economies. Around 89-99 per cent of firms in ASEAN are SMEs, creating between 52-97 per cent of employment, and contributing to 10-30 per cent in total exports (ERIA 2014).

A survey conducted by GIZ (2014) reveals that companies in Laos face both internal and external constraints. Internally, the lack of capital was reported by both SMEs and large firms as the most significant obstacle that hinders their growth. The causes were attributed to difficulties in meeting complex application procedures, high collateral requirements, and high lending rates. A shortage of labour (both skilled and unskilled) was also reported to be problematic for large firms while medium enterprises cited low level of technology and high wages. As for external constraints, high taxes and duties were perceived to be a critical issue for most firms. In addition, SMEs reported that they were more sensitive to shocks and experienced greater volatility in turnovers and profit than large companies.

2.4 Innovation and technology

Innovation and technology institutions in Laos are composed of the Ministry of Science and Technology, National Institute of Social Science, National Sciences Council, relevant line ministries and agencies as well as universities and research institutes. Policy and legal framework underpinning innovation and technology includes the National Science and Technology Policy of 2010. Other documentations in the pipeline of preparation include the National Strategy on Science and Technology, Law on Science and Technology, Decree on Technology Transfer, and Decree on National Science and Technology.

Laos was ranked 138th out of 141 economies in the Global Innovation Index in 2012.[10] Within ASEAN, Singapore ranked third whereas Malaysia and Thailand were at the 32th and 57th places, respectively. While the aim for innovation and technology upgrading is stipulated in the various policies of Laos, including enterprises, industry, human resource, education and research, no consistent approach nor indication of implementation actions has been observed (ERIA 2014). Table 2.3 in the Annex also shows the relative low proportion of Lao firms with internationally-recognised quality certification in comparison with those in EAP, 11.7 compared to 16 per cent. Around 20.4 per cent of Lao firms have their own websites compared to 30.4 per cent average in the region.

Technological improvement can be achieved by either creating new knowledge, or learning by doing (Grossman & Helpman 1995). First, knowledge creation is the result of investments in activities undertaken with the aim of discovering new technologies, e.g. R&D. Technological improvements may be targeted at intermediate goods or at final goods. Newly discovered products may be better than older varieties or merely different from them. Investments in knowledge can generate widespread benefits or payoff that is fully appropriable by investors. Second, learning by doing is the repetition of certain productive activities, which allow firms and industries to uncover new (better) ways of doing things. Given the high costs of R&D, developing countries like Laos may be better off relying on the second approach to upgrade its technological capabilities through technology transfer.

In the context of trade, learning by importing is equally important as learning by exporting. Importing opens opportunities to countries/firms for greater accessibility to world class technologies (Kam 2013). A wider range of inputs offers a better, more efficient mix of inputs, thereby improving efficiency known as ‘market thickness’ (Grossman & Helpman 2005). In addition, exporting enables firms to innovate through interactions with foreign clients and learning about market requirements to stay competitive. Technology transfer can be in the form of knowledge spillovers across firms within an industry, across industries within a country, or across national borders as suggested by Grossman & Helpman (1995).

[10] For some reasons, there are no GII rankings for Laos in 2013 and 2014.

What important for Laos is the cross-country spillovers such as via trade and investment linkages. However, technology transfer is not automatic and a significant level of absorptive capacity is required on the part of the host countries and a complex process to internalize disseminated knowledge to fit the local conditions (Ernst & Kim 2002). This depends on the availability of factor endowments (e.g. skilled labour) and innovation-enabling institutions of the technology recipient countries (Almeida & Fernandes 2008). This underscores the importance of human capital and institutional quality for Laos to be able to absorb and build up national technological capabilities.

3 Theoretical framework and research methodology

This section first discusses different theories related to trade and investment as a prelude to developing framework for analysing the determinants and mechanisms that affect the pattern of production networks. The macro analysis employs the gravity model adapted for evaluating trade in intermediate goods following the critique of Baldwin and Taglioni (2011). To better grasp firms' behaviours in particular SMEs, a firm-level model is developed based on the firm heterogeneity theory. The theories and econometric models for macro and micro analyses are explained in turn below.

3.1 Macro analysis

Theories related to production networks

There are two strands of theories relevant for macro analysis of the determinants of production networks and the link to technology. First, the new trade theories explian how technological differences shape the patterns of trade. Their predictions depend upon whether technology is assumed to be exogenous or endogenous (Grossman & Helpman 1995). The exogeneous technology strand includes the models of technology gap (Krugman 1986) and product life cycle (Helpman 1993). Built upon the classical Ricardian theory, the technology gap model submits that more advanced countries will export the more technologically-sophisticated goods given their advantage in producing these goods as technology gap matters relatively least for the goods that experience the slowest technological progress. The product life cycle model assumes that all innovations take place in developed countries which produce new goods. On the contrary, developing countries learn how to produce these goods only after an adoption lag. The sequence of innovation and diffusion to developing countries affects the patterns of trade. That is developed countries enjoy comparative advantage in relatively new goods, while developing countries' comparative advantage is in older products. Another stream of trade theories takes the evolution of technology as endogenous. Given that the initial pattern of specialization depends not only on intrinsic ability but also on the initial stocks of knowledge in each country, history matters in determining long-run trade pattern (Grossman & Helpman 1995). Instead of investing in R&D, developing countries may benefit from technology transfer and knowledge spillovers. The spillovers can be spread across firms within an industry (inter-firm), across industries within a country (inter-industry), or across national borders (inter-country).[11] In essence, natural comparative advantage determines trade pattern in the long run if externalities in the learning process spread rapidly around the world, but country size and initial conditions may also be important if the extent of spillovers differs with distance from the source (Grossman & Helpman 1995).

The second strand of theories related to production networks is the fragmentation theories (Jones & Kierzkowski 2005). This suggest that production processes can be fragmented into separate segments and located in different economoies, opening up new possibilities for exploiting gains from finer specialization, and thereby enhancing efficiency. Production can be fragmented because of three contributory factors: first, fragmentibility in production technology which enables productions to be sliced into different stages; second, trade and investment liberalization; and third, improvemtns in ICT and transport infrastruture which contribute to a decline in the costs of service links (Wignaraja et al. 2013; Athukorala 2013). Production fragmentation often involves decisions by MNCs in moving their operations overseas to take advantage of efficiency in different locations. The relocation decisions depend upon whether the costs saved from cheap wages and transport outweigh the costs of coordinating the remotely located segments (Ando 2012). Combining the new trade and fragmentation theories, we can see why MNCs such as from Japan relocate some of their high-tech productions (e.g. in the ICT sector) to newly-industrialized economies

[11] See a review in Grossman & Helpman (1995).

(Korea, Taiwan) with low-tech segments to ASEAN (Malaysia, Thailand), and do the final assembly in China to take advantage of cheap labours (Kimura et al. 2008; Kimura & Obashi 2011).

The gravity model

The above two strands of theories provide conceptual framework about production fragmentation and how technology differences affect trade patterns. An empirical analysis of the determinants of bilateral trade requires the use of the gravity model. The gravity model originated from the law of gravitation in physics as pioneered by Tinbergen (1962). Bilateral trade is amplified by the relative mass (scale) of trading partners but gravitated by their distance (Baldwin & Taglioni 2006). The early use of the gravity model was criticized for the lack of theoretical underpinnings, which has changed with rigorous derivations led by Anderson (1979) and Bergstrand (1985, 1989). The derivations of the structural gravity equations can be categorized as demand-side or supply-side. In the former, the exogenous wage combined with constant returns to scale or constant markups neutralizes the supply side of the model. The demand-side gravity derivations include the models of Anderson-Armington based on a product differentiation assumption (Anderson 1979), Dixit-Stiglitz-Krugman under a monopolistic competition framework (Bergstrand 1985; Baier & Bergstrand 2001), and heterogeneous consumer type (Anderson et al. 1992). The supply-side derivations include the models of Eaton & Kortum (2002), Chaney (2008), (Helpman et al. 2008).[12] Eaton & Kortum (2002) base their framework on the heterogeneous industry assumption while Chaney (2008) and Helpman et al. (2008) embed heterogeneous firm postulation in a Dixit-Stiglitz framework to generalize the Melitz (2003) model in a multi-country setting.[13]

The application of the gravity model has also been beyond the traditional analysis of trade in final goods. It was used to examine the determinants of trade in production networks (Kimura et al. 2008), intermediate goods (Bergstrand & Egger 2010; Baldwin & Taglioni

[12] The supply-side derivation also has demand equations but distributional assumptions used in these models (Fréchet or Pareto) result in the demand-side terms to be eliminated from the final formulation.
[13] See a review of more models in Head & Mayer (2015).

2011), intra-industry trade (Egger and Egger 2007), and at the sectoral/disaggregated level (Eaton & Kortum 2002; Baier et al. 2007; Martínez-Zarzoso et al. 2011). A contribution that this research tries to make is to extend the gravity model to explain the factors that influence the participation in production networks by focusing on the significance of technology. First, the model will be adapted by augmenting the GDPs of trading partners to reflect the total demand for and supply of parts and components in response to the Baldwin & Taglioni (2011) critique. Second, it will incorporate technology into the model following the competitive-based gravity formulation. It will also take advantage of the availability of panel data and advanced econometric techniques to test and address potential estimation problems (e.g. endogeneity, heterogeneity, zero trade flows).

Determinants of bilateral trade

In its simplest form, the gravity model is a function of trade that is associated positively to mass and negatively to distance. That is,

$$Trade = f(mass, distance) \tag{3.1}$$

The determinants of the gravity model can be further broken down to 4 categories: mass/scale, endowments, economic distance and multilateral resistance (Armstrong 2012). The mass/scale effects increase bilateral trade while economic distance and multilateral resistance reduce trade flows. Endowment differences between countries explain the patterns of trade. A complementarity index, calculated from a ratio of exports and imports difference to reflect the complementarity in trade structure following Drysdale & Garnaut (1982), was used in Armstrong et al. (2008) to capture the endowment effects as it reflects how the commodity compositions of two trading partners complement each other. Ekanayake et al. (2010) uses relative factor endowment (measured by the absolute value of the difference between log per capita GDPs between trading partners) to proxy for capital-labor ratio.

This study groups the determinants in a slightly different configuration given its focus on technology rather than factor endowments.

$$X_{ij} = G S_i M_j \varnothing_{ij} \quad (3.2)$$

where X_{ij} is export flows from country i to j; Si denotes exporter-specific factors representing exporter's total supply; Mi represents importer-specific factors that make up importer's total demand; $\varnothing_{ij}$ represents economic distance; and G captures multilateral resistance, i.e. factors that do not depend on i or j.

Each of the components is discussed as follows. The mass effects are now split into two elements. First, the *exporter's specific factors (S_i)* to represent the "capabilities" of exporter *i* as a supplier to all destinations. Second, the *importer's specific factors (M_j)* to capture all characteristics of destination market *j* that promote imports from all sources. The gravity equation can be estimated at the aggregate or industry level. At the aggregate level, the measure of S_i should be gross production (not value-added) of traded goods and M_j should represent the consumption of goods (production plus imports minus exports). This reflects two underlying assumptions of the (structural) gravity model: the first imposes market-clearing conditions for the exporter, and the second governs spatial allocation of expenditure for the importer (Head & Mayer 2015). However, in practice GDP's are often used as a proxy for both S_i and M_j.

Economic distance ($\varnothing_{ij}$)

The use of economic distance in the gravity model is more appropriate as geographical distance constitutes only part of trade costs. Economic distance can be decomposed into natural (spatial) and man-made (non-spatial) components (Baldwin & Taglioni 2006; Armstrong 2009). Natural components include physical distance while man-made components cover a range of policy-induced elements. For the latter, tariff protection discourages trade while regional trade agreements (RTAs) promote commercial activities among trading partners. It is quite popular to even expand the notion of distance to go beyond economic sphere. Cultural similarity (language, colonial relationship) can promote bilateral trade while institutional rigidity and political conflicts may reduce trade (Armstrong 2009).

Given this paper will analyse production networks related to trade in components, the use of logistic performance index (LPI) to capture the (inverse) effect of trade costs is more appropriate than the (one plus) tariff rate as often used for the final goods.[14] Trade in parts and components are found to be more sensitive to improvements in customs clearance and other logistic infrastructure than in trade in final goods (Saslavsky & Shepherd 2012).[15] Therefore, the economic distance can be delineated to.

$$t_{ij}=Distance_{i}\ \delta_1 . \exp \delta_1 Logistic_i+\delta_2 Logistic_j+\delta_3 Border_{ij}+\delta_4 Landlocked_i+\delta_5 Landlocked_j$$

$$+\delta_6 Language_{ij}+\delta_{7k} \sum_k RTA_k \qquad (3.3)$$

where $Distance_{ij}$ is geographical distance while $Logistic$ is measured by the logistic performance index. $Border_{ij}, Landlocked_{i,j}, Language_{ij}$, and RTA are dummy variables denoting whether the two countries have a common border, whether one or two are landlocked countries, whether the two countries have a common language, and whether they are in the same regional groupings, respectively.

Multilateral resistance (G)

Bilateral trade is not only determined by the factors that are specific to the two trading partners. There is also third-party effects, which is called the multilateral resistance (Anderson & van Wincoop 2003), remoteness (Frankel & Wei 1997), or the gravitational un-constant (Baldwin & Taglioni 2006). To illustrate, the third-party effects include neighbouring countries' sizes or the proximity of third-party countries (Armstrong 2009). The specification that fails to take multilateral resistance into account will result in biased estimates, known as the 'golden mistake' (Baldwin & Taglioni 2006).

Even though multilateral resistance is unobservable, there are some ways to capture it. One approach is to use an iterative method to obtain the estimates of the price-raising effects of barriers to multilateral resistance (Anderson & van Wincoop 2003). This is, however, not frequently used because a non-linear least square procedure is required to calculate. A simpler alternative is to use country fixed effects as implemented by Rose & van Wincoop (2001), Feenstra (2004), and Baldwin & Taglioni (2006). Note this hinges upon the

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[14] Different measures of trade costs will also be tried, including institutional quality and barriers to firm entry.

[15] The LPI, scaled from 1 to 5 (worst to best), is a weighted average of six components: efficiency of the clearance process, quality of infrastructure, ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments, and timeliness of shipments. See Saslavsky & Shepherd (2012) for a review.

assumption of fixed effects that are constant, which is more appropriate for a shorter timeframe that does not imply structural change.

Adapting the gravity model to analyse production networks

The gravity model cannot be used for analysing production networks without adaption. The problem lies in the mass variables, i.e. using GDPs to represent the consumer demand (for final goods) of the exporter and the total supply of the importer. This breaks down for the case of intermediate goods trade as maintained by Baldwin & Taglioni (2011). The standard formulation is derived from expenditure equations using the general equilibrium constraints whereas for production networks, the demands are now driven both by consumer demand and producer demand. For the consumer demand, income is a shifting factor while for producer demand it is total production costs that is the demand shifter. As a result, the use of the final goods version of the gravity model can lead to (downward) biasedness of the estimates for the mass variables. This has three implications for econometric analysis of trade in production networks (Baldwin & Taglioni 2011). First, the estimated coefficients on the GDPs are lower for nations where parts trade is important. Second, as vertical specialisation trade has become more important over time, the GDP point estimates are lower for later years. Third, where the GDPs of the trade partners lose explanatory power, bilateral trade should be increasingly well explained by the third country demand.

So how can we address this problem? Baldwin & Taglioni (2011) propose some solutions. A preferred fix would require data on total costs to calculate the demand shifter for intermediates imports. If the economy is competitive, gross sales can be a good proxy for the total costs. In reality, such data are not available especially for developing countries. Similarly, on the mass variable for the exporter, gross output should be used rather than value added. Such data are also not widely either. The biasness can be remedied by augmented the GDPs with the trade (imports or exports) of intermediate goods given that a bilateral flow of total goods is the sum of goods whose demand depends upon the importer's GDP (i.e. consumer goods) and goods whose demand depends upon the total costs of the sector buying the relevant intermediates. This suggests a first measure that adds imports of intermediates to GDP. This is to capture the direct definition of total costs to be the cost of primary inputs plus the value of intermediate inputs.[16] As for the importer, we can use its value added in manufacturing and its purchases of intermediate inputs from all sources except from itself (Baldwin & Taglioni 2011).

Accounting for the role of technology

The effect of technology on bilateral trade can be analysed in a competitiveness-based gravity model. It is the supply-side structural model, which captures the effect of technology on trade flows through productivity or lower supplying costs. Productivity (z) is assumed to be distributed Fréchet with a cumulative distribution function (CDF) of $\exp\{-T_i z^{-\theta}\}$, where T_i is a technology parameter that increases the share of goods for which country i is the low-cost supplier and θ determines the amount of heterogeneity in the productivity distribution (Head & Mayer 2015). In this light, the parameter θ corresponds inversely to dispersion in productivity instead of tastes in the case of the demand-side derivations. The competitiveness-typed gravity models are implemented by two approaches (Head & Mayer 2015). First, estimate the exporter' fixed effect in the first stage, and regress it on wages in the second stage (Eaton & Kortum 2002). The exporter fixed effect is first constructed from a transformed bilateral trade variable, and this is then regressed on proxies for technology (R&D expenditure, average years of education) and wages. Second, directly estimate the gravity equation using the determinants of the exporter's capabilities by regressing log (adjusted) exports on log productivity as measured by producer prices (Costinot et al. 2012).[17]

Given that data on wages/producer prices is not available for disaggregated trade, only the proxies for technological capabilities (R&D expenditure over GDP, gross secondary school enrolment ratio) will be used in this study. In addition, only the exporter's technological

[16] For any given local firm, some intermediates are purchased from local suppliers. When summing across all sectors and firms within a country, such intermediates will cancel out which leaves only payments to local inputs and imports of intermediates (Baldwin & Taglioni 2011).

[17] Adjusted exports are the (log of) exports, disaggregated by exporting and importing countries, differenced across exporters and industries, and corrected for differences in levels of openness across exporting countries.

capabilities are present given the competitiveness-based configuration. However, the use of country dummy variables as explained in multilateral resistance section can capture country differences production costs along with other aspects (institutional quality, political) of the importer and exporter.

Model specification and estimation

Taking together, the econometric model for analysing the determinants of a country's production network participations takes the form.

$$lnX_{ij}=a0+a1lnY_i+a2lnY_j+a3lnDistance_{ij}+a4Logistic_i+a5Logistic_j+$$
$$+a6Border_{ij}+a7Landlocked_i+a8Landlocked_j+a9Language_{ij}+$$
$$+a10,kkRTA_k+a11RnD_j+a12School_j+\varepsilon_{ij} \quad (3.4)$$

where X_{ij} is trade flows of production networks measured by the exports of parts and components and assembled products (current prices) from country (or economy) *i* to *j*, using data reported by trading partners.

Y_i and Y_j are the GDPs augmented by part and component exports (current prices) of country *i* and *j,* respectively.

$Distance_{ij}$ is the relative distance of economic cities between country *i* and *j.*

$Logistic_i$ and $Logistic_j$ is the logistics performance index (scale 1 to 5) of country i and j, respectively.

$Border_{ij}$ is a dummy variable taking 1 if *i* and *j* share a common land border (contiguity), zero otherwise.

$Landlocked_i$ and $Landlocked_j$ are dummy variables taking 1 if *i* or *j* is landlocked country, zero otherwise.

$Language_{ij}$ is a dummy variable taking 1 if *i* and *j* share common official language.

RTA_k is a dummy variable taking 1 if both *i* and *j* are RTA members, zero otherwise.

RnD_j and $School_j$ represent technological capabilities of the exporter, proxy by R&D expenditure over GDP, and gross secondary school enrolment ratio.[18]

[18] These two variables enter the gravity separately rather than combining in a single index of technological capabilities so as to evaluate their effects on trade on its own right. As for the dependent variable (export), Costinot et al. (2012) uses the ratio measure (sectoral exports over total exports), but this study simply uses the

The signs for Y's, Logistic, Border, and Language variables are expected to be positive. For augmented GDPs, it means the bigger the economies are the more they will trade. Likewise, language similarity will encourage more trade in production networks given the cultural closeness. Higher logistic performance index will enhance trade as it represents the relative ease and efficiency of product movements (inverse of trade costs). However, the signs for Distance and Landlocked are expected to be negative. The sign for RTA can be positive or negative depending on the trade creating or diverting nature of a given trade arrangement. RTA can also be interpreted as the effects of trade (and investment) liberalisation as predicted by the fragmentation theories.

The key variables of interest are RnD and School which represent technological capabilities.[19] The signs for both RnD and School are expected to be positive as technological capabilities of the exporter matter for attracting FDI and promoting production networks. The model specification in (3.4) will be used to analyse trade flows in total production networks (all four sectors), and also for case study: textiles & clothing, and automotives.

This research will use the fixed/random effect method to exploit the availability of panel data and control for multilateral resistance. Other estimation methods such as Poisson pseudo-maximum likelihood (PPML) will also be used to test robustness of the results. The PPML estimation is normally used for testing zero trade flow bias and it is quite relevant in analysing production networks or working with disaggregated trade data (Saslavsky & Shepherd 2012).[20] In addition, the tests for endogeneity of technology and other explanatory variables (e.g. RTA) will also be conducted. As for technology, it is possible that production networks and technology may have bidirectional causation. Higher technological

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value of exports. This is for convenience of interpreting the elasticity and also to prevent a possibility to adopt the ratio measure for other variables, e.g. GDPs.

[19] A robustness test may be performed on using other proxies of technology such as patent applications, researchers in R&D, depending on data availability.

[20] The firm heterogeneity theory suggests that exporting involves fixed costs and only the most productive firms will export. Failure to capture the behaviours of less productive firms in the economy (their competition in the domestic market and asymmetric effects of trade costs on small and large firms) can result in biased estimates (Head & Mayer 2015).

capabilities can encourage for higher participation in production networks and vice versa. If endogeneity problem is detected, appropriate instruments (e.g. lag of technology variable) or alternative methods will be employed. Lastly given the use of panel data, heteroscedasticity will also be tested and addressed.

3.2 Firm-level analysis

Theories on firm-specific advantages and technology

Theories that relate firm-specific advantages to technology can be found in two canons: trade and investment, and national innovation systems. The first cannon is the firm heterogeneity theories or the new "new" trade models (Melitz 2003; Helpman et al. 2004). These suggest that export entry incurs fixed costs that are sunk whereby only highly productive firms can export. Other firms who are less productive (with higher cost) will shrink and only operate in the domestic market while the worst performing firms will exit. The process of export entry (self select) and exit leads to the overall improvements in the industry efficiency. It follows that the patterns of trade are explained by not only comparative advantage of a country but also of firms given firm-specific characteristics (Wiganara 2013). These theories were built upon the neo-Hecksher-Ohlin model and Posner-Vernon theories of neo-technology that emphasise the roles of firm-specific advantages due to skill and technology differences. Nevertheless, these theories assume that technology acquisition is costless, which does not reflect the prevailing conditions of developing countries.

This links to the second canon of theories on technological capabilities and national innovation systems, which explains how technology adoption affects firm performance (Lall 1992; Iammarino et al. 2008). That said differences in mastering imported technologies or technological capabilities determine comparative advantage between countries and firms. Technological capabilities influence firm performance directly or through spillover effects (Wakelin 1998; Almeida & Fernandes 2008). Innovating and non-innovating firms behave differently as regards to export performance in both aspects (Wakelin 1998). It follows that technological capability development at the firm level is the outcome of a complex interlink between incentive structures, human capital, technological efforts and institutions (Lall 1992). Firm-specific processes and complex interactions with institutions are required to efficiently absorb imported technologies. As technology is not easily codified, technological transfer and diffusion can occur only at a slow pace. As such firms in developing countries tend to focus on minor innovative activities in order to learn and adopt foreign technologies rather than investing in R&D (Wignaraja et al. 2013).

Analytical model on firms' exporting behaviours

An analytical model will be first developed before proceeding to an econometric model for analysing the determinants of firm participation in production networks. The firm heterogeneity model suggests that potential firms can export by paying a fixed entry cost which is then sunk. They face ex ante uncertainty as regards their productivity. Once the sunk entry cost is paid, a firm draws its productivity from a fixed distribution and productivity remains fixed thereafter. Firms produce differentiated varieties under conditions of monopolistic competition. The existence of a fixed cost implies that firms drawing a productivity level below the zero-profit productivity cutoff would make negative profits and therefore exit. Fixed and variable costs of exporting ensure that only those active firms that draw a productivity above a higher productivity cutoff and find it profitable to export (Melitz & Trefler 2012).[21]

This provides the framework for understanding of analytical model to be used in this research which is adapted from Roberts & Tybout (1997). They developed a dynamic discrete-choice model that expresses each firm's current exporting status as a function of its previous exporting experience, and observable characteristics that affect its future profits from exporting. The model can be used to quantify the effects of firm's characteristics, macroeconomic shocks, and prior experience on the probability of participating in the market. It is also applied in analysing a wide range of firm's performance including the decision to enter a new market, introduce a new product, and undertake capital or R&D

[21] An alternative framework is in Bernard et al. (2003), which assumes Bertrand competition in the stochastic multi-country Ricardian model of trade of Eaton & Kortum (2002). Yeaple (2005) treats firms as ex ante identical, but the heterogeneity of firms emerges ex post through the allocation of heterogeneous workers across firms.

investments.

We start with a profit-maximizing firm, whose export decisions depend upon a profit function composing of revenue, variable cost and fixed cost as expressed below.[22]

$$\pi it = Rit - cit - F\cdot(1 - Yit-1) \quad (3.5)$$

where Rit is the expected revenue, cit is the variable cost of producing a good for the export market, F is the sunk cost of exporting, and $Yit-1$ denotes a firm's exporting status in the period t-1. If a firm exported in the previous period, it does not have to pay the sunk cost.

The revenue and cost components of can be further expanded. The expected revenue is composed of sales from the current period and the present value of all the streams of those expected in the future.

$$Rit \equiv ptqit* + \delta Et[Vit+1(\cdot)Yit=1] - Et[Vit+1(\cdot)Yit=0] \quad (3.6)$$

where pt is the price of the exported good, qit∗ is the optimal quantity of the good, δ is the discount factor, and Et[Vit+1] is the expected revenue in period t+1 given the firm's status as an exporter (Yit=1) or a non-exporter (Yit=0) in period t.

The variable cost can also be further expanded.

$$cit = cit(Xt, Zitqit*)$$

(3.7)

where Xt is a set of exogenous variables affecting a firm's cost structure including macroeconomic conditions (exchange rate and other market conditions in exporting markets). Zit is firm-specific factors including firm size, age, productivity, and ownership structure.

Substitute the revenue and variable cost equations, (3.6) and (3.7), into the profit function

[22] The following derivations are adapted and simplified from both Roberts & Tybout (1997) and Bernard & Jensen (1999). The original papers involve the use of Bellman's equations in solving a profit-maximisation problem given the streams of expected revenue.

(3.5), we get

$$\pi_{it} = p_t q_{it}^{*} + \delta E_t[V_{it+1}(\cdot) | Y_{it}=1] - E_t[V_{it+1}(\cdot) | Y_{it}=0]$$
$$- c_{it}(X_t, Z_{it} | q_{it}^{*}) - F \cdot (1 - Y_{it-1}) \quad (3.8)$$

Equation (3.8) implies that the combination of sunk costs and uncertainty will induce persistence in producers' exporting status. That is, firms who have already incurred the sunk start-up costs will be relatively likely to export in the current period. Persistence in exporting status might be due to sunk costs or caused by underlying firm's heterogeneity. For example, persistent differences across firms in the gross profit from exporting would explain why some plants are always in the export market while others are not (Roberts & Tybout 1997).

Model specification and estimation

The above analytical model forms the basis for developing an econometric model. The model of a firm's exporting decision begins with the participation condition given by (3.8) as the latent variable representing the expected increment to gross future profits for plant i if it exports in period t. That is, a firm will be an exporter if the maximising profit from the export entry is positive.

$$Y_{it} = \begin{cases} 1 & if \quad \pi^{*}_{it} \geq 0 \quad or \quad R_{it} - c_{it}(X_t, Z_{it} | q_{it}^{*}) - F \cdot (1 - Y_{it-1}) \geq 0 \\ 0 & otherwise \end{cases} \quad (3.9)$$

There are two ways to estimate equation (3.9). First, a structural representation of the export entry condition by making specific assumptions about a form of the profit function and/or the processes that generate the market-level forcing variables (X_t) and firm-specific factor variables (Z_{it}). Alternatively, we can forego the identification of structural parameters can to analyse the approximate of the revenue comparing with fixed cost of entry in a reduced form (given the prevailing market conditions and observable firm-specific characteristics). As discussed in Roberts & Tybout (1997), instead of attempting to parameterize the profit function in a structural form, it is possible to work on a reduced form. Therefore, the focus can be on identifying firm-specific factors that increase the probability of a firm to export. That is, a firm will be an exporter if its productivity (determined by firm characteristics such as firm size, ownership structure) is high enough so that it can cover the sunk cost in order to export. Equation (3.9) can be delineated to be a binary dependent regression with the dependent variable (*Yit)* equal to 1 if a firm has an exporter status, and zero otherwise.

$$Y_{it} = \beta X_{it} + \varepsilon_{it} \qquad (3.10)$$

where β is the set of parameters to be estimated, X_{it} are independent variables representing firm-specific characteristics, and ε_{it} is the error term.

The research takes this further to analysing firms' decision to participate in production networks based on the profit-maximising conditions that relates to expected revenues and fixed cost arising from such participation. It will analyse the determinants of firm's participation in production networks focusing on the role of technological capabilities while controlling for other firm-specific characteristics (capital, human capital, size, foreign ownership, age). The specification following Wignaraja (2013) is expressed below.

$$PN = \alpha_0 + \alpha_1 CAP + \alpha_2 ETM + \alpha_3 EDUC + \alpha_4 EXP + \alpha_5 TC +$$
$$+ \alpha_6 SME + \alpha_7 FOR + \alpha_8 AGE + \varepsilon \qquad (3.11)$$

where *PN* is a dummy variable taking 1 if a firm exports directly and sources inputs from abroad, zero otherwise.

CAP represents physical capital measured by net value of production machinery and equipment per employee. It is expected to positively affect production network participation given that its higher level provides a firm with competitive advantage.

Human capital is represented by three variables: (i) the share of technically qualified employees in employment *(ETM),* (ii) education level of general manager *(EDUC),* and (iii) experience of general manager *(EXP).* A higher level of human capital is predicted to have a positive impact on the probability of participating in production networks as it is associated with more rapid technological adoption and development of effective business strategy that give firms competitive edge (Wignaraja et al. 2013).

TC is technological capabilities measured by a combined index of nine technical functions related to investment, production and linkage.[23] The sign of its coefficient is expected to be positive because firms can be more cost-efficient from engaging in innovative activities and are more likely to engage in production networks.

SME is a dummy variable taking 1 if the number of (permanent) employees less than 100, zero otherwise. It is expected to be negatively associated with participation in production networks as SMEs are hypothesised to be inferior to larger firms in bearing the risks related to exporting.

FOR is the percentage of foreign equity, expected to have a positive effect on production network participation. Foreign invested firms tend to be larger than wholly domestic-owed enterprises because the former enjoys greater efficiency that enables them to export more.

AGE is represented by the number of years in operations, expected to be positively associated with participation in production networks as firms with more experience enjoy greater experimental and tacit knowledge. However, a negative association can also be expected as this holds at certain threshold. An additional term, *AGE* squared, may be added to accommodate this.

Our variable of interest is technological capabilities (TC). This study will test whether technological capabilities have a significantly effect on firm's participation in production networks while controlling for firm-specific factors. Industry dummy variables will be added to capture the industry-specific effects. Equation (3.11) can be estimated by a Probit estimation as it is a binary dependent variable model. The Logistic and Tobit estimations will also be employed to compare the results. Different diagnostic tests will be carried out to detect and address potential problems including endogeneity and heteroscedasticity. Robustness tests will be conducted to test sensitivity of the findings, e.g. using single measure of technological capabilities instead of the combined index. It may also be interesting to use different measures of firm size: dummy variables for small, medium, and non-SME firms, or the (log) number of employees so as to evaluate the different magnitude of impact.

4 Data

Data for the gravity model for macro analysis will be drawn from various sources: bilateral

[23] Investment is captured by 2 functions: upgrading equipment and technology licensing. Production is represented by 5 technical functions (quality certification, process improvement, adaptation of a product, introduction of a new product, and R&D activity). Linkages consist of 2 functions: sub-contracting to other firms and linkages with science and technology institutions.

trade from the UN Comtrade, macroeconomic variables (GDPs, logistics performance, R&D, school enrolment) from the World Bank's World Development Indicators, RTAs from the WTO, and the rest (distance, contiguity, landlockedness, language) from the CEPII database. The gravity analysis will cover the world's top 80 exporters, with all ASEAN members included, for the period between 2000 and 2013. The micro analysis will use firm-level data from the World Bank's enterprise surveys, whereby data on Laos is available for 2009 and 2012.[24]

To supplement econometric analysis, more information about recent developments and policies about Laos including on selected sectors for the case study will be gathered. This is to be done through desk research and primary data collection, including interviews with key businesses and government agencies.

[24] Another survey is expected in late 2015 or early 2016.

5 Proposed thesis outline

Below is the proposed outline to be dealt in details in the thesis.

Chapter 1 Introduction

- The issues
- Research questions
- Scope and limitations
- Expected contribution
- Structure and preview

Chapter 2 A survey of theories and empirics on production network and its linkage with technology

- Introduction
- Regional production networks
- A survey of theories
    - Production networks (production fragmentation, agglomeration theories etc)
    - International trade and firm heterogeneity
    - Trade and technology nexus (exogenous, endogenous technology models)
- Empirical studies
- Research coverage
    - Macroeconomic level analysis
    - Firm level analysis
- Concluding remarks

Chapter 3 Trend in production networks and technology

- Introduction
- Patterns and depth of regional production networks in East Asia
- Patterns and depth of regional production networks in ASEAN
    - ASEAN participation in textile and clothing production networks
    - ASEAN participation in automative production networks
- Innovation and technology transfer in ASEAN
- Concluding remarks

Chapter 4 Overview of the Lao economy

- Introduction
- Economic development
    - Economic growth
    - Trade integration
        - Recent trade performance
            - Exports, imports and direction of trade

            - Participation in production networks (country and firm levels)
        - Integration into ASEAN, other regionalism, and the WTO
- Private sector development and SMEs
- Economic policies (trade, industrial, private sector and SMEs, technology)
- Concluding remarks

Chapter 5 Determinants of ASEAN production networks: macroeconomic analysis

- Introduction
- Theoretical framework
- Model specification (Gravity model focusing on the role of technology)
- Estimation issues
- Variable description and data
- Results and robustness tests
- Concluding remarks

Chapter 6 Case studies: textiles & clothing, and automotives

- Introduction
- Historical developments and policies of Laos' selected manufacturing sectors
    - Textiles and clothing
    - Automotive, including motorcycles and parts
- Determinants of textile and clothing production networks (macro analysis)
    - Model specification and data disaggregation
    - Results and robustness tests
- Determinants of automotive production networks (macro analysis)
    - Model specification and data disaggregation
    - Results and robustness tests
- Policy implications (technological capability, trade costs, and infrastructure)
- Concluding remarks

Chapter 7 Technology and firms' participation in production networks: microeconomic analysis

- Introduction
- Insights from enterprise surveys
  (firm characteristics, production network participation, SMEs and their challenges)
- Theoretical framework
  (theories on firm heterogeneity and innovation-induced trade)
- Model specification
- Variable description and data
- Results and robustness tests
- Concluding remarks

Chapter 8 Conclusion

- Summary of findings
- The significance of the findings

- Limitations and further research

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Annex

Table 2.1 Laos' exports in production networks by sectors, 1990-2014 (US$000)

	1990	2000	2010	2011	2012	2013	2014
Total exports	*108,348*	*600,874*	*3,233,388*	*4,206,194*	*5,774,607*	*6,613,540*	*4,414,085*
of which (%)							
Electrical products	4.2	5.4	2.9	2.8	2.7	3.0	2.2
ICT	6.3	5.9	3.9	4.3	7.1	11.0	5.2
Automotives	12.2	17.0	13.5	14.2	15.3	14.9	13.9
Textiles & clothing	6.9	10.8	8.3	3.2	2.4	2.1	2.0
Total	**29.6**	**39.0**	**28.6**	**24.5**	**27.5**	**31.0**	**23.4**
Manufacturing exports	*85,148*	*412,261*	*2,189,019*	*2,732,313*	*3,944,796*	*4,649,832*	*2,575,000*
of which (%)							
Electrical products	5.4	7.8	4.3	4.4	4.0	4.2	3.9
ICT	8.0	8.6	5.7	6.6	10.4	15.7	8.9
Automotives	15.5	24.8	19.9	21.9	22.4	21.2	23.8
Textiles & clothing	8.8	15.7	12.3	4.9	3.5	2.9	3.5
Total	**37.7**	**56.9**	**42.2**	**37.8**	**40.2**	**44.1**	**40.1**

Sources: Author's calculation from WITS/Comtrade reported by trading partners.

Notes: Electrical appliances (SITC77-772-776), ICT (SITC75+76+772+ 776), automotives (SITC78), textiles & clothing (SITC65+724+84), and manufacturing (SITC5 to 8 -68).

Table 2.2 Laos' imports in production networks by sectors, 1990-2014 (US$000)

	1990	2000	2010	2011	2012	2013	2014
Total imports	*59,066*	*364,851*	*2,072,008*	*3,021,404*	*3,210,331*	*3,924,437*	*1,749,107*
of which (%)							
Electrical products	0.1	0.1	1.0	0.5	0.6	0.5	0.9
ICT	0.1	0.1	0.1	0.1	0.1	0.2	8.1
Automotives	0.3	17.1	0.4	0.2	0.3	0.4	0.1
Textiles & clothing	10.5	36.8	12.1	9.8	8.6	7.1	6.7
Total	**10.9**	**54.1**	**13.6**	**10.6**	**9.6**	**8.2**	**15.9**
Manufacturing imports	*10,810*	*208,199*	*364,575*	*420,827*	*482,478*	*526,663*	*378,940*
of which (%)							
Electrical products	0.3	0.2	5.7	3.7	3.9	4.0	4.3
ICT	0.4	0.2	0.7	0.5	0.7	1.8	37.6
Automotives	1.5	30.0	2.2	1.7	2.1	2.7	0.5
Textiles & clothing	57.4	64.5	68.8	70.0	57.0	52.6	31.0
Total	**59.7**	**94.9**	**77.5**	**76.0**	**63.7**	**61.2**	**73.4**

Sources: Author's calculation from WITS/Comtrade reported by trading partners.

Notes: Electrical appliances (SITC77-772-776), ICT (SITC75+76+772+ 776), automotives (SITC78), textiles & clothing (SITC65+724+84), and manufacturing (SITC5 to 8 -68).

Table 2.3 Comparison of firms in Laos with other economies in 2012

Indicators	Laos	East Asia & Pacific**	All countries**
Firm characteristics			
Firm size (permanent full-time workers)	43	36.7	34.3
Firm age (years in operations)	12.1	13.8	15.9
Firm ownership			
Private domestic (%)	91.8	88.3	87.7
Private foreign (%)	7.8	10	9.2
State-own (%)	0.4	0.6	0.4
Performance & trade			
Capacity utilization (%)*	75.7	79.4	72.5
Labour productivity (annual growth, %)	8.5	6.9	1.8
Proportion of firms as direct/indirect exporter (%)	28.2	13.1	17.5
Proportion of firms sourcing inputs from overseas* (%)	45.7	55.4	63
Innovation & technology			
Having inter. recognized quality certification (%)	11.7	16	17.7
Technology licensing from foreign firms* (%)	17.4	15.8	14.7
Having own websites (%)	20.4	30.4	41.1
Human resources			
Top manager's years in the firm	14.1	15.2	16.7
Ratio of unskilled over production workers* (%)	30.2	30.7	29.3

Source: Author's calculation from World Bank enterprise surveys.

Notes: * manufacturing firms only. ** Country coverage available on http://www.enterprisesurveys.org.

Table 2.4 Manufacturing firms in and not in production networks in 2012

Key characteristics	Participating in production networks (20.4%)	Not participating in production networks (79.6%)
Firm size (number of employees)		
- Small (less than 20)	5.3%	43.2%
- Medium (between 20 and 99)	10.5%	44.6%
- Large (100 or more)	84.2%	12.2%
Firm age (years in operations)	12.9	13.1
Having foreign equity		
- Yes	31.6%	12.2%
- No	68.4%	87.8%
Having inter. recognised quality certification	21.1%	12.5%
- Yes	78.9%	87.5%
- No		

Source: Author's calculations from the World Bank's enterprise surveys.

Notes: The calculation is adjusted for some missing observations. There are 270 firms in the 2012 survey, of which 96 are manufacturers, 58 as retail business and the rest as other categories.