Outsourcing and International Production of a Multinational:

A Theoretical Model and Empirical Evidence from Toyota, Thailand

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Abstract: A stylised partial equilibrium model of an MNC is developed. The model incorporates key aspects of outsourcing in a world of falling trade costs. The multinational, with firm-specific capital operates in two countries that differ in factor prices; it produces final goods with firm specific capital but can source multiple intermediate goods internally from each subsidiary (produced with firm-specific capital and labour), or outsource them from domestic or foreign suppliers. There is a potential trade off between scale of final good production and scope of in-house component production. Trade liberalization can affect both country and organization choices of the firm's component sourcing and final-good production. We also use a previously unused data set on component trade of Toyota in Southeast Asia to conduct an empirical investigation informed by the model insights.

Key words: Intra-firm Trade, Trade in intermediate inputs, direct foreign investment, multinational corporations and outsourcing.

JEL Code: F14, F15, F23, L22, L62

I. Introduction

International trade and global FDI have been growing rapidly. From 2000 to 2005, world merchandise exports grew by 10 per cent per year (WTO, 2006). These trends have been accompanied by the growing fragmentation of production. Yeats (2001) finds that the share of trade in 'parts' and 'components' of machinery goods increased from 26 per cent of OECD exports in 1978 to 30 per cent in 1995. [1] More recently, this trend is especially notable in East Asia, including China, ASEAN-4, NIE, and Japan. According to Ando and Kimura (2005), the share of machinery parts and components in the total exports of the region increased from 19 per cent to 30 per cent during the period 2000-03.

Many studies have documented that much of trade in intermediate input and services is related to the global sourcing strategies of MNCs.[2] Falling trade costs and lowering of investment barriers among the members of integrating region may be a relevant fact accelerating the expansion of international production network.[3]

Global sourcing is not confined to intra-firm trade, but international outsourcing also contributes to the phenomenon.[4] This phenomenon has triggered extensive research geared towards understanding the changes in the trade and investment patterns of multinational firms. By its very nature, this phenomenon is of interest to researchers in international trade as well as to those in industrial organization and corporate strategy. A part of the literature focuses on firms' decisions on vertical FDI and international fragmentation of production using international trade models (e.g. Feenstra and Hanson, 1996a, 1996b; Grossman and

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[1] Electric machinery and transport equipment accounts for the majority of trade in parts and components of machinery goods.

[2] See, e.g. Feenstra et al., 2000; Hanson et al., 2001 and 2005; Kleinert, 2003; and Swenson, 2004.

[3] For example, Hummels et al. (1998) find that the elimination of tariff reductions on automotive trade between the US and Canada in 1965 raised the share of total trade accounted for by vertical specialization from zero to 20 per cent in six years.

[4] The use of the term 'outsourcing' in the public debate has not been standardized. Outsourcing, generally, refers to transferring organizational controls over non-core operations from internal production to a third party (WTO, 2005). Outsourcing can be domestic or international. Domestic outsourcing involves buying services or material inputs from an unaffiliated firm in a country where the core operation is located. International outsourcing refers to importing services or intermediate inputs from an unaffiliated firm in another country. International outsourcing is a part of the term 'offshoring'. Offshoring refers to procuring services or material inputs from a source in a foreign country (NAPA, 2006). Offshoring can be conducted in-house or at arms-length. Thus, offshoring includes both international outsourcing and intra-firm trade. The term '(vertical) integration' is the opposite of 'outsourcing'. It means acquiring inputs or services from a related party. Note that 'integration', 'in-house sourcing', 'insourcing', 'internal-sourcing', and 'intra-firm sourcing' are sometimes used interchangeably. However, when this related party is located in a foreign country, the terms 'foreign direct investment (FDI)' or 'offshore integration' or 'intra-firm trade' are used.

Rossi-Hansberg, 2006; Helpman, 1984 and 1985; Jones, 2000; Markusen, 1998 and 2005). International trade researchers have asked the questions: When would a firm choose to split the production process that was once centralized in a single country into sub-processes, and locate them in different countries? How is the set of traded components or 'tasks' determined? What are the effects on resource allocation, trade flows, welfare and factor prices?

Another branch of the literature focuses on outsourcing in a corporate context using the industrial organizational (IO) literature. After Coase (1937), a path-breaking paper for understanding the firm-boundary, the key focus of the literature is the firm's make-or-buy decision. The literature on make-or-buy decisions of the firm follows two leading theories: the Transaction Cost Economics (TCE) of Williamson (1975, 1985), and the Property Rights Theory (PRT) of Grossman and Hart (1986) and Hart and Moore (1990). These frameworks enable IO economists to ask: When will a firm choose to make components and when will it buy them from an arms-length supplier?

More recently, as offshore outsourcing has gained prominence, a synthesis of the two strands of literature has started to emerge.[5] Trade and IO researchers now address new questions: When will firms choose to outsource in a foreign county rather than at home? When will MNCs choose to integrate in a foreign country (FDI), rather than integrate at home? (e.g. Antràs, 2003 and 2005; Antràs and Helpman, 2004; Feenstra and Hanson, 2005; Grossman and Helpman, 2002, 2003 and 2005; and McLaren, 2000.

The existing models have often tended to be complex, incorporating contractual incompleteness, imperfect information, and matching problems that do not lend easily to empirical testing. Many models were very restrictive in their approaches, and dealt with the case where only a particular component can be outsourced, and did not allow for endogenous determination of the sets of components acquired by different modes and locations of outsourcing. Recent models have started to address some of these limitations by dealing with the case of multiple inputs or tasks (e.g. Grossman and Rossi-Hansberg, 2006). However, available models all have important limitations for understanding the MNC's behaviour (and related intra-firm trade in components and output) when the

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[5] See e.g. Helpman (2006) and Spencer (2005) for comprehensive reviews.

presence of MNC operations in different countries provides multiple sourcing options (offshore vs onshore; inside firm (subsidiary) vs outside supplier etc.) of multiple components or tasks, and involve international trade in final goods and inputs.

In this paper, I develop a stylized model of an MNC operating in two countries that differ in factor endowments, and whose operations are undergoing changes in response to ongoing trade and investment liberalization. The model incorporates multiple components, make-or-buy decisions, intra-firm trade, and international trade of components and output to look at the empirically realistic case where the MNC has four component options: manufactures some components itself; is able to import from its own subsidiaries; and can also outsource some components to outside suppliers at home, and overseas. In this context, trade liberalization can affect both country and organization choices of the firm's component sourcing. This model is partial equilibrium so as to focus on firm-level decisions. Hence, non-firm factor prices are assumed exogenously given, and there is no tendency towards international FPE. For simplicity, the model assumes away scale economies and ignores game-theoretic complexities. We abstract from, or do not explicitly focus on, many other issues in the TCE and PRT literature, such as imperfect information, contractual incompleteness and hold-up problems.

Our model has some important similarities to the continuous tasks model of Grossman and Rossi-Hansberg (2006) and the continuous components model of Feenstra and Hanson (1996b). In their models firms are constrained to obtain inputs from outside suppliers, and there is no FDI by the firms. In contrast, our model allows a multinational to have a more complex set of production and investment decisions. Moreover, our research also relates to Feenstra and Hanson (2005) in the sense that the set of outsourcing components are endogenous. In Feenstra and Hanson (2005), producing a final good involves two tasks (input procurement and assembly) that have to be conducted in China. In contrast, we assume that producing a final good requires multiple components that can be made or bought in different countries.

The model is used to gain insights into two major issues. The first one is the relationship between different modes of component outsourcing and input characteristics: Which components will be internally produced and where, which ones will be outsourced, and from which country? Secondly, how does trade liberalization in intermediate inputs and/or

final goods impact on the component sourcing decisions, production and trade patterns of the MNC? We draw on the insights of this model and, then, quantitatively explore a previously unused data set on the component trade of Toyota in Southeast Asia, a region which has undergone substantial trade liberalization in recent years as part of the preferential trading bloc, ASEAN.

An outline of the rest of the paper is as followed. Section 2 presents the theoretical model. Section 3 is empirical investigation, and Section 4 is the conclusions.

II Theoretical Model

We build a partial equilibrium model of the firm's outsourcing and offshoring decisions. The model is built based on some basic features of the standard Hecksher-Ohlin. We model a multinational firm operating in two countries ('North' and 'South') which differ in relative factor endowments that generates factor price differences.[6] The multinational is a monopoly producer of a final good that is internationally tradable, unless its trade costs are prohibitive. We assume that the firm produces a final good using firm-specific asset – 'headquarter capital'– and a continuum of tradable components (intermediate goods) that differ in factor intensities.

We assume that, in the short-run, the MNC has fixed endowments of headquarter capital in each country. Headquarter capital is essential for final goods production but can also be used for components (in combination with labour). It is non-tradable across firm boundaries; hence it has no market value outside the firm. Profit maximization requires the full employment of headquarter capital. Thus, the firm-specific capital has an opportunity cost – a shadow cost– in each of its competing uses within the firm reflecting the foregone opportunity of using it in its alternative use. This varies depending on different allocations of headquarter capital.

The MNC faces decision problems regarding component sourcing. In principle, components can be obtained in four ways: internal production within the firm, importing

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[6] The North is a relatively capital-rich country, while the South is relatively labour-rich. Wages are higher in the North, i.e. ($w > w^*$).

components from the foreign subsidiary, purchasing from a domestic outside supplier, and importing from a foreign outside supplier.

These sourcing options are indifferent in terms of technology; however they are different in terms of embedded transaction costs. Transaction costs are assumed to increase with the external factor intensity of production.[7] Accordingly, a component i outsourced in a given country is subject to higher transaction costs than such a component produced by the firm's subsidiary in that country. The cross-country trade costs add to the transaction cost differences across input options for the offshoring activities.

The interested issue here is the component sharing between the firm and outside suppliers. Therefore, we assume the parameter values that the firm is not optimal to produce output for domestic market only, to produce all components, or to outsource all components. In addition, we assume the parameter values that allow international sourcing, both intra-firm trade and cross-firm trade, unless specify otherwise. The model set-up is specified as follow: [8]

Final good

The MNC faces downward sloping demands for its final output in each country. Assuming a quasi-linear utility function, the North consumers' demand for the MNC's final good is given by:

$$P = A - B\left(C_d + \frac{M}{T}\right), \qquad (1)$$

where C_d is the domestic output for domestic consumption, , and M is the amount of imported output. The imported good incurs an ad valorem trade cost (t), which is modeled as an iceberg cost: $T \equiv 1 + t$.[9] A is a market parameter which capture the market size, and B is a slope parameter related to the demand elasticity.

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[7] These transaction cost features are consistent with the insights of transaction cost economics which have evolved from Coase (1937) and Williamson (1975, 1985). They assume that the firm faces higher transaction costs in outsourcing than in in-house production because of the risk of hold-up problems.

[8] We specify the equations for the MNC's optimization in the North and note that the same equations hold for its optimization in South, where a superscript * denotes a foreign variable, unless stated otherwise.

[9] These trade costs reflect costs involved in international exchange, such as transport costs and tariffs. We model these costs as using real resources of the firm. Note that we do not take into account the income effects of tariffs because this is a partial firm-equilibrium model.

The production function of the MNC's output takes the Leontief form:

$$Q = \min\left\{\frac{H_Q}{a}, \frac{Z_0}{a_z}, ..., \frac{Z_1}{a_z}\right\}, \qquad (2)$$

where H_Q and Z_i are the amounts of headquarter capital and component i employed by the firm to produce output, Q, in the North. Each unit of the final good uses fixed a units of headquarter capital and fixed a_z units of an intermediate input.

Intermediate Inputs

Production of each intermediate input requires capital and labour in the Cobb-Douglas manner. The MNC can produce input i in any country by using headquarter capital and labour. The production technology of an in-house component i is given by:

$$z_{iv} = \Theta\left(H_i^{\alpha_i} L_i^{1-\alpha_i}\right), \qquad (3)$$

where $\Theta \equiv \alpha_i^{-\alpha_i}\left(1-\alpha_i\right)^{-(1-\alpha_i)}$ is a constant, and $0<\alpha_i<1$.

Outside the firm, there are component suppliers who produce and sell intermediate goods in perfectly competitive component markets. Suppliers produce components by using 'normal' capital and labour with the same technology. Firms are price takers in these capital and labour markets.

$$z_{is} = \Theta\left[K_i^{\alpha_i} L_i^{1-\alpha_i}\right]. \quad (4)$$

Thus, the dual unit-costs of an in-house component and an outsourcing component are given by:

$$c_{iv} = \lambda^{\alpha_i} w^{1-\alpha_i} \quad , \qquad (5)$$

$$c_{is} = r^{\alpha_i} w^{1-\alpha_i} \quad , \qquad (6)$$

where λ is the shadow cost of headquarter capital.

Capital intensity of component i is increasing with its capital cost sharing parameter, α_i. For convenience, a component spectrum is arranged such that the component index represents the relative capital intensity of components. That is, capital intensity is increasing with the index: $\left(\partial\alpha_i/\partial i\right)>0$. To simplify the algebra, we define $\alpha_i \equiv i$.

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4) Bringing component goods or factors, including labour, from outside into the firm boundaries is subject to transaction costs. Cross-firm transactions are subject to an *ad valorem* transaction cost t_F, and imported goods are subject to *an ad valorem* trade cost at t_C. To simplify the notation, we denote trade and transaction costs in an iceberg form: $T_j = 1 + t_j$, where $j \in (C, F)$. In addition, we do not interest in cross-country differences in transaction and trade costs.

Transaction costs depend positively on utilization of external factors in component production. Each outsourced component is totally external factor-intensive. Thus, the transaction cost of outsourcing component is T_F . In contrast, the transaction cost of an in-house component is an increasing function of the labour intensity, i.e. $T_{Fi} = f(1 - \alpha_i)$, where $f'_{1-\alpha_i} > 0$. Here, a specific functional form of cross-firm transaction costs is applied: an in-house production of component i is subject to ad valorem transaction costs at $T_{Fi} \equiv T_F^{1-\alpha_i}$. [10] [11]

For offshore sourcing, tariffs are applied on top of the FOB component value. An imported outsourcing component from the South to the North incurs the total trade and transaction costs of $T_{FC} \equiv T_C T_F = (1 + t_C)(1 + t_F)$, meanwhile these costs of an intra-firm imported component i are $T_{Ci} \equiv T_C T_F^{1-\alpha_i} = (1 + t_C)(1 + t_F)^{1-\alpha_i}$.

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[10] This functional form makes the model isomorphic between assuming that in-house capital is more productive than external capital, and assuming that equally productive intermediate inputs are traded across firm boundaries with additional transaction costs. For example, suppose that there is no transaction cost but a unit of headquarter capital is b (>1) units more productive than a unit of external capital. The production technology of an outsourcing component would be $z_{is} = \Theta\left[\left(\dfrac{K_i}{b}\right)^{\alpha_i} L^{1-\alpha_i}\right]$. The unit cost would be $c_{is} = (br)^{\alpha_i} w^{1-\alpha_i}$. We can always choose the unit of b such that $b = T_F$, which will give the same result as that obtained in the later sections.

[11] In addition, it makes the model isomorphic to a model having transaction costs in hiring capital but no transaction costs in hiring labour. Grossman and Rossi-Hansberg (2006) make a related assumption that the transaction cost of offshoring components increases with the component index.

Thus, sourcing a component i from different alternatives involves different transaction costs. Onshore internal sourcing is subject to the lowest transaction cost, while offshore outsourcing is subject to the highest transaction costs:

$$T_F^{1-\alpha_i} < T_F < T_C T_F^{1-\alpha_i} < T_C T_F .$$

The demand equal supply condition of component i gives the input sufficiency condition as follows:

$$Z_i = \frac{z_{iv}}{T_F^{1-\alpha_i}} + \frac{z_{is}}{T_F} + \frac{m_{iv}}{T_C T_F^{1-\alpha_i}} + \frac{m_{is}}{T_C T_F} , \qquad (7)$$

Z_i is the amount of component i required for output production. The MNC has four sourcing options for a component i. z_{iv} is onshore internal sourcing (vertical integration), z_{is} is onshore outsourcing, m_{iv} is intra-firm import, and m_{is} is the outsourcing import of component i. Trade and transaction costs are presented in an ice-berg form.

Endowment Constraints of the Firm

The MNC has initially allocated headquarter capital for its production in the North at a given amount ($\bar{H}$). The firm allocates the headquarter capital between producing final goods and intermediate products. We assume that the headquarter capital stock cannot be moved across countries, at least in the short-run. Thus, the endowment constraint is given by:

$$\overline{H} \geq H_Q + \int_{i=0}^{1} H_i di , \quad (i = \alpha_i),$$

where H_Q and H_i are the headquarter capital amounts used by the MNC to produce output and components in the North.

Equilibrium Conditions

We solve for the firm equilibrium by maximizing the MNC's total profit. The firm seeks an optimal allocation of headquarter capital in each country. This means that the MNC chooses optimal production of final goods and intermediate products. It also seeks an optimal combination of input sourcing. The MNC's optimization yields the full employment of headquarter capital in each country, i.e.

$$\overline{H} = H_Q + \int_{i=0}^{1} H_i di \qquad (8)$$

This also suggests that the firm's optimization leads to a maximized shadow value of headquarter capital.

The Leontief technology of output production in equation (2) yields demands for headquarter capital and a component i:

$$H_Q = a\, Q, \qquad (9)$$

and $\quad Z_i = a_z Q\,. \qquad (10)$

The Cobb-Douglas technology of component production yields derived demands for headquarter capital and labour:

$$H_i = \alpha_i \left(\frac{w}{\lambda}\right)^{1-\alpha_i} \left(z_{iv} + m_{iv}^*\right), \qquad (11)$$

$$L_i = (1-\alpha_i)\left(\frac{w}{\lambda}\right)^{-\alpha_i} \left(z_{iv} + m_{iv}^*\right).$$

Equilibrium output production requires demand equals supply of the final good. Thus, the total output produced in the North equals to domestic consumption plus output export:

$$Q = C_d + M^*. \qquad (12)$$

Using (9), (11) and (12), the endowment constraint in (8) becomes:

$$a\left(C_d + M^*\right) + \int_{i=0}^{1} \alpha_i \left(\frac{w}{\lambda}\right)^{1-\alpha_i} \left(z_{iv} + m_{iv}^*\right) di = \overline{H}. \qquad (8a)$$

Using (10) and (12) in (7):

$$a_z\left(C_d + M^*\right) = \frac{z_{iv}}{T_F^{1-\alpha_i}} + \frac{z_{is}}{T_F} + \frac{m_{iv}}{T_C T_F^{1-\alpha_i}} + \frac{m_{is}}{T_C T_F} \qquad (7a)$$

The MNC can produce output domestically or intra-firm import from overseas. Profit maximization with respect to domestic production (C_d) and intra-firm import (M) gives the Kuhn-Tucker conditions for optimal domestic production and output import. μ_i and μ_i^* denote the shadow costs of component i employed in the output produced in the North

and South, respectively. The unit cost of domestically produced output is given by $\lambda a + a_z \int_{i=0}^{1} \mu_i di$, the cost of output production plus the cost of intermediate inputs, while the unit cost of an intra-firm imported final-good is given by $T(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di)$. The conditions suggest that the firm seeks for the minimal cost of output:

$$C_d > 0 \text{ and } M = 0 \text{ if } (\lambda a + a_z \int_{i=0}^{1} \mu_i di) < T(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di), \tag{13a}$$

$$C_d = 0 \text{ and } M > 0 \text{ if } (\lambda a + a_z \int_{i=0}^{1} \mu_i di) > T(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di), \tag{13b}$$

$$C_d > 0 \text{ and } M > 0 \text{ if } (\lambda a + a_z \int_{i=0}^{1} \mu_i di) = T(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di). \tag{13c}$$

Optimal output requires marginal revenue equals marginal cost. Using the Kuhn-Tucker conditions (13a, 13b and 13c) and MR = MC gives

$$A - 2B\left(C_d + \frac{M}{T}\right) = \min\left\{(\lambda a + a_z \int_{i=0}^{1} \mu_i di), T(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di)\right\}, \tag{14}$$

For each component, the MNC has options to produce the component in the North, produce in the South, outsource to an outside firm in the North, and outsource to an outside firm in the South. Profit maximization with respect to input choices gives the Kuhn-Tucker conditions for optimal mode of input sourcing:

$$z_{iv} > 0 \text{ if } \mu_i = T_F^{1-\alpha_i} c_{iv} = \min\left\{T_C T_F c_{is}^*, T_F c_{is}, T_C \left(T_F\right)^{1-\alpha_i} c_{iv}^*, T_F^{1-\alpha_i} c_{iv}\right\}, \text{ else } z_{iv} = 0. \tag{15a}$$

$$m_{iv} > 0 \text{ if } \mu_i = T_C \left(T_F\right)^{1-\alpha_i} c_{iv}^* = \min\left\{T_C T_F c_{is}^*, T_F c_{is}, T_C \left(T_F\right)^{1-\alpha_i} c_{iv}^*, T_F^{1-\alpha_i} c_{iv}\right\}, \text{ else } m_{iv} = 0. \tag{15b}$$

$$z_{is} > 0 \text{ if } \mu_i = T_F c_{is} = \min\left\{T_C T_F c_{is}^*, T_F c_{is}, T_C \left(T_F\right)^{1-\alpha_i} c_{iv}^*, T_F^{1-\alpha_i} c_{iv}\right\}, \text{ else } z_{is} = 0. \tag{15c}$$

$$m_{is} > 0 \text{ if } \mu_i = T_C T_F c_{is}^* = \min\left\{T_C T_F c_{is}^*, T_F c_{is}, T_C \left(T_F\right)^{1-\alpha_i} c_{iv}^*, T_F^{1-\alpha_i} c_{iv}\right\}, \text{ else } m_{is} = 0, \tag{15d}$$

These conditions suggest that the optimal mode of sourcing a component i gives the minimal unit-cost of the component:

$$\mu_i = \min\left\{T_C T_F c_{is}^*, T_F c_{is}, T_C \left(T_F\right)^{1-\alpha_i} c_{iv}^*, T_F^{1-\alpha_i} c_{iv}\right\}, \tag{16}$$

where $c_{is}^* \equiv \left(r^*\right)^{\alpha_i} \left(w^*\right)^{1-\alpha_i}$, $c_{is} \equiv r^{\alpha_i} w^{1-\alpha_i}$, $c_{iv}^* \equiv \left(\lambda^*\right)^{\alpha_i} \left(w^*\right)^{1-\alpha_i}$, $c_{iv} \equiv \lambda^{\alpha_i} w^{1-\alpha_i}$ are, respectively, unit production costs of component i sourced from an outside firm in the South, from an outside firm in the North, from its own firm in the South, and its own firm in the North.

These Kuhn-Tucker conditions give the critical values of headquarter capital. The MNC would not source any component inside if the shadow value of its capital is higher than the 'adjusted' cost of external capital. Conditions (15a) and (15c) imply that the firm will source a component i inside (z_{iv} >0) if $\lambda \leq T_F r$. Conditions (15b) and (15d) imply that the firm will intra-firm import the component (m_{iv} >0) if $\lambda^* \leq T_F r^*$.

These equations will form the basis for analyzing the effects of trade liberalization on the firm's decisions on outsourcing and offshoring of components and output.

Results

We begin the analysis by determining the equilibrium outsourcing and offshoring of the firm in autarky, and then compare this to the equilibrium outcome when we allow trade in components and, then, in output at intermediate levels of trade costs. Finally, we conduct comparative static analysis to investigate implications of the model on the impacts of lowering trade costs on the firm boundary, intra-firm trade and international trade.

a) Specialization Pattern in the Closed Economy

In autarky, high trade barriers do not allow importing components or outputs (i.e. $T, T_C \rightarrow \infty$). Thus, the firm produces output just for domestic consumption, i.e. condition (13a) is applicable:[12]

$$C_d = Q, \qquad M = 0. \qquad (17)$$

The input sourcing choices of the firm in autarky are domestic outsourcing and domestic production, i.e. the relevant input sourcing conditions are (15a) and (15c). The firm would

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[12] We only consider the MNC's optimization in the North subsidiary here, because similar arguments apply to the South.

not produce any component unless $\lambda \le T_F r$ in the initial equilibrium. The firm can increases its profits by producing more components inside the firm up until the shadow cost of headquarter capital rises to $\lambda = T_F r$. In other words, the firm has an incentive to produce a component only if headquarter capital is cheaper than external capital (adjusted by a transaction cost). Hence, as long as the firm has incentives to produce a component, the marginal profit is higher for producing a relatively capital intensive component. In addition, the assumption that the firm faces higher transaction costs in producing components with higher external factor intensities means that the firm has a preference towards producing the more capital-intensive components. The firm can move progressively towards the optimal point using factor content-based ordering, moving from more capital-intensive components to less capital-intensive components until it reaches the equilibrium $\lambda = T_F r$ at the marginal component of the autarky equilibrium is denoted by $i = \alpha_A$.[13]

The input sufficiency condition (7a) and the optimal output condition (17) give:

$$i \in (\alpha_A, 1): \quad z_{iv} = T_F^{1-\alpha_i}(a_z Q) \qquad (\, z_{is} = 0 \,,\ m_{iv} = 0 \ \text{and}\ m_{is} = 0\,). \qquad (18a)$$

$$i \in (0, \alpha_A): \quad z_{is} = T_F^{1-\alpha_i}(a_z Q), \qquad (\, z_{iv} = 0 \,,\ m_{iv} = 0 \ \text{and}\ m_{is} = 0\,). \qquad (18b)$$

The optimal output in autarky is derived using (12), (14), (16), (17) and (18a and b):

$$Q = \frac{1}{2B}\left(A - T_F ra - a_z \int_{i=0}^{1} T_F w^{1-\alpha_i}(r)^{\alpha_i}\, di \right). \qquad (19)$$

Substituting $\lambda = T_F r$, $C_d = Q$, $z_{iv} = T_F^{1-\alpha_i}(a_z Q)$ and $m_{iv} = 0$ in the full employment condition of headquarter capital (8a) gives the equilibrium condition that determines the marginal component $i = \alpha_A$:

$$a(Q) + \int_{i=\alpha_A}^{1} \alpha_i \left(\frac{w}{r}\right)^{1-\alpha_i}(a_z Q)\, di = \overline{H} \qquad (20)$$

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[13] In principle, when there are an infinite variety of different components, multiple equilibria may exist because the firm may be able to choose more than one combination of quantities and varieties for internal production such that the $\lambda = T_F r$ condition is satisfied. But when the number of components is finite, as is the real world case, the optimal condition will be satisfied in general as an inequality, and the equilibrium will be, in general, unique. (With finite components, the equilibrium shadow cost in general will be infinitesimally below $T_F r$.) One might also imagine that a plausible rule of thumb for the firm's managers would be to keep the most capital-intensive activities inside the firm.

b) Specialization Patterns in Trading Equilibrium

Reducing trade costs from autarky to an intermediate level can lead to international trade of components and output. We begin the analysis by the firm equilibrium when allowing trade in components, and, then allowing both trade in components and output.

b.1) Intermediate Trade Costs in Components, High Trade Costs in Output

When trade in components is possible, offshore sourcing may be optimal. Component sharing between the two countries means some components are cheaper to source from the North, while other are cheaper to source from the South, and there is the marginal component where the costs are indifferent. The marginal component is denoted by $i = \alpha_2$,

$$T_C T_F \left(w^* \right)^{1-\alpha_2} \left(r^* \right)^{\alpha_2} = T_F w^{1-\alpha_2} \left(r \right)^{\alpha_2}$$

Then, $\qquad \alpha_2 = \dfrac{\ln \dfrac{T_F}{T_{FC}} + \ln \dfrac{w}{w^*}}{\ln \dfrac{r^*}{r} + \ln \dfrac{w}{w^*}}$, where $\dfrac{T_F}{T_{FC}} \equiv \dfrac{\left(1 + t_F\right)}{\left(1 + t_F\right)\left(1 + t_C\right)}$ $\qquad$ (21). [14]

In the South, the marginal component $i = \alpha_2^*$ is given by: $T_F \left(w^* \right)^{1-\alpha_2^*} \left(r^* \right)^{\alpha_2^*} = T_C T_F w^{1-\alpha_2^*} r^{\alpha_2^*}$.

$$\alpha_2^* = \dfrac{\ln \dfrac{T_{FC}}{T_F} + \ln \dfrac{w}{w^*}}{\ln \dfrac{r^*}{r} + \ln \dfrac{w}{w^*}}, \quad \text{where } \dfrac{T_{FC}}{T_F} \equiv \dfrac{\left(1 + t_F\right)\left(1 + t_C\right)}{\left(1 + t_F\right)} \qquad (22).\ [15]$$

Component sharing means $\alpha_2, \alpha_2^* \in (0,1)$. This require that Factor-price differences are sufficiently large. As a result of $\dfrac{r^* / w^*}{r / w} > 1$, outsourcing from the North is relatively cheaper than outsourcing from the South for the components that are more capital-intensive than the marginal components.
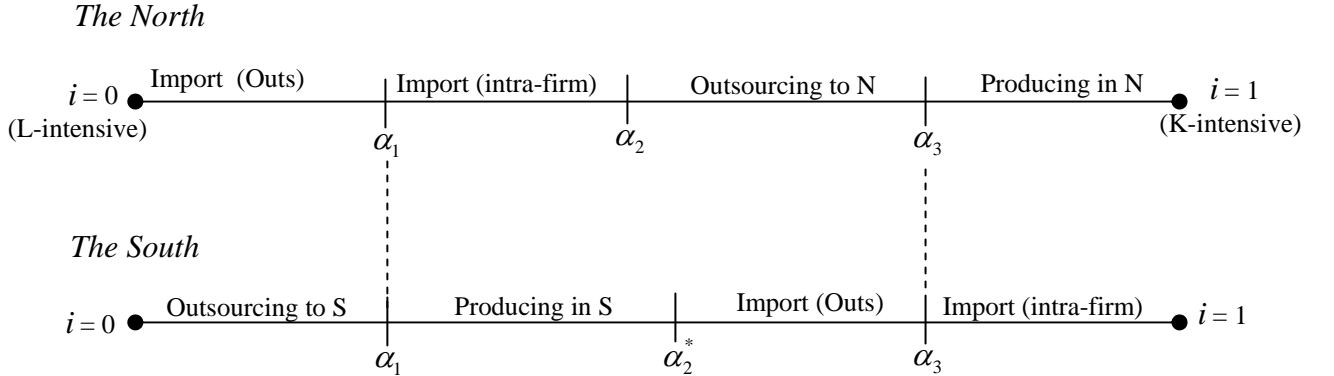
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[14] A necessary condition for $\alpha_2 \in (0,1)$ is: $\dfrac{w}{w^*} > \dfrac{T_{FC}}{T_F}$ (where $\dfrac{T_{FC}}{T_F} \equiv \dfrac{T_C T_F}{T_F} > 1$).

[15] A necessary condition for $\alpha_2' \in (0,1)$ is $\dfrac{r^*}{r} > \dfrac{T_{FC}}{T_F}$.

In-house component sharing between the two countries follows the similar pattern. The MNC produces some components in the North when $\lambda \le T_F r$, while it produces some components in the South when $\lambda^* \le T_F r^*$. The factor-prices differences suggest that in-house sourcing in the North would be more capital-intensive components than intra-firm sourcing from the South. Meanwhile, $\lambda \le T_F r$ suggests that in-house production of the North (z_{iv}) is more capital-intensive than domestic outsourcing (z_{is}), while $\lambda^* \le T_F r^*$ suggests that the intra-firm imports from the South (m_{iv}) are more capital-intensive than the imports from outside suppliers (m_{is}).

Therefore, if it is profitable for the MNC to produce some components in the North and South subsidiaries, and buy some components from suppliers in the North and South countries, then the most capital-intensive range of components are sourced inside the firm in the North, followed by outsourcing in the North, in-house production in the South, and finally, outsourcing in the South (Figure 1).

Figure (1) Patterns of Component Sourcing : Input Trading Equilibrium

The North

$i=0$	Import (Outs)	Import (intra-firm)	Outsourcing to N	Producing in N	$i=1$
(L-intensive)		α_1	α_2	α_3	(K-intensive)

The South

$i=0$	Outsourcing to S	Producing in S	Import (Outs)	Import (intra-firm)	$i=1$
		α_1	α_2^*	α_3	

The marginal component $i = \alpha_3$ is determined by the full employment condition (8a):

$$a(Q) + \int_{\alpha_3}^{1} \alpha_i \left(\frac{w}{\lambda} \right)^{1-\alpha_i} \left(z_{iv} + m_{iv}^* \right) di = \overline{H}, \qquad (23)$$

where $\lambda = T_F r$, $z_{iv} = T_F^{1-\alpha_i} \left(a_z Q \right)$, $m_{iv}^* = T_C T_F^{1-\alpha_i} \left(a_z Q^* \right)$.

Similarly, the marginal component $i = \alpha_1$ is determined by:

$$a(Q^*) + \int_{\alpha_1}^{\alpha_2} \alpha_i \left(\frac{w}{\lambda^*} \right)^{1-\alpha_i} \left(m_{iv} \right) di + \int_{\alpha_1}^{\alpha_2^*} \alpha_i \left(\frac{w}{\lambda^*} \right)^{1-\alpha_i} \left(z_{iv}^* \right) di = \overline{H}. \qquad (24)$$

The optimal output is given by:

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$$Q = C_d = \frac{1}{2B}\left(A - T_F ra - a_z \left(T_C T_F \int\limits_{i=0}^{\alpha_2} \left(w^*\right)^{1-\alpha_i} \left(r^*\right)^{\alpha_i} di + T_F \int\limits_{i=\alpha_2}^{1} w^{1-\alpha_i} \left(r\right)^{\alpha_i} di \right)\right). \qquad (25)$$

Note that offshore sourcing reduces marginal cost of output production from the marginal cost in autarky. Therefore, the firm produces more output in this trading equilibrium than in autarky.

b.2) Intermediate Trade Costs in Components and Output

Reducing output tariffs allow the MNC to export output from the country that has cost advantage. c_q and c_q^* denotes the unit-costs of output produced in the North and South, respectively:

$$c_q = (\lambda a + a_z \int\limits_{i=0}^{1} \mu_i di), \text{ where } a_z \int\limits_{i=0}^{1} \mu_i di = a_z T_F \left(T_C \int\limits_{i=0}^{\alpha_2} \left(w^*\right)^{1-\alpha_i} \left(r^*\right)^{\alpha_i} di + \int\limits_{i=\alpha_2}^{1} w^{1-\alpha_i} r^{\alpha_i} di \right). \qquad (26)$$

$$c_q^* = (\lambda^* a + a_z \int\limits_{i=0}^{1} \mu_i^* di), \text{ where } a_z \int\limits_{i=0}^{1} \mu_i^* di = a_z T_F \left(\int\limits_{i=0}^{\alpha_2^*} \left(w^*\right)^{1-\alpha_i} \left(r^*\right)^{\alpha_i} di + T_C \int\limits_{i=\alpha_2^*}^{1} w^{1-\alpha_i} r^{\alpha_i} di \right). \qquad (27)$$

At $\lambda = rT_F$ and $\lambda^* = r^* T_F$, $c_q < T\left(c_q^*\right)$. The equilibrium condition (13a) suggests $M = 0$. Hence, The MNC will not import output from the South to the North. In other word, the MNC will not export output from the South to the North. In contrast, the MNC may export output from the North to South if conditions (13b or 13c) is satisfied, i.e. $M^* > 0$ if $T(c_q) \leq c_q^*$. In other words, the necessary condition for the existence of a North output export is:

$$M^* > 0 \text{ if } \lambda \leq \frac{\lambda^*}{T} + \frac{a_z}{a}\left(\frac{1}{T}\int\limits_{i=0}^{1} \mu_i^* di - \int\limits_{i=0}^{1} \mu_i di \right) \qquad (28)$$

The firm does not export components from the South suggests that the firm produce output and components there. Thus, $\lambda^* = r^* T_F$, and

$$M^* > 0 \text{ if } \lambda \leq \frac{r^* T_F}{T} + \frac{a_z}{a}\left(\frac{1}{T}\int\limits_{i=0}^{1} \mu_i^* di - \int\limits_{i=0}^{1} \mu_i di \right). \qquad (29)$$

Note that the likelihood of international trade in output decreases with an output tariff, while increases with capital-cost differences. $\lambda = rT_F$ in the initial equilibrium. Hence, the

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MNC would export output from the North if an output tariff is sufficiently low relative to the differences in capital costs.

Assume that outputs are produced in both countries, condition (29) is binding at strict equality, and λ is determined by:

$$(\lambda a + a_z \int_{i=0}^{1} \mu_i di) = \frac{1}{T}(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di) < T(\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di) \text{, where } \lambda^* = r^* T_F \qquad (30)$$

These imply that $Q = C_d + M^*$, $Q^* = C_d^*$.

Output export increases the shadow cost of headquarter capital (λ) of the export producer from the initial equilibrium level ($\lambda > r T_F$). In other word, output export increases demands for headquarter capital, and the MNC has to outsource components that were produced inside the firm in the North to other firms in that country (Figure 2).

Figure (2) Patterns of Component Sourcing Options:

Output and Input Trading Equilibrium

The North

The South
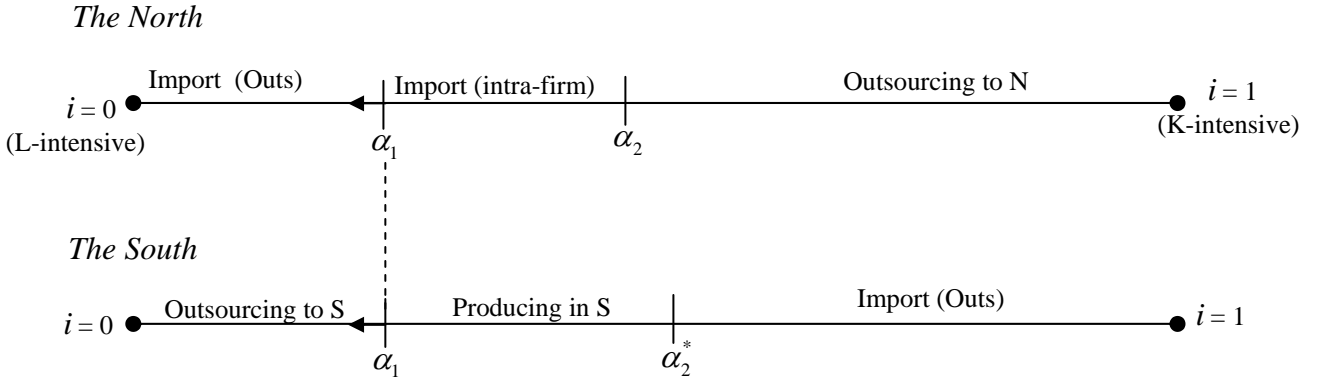
Output production in the North increases from the initial equilibrium, and it is given by equation (8a) and $z_{iv} + m_{iv}^* = 0$:

$$Q = C_d + M^* = \frac{\overline{H}}{a}. \qquad (31)$$

Marginal revenue equals marginal cost of output determine the optimal output for domestic (North) market:

$$C_d = \frac{1}{2B}\left(A - (\lambda a + a_z \int_{i=0}^{1} \mu_i di)\right) \qquad (32)$$

The output export is the excess output of the North: $M^* = \frac{\overline{H}}{a} - C_d$.

Using (30), (31) and (32):

$$M^* = \frac{\overline{H}}{a} - \frac{1}{2B}\left(A - \frac{1}{T}(\lambda a + a_z \int_{i=0}^{1} \mu_i \, di) \right), \qquad (33)$$

In contrast, output production in the South decreases from the previous equilibrium by the amount of output import:

$$Q^* = C_d^* = \frac{1}{2B^*}\left(A^* - (\lambda^* a + a_z \int_{i=0}^{1} \mu_i^* di) \right) - \frac{M^*}{T}. \qquad (34)$$

Substituting Q and Q^* from equations (31) and (34) in the full employment of headquarter capital in the South (equation 24) decreases α_1 index from the previous equilibrium level (Figure 2). Output reduction in the South releases some of the headquarter capital. Therefore, the MNC uses the released capital to produce more components in the South and reduces outsourcing.

Comparative Static Analysis

In this section, we draw implications of the model on the impacts of trade liberalization on the firm boundary, intra-firm trade and international trade. To show the different impacts between trade liberalization in components and in final goods, we assume that the North and South progressively liberalize their trade, starting with autarky to free trade in components and, then, free trade in output.

We conduct comparative static analysis based on the assumption that factor-price differences create trade incentives at an intermediate level of trade costs. However, the two countries are similar in other parameter values, including demand conditions, transaction and trade costs, and headquarter capital endowments. This also implies that tariff reductions are common between the two countries.

The results of tariff reductions on the MNC's production and outsourcing patterns in the North and South are graphed in Figure (3) and (4), respectively.[16] The left part of each figure shows the allocation of headquarter capital between output production for domestic

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[16] The parameter values in the simulation, unless otherwise specified are as follows: $A = A^* = 200$, $B = B^* = 1.5$, $H = \overline{H}^* = 100$, $T_F = 1.1$, $a = 1$, $a_z = 1$, $w^* = 1$, $r^* = 10$, $w = 2$, $r = 5$.

market, for export, and component productions. The right parts illustrate the firm boundaries along the extensive margin of components. We compare the changes the firm's resource allocation and boundaries from autarky to free trade.

The three parts along a vertical axis show the impacts of progressive trade liberalization, starting with autarky at the upper part, trade liberalization in components at the middle part and, then, trade liberalization in output at the lower part. In autarky. the MNC sources all components domestically: Relatively capital-intensive components are source inside the firm, while relatively labour-intensive are outsourcing. This continues to be the case up until component tariffs are higher than 100 per cent ($T_C > 2$). Meanwhile, the firm produces output for domestic market, not for export, if output tariffs are greater than 68 per cent, ($T > 1.68$).

Figure (3) Production and Outsourcing Patterns in the North
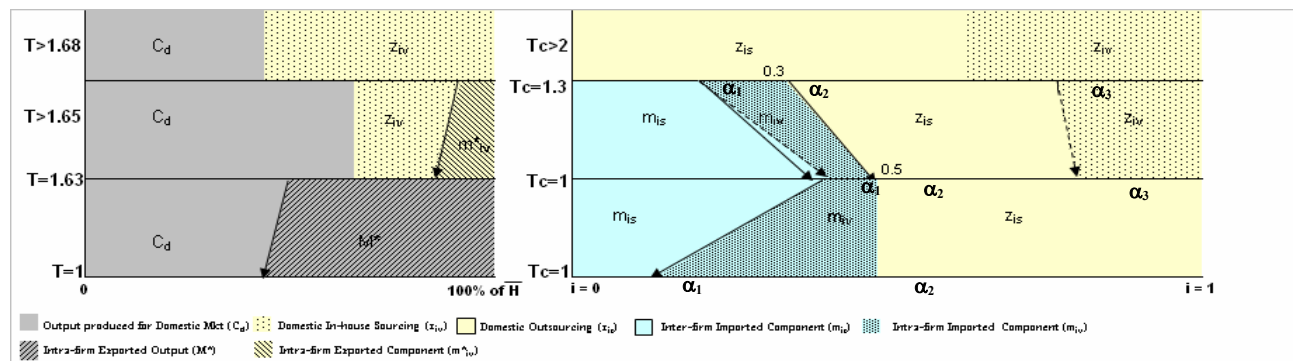
Figure (4) Production and Outsourcing Patterns in the South
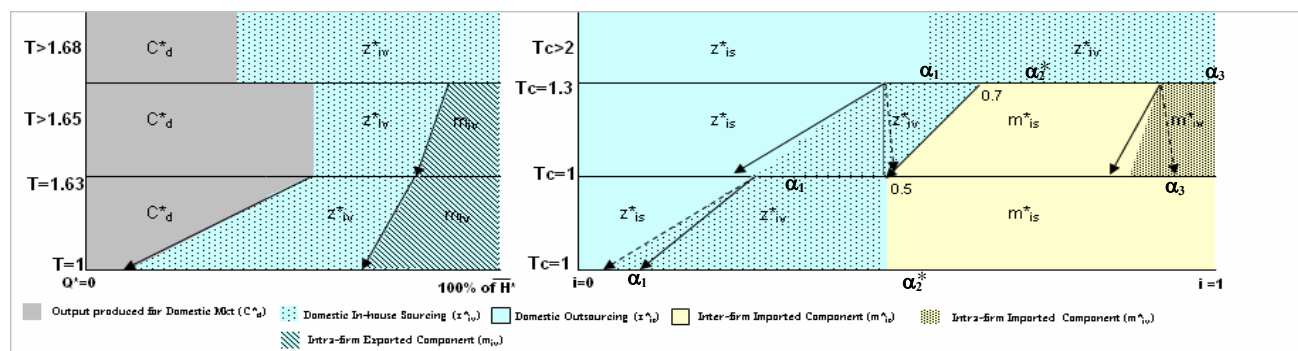
As trade costs continue to fall, there are incentives to offshore sourcing. The interested range of parameter values is that allow component sharing between countries and firms. The MNC produces different components in each country and trades these components intra-firm. The firm also outsources components from both domestic and foreign suppliers. Therefore, the firm boundaries are determined by equations (21, 22, 23, and 24).

As input tariffs fall from 30 to 0 per cent, an output tariff of greater than 65 per cent prohibits trade in the final good. A reduction of input tariff has direct and indirect impacts on the firm boundaries. The direct impacts are on component production ($\frac{\partial \alpha_1}{\partial t_C}$, $\frac{\partial \alpha_2}{\partial t_C}$ and $\frac{\partial \alpha_3}{\partial t_C}$), while the indirect impacts are the second-round effects of tariff impacts on output ($\frac{\partial \alpha_1}{\partial Q}\frac{\partial Q}{\partial t_c}$, $\frac{\partial \alpha_1}{\partial Q^*}\frac{\partial Q^*}{\partial t_c}$, $\frac{\partial \alpha_3}{\partial Q}\frac{\partial Q}{\partial t_c}$ and $\frac{\partial \alpha_3}{\partial Q^*}\frac{\partial Q^*}{\partial t_c}$). We illustrate direct and indirect effects by line and dash arrows, respectively. Then, the net effect is the total of those two effects.

The direct impacts of tariff reductions are ambiguous. A North tariff reduction may decreases the range of in-house sourcing components (Figure 3), while a South tariff reduction may expand the firm boundary along the extensive margin (Figure 4). A falling North tariffs encourage the firm to import more components from the South to the North, i.e. the marginal component of intra-firm imports (α_2) tends to shift toward a relatively more capital-intensive component. Therefore, the demand fore headquarter capital increases, and this forces the firm to increase outsourcing (shifting α_1 rightward). Note that outsourcing increases by more than intra-firm sourcing in order to achieve the required higher capital intensity of intra-firm import ($\Delta\alpha_1 > \Delta\alpha_2$). In contrast, a South tariff reduction encourage the MNC to import more components from the North to the South, i.e. the marginal component of intra-firm imports (α_2^*) tends to shift toward a relatively more labour-intensive component. Thus, some headquarter capital is released. Ignoring indirect effects, the firm uses the released capital to produce more components in the South.

For the indirect impacts, a tariff reduction in any country may decrease the range of in-house sourcing along the extensive margin in order to trade off for the increasing volume of output. However, the indirect tariff effect is positive and decreasing in Q and Q^*. Thus, the effects tend to be small in magnitude if the production volume is relatively large.

In principle, the tariff effect is ambiguous. The net effect of liberalization of trade in components depends on factors such as relative market sizes in the two countries and how responsive final good demands are to tariff changes. If there is a tariff reduction, it is likely

that an MNC may expand its firm boundary if its South market is large, or the demands for final good in the South are highly elastic. In contrast, if the North is a large market or highly elastic demand, the effect of the North tariff reduction might dominate.

However, if we observe particular trends in component trade following input-trade liberalisation, we can draw some conclusions about what may be happening to the nature of in-house component production within the MNC subsidiaries. For example, if we observe that higher imports by the North may indicate shrinking of the firm boundary, while higher imports by the South may suggest that the firm boundary is expanding.

We now turn to the effects of output liberalization. Given that component trade is freed, trade in output begins as an output tariff falls to 63 per cent. The MNC produces output in the North and components in the South, and then intra-firm export them to each other country. The firm still produces output in the South given that the stock of headquarter capital in the North is relatively small compared to the jointed output market. As an output tariff falls from 65 to 0 per cent, output export expands and so does the range of in-house sourcing. Hence, liberalization of trade in output tends to enhance international production network and expand in-house sourcing along the extensive margin.

III Empirical Investigation

We have been fortunate in being able to access a unique data set on component imports by Toyota subsidiaries in ASEAN countries; this data set includes both their imports from Toyota Thailand, and also from outside (non-Toyota) suppliers in Thailand. The period covered by the data set - 1999 to 2003 – was one during which substantial changes took place in the trade barriers affecting car component trade within ASEAN. Under the AICO program, significant progress was made on intra-regional trade liberalization in car components, but not on trade in finished cars. Thus, the model implications on trade liberalization in components from the previous section may be applicable to the AICO trade liberalization of auto components in ASEAN.

In the circumstances, we have attempted to exploit the data set as much as possible by specifying an empirically implementable econometric model that is informed by the key insights of the theoretical model. The empirical model presented below should not be

interpreted as derived strictly from the theoretical model, because even this unique and quite rich data set does not permit us to test our model directly. Nevertheless, we would argue that it is based on conceptualizations about relationships that are empirically plausible and consistent with the core features of the theoretical model.

We use the data set to investigate the following issues. First, we investigate the factors that influence which components will be imported from Toyota's affiliates, and which ones will be imported from outside firms. We assume that components with high value or high engineering complexity can be rated as capital-intensive components. In the context of our model, such components are taken to be intensive in their use of headquarter capital. Under this interpretation, the theoretical model in chapter 3 would suggest that intra-firm imports from Toyota Thailand by Toyota subsidiaries in other ASEAN-4 countries (i.e. intra-firm imports) would tend to be of higher value or higher engineering complexity than components imported from unaffiliated firms (i.e. outsourced) in Thailand.

Second, we investigate the relationship between intra-firm sourcing of components and their link to various car models. We conceptualize that transaction costs are positively correlated with the 'quality factor', because components used in the higher quality car models would tend to be of higher quality requiring a higher level of quality control, monitoring, and so on.[17] Therefore, we assume that transactions costs incurred for components to be used in higher quality cars will tend to be higher. In this case, the theoretical model would suggest that components used in higher quality cars are more likely to be sourced within the firm.

Third, we investigate how trade liberalization affects the Toyota ASEAN subsidiaries' decisions to choose between sourcing components from Toyota Thailand and sourcing from non-Toyota suppliers in Thailand. To the extent that Thailand can be considered a 'North' country with respect to other ASEAN countries, the model prediction would be that intra-firm sourcing from Thailand by Toyota's ASEAN subsidiaries is likely to expand.[18] [19]

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[17] Williamson (1985) and Dyer (1997) consider quality controls as a firm activity that gives rise to transaction costs.

[18] We observe rapidly increases of component imports by Toyota ASEAN from Thailand.

[19] Thailand and Malaysia are higher wage countries relative to Indonesia and the Philippines. Because some imports are from subsidiaries in Malaysia, the actual trade pattern may not strictly conform to the implication drawn here.

We track Toyota's applications for AICO arrangements submitted to Thailand's Ministry of Industry. The applications show the planned component imports of Toyota subsidiaries in Malaysia, Indonesia, and the Philippines from Toyota Thailand and also from outside suppliers in Thailand.[20] The component trade requires approval from the government of trading partner countries in order to get AICO tariff preferences. The AICO applications cover 900 types of components used in three different models of Toyota passenger cars. These components are produced in Thailand by 97 component suppliers; which some of these are Toyota affiliates and some are not. The components are imported by Toyota subsidiaries in Malaysia, Indonesia, and the Philippines as intermediate inputs.[21]

These component imports of Toyota's subsidiaries provide 1,923 observations in the data set. Each observation is a component specified by the component's sourcing mode. There are three component's sourcing modes, which differ by the degree of sourcing inside the firm: First, components produced by Toyota's affiliates are defined as 'vertically integrated' components. Second, components produced by the affiliates of Toyota's keiretsu suppliers are defined as 'semi-integrated' or, in other words, 'keiretsu outsourced'. Finally, components produced by independent suppliers are defined as 'independent outsourced'. We rate these component sourcing forms according to the degree of vertical integration. Specifically, we assign a highest score (2) to sourcing from Toyota's affiliates, while we assign a lowest score (0) to independent outsourcing.

We investigate what are factors explain these component sourcing decisions of Toyota. The choice of organizational form is our dependent variable. The underlying specification is

$$y_i = \delta_i + \mathbf{x}_i \boldsymbol{\beta} + \varepsilon_i,$$

where y_i is the rating of vertical integration in a component i as specified above, $\mathbf{x}_i$ is a vector of sourcing determinants, δ_i is a parameter, and ε_i is a normally distributed error term. We estimate the probability of the organizational choice by ordered PROBIT such that $\Pr(y_i = v | \mathbf{x}_i)$, where $v(\text{outsourcing}) = 0$, $v(\text{keiretsu}) = 1$, and $v(\text{integration}) = 2$.

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[20] Our data opportunity has been created due to the strict administrative procedures of the AICO program. Each product traded under the AICO program has to be approved by the governments of the exporting and importing countries. AICO tariff preferences are exclusive and applicable only to approved products with approved product uses, approved traded volume, approved participating companies, and approved trade destination. A final-good producer that would like to participate in the AICO program has to apply by submitting required information about traded products to the governments of participating countries.
[21] There was no trade in the final outputs during the data period.

Therefore, the positive coefficients of the explanatory variables will imply the increased likelihood of sourcing inside the firm. In other words, it implies the decreased probability of outsourcing. $\mathbf{x}_i$ includes key component characteristics, such as component's producer price, tariff preferences, index of car model which the component will be used. These variables are also observed from the AICO data set. In addition, we add other independent variables, including engineering complexity rating and Thailand's 'local content requirement (LCR)' point, to the data set. We now turn to discuss the explanatory variables in more details.

Index of Car Models

The index of car models represents a range in quality of final products. Components in the data set are the auto-parts for the three ranges of Toyota sedans assembled in Southeast Asian countries: the Camry (high-range), the Corolla (mid-range), and the Soluna-Vios (low-range). Camry is produced for relatively upper market, Soluna-Vios is for relatively lower market, and Corolla lies in between. The market price of a Camry is the highest (approximately US$30,000-35,000 in the Thai market), Soluna-Vios is the lowest priced model (about US$12,000-15,000) and Corolla price lies in between the others (about US$20,000-22,000). Hence, a discrete numerical value from zero to two is assigned to these car models, such that the highest value of the index represent components of the high-range model while the lowest value represents components of the low-range model.

Component Price

Toyota reports producer prices of components in US dollar terms. Therefore, the same price is applied to a specific component of a specific car model regardless of export destinations. We did not adjust for inflation. We felt that there was no reasonably practical procedure that could be adopted to properly adjust all the relevant prices during this period when the ASEAN-4 countries floated their currencies and there were huge differences of inflation rates across countries.

Engineering Complexity Rating (ECR)

Data on engineering complexity rating (ECR) are obtained from Head et al. (2004). We classify components into groups by end-use functions according to the classification of Thailand's Ministry of Industry. We then code the ECR index from Head et al. (2004) to

matching component groups in order to represent the group-specific technical characteristics of components. The rating ranges from 1 to 10 according to the engineering complexities rated from low to high.[22] However, there are limited matching data, and thus only some groups of components can be coded with the ECR.

Tariff Barriers

The AICO program offers exemption from the MFN tariff to intra-ASEAN trade of approved products. Thus, AICO tariff reductions on specific components are equal to the prevailing MFN tariffs. MFN tariffs on car components from ASEAN countries are discrete from 0-30 per cent.

Local Content Requirement (LCR) points

LCR points are another indicator of substantial changes that took place during 1999-2003 in the trade barriers affecting the car component trade of Thailand and other ASEAN-4 countries, which all had quite similar LCR policy barriers.[23] Car producers would get LCR points from components sourced domestically and were obliged to meet the minimum requirement for accumulated LCR points. We conceptualize that LCR points are positively related to component trade barriers, because a car producer would have a higher incentive to domestically source components in a group with a relatively high LCR point. Components imported under the AICO program would receive Local Content accreditation and other incentives given to locally-produced components by the importing countries' governments.[24] Therefore, we use LCR points as an alternative measure of tariff

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[22] Head et al. (2004) apply the information provided in Monterverde and Teece (1982) to obtain the ECR rating. They use the ECR as an indirect measurement of the technical specificity of products in order to find support for the TCE approach.

[23] Under the Local Content Requirement (LCR) program, each component group classified by end-uses was rated by the Thai government according to, in principle, the extent of its input into a car's value and, in practice, the government's priority in promoting domestic production of targeted industries (from interviews with the Office of Industrial Economics, Thailand's Ministry of Industry). In principle, the LCR points were supposed to reflect their cost shares of components in a car's value. However, we find that LCR points are more correlated with engineering characteristics than component costs. The correlation between engineering complexity rating and LCR points is 79 per cent, while the correlation between component price and LCR points is minus 4 per cent. This likely means that the government gave relatively high LCR points to targeted auto parts regardless of their cost shares in a car's value, and the targeted auto-part industries tended to be relatively engineering-complex. For details about LCR, see e.g. Abdulsomand (2003), Bunjongcheep (1995), Wattnasiritham (2000) and Chanaratcharak (2004).

[24] The LCR policy is removed by 2003 as a part of ongoing trade liberalization.

preferences to measure trade liberalization in the car component trade of ASEAN countries.[25]

Some limitations of the data should be noted. First, the data set does not cover components sourced from non-ASEAN countries, mainly from Japan which accounts for 40-70 per cent of the auto-part imports of the ASEAN countries in 2003. Second, the data represent *planned* annual trade, not actual trade. The proposals are made at least a year in advance before approval is granted, and the actual trade started. Thus, there could be some variations between proposed and actual transactions. However, comparable data on actual AICO trade were not available to us. Third, the data are available for only four years, from 1999 to 2003. Since 2003 the AICO program has been integrated into AFTA, and thus there have been no comparable data since then. Despite these limitations, the AICO data is a rich source of information that provides a valuable opportunity to investigate outsourcing at the firm level. Because supplier information is usually confidential, it is almost impossible to get such comprehensive data as that obtained from the AICO program.

Descriptive Statistics

Table (1) compares data characteristics across the organizational structures of component suppliers and with those of the overall data set. Independent outsourcing accounts for over a half of the observations. The three forms of input sourcing tend to differ by component prices. On average, in-house components are relatively high-value components compared to the other groups, while independent outsourcing components are relatively low-value, and keiretsu outsourcing lies in between. Mean comparison tests confirm that the price differences are statistically significant at the one per cent level.

Components with tariffs at 25-30 per cent dominate the data set. They account for 50.1, 49.1 and 63.1 per cent of components under independent outsourcing, keiretsu outsourcing and vertical integration, respectively. Components with tariffs at 10-15 per cent account for 38.5, 39.0 and 27.9 per cent of those sourcing forms, respectively.

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[25] Note that the data on tariff preferences are measured by the MFN tariffs of the importing countries (Malaysia, Indonesia, and the Philippines), while LCR points are the exporting country's data (Thailand).

Moreover, the tariff rates seem to be country specific. 97 per cent of components exported to the Philippines are waived from the Philippines' 10 per cent tariff, and 84 per cent of the exports to Malaysia are waived from Malaysia's 25-30 per cent tariffs. About 52 per cent of the Indonesian procurements are waived from the 15 per cent tariff, while the rest generally vary from 5, 10 and 25 per cent at the proportions of 17.5, 11 and 14 per cent of the observations.

Table (1) Descriptive Statistics, by Sourcing Options

	Vertical Integration (V)	Keiretsu Outsourcing (K)	Independent Outsourcing (S)	Whole Data set
# Obs	312	609	1,002	1,923
% Obs	16.2	31.7	52.1	100.0
Component Price(US$)				
: Average	13.8	7.7	3.7	6.6
: SD	21.5	10.6	8.1	12.6
: Min	1	1	1	1
: Max	136	89	136	136
Mean Diff. test : Differences	$P_v - P_k = 6.07^{/a}$		$P_k - P_s = 4.11^{/a}$	
: (SE)	(1.29)		(0.50)	
Price per centiles (US$) : 25th	1	2	1	1
: 50th	4	3	1	2
: 75th	13	10	3	6
: 95th	61	32	13	32
Sourcing Structures by Models (%) :				
Camry : 100	21.0	34.7	44.3	
Corolla : 100	14.3	29.2	56.5	
Vios : 100	16.5	34.6	48.9	
Sourcing structures by countries (%)				
Indonesia : 100	19.2	39.3	41.5	
Malaysia : 100	18.2	30.6	51.2	
Philippines : 100	10.8	30.7	58.5	
Tariff Structure (% Obs)				
MFN Tariff Rates (%): 0	1.3	4.3	1.7	2.4
5	7.4	3.9	2.8	3.9
7	0.0	1.0	0.1	0.4
10	18.6	27.8	33.0	29.0
15	9.3	11.2	5.5	7.9
20	0.3	2.8	6.8	4.5
25	41.3	24.3	31.9	31.0
30	21.8	24.8	18.2	20.9

Note: [a] Significance at less than 1% level.
Source: Compilation from AICO data.

Econometric Evidence

The main findings are presented in Table (2). The core variables are estimated in column (1). The results support key predictions of the theoretical model. The estimated coefficient of component price is statistically significant at less than the one per cent level, which means component value raises the probability of intra-firm imports. In addition, the quality

of final products and tariff preferences tend to increase the likelihood of intra-firm import. The estimated coefficients of car model and tariff preference are statistically significant at the five per cent level.

Table (2)   Outsourcing of Toyota:

Ordered Probit from the Thai Exported Parts of Camry, Corolla and Vios

	(1)	(2)	(3)	(4)	(5)	(6)
Model	0.103 /b	0.099 /b	0.111 /b	0.094 /b	0.090 /b	0.086 /b
	(0.042)	(0.042)	(0.044)	(0.040)	(0.040)	(0.041)
P_i	0.027 /a	0.027 /a	0.027/a	0.030 /a	0.030 /a	0.030 /a
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Tariff Pref.	0.707 /b	0.727 /b	0.708/b			
	(0.318)	(0.316)	(0.325)			
Point				3.174 /a	3.180 /a	3.886 /a
				(0.322)	(0.323)	(0.533)
Avg Point		0.158	0.072		0.160	0.252 /b
		(0.113)	(0.112)		(0.112)	(0.118)
ECR			0.086 /a			-0.043 /c
			(0.014)			(0.022)
cut1	0.460	0.482	0.965	0.636	0.654	0.464
	(0.092)	(0.092)	(0.117)	(0.061)	(0.062)	(0.106)
cut2	1.451	1.472	1.974	1.667	1.686	1.492
	(0.097)	(0.096)	(0.118)	(0.068)	(0.066)	(0.106)
Obs	1923	1923	1824	1923	1923	1824
Log Likelihood	-1836.6	-1836.6	-1735.8	-1790.2	-1789.3	-1713.2

Notes: The dependent variable is the ordinal index of vertical integration (V =0,1,2). The table reports ordered probit estimates with robust standard errors in parentheses.
　　　/a significant at 1%, /b significant at 5%, /c significant at 10% level.

Group characteristic variables are added to the specifications in columns (2) and (3). Column (2) introduces average LCR points.[26] Using average LCR points rather than absolute LCR points means the point variable is deflated by group size. The coefficient of average point is positive but not significant.[27] Column (3) is estimated from a sub-sample of data, including components in the groups rated by engineering complexity in Head et al. (2004). It suggests that groups of complex components tend to be more vertically integrated than groups of simple components at the one per cent significance level.

Columns (4) to (6) repeat estimations (1) to (3) but change the policy variable from tariff to local content points. Similar to the tariff, the LCR points show positive relationships with

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[26] Avg. LCR Point of group j = LCR Point of group j / # AICO parts in group j .

[27] However, we use the number of AICO parts in an individual component group to calculate the average points of each group, because there are auto parts sourced outside the AICO program.

the probability of intra-firm import. Components in the groups that received higher LCR points have a higher probability of being sourced within the firm boundary than components in the groups that had lower LCR points. The estimated coefficient of another group-specific engineering index, ECR, becomes less significant and average LCR points become moderately significant when introducing LCR points into the estimation as shown in column (6). This may be due to a high correlation between engineering characteristics and how the points are determined.

Table (3) presents the resulting marginal effects coefficient for the statistically significant variables specified in Table (1). The marginal effects reflect the change in the predicted probability of $v = 2$ (vertically integrated components) given a change in the variable. The probability changes are evaluated at the mean value of the independent variables (and at the mid-range model of the car-model variable). The marginal effect suggests that an increased tariff preference tends to increase the probability of intra-firm import. The quality level of car models increases the probability of intra-firm imported components. Increases in component value and the engineering complexity index give rise to the probability of intra-firm imports. However, no evidence of the ECR effect is found if the LCR points are used as the measure of policy.

Table (3) Marginal Effects for Vertical Integration ($v = 2$)

Variable	dy / dx			
	(1)	(2)	(3)	(4)
Model = 1	0.024 /b	0.021 /b	0.027 /b	0.022 /b
	(0.010)	(0.009)	(0.010)	(0.010)
Discrete Change:				
Model: $0 \rightarrow 1$	0.023	0.020	0.025	0.021
Model: $1 \rightarrow 2$	0.025	0.022	0.028	0.023
P_i = mean: 6.9	0.006 /a	0.007 /a	0.007 /a	0.007 /a
	(0.001)	(0001)	(0.001)	(0.001)
Tariff Pref.= mean: 19	0.00166 /b		0.00166 /b	
	(0.074)		(0.074)	
Point = mean: 1		0.0724 /a		0.0857 /a
		(0.074)		(0.130)
ECR = mean: 6.037			0.021 /a	-0.007
			(0.003)	(0.005)
$\Pr(v = 2 \mid x)$	0.152	0.145	0.155	0.152
#Obs	1923	1923	1824	1824

Notes: The dependent variable is the ordinal index of vertical integration (V=0,1,2). The table reports the marginal effect of vertical integration from ordered probit estimation with standard errors in parentheses.
         /a significant at 1%, /b significant at 5%, /c significant at 10% level.

Robustness Checks

Endogeneity may be a problem in the estimation of the effects of trade liberalization on the firm's component options. This might occur if tariff levels and LCR points are endogenous with respect to the carmaker's sourcing decisions. For example, Toyota might have lobbied for the high LCR points on components made inside the firm in response to the progressive local content requirement, or the firm might have lobbied the governments of hosting countries for high tariff protection on the firm's in-house components against imports from other firms. If these endogeneity problems exist, they could lead to inconsistent estimates of the impacts of trade liberalization on component choices.

We tested for the existence of endogeneity problems using the instrumental variable (IV) approach. We use average LCR points as an instrument of tariff preferences and LCR points. (Table 4). Average points satisfy the main requirements for using IV: It does not correlate with the error term of the baseline specification as shown in columns (2) and (3) of Table (1), and it correlates with tariff preferences and LCR points at the one per cent and 8 per cent level, respectively.

Table (4)

The First-stage OLS Regressions of Tariffs and LCR Points on Average Points

	Coefficient	$P > |t|$	R^2	Prob > F	Obs.
Dependent Variable: Tariff					
Avg. Point	-0.287 /a (0.010)	0.006	0.005	0.0065	1923
Dependent Variable: Point					
Avg. Point	-0.008 /c (0.005)	0.073	0.0005	0.073	1923

Notes: The table reports OLS estimates with robust standard errors in parentheses.
/a significant at 1%, /b significant at 5%, /c significant at 10% level.
Source: Compilation from AICO data.

The coefficients of the policy variables become negative and statistically insignificant when the IV approach is applied (Columns (2) and (5) of Table 5). These results suggest that endogeneity problem may be present. However, this may also be due to the quality of the instrument variable: average LCR points may not be a very good instrument variable, as the first-stage estimation shows that the R-square of the first-stage regressions of tariff and LCR points on the instrument variable is low.

However, some remarks should be noted about the tariff preference variable. First, the variations in tariff variables in the data set come from country differences in auto-part tariff levels, but tariff levels do not vary across products. For example, the Philippines' tariffs on most auto-parts in the data set are ten per cent, while Malaysian imports in the data set are largely subject to tariffs at 25-30 per cent. Second, if the endogeneity issue is the case, it likely means that the tariff level is intensified in order to protect in-house components of the firm in hosting countries against imports. Thus, tariff reduction would lead to an increase in the outsourcing of imports. If this was the case, we would see negative tariff coefficients in the original regressions. However, the original tariff coefficient does not show a negative sign.

Table (5) 2SLS Estimates of Instrument Variables

	(1)	(2) 2SLS	(4)	(5) 2SLS
Model	0.103 /b (0.042)	0.071 /c (0.040)	0.094 /b (0.040)	0.071 /c (0.040)
P_i	0.027 /a (0.004)	0.027 /a (0.004)	0.030 /a (0.004)	0.027 /a (0.001)
Tariff Pref.	0.707 /b (0.318)			
Tariff Pref. (IV)		-5.066 (0.199)		
Point			3.174 /a (0.322)	
Point (IV)				-17.258 (13.431)
cut1	0.460 (0.092)	-0.680 (0.764)	0.636 (0.061)	-1.419 (1.407)
cut2	1.451 (0.097)	3.08 (0.765)	1.667 (0.068)	-0.431 (1.406)
Obs	1923	1923	1923	1923
Log Likelihood	-1836.6	-1838.3	-1790.2	-1838.3

Notes: The dependent variable is the ordinal index of vertical integration (V =0,1,2). The table reports ordered probit estimates with robust standard errors in parentheses.

2SLS Estimation is performed by using average LCR points as an instrument of tariff preferences and LCR points.

/a significant at 1%, /b significant at 5%, /c significant at 10% level.

IV Conclusions

This paper offers insights as to why an MNC chooses to source particular types of components inside the firm boundary, while outsourcing other components to outside firms.

We develop a model of endogenous outsourcing decisions which in corporates key aspects of an MNC operating in a world of falling trade costs. The partial-equilibrium model allows for international intra-firm trade in components, outsourcing across country boundaries, as well as trade in output. Our approach provides a factor content-based ordering of the components sourced from the various options. The component sorting pattern within the production network is somewhat similar to complete specialization in the trade literature. That is, the factor intensity of component production determines intra-product specialization across countries. In addition, the intensity of the firm-specific asset determines the means of component sourcing in each country.

A general prediction is that internal sourcing within the firm in each country tends to be relatively more capital-intensive than outsourcing within the same country. Our model provides a factor intensity ordering of the components sourced from the various options. If the MNC sources components from both within and outside the firm, and in both countries, the most capital-intensive components of the range tend to be produced internally in the North, the intermediate capital-intensive components tend to be outsourced to the North suppliers, the intermediate labour-intensive components tend to be produced internally in the South, and the most labour-intensive components of the range will be outsourced to the South suppliers. In addition, if international trade in output takes place, the MNC will export output from the North, and, then, reduces its component production there. The firm may no longer produce a component in the North if the market sizes are large relative to the firm's capital endowment there.

In addition, the model enables us to analyze the effects of trade liberalization on the firm boundary, where international trade takes place in components and in final goods. Our comparative static analysis shows that the impact of component tariff reductions on the firm boundary is ambiguous. However, if we observe particular trends in component trade following a tariff reduction, they may enable us to draw some conclusions about what may be happening to in-house component production within the MNC. For example, trade liberalization which generally stimulates MNCs to offshore sourcing of relatively capital-intensive activities tends to increase the firm boundary along the extensive margin. In contrast, an output tariff reduction allows the North to export final good, while the South can expand in-house production.

We quantitatively explore some model implications using a previously unused data set on the component trade of Toyota in Southeast Asia. The empirical results are broadly consistent with the model implications. We find that components with high value or high engineering complexity are likely to be sourced within the firm boundary. Differences in the quality levels of final products tend to increase the likelihood of intra-firm sourcing. In addition, we find that the empirical evidence supports our model prediction concerning the effects of input-trade liberalization on the firm boundary. The estimation results show that trade liberalization in ASEAN stimulates component imports from Thailand (considered to be a relatively advanced automotive producer within the region) by Toyota subsidiaries in Indonesia, Malaysia and the Philippines, and increases the likelihood of intra-firm sourcing.

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