EMPIRICAL AND THEORETICAL STUDIES OF PRODUCT QUALITY AND MULTINATIONAL FIRMS IN INTERNATIONAL TRADE

by

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Empirical and Theoretical Studies of Product Quality and Multinational Firms in International Trade

Thesis directed by Professor Keith E. Maskus and Professor James R. Markusen

This thesis consists of three topics. Each of them is self-contained in one chapter and can be read independently. The empirical chapter on the contribution of product quality to China's export performance during 1991-2004 employs Dixit-Stiglitz "love of variety" formulation to calculate quality measure at 3-digit SITC level. The regression results suggest that doubled quality level of China's exports was associated with 4.6 percentage-point gain in destination export market share.

The following chapter of partial equilibrium analysis extends Markusen's single-firm plant location model to further allow separable intermediate production stage. This chapter attempts to reconcile the empirical findings of fewer occurrences of pure horizontal and vertical firm types with standard model of FDI location choice by exploring the role of intermediate plant-level scale economies and trade costs associated with intermediate products.

A computable general equilibrium analysis is employed in the last chapter to model the effects of knowledge spillover from FDI on factor price, production activity, trade, unit expenditure and real consumption. The simulation results suggest that FDI-importing country gains in welfare in both regime shift of investment liberalization and knowledge spillover, while FDI-exporting country loses.

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For Dingxiao Yuan

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CHAPTER 1

INTRODUCTION

Chapters following this introduction constitute empirical study of product quality in international trade, partial-equilibrium analysis of multinational firm's plant location choices and general-equilibrium analysis of knowledge spillover from foreign direct investment (FDI). Even though each topic is treated in a single chapter, chapter 2 and 4 share the same background story that product quality changes with knowledge spillover from FDI, and chapter 3 and 4 involve with multinational activities and trade.

The empirical study attempts to measure the contribution of product quality to China's export performance during 1991-2004 when China experienced steady increase in foreign direct investments. Quality measures for every 3-digit category China had an export flow to a specific country in a specific year. All coefficient estimates from Tobit regression are positive and statistically significant. The general result suggests that doubled quality level of China's exports was associated with 4.6 percentage-point gain in destination export market share. The regression by manufacturing sector reveals that the same percentage change in quality had larger effects on destination market share in labor-intensive sectors relative to capital-intensive sectors. The regression by income group suggests that the same percentage change in quality was associated with higher gain in market share of exports to low income group. The comparison with Brazil, India, Mexico and Thailand indicates that for the same percentage change in both quality and variety, China had the largest gain in destination market share. In addition, China excels in all manufacturing sectors on the effect of quality.

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The partial-equilibrium analysis in chapter 3 is an extension based on principal elements of Markusen's (2002) model. This extension gives firm more plant location choices by allowing separable intermediate production stage and serves as a theoretical supplement to standard model of pure horizontal and vertical FDI. Location options for the single firm headquartered in the home country are categorized into four types: full horizontal, national, full vertical and intermediate-vertical assembly horizontal. Experiments are conducted to show how changes in country and technology characteristics affect the firm's plant location choices.

The types other than the standard horizontal and vertical types are of special interests when it comes to intermediate scale economies, specialization, trade and investment policies. When intermediate scale economies become more important or trade costs on intermediates are lower, firm would be more willing to have single intermediate plant rather than to duplicate all plants in another country. Also, firm has more willingness to pay for an assembly plant when the savings from intermediates production is sufficiently large, leading to the dominance over pure vertical type of firm. The main implication of welfare analysis remains as in Markusen's study that a country's welfare will be lower if it has to pay higher costs for imports of intermediates and/or finished goods. Consumption of local production is preferred unless it is cheaper to import.

In chapter 4, the impact of knowledge spillover from FDI is modeled as consumer's perception to the quality change. A willingness-to-pay problem is formed and computable general-equilibrium (CGE) modeling is applied to provide quantitative analysis. The effects of investment liberalization and knowledge spillover on factor prices, welfare, trade, affiliate production and domestic production are examined based on three

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scenarios constructed. In this 2x2x2 model, the host country's welfare function is specified with a demand shifter in the value share to represent the degree of knowledge spillovers. When quality improves from knowledge spillover, this demand shifter shifts more demand away from high-quality towards low-quality goods. Besides, this change in consumer preference leads to higher utility level from composite manufacturing consumption. Zero-profit, market-clearance and income-balance conditions in the numeric general-equilibrium system are generated in a process closely followed Markusen's (2002) derivation and subscription, and coded in GAMS/MPSGE. Simulations are conducted with changes in parameters representing regime shift from non-liberalization to investment liberalization, and to the regime of knowledge spillover with different degrees.

Investment liberalization displaces part of the production in home country for exports with affiliate production of high-quality goods in the host country. The entering of multinational firms into the host country demands more skilled labor relative to unskilled labor. Therefore, investment liberalization pushes up the price of scarce factor and lowers the price of the abundant factor in both countries. Home country loses in welfare. This is because the fall in the price of skilled labor is sufficiently large to result in a lower factor income relative price index. The host country gains in welfare. This is because the rise in the price of skilled labor in host country is sufficiently large to end up with higher factor income relative to price index.

Knowledge spillover leads to less demand for high-quality goods in the host country; Firms making high-quality goods would be more willing to transport the high-quality goods rather than bear the fixed cost for affiliate production. This results in less

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affiliate production and fewer multinational firms in host country. More preference for low quality goods leads to higher demand and increased supply with more firms producing goods with lower markup and sold at lower prices. The marginal gain in welfare in home country results mostly from lower consumption of expensive X with rising real factor income. The FDI-importing country has substantial gain in welfare due to the increased consumption at lower prices with rising real factor income.

Edge-worth box examination shows that FDI-exporting country will have a gain in welfare only when it is large in size; otherwise incur lower domestic production of manufacturing goods along with welfare loss, higher price index and higher markup. FDI-importing country will have substantial gain in welfare along with higher production of domestic firms and lower price index. This study has policy implications on intellectual property rights protection in the sense that stringent IP protection results in low degree of knowledge spillover. This can help explain the observation of relative more multinational activities in countries with relatively strict IP protection and of relative more supply through imports in countries with weak protection.

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CHAPTER 2

QUALITY OF CHINA'S EXPORTS

2.1 INTRODUCTION

This paper is motivated by the rapid growth of China's trade flows since China's open-up policy in 1978, and the increasing speed of foreign direct investment (FDI) flowing into China for the last decade. As a labor abundant country, China has comparative advantage in labor-intensive manufacturing production which takes a large share of its exports. Along with the huge market size, cheap labor cost attracts a considerable amount of FDI into the country. These foreign direct investments not only bring in capital which improves the relative capital stock of China, but also come with technological spillover which helps increase the productivity of local firms. The latter issue on the link of FDI, spillover and productivity has been investigated by some empirical studies. Branstetter (2005) bases his work on firm level data and shows that FDI increases the flow of knowledge spillovers both from and to the investing Japanese firms in the United States. Keller and Yeaple (2002) find that FDI spillover has a stronger effect on productivity gains than does import-related spillover. It follows that, with more FDI flowing in, China's domestic firms are expected to experience an increase in productivity.

An increase in productivity can be translated in two dimensions. One is lower priced products due to more output from a given amount of input, and the other is better product quality as an outcome of interrelated factors (human factors, technological and managerial factors). Either the lower price or the better quality can make firms more

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competitive in the global market. Focusing on the second dimension of productivity gains, this paper attempts to derive a quality measurement of Chinese products which can be used in later investigation of the effect of quality upgrading on market share growth.

Even though technological spillover from FDI is regarded as public good which is free and available to all firms in the industry, only small portion of the firms can benefit. Usually those firms that are able to receive and absorb the most of FDI spillovers are competitive in the industry due to their high production efficiency and export capacity which bring them close in contact with the multinational firms. This makes those firms receiving the most of these positive spillovers capable of achieving the greatest improvement in their product quality which is embodied in what they sell domestically and export. The extent and impact of FDI spillovers on quality changes can, therefore, be direct to an examination in what those domestic recipients produce. Since detailed international trade data are more readily available and accessible than domestic sales data, the significance and magnitude of the quality improvement contribution are, thereby, investigated with data on China's exports to the rest of world.

As to the quality improvement of China's exports, several researchers approach this issue and identify that China exports growing number of high quality products. Rodrik (2006) explains that China could manage an export bundle that of a country with income-per-capita level three-time higher is due to the overall quality, but not the volume, of its exports. He bases his comparisons on an index of the "income level of a country's exports," as a measurement of the productivity level associated with a country's export basket. Schott (2006) employs Finger and Kreinin's (1979) export similarity index (ESI), and unit values to compare China with other exporter groups based on income level. His

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analysis is based on the 10-digit Harmonized System U.S. import data over 1972 – 2001. Results in his work show that China's export bundle increasingly overlaps with that from OECD country group even though endowment-based comparative advantage implies China's exports should more closely resemble that of income-level comparable countries than developed countries. He focuses comparison in manufacturing industries SITC 5 (Chemicals), SITC 7 (Machinery), SITC 6 (Manufactured Materials) and SITC 8 (Miscellaneous Manufacturing), from the most capital-intensive to the least.

As to the derivation of quality measurement, the standard approach in most empirical studies uses unit value as a proxy for quality, which is calculated as the ratio of the total value and the total volume of traded goods. This method is based on the expectation that higher quality goods sell at higher prices, and the quality measurement obtained can be interpreted as higher unit price representing higher quality. Brooks (2006) proposes a measure of relative quality calculated as the percentage difference between the unit value of exports for Columbia and the G7 countries. Hallak (2006) constructs a quality supply indicator at the sectoral level from export unit values.

Despite the aggregation bias and measurement errors inevitable with the use of available trade data, one concern with this method is that it only captures vertical quality differentiation by the equivalence of price variation and quality variation. This is recognized in Schott (2004) that unit value is positively related to vertical differentiation. However, other factors such as comparative advantage, currency misalignment and the horizontal differentiation implied by the differences in consumer preferences across different varieties also contributes to the price variation. Hallak and Schott (2005) argue that "consumer love of variety implies that countries producing a larger number of

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varieties in a product category export larger quantities and therefore exhibit higher trade surplus. Unless the number of horizontal varieties that countries export is accounted for, this increase in net trade will be interpreted, erroneously, as higher product quality." To allow for the price variation being explained by factors other than quality, Hallak and Schott (2005) develop a methodology to extract quality information from a decomposition of observed export prices into quality and quality-adjusted price components, and further relate sectoral net trade to the value of the pure prices (quality-adjusted components) and trade costs. Thus consumer's valuation of country products can be examined which is not possible with the unit value method.

This paper differs in quality measurement of goods in trade from previous empirical works by deriving quality measures based on a Dixit-Stiglitz "love-of-variety" framework. With the use of the most detailed and complete import data reported by most countries in the world over 1991-2004, quality measurement is derived for every category based on the assumption that quality varies across countries and quantity per variety is proportional to country size in labor. Econometric statistics of this study overwhelmingly accept quality as one important factor contributing to the growth of China's export destination market share. A general result from tobit regression at 3-digit SITC level suggests that doubling the export quality level lead to a 4.6 percentage-point increase in export destination market share. Besides, econometric results also suggest that variety had positive and significant effects on export market share of Chinese products. Doubling the number of varieties in the export could lead to 6.9, 7.5 and 16 percentage-point increases in the export market share of high income countries, medium income countries and low income countries respectively. Cross-country comparisons with other developing

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countries (Brazil, Mexico, India, and Thailand) in manufacturing sectors show that for the same percentage change in both product quality and variety, China experienced the largest gain on destination market share of exports to high income and low income countries in all manufacturing sectors.

This study makes several contributions to the line of literature on quality and variety of international trade. First, the actual quality measurement derived based on Dixit-Stiglitz "love-of-variety" import utility framework considers total quantity, number of trading varieties and elasticity of substitution. This is different from unit value, a common proxy for quality employed by most of prior studies. Second, data set in this empirical study is by far the broadest in range of importing countries and longest in duration of testing period. 167 trading partners of China over 14 years are considered. Third, this is the first study to explore the contribution of quality and variety of China's exports to the growth of destination market share.

The next section of the paper provides the theoretical framework, based on which quality measurement is derived. Section 2.3 describes data sources and discusses data used in analysis. Section 2.4 presents econometric results on China's exports. Cross-country comparisons are also included in this section. Section 2.5 concludes.

2.2 QUALITY MEASUREMENT

The theoretical framework follows the set up on quality differentiation in Hummels and Klenow (2004). Consider country i imports from J countries. Each exporter produces quality differentiated products in category s. Representative consumer in country i maximizes utility from imports based on a Dixit-Stiglitz formulation with a

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single elasticity of substitution ($\sigma > 1$) between goods in different categories and from different countries.

$$U_i = \left[\sum_j^J \sum_s^S Q_{jis} N_{jis} x_{jis}^{1-1/\sigma} \right]^{\frac{\sigma}{\sigma-1}} \qquad s.t. \ \sum_j^J \sum_s^S N_{jis} p_{jis} x_{jis} \le Y_i$$

where Q_{jis} and N_{jis} denote the quality and number of varieties imported by country *i* from country *j* in category *s*, respectively. x_{jis} and p_{jis} are the import quantity per category and the unit value of each category from *j* to *i* in category *s*, respectively.

Based on the assumption that countries produce goods of differential quality, and the quantity per variety is proportional to the country size in labor, quality and within-category variety in terms of the observed prices and quantities and the elasticity of substitution can be derived from the consumer's utility maximization problem:

$$\ln(Q_j) + \frac{1}{\sigma}\ln(N_j) = \ln(p_j) + \frac{1}{\sigma}\ln(N_j x_j)$$

Given the observable quantity ($N_j x_j$), number of varieties (N_j) and unit value per variety (p_j), quality level of goods traded from country *j* to country *i* in category *s* can be calculated. Elasticity of substitution at certain aggregation level is taken from Broda and Weinstein's (2004) empirical estimation[1].

Quality measurement here is different from unit value, a common proxy for quality employed in most empirical works. As a demand shifter in utility function, quality measurement in this paper takes not only average price in the category, but average quantity traded per variety and elasticity of substitution across categories into account, while unit value method only considers average price as a measurement of quality.

[1] For the period between 1990 and 2001, the average elasticity was 8.2 for 10-digit (HTS) goods, 5.6 at SITC 5-digit level and 3.9 at SITC 3-digit level.

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Although neither of these methods can avoid composition problem from aggregation bias due to the disaggregation level for which data are available at, quality measurement in this work is more preferable at each given level of aggregation in terms of consideration on quantity, variety and substitution effect.

In contrast to the quality measures calculated in other studies using export data excluding insurance and freight (FOB), the quality measurement in this work is derived with import data including insurance and freight (CIF). Given that the valuation at the factory gate truly represents quality of the product, quality measurement calculated with the use of CIF import prices tends to be overestimated since it includes noise from trade costs which contribute nothing to the production of quality. The FOB prices reported by exporting countries free of these trade costs noises, however, may not be a good choice when one takes the completeness and reliability into consideration. As recognized in Hummels and Lugovskyy (2003), importers may provide more coverage and better tracking of trade data than exporters since countries care more about what they import. This makes CIF import data a reliable base for quality measurement calculation if we assume that consumers are more willing to pay higher trade costs for higher quality. Moreover, according to the import utility function, the representative consumer reacts to CIF import prices which include freight, insurance, and duty at the customs besides cost of the product at the factory gate. That is, the CIF import price might strongly co-vary with quality level of the product despite being systematically different in levels. The estimated coefficient of quality will depend on this "systematic difference" in the following manners. If quality measures are overestimated by the same magnitude for all quality levels, the coefficient will not be affected. If all quality measures are

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overestimated by the same percentage, equivalently speaking of higher quality goods with higher trade costs (high tariff, high insurance of values), the coefficient estimates should be larger for the true quality. Otherwise, the opposite is true.

2.3 DATA

Data set in this paper covering imports reported by 167 countries from China and the world in 4106 commodities at 5-digit Standard International Trade Classification (SITC, Rev. 3) level during 1991-2004 is extracted from UN Commodity Trade Statistics Database (UN Comtrade). The UN Comtrade database collects the most specific and complete cross-country information commodity trade statistics, covering 90% of world trade. All statistics are detailed by commodity and partner country and all trade values come in US dollars[2]. The finest classification available in 5-digit Standard International Trade Classification (SITC, Rev. 3) is taken as variety, 1-digit SITC level as industry and any aggregation level in between as category.

The reason to employ this data set instead of the one with 10-digit product-level classification on which Schott (2006) bases his results is simply to relax the assumption that China's exports to the U.S. can accurately reflects domestic production as well as exports to other countries. Schott notes in his paper that the existence of trade costs such as freight, insurance, tariff and non-tariff barriers can be influential in determining which goods are exported and where they are exported. Besides trade costs, importing country characteristics such as income level, industry structure also are important considerations on what are imported and the quality of imports. Therefore, a panel containing trading

[2] All values are converted into current US dollars prices using exchange rates supplied by the countries, or derived from monthly market rates and volume of trade. Quantities are, if provided by the country and if possible, converted into metric units.

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partners all over the world with different country characteristics, differentiated trade costs added onto the goods of the same quality level is preferred in this study. The trade-off here is by using 5-digit data, I sacrifice what is called 10-digit product-level information which is more disaggregated and supposed to provide better variety effects with the opportunity to explore the quality pattern of China's exports to different countries.

To facilitate comparisons over time and filter the inflation of US dollar out of quality measurement, the U.S. Import Price Indexes (MPI = 100 in year 2000) for all commodities provided by U.S. Bureau of Labor Statistics are used to convert trade value in current prices into 2000 U.S. dollars. The U.S. Import Price Indexes applies to imports by all trading partners of China since all of their imports are reported in U.S. dollars.

In principle, quality measurement at any aggregation level above 5-digit can be calculated. In order to minimize the aggregation bias, I take 3-digit level as calculation base for quality since 4-digit level might render few variety counts in some categories and 1-digit or 2-digit level tend to give inaccurate unit values. Number of variety is counted as the number of 5-digit non-zero import under the same 3-digit category, and total quantity imported is obtained by summing up all quantities at 5-digit level under the same 3-digit category. Unit value at 3-digit level is thereafter calculated as summation of trade value at 5-digit level under the same 3-digit category divided by total quantity imported at 3-digit level calculated above.

2.4 EMPIRICAL RESULTS

Estimation is performed on a panel of cross-country, cross-industry and over the period of 1991-2004. Table 2.1 lists all trading partners of China during 1991-2004.

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Trading partners are grouped into high, medium and low income level based on the average per capital GDP over the period. Figure 2.1 and 2.2 plot the destination market share and variety share of China's exports to the world during the period by industry, respectively. Compared to resource industries (SITC 0 - SITC 4), all manufacturing industries (SITC 5 - SITC 8) experience strong and persistent increases both in market share and variety share of the world exports.

Figure 2.3 and 2.4 plot the market share and variety share of China's exports to the world during the sample period by income level of trading partners. China's export market share to the high income group grows steadily and quickly from about 6% to 16%, while the export market share to the low income group experiences a jump up to 17% during early 90's and ups and downs around 15% later years. Export market share to the medium income group is the lowest among three groups but continues to grow at a moderate speed. China's variety share to the high income group tops in terms of the share level in all years while the variety share to the low income group excels in terms of the amount of increase (30%) over the sample period, with the medium income group standing in between in both levels and growth rates.

Figure 2.5 presents simple regression plots of quality against variety of China's exports to each income group. China's exports to the high and medium income group show to be approximately equally correlated between quality and variety with market share, respectively, and both stronger than to the low income group.

Table 2.2 reports the summary statistics on market share, quality measures and variety by income group and manufacturing sector. These sectors, from the most capital-intensive to the least, are SITC 5 (Chemicals: Organic and Inorganic chemicals,

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pharmaceutical products), SITC 7 (Machinery and transport equipment), SITC 6 (Manufactures of leather, rubber, paper, fabrics, metals) and SITC 8 (Miscellaneous Manufactured articles: furniture, instruments, apparel, footwear)[3]. Several points are noteworthy in this report. First, the destination market share decreases in capital intensity of the sector for all income groups. China's exports to low income countries in the most labor-intensive sector SITC 8 took the largest mean of destination market share (14.4%), followed by a fairly large mean of share (13.3%) to high income group in the same sector. The smallest mean of the share (3.5%) happened on the exports to medium income countries in the most capital-intensive sector (SITC 5). Second, in all sectors, the mean of destination market share of exports to low income group was the highest, and this share of exports to medium income group was the lowest. Third, the means of destination market share are about twice as much in labor-intensive sectors as in capital-intensive sectors for all income groups. This confirms in theory that China has comparative advantage in sectors intensively using its abundant factor. Fourth, the mean of quality measures of China's exports was the highest for high income group in all manufacturing sectors. This confirms the theoretical prediction that rich countries tend to import relatively more high quality goods[4]. Note that the mean of quality measures increased in income level for relatively labor-intensive sectors (SITC 8 and SITC 6), but the direction reversed for medium and low income groups in relatively capital-intensive sectors (SITC 7 and SITC 5). The last, the increasing mean of varieties in income level for all sectors suggests that rich countries tend to import more varieties besides better quality products.

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[3] Schott (2006) ranks these four industries based on capital intensity.
[4] The empirical results in Hallak (2005) based on cross-section bilateral trade flows between 60 countries confirm this prediction.

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This corresponds to the findings in Hummels and Klenow (2004) that the extensive margin (a larger set of goods) accounts one-third of the greater imports of richer countries.

To measure the contribution of product quality to export performance, the export market share discussed above is taken as the dependent variable of all estimation specifications in Table 2.3-2.7. The log value of quality measurement and variety counts are taken as explanatory variables. Since the dependent variable is bounded in value from zero to one, OLS estimation will result in biased coefficient of the independent variable which depends on the value of dependent variable, tobit regression method for a censored dependent variable based on maximum likelihood is used.

Taking heterogeneity in effects across importing countries and industries, control variables in country dummy, industry dummy and year dummy are included for all tobit estimation procedures presented in Table 2.3. Same regression procedures are repeated for four other developing countries for comparison purpose in Table 2.4 through Table 2.7.

Table 2.3 presents tobit regression of destination market share of China's exports on quality measurement and variety counts by income group and pooled regression. All coefficient estimates on quality and variety are positive and statistically significant at 1% level. The first column in Table 2.3.1 gives a pooled tobit regression result, which suggests that destination export market share would increase by 4.6 percentage points in response to doubled quality level of China's exports, and by 8.5 percentage points with respect to doubled variety of China's exports. The next three columns show the estimation results by income group. For a doubled quality level, destination market share of China's exports to high income countries could increase by 4.49 percentage points, to

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medium income countries by 4.47 percentage points and to low income countries by 5.24. Table 2.3.2 shows the estimation results by manufacturing sector. The coefficients on quality demonstrate greater effect of quality changes in terms of percentage points in labor-intensive sectors relative to capital-intensive sectors.

The subsequent sub-tables (Table 2.3.3, 2.3.4 and 2.3.5) present the regression results for each income group by manufacturing sector. A general trend inferred from these tables and Table 2.2 is that, the same percentage change in quality and that in variety had larger effects on relatively labor-intensive sectors (SITC 8 and SITC 6) than on relatively capital-intensive sectors. Also observe that, except for SITC 7, the same percentage change in variety had larger effects in terms of percentage-point increase in market share of exports to richer countries.

Note in Table 2.2 that destination market shares of China's exports to medium income countries are the lowest in all manufacturing sectors. An intuitive explanation might be their self-sufficiency of the medium quality goods. The further observation of the mean of quality measures of China's exports to medium income countries in SITC 5 and SITC 7 very close to that to low income countries, combining with the regression results of least responsiveness in percentage-point gain of market share to medium income group as shown in the last three sub-tables of Table 2.3 (SITC 5 1.3% and SITC 7 1.7%), might suggest some loyalty issue in trade.

For comparison purpose, the same estimation procedures are carried out for other four developing countries, Brazil, India, Mexico and Thailand. Results for these countries are presented in Table 2.4.7. Again, all coefficient estimates on quality and variety in all tables are positive and statistically significant at 1% level. The pooled regression results

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indicate that the same percentage change in both quality and variety of China's exports had the largest effect in terms of percentage-point gain on destination market share. In addition, China excels in almost all manufacturing sectors on the effect of quality and variety. The comparison by income group also reflects a larger effect from quality of China's exports relative to that of any other's exports to high income and low income countries.

Among these comparison countries, India had the largest effect from quality upgrading on market share of exports to high-income (0.0203) and low-income (0.0601) countries while Brazil was leading in exports to medium income countries (0.0533). Brazil also enjoyed the largest gain in export market share of almost all manufacturings in response to the same percentage change in quality and variety. Statistics are listed in Table 2.4.2.

Self-comparison of coefficient estimates across destination income levels and export sectors in each country demonstrate that both Brazil and Mexico had stronger effects from quality improvement and variety expansion on market share of exports to medium income countries in manufactured goods sector (SITC 6), 0.0445 and 0.0327 respectively. The quality improvement of India's and Thailand's exports to low income countries in all manufacturing sectors led to the largest gains in destination market share, as shown in Table 2.5.2 and Table 2.7.2, respectively. In addition, I also found that for all five exporters, the same percentage change in quality was associated with the smallest effect in machinery and transportation equipment sector

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2.5 CONCLUSION

The estimation of this paper attempts to shed light on the increasing market share of China's export from the examination of quality and variety of traded goods. Quality measurement of China's exports is derived based on a Dixit-Stiglitz "love of variety" formulation. Empirical results widely and strongly accept quality as one important factor which had positive and significant effects on the export market share of Chinese products during the period of 1991-2004. A general result from tobit regression at 3-digit SITC level suggests that doubling the export quality level lead to a 4.6 percentage points increase in China's export destination market share. Besides, export variety also gives good support to market share growth of China's exports in manufacturing industry. Comparisons with other four developing economies in manufacturing sectors show that for the same percentage change in both product quality and variety, China experienced the largest gain on destination market share of exports to high income and low income countries in all manufacturing sectors.

Future research can take the following candidates that contributed to the persistent growth in quality of China's exports into consideration: productivity gains from high technology acquirement (licensing of patented technologies), knowledge-spillovers from importing goods and foreign direct investments, increasing R&D expenditures and huge efforts on human capital development (education). The methodology of quality measurement derivation in this paper provides an alternative approach thus facilitating studies in the related fields. However, further investigations pursued in this direction should take a careful note on the assumptions with the approach.

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Table 2.1: China's Trading Partner List by Income Level during 1991-2004

Reporter	Income Group	Reporter	Income Group	Reporter	Income Group
Andorra	high	Cape Verde	med	Serbia and Montenegro	med
Aruba	high	Chile	med	Seychelles	med
Australia	high	Colombia	med	Slovakia	med
Austria	high	Congo	med	South Africa	med
Bahamas	high	Cook Isds	med	Sri Lanka	med
Bahrain	high	Costa Rica	med	Suriname	med
Barbados	high	Croatia	med	Swaziland	med
Belgium	high	Cuba	med	Syria	med
Brunei Darussalam	high	Czech Rep.	med	TFYR of Macedonia	med
Canada	high	Côte d'Ivoire	med	Thailand	med
China, Hong Kong SAR	high	Dominica	med	Trinidad and Tobago	med
China, Macao SAR	high	Ecuador	med	Tunisia	med
Cyprus	high	Egypt	med	Turkey	med
Denmark	high	El Salvador	med	Tuvalu	med
Finland	high	Estonia	med	Ukraine	med
France	high	Fiji	med	Uruguay	med
French Polynesia	high	Gabon	med	Vanuatu	med
Germany	high	Georgia	med	Venezuela	med
Greece	high	Grenada	med	Zimbabwe	med
Iceland	high	Guatemala	med	Bangladesh	low
Ireland	high	Guyana	med	Benin	low
Israel	high	Honduras	med	Bhutan	low
Italy	high	Hungary	med	Burkina Faso	low
Japan	high	Indonesia	med	Burundi	low
Kuwait	high	Iran	med	Cambodia	low
Luxembourg	high	Jamaica	med	Central African Rep.	low
Malta	high	Jordan	med	Chad	low
Netherlands	high	Kazakhstan	med	Comoros	low
New Caledonia	high	Kiribati	med	Eritrea	low
New Zealand	high	Latvia	med	Ethiopia	low
Norway	high	Lebanon	med	Gambia	low
Portugal	high	Libya	med	Ghana	low
Qatar	high	Lithuania	med	Guinea	low
Rep. of Korea	high	Malaysia	med	India	low
Singapore	high	Maldives	med	Kenya	low
Slovenia	high	Mauritius	med	Kyrgyzstan	low
Spain	high	Mexico	med	Madagascar	low
Sweden	high	Montserrat	med	Malawi	low
Switzerland	high	Morocco	med	Mali	low
USA	high	Namibia	med	Mongolia	low
United Arab Emirates	high	Nicaragua	med	Myanmar	low
United Kingdom	high	Oman	med	Nepal	low
Albania	med	Pakistan	med	Niger	low
Algeria	med	Panama	med	Nigeria	low
Antigua and Barbuda	med	Papua New Guinea	med	Rep. of Moldova	low
Argentina	med	Paraguay	med	Rwanda	low
Armenia	med	Peru	med	Sao Tome and Principe	low
Azerbaijan	med	Philippines	med	Senegal	low
Belarus	med	Poland	med	Sierra Leone	low
Belize	med	Romania	med	Sudan	low
Bolivia	med	Russian Federation	med	Togo	low
Bosnia Herzegovina	med	Saint Kitts and Nevis	med	Uganda	low
Botswana	med	Saint Lucia	med	United Rep. of Tanzania	low
Brazil	med	Saint Vincent and the Grenadines	med	Yemen	low
Bulgaria	med	Samoa	med	Zambia	low
Cameroon	med	Saudi Arabia	med		

167 countries are grouped into three income levels based on average per capita GDP over 1991-2004.
36 Countries with average per capita GDP less than and equal to US$529 are labeled into low income group. 89 Countries with average per capita GDP higher than US$529 and less than and equal to US$8100 are labeled into medium income group. 42 Countries with average per capita GDP more than US$8100 are labeled into high income group.

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Figure 2.1: Market Share of China's Exports to the World by Industry

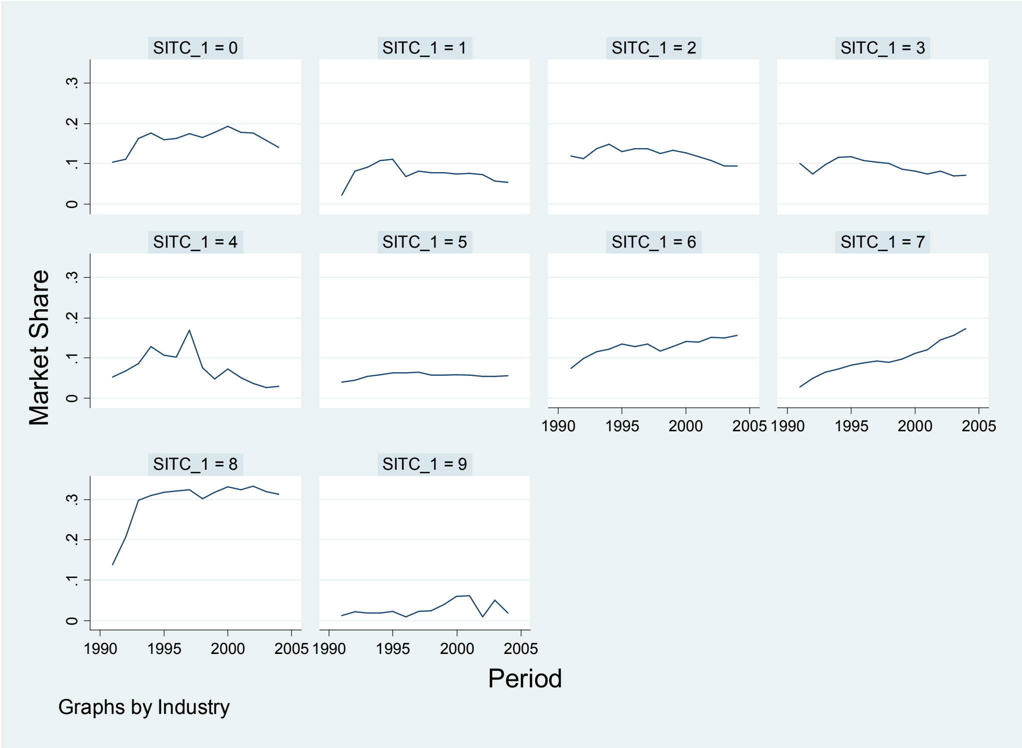

Figure 2.2: Variety Share of China's Exports to the World by Industry

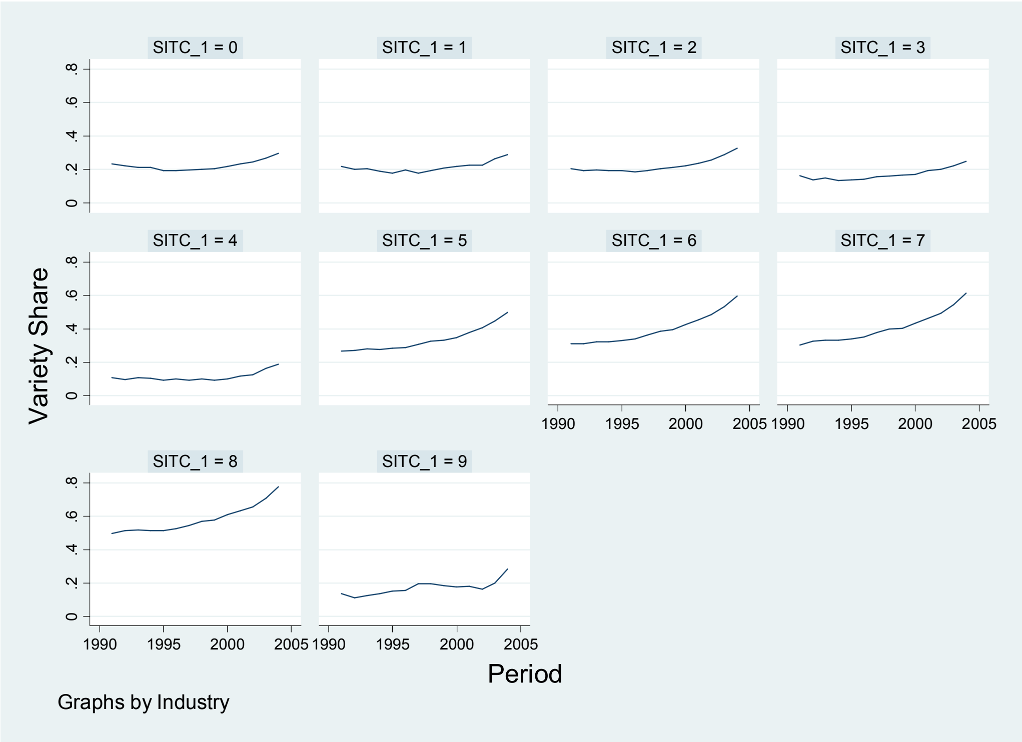

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Figure 2.3: Market Share of China's Exports by Income Group

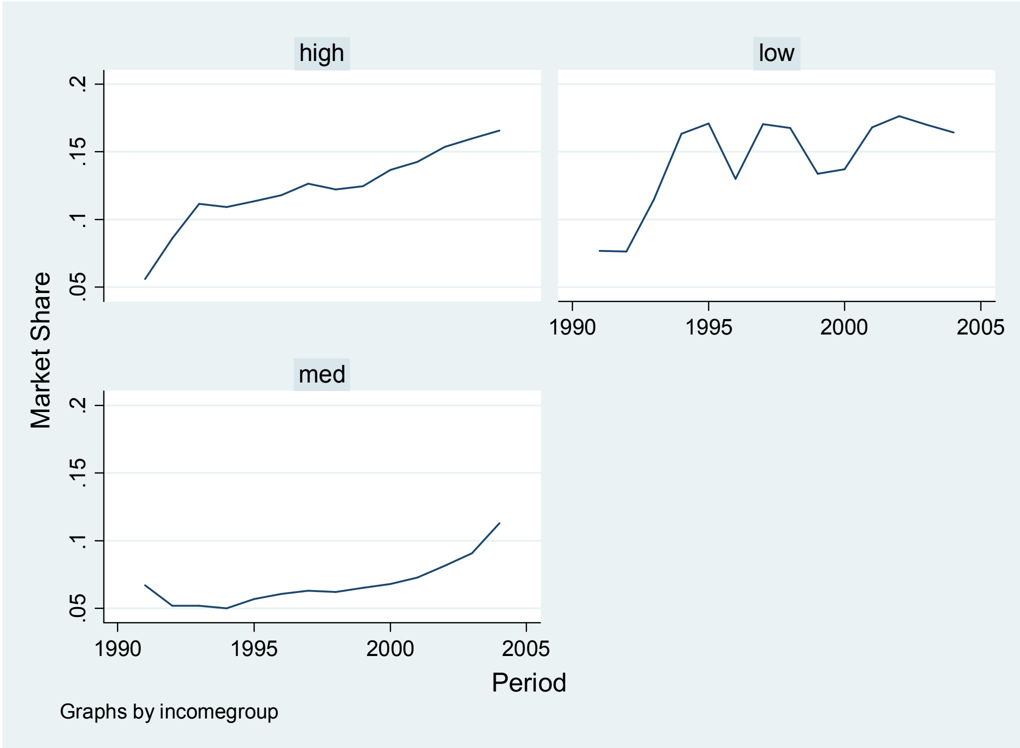

Figure 2.4: Destination Variety Share of China's Exports by Income Group

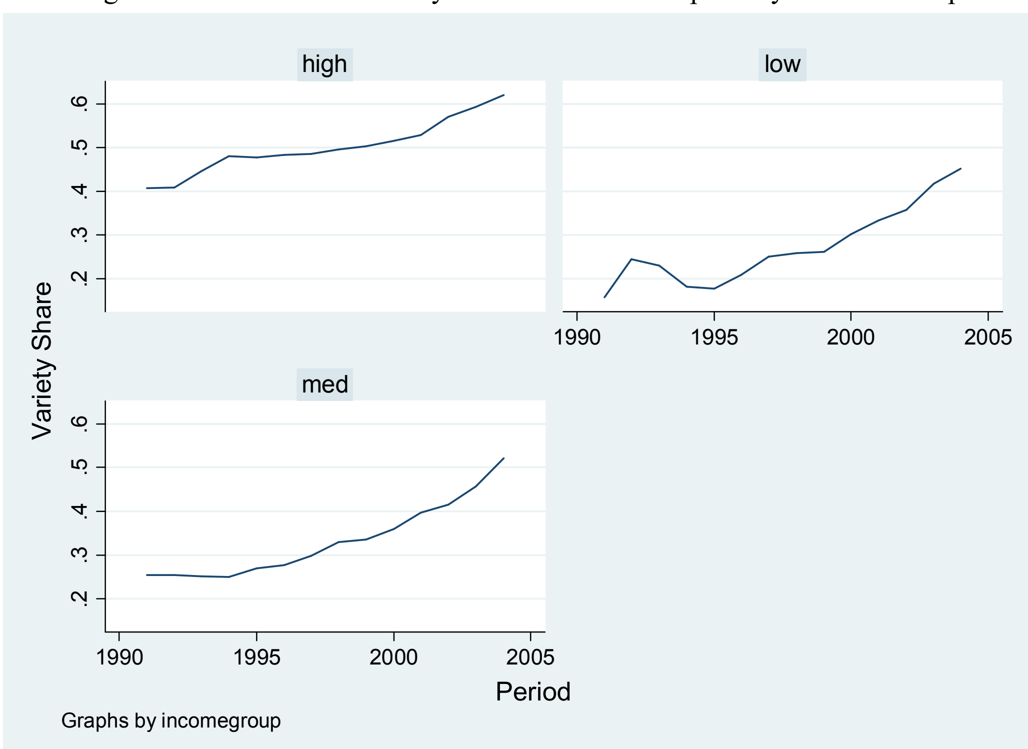

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Figure 2.5: Linear Fitted Lines for Quality on Variety of China's Exports by Income Group

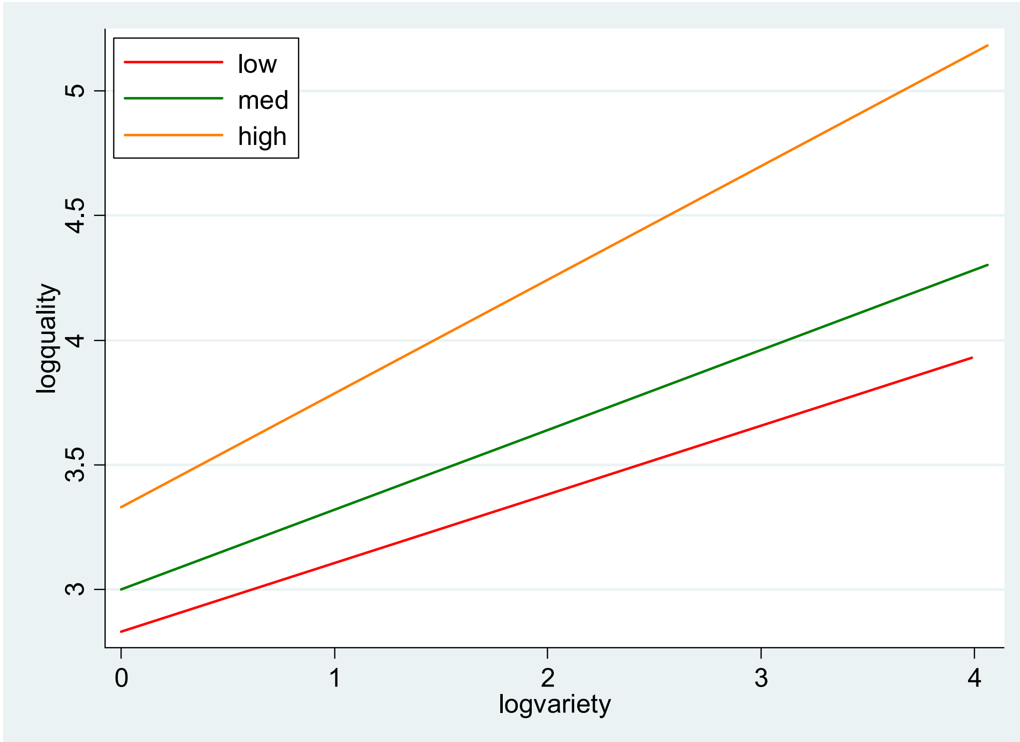

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Table 2.2: Summary Statistics by Income Group and Manufacturing Sector

MANUFACTURING SECTOR	VARIABLE	INCOME GROUP	MEAN	STD. DEV.	MIN	MAX
SITC1 = 5 Chemicals	MARKET SHARE	HIGH	0.039	0.097	0	1
		MED	0.035	0.081	0	1
		LOW	0.077	0.142	0	1
	QUALITY	HIGH	189	6916	0	744769
		MED	82	770	0	59613
		LOW	144	4920	0	330850
	VARIETY	HIGH	9.41	7.16	0	39
		MED	8.20	6.40	0	42
		LOW	6.86	5.39	0	38
SITC1 = 6 Manufactured Goods	MARKET SHARE	HIGH	0.072	0.132	0	1
		MED	0.065	0.120	0	1
		LOW	0.126	0.177	0	1
	QUALITY	HIGH	135	2949	0	383992
		MED	52	351	0	26238
		LOW	42	266	0	10251
	VARIETY	HIGH	11.73	9.26	0	58
		MED	9.96	7.99	0	58
		LOW	8.51	6.67	0	54
SITC1 = 7 Machinery and Transport Equipment	MARKET SHARE	HIGH	0.044	0.096	0	1
		MED	0.043	0.088	0	1
		LOW	0.073	0.128	0	1
	QUALITY	HIGH	9424	242125	0	18800000
		MED	923	22900	0	2269435
		LOW	2885	63409	0	4682893
	VARIETY	HIGH	9.74	7.30	0	44
		MED	8.87	6.90	0	43
		LOW	7.23	5.48	0	43
SITC1 = 8 Miscellaneous Manufactured Articles	MARKET SHARE	HIGH	0.133	0.188	0	1
		MED	0.105	0.148	0	1
		LOW	0.144	0.184	0	1
	QUALITY	HIGH	336	7928	0	874927
		MED	106	699	0	50543
		LOW	85	727	0	37861
	VARIETY	HIGH	13.82	8.49	0	45
		MED	11.78	7.56	0	45
		LOW	8.65	5.80	0	44

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Table 2.3: Tobit Regression – China

Table 2.3.1

	Market Share			
	Pooled	High Income Group	Med. Income Group	Low Income Group
log(quality)	0.046**	0.0449**	0.0447**	0.0524**
log(variety)	0.085**	0.0692**	0.0753**	0.1597**
Number of obs	621390	204988	322839	93563
Left-censored	391681	119322	209541	62818
Uncensored	229709	85666	113298	30745

Table 2.3.2

	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0442**	0.0590**	0.0245**	0.0590**
log(variety)	0.0549**	0.0662**	0.0639**	0.0855**
Number of obs	84508	135303	136758	81007
Left-censored	51360	79749	80038	44641
Uncensored	33148	55554	56720	36366

Table 2.3.3

High Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0449**	0.0603**	0.0193**	0.0762**
log(variety)	0.0397**	0.0404**	0.0559**	0.0558**
Number of obs	27394	43745	43407	25604
Left-censored	15501	24039	23884	13343
Uncensored	11893	19706	19523	12261

Table 2.3.4

Med. Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0351**	0.0529**	0.0258**	0.0507**
log(variety)	0.0494**	0.0628**	0.0532**	0.0807**
Number of obs	44054	70739	71656	42790
Left-censored	27369	42709	42829	23868
Uncensored	16685	28030	28827	18922

Table 2.3.5

Low Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0608**	0.0762**	0.0315**	0.0564**
log(variety)	0.1178**	0.1352**	0.1118**	0.1474**
Number of obs	13060	20819	21695	12613
Left-censored	8490	13001	13325	7430
Uncensored	4570	7818	8370	5183

* Significant at 5% level; ** significant at 1% level

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Table 2.4: Tobit Regression – Brazil

Table 2.4.1

	Market Share			
	Pooled	High Income Group	Med. Income Group	Low Income Group
log(quality)	0.0397**	0.0184**	0.0533**	0.0313**
log(variety)	0.0819**	0.0371**	0.0978**	0.1217**
Number of obs	537470	178617	287573	71280
Left-censored	391699	119326	209555	62818
Uncensored	145771	59291	78018	8462

Table 2.4.2

	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0321**	0.0445**	0.0203**	0.0249**
log(variety)	0.0634**	0.0693**	0.0592**	0.0369**
Number of obs	72386	115628	116582	63604
Left-censored	51362	79753	80040	44646
Uncensored	21024	35875	36542	18958

Table 2.4.3

High Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0082**	0.0169**	0.0059**	0.0029**
log(variety)	0.0103**	0.0196**	0.0142**	0.0045**
Number of obs	23459	38477	37547	21623
Left-censored	15501	24040	23884	13346
Uncensored	7958	14437	13663	8277

Table 2.4.4

Med. Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0420**	0.0556**	0.0282**	0.0346**
log(variety)	0.0816**	0.0884**	0.0721**	0.0476**
Number of obs	39194	61852	63090	33814
Left-censored	27371	42712	42831	23870
Uncensored	11823	19140	20259	9944

Table 2.4.5

Low Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0207**	0.0373**	0.0118**	0.0158**
log(variety)	0.0674**	0.0883**	0.0495**	0.0461**
Number of obs	9733	15299	15945	8167
Left-censored	8490	13001	13325	7430
Uncensored	1243	2298	2620	737

* Significant at 5% level; ** significant at 1% level

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Table 2.5: Tobit Regression – India

Table 2.5.1

	Market Share			
	Pooled	High Income Group	Med. Income Group	Low Income Group
log(quality)	0.0347**	0.0203**	0.0312**	0.0601**
log(variety)	0.0687**	0.0300**	0.0572**	0.1824**
Number of obs	566045	187293	291678	87074
Left-censored	391697	119326	209553	62818
Uncensored	174348	67967	82125	24256

Table 2.5.2

	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0315**	0.0377**	0.0194**	0.0244**
log(variety)	0.0523**	0.0532**	0.0533**	0.0397**
Number of obs	77673	123117	120689	72846
Left-censored	51364	79753	80039	44647
Uncensored	26309	43364	40650	28199

Table 2.5.3

High Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0173**	0.0211**	0.0061**	0.0129**
log(variety)	0.0177**	0.0145**	0.0114**	0.0109**
Number of obs	24895	40663	38616	23731
Left-censored	15501	24040	23884	
Uncensored	9394	16623	14732	

Table 2.5.4

Med. Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0242**	0.0269**	0.0129**	0.0207**
log(variety)	0.0397**	0.0392**	0.0308**	0.0331**
Number of obs	40441	63361	62332	37819
Left-censored	27373	42712	42830	23871
Uncensored	13068	20649	19502	13948

Table 2.5.5

Low Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0628**	0.0699**	0.0422**	0.0459**
log(variety)	0.1439**	0.1731**	0.1400**	0.1207**
Number of obs	12337	19093	19741	11296
Left-censored	8490	13001	13325	7430
Uncensored	3847	6092	6416	3866

* Significant at 5% level; ** significant at 1% level

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Table 2.6: Tobit Regression – Mexico

Table 2.6.1

	Market Share			
	Pooled	High Income Group	Med. Income Group	Low Income Group
log(quality)	0.0272**	0.0120**	0.0383**	0.0170**
log(variety)	0.0458**	0.0192**	0.0577**	0.0513**
Number of obs	490084	161871	263223	64990
Left-censored	391702	119326	209558	62818
Uncensored	98382	42545	53665	2172

Table 2.6.2

	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0253**	0.0327**	0.0142**	0.0177**
log(variety)	0.0511**	0.0446**	0.0242**	0.0163**
Number of obs	66948	100821	106311	60951
Left-censored	51364	79753	80044	44647
Uncensored	15584	21068	26267	16304

Table 2.6.3

High Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0089**	0.0097**	0.0096**	0.0122**
log(variety)	0.0140**	0.0126**	0.0182**	0.0105**
Number of obs	21614	33118	34789	20802
Left-censored	15501	24040	23884	13346
Uncensored	6113	9078	10905	7456

Table 2.6.4

Med. Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0334**	0.0446**	0.0186**	0.0218**
log(variety)	0.0638**	0.0603**	0.0267**	0.0194**
Number of obs	36427	54284	57502	32418
Left-censored	27373	42712	42835	23871
Uncensored	9054	11572	14667	8547

Table 2.6.5

Low Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0080**	0.0186**	0.0072**	0.0101**
log(variety)	0.0242**	0.0349**	0.0171**	0.0285**
Number of obs	8907	13419	14020	7731
Left-censored	8490	13001	13325	7430
Uncensored	417	418	695	301

* Significant at 5% level; ** significant at 1% level

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Table 2.7: Tobit Regression – Thailand

Table 2.7.1

	Market Share			
	Pooled	High Income Group	Med. Income Group	Low Income Group
log(quality)	0.0246**	0.0196**	0.0253**	0.0374**
log(variety)	0.0496**	0.0357**	0.0501**	0.1085**
Number of obs	534915	183869	273012	78034
Left-censored	391902	119326	209693	62883
Uncensored	143013	64543	63319	15151

Table 2.7.2

	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0230**	0.0212**	0.0087**	0.0183**
log(variety)	0.0353**	0.0291**	0.0228**	0.0328**
Number of obs	67456	113633	114765	71868
Left-censored	51381	79805	80092	44686
Uncensored	16075	33828	34673	27182

Table 2.7.3

High Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0208**	0.0167**	0.0061**	0.0105**
log(variety)	0.0202**	0.0149**	0.0142**	0.0126**
Number of obs	22829	38971	38670	24189
Left-censored	15501	24040	23884	13346
Uncensored	7328	14931	14786	10843

Table 2.7.4

Med. Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0188**	0.0175**	0.0087**	0.0172**
log(variety)	0.0293**	0.0277**	0.0198**	0.0342**
Number of obs	34249	57872	58926	36887
Left-censored	27384	42749	42860	23901
Uncensored	6865	15123	16066	12986

Table 2.7.5

Low Income Group	SITC1 = 5	SITC1 = 6	SITC1 = 7	SITC1 = 8
log(quality)	0.0359**	0.0395**	0.0151**	0.0341**
log(variety)	0.0930**	0.0790**	0.0610**	0.0755**
Number of obs	10378	16790	17169	10792
Left-censored	8496	13016	13348	7439
Uncensored	1882	3774	3821	3353

* Significant at 5% level; ** significant at 1% level

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CHAPTER 3

AN EXTENSION OF PARTIAL-EQUILIBRIUM, SINGLE-FIRM MODEL OF PLANT LOCATION

3.1 INTRODUCTION

The purpose of this chapter is to extend a partial equilibrium model which Markusen (2002) develops for single firm's plant location over two countries with trade costs, firm-level and plant-level fixed costs under consideration. In his settings, there are two goods, one factor. Good *Y* subject to constant return to scale is produced in both countries. Good *X* is produced by a single firm, which has options for plant location in types of domestic, horizontal and vertical production. Labor is the only factor of production assumed for simplicity.

Following the principal elements of Markusen's model, an extension with more plant location options are possible if intermediate production stage is introduced. With the separation of production stages, plant-level fixed costs are split into two parts, plant-level costs for intermediate production and plant-level costs for assembly (final) production. Accordingly, costs of production are split into cost of intermediate production and cost of assembly. Besides, trade cost on intermediate goods is considered different from trade cost on final goods.

This extension is based on the fact that trade in intermediate inputs plays a more important role in the total world trade as multinational firms allocate different production stages in different places and ship all intermediate inputs (components and parts) to assembly plants to make finished products for local sales and/or exports. Yeats (2001) provides some evidence to show that in 1995 approximately 30% of all OECD exports in SITC 7 (machinery and transport equipment) constitute production sharing components

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and parts. This share is even higher in the US to about 40%. Moreover, he finds that trade in components and parts has been growing at a much faster pace than that for assembled goods, delivering the information that the growth of world trade was driven largely by the growth of component trade. Japan experienced the most rapid growth in component trade share from 15% to 26% in a 17-year period.

The trade in intermediates can be viewed as substitute for the trade in final goods when local assembly plant is located in the country of sales due to the market-access motive thus intermediate inputs are imported rather than final goods. It also can be taken as complement for the trade in final goods when the assembly plant is established as a export platform to take the advantage of the factor-price differentials, thus intermediate inputs are imported and the assembled goods are distributed to the country of sales, home country, local markets or elsewhere. The former case is encouraged by low trade costs on intermediates relative to the high trade costs on final goods, large market size of the host country and low fixed costs of assembly plant.

The fragmentation of intermediate and assembly plants either geographically provides more alternative plant location options in addition to the horizontal and the vertical FDI of standard models in the multinational literature. Some of these options involve in the intermediates trade replacing the trade in final goods, and others with trade in intermediates and final goods. Since different stages of production activities vary by industry in factor intensity, these new options may render more profits if appropriate arrangement can capture the cross-country variation of production technology and factor endowment, thus to achieve the production efficiency through specialization. High intermediate plant-level fixed cost favors single intermediate-plant type rather than

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having all production plants duplicated in both countries. Semiconductor manufacturing sector provides a very good example. Since the wafer fabrication plant easily costs about 2-3 billion dollars, international electronic firms usually consider establishing the wafer fabrication plant in one place from where the finished wafers are transported to plant(s) in other location(s) for final assembly and testing. This intermediate plant-level scale economies helps explain the small likelihood of pure horizontal type of firms. In addition to these technology characteristics, country characteristics such as market size, trade policies (tariffs) and investment restrictions (ownership requirements, technology transfer costs) also matter on the number and location of intermediate and assembly plants.

As argued in Hanson, Mataloni and Slaughter (2001), firms can locate different production stages – headquarters, intermediates and assembly in different countries as long as these stages are physically separable. One feature of the location choice is to associate factor intensity of the production stage with factor endowment of the locating country, thus making distinctive production activity the most efficient. The industry-varied intermediate plant-level scale economies distinguishes this new type of location choice from the horizontal and the vertical FDI when it becomes relatively more important in the total fixed costs. However, larger market size of the host country and high trade costs on the intermediates can reinforce the firm's decision to be of pure horizontal type: duplicating intermediate plant abroad instead of exporting those intermediates for assembly overseas.

The consideration of fragmentation serves as theoretical supplement to standard model of horizontal and vertical FDI, and also as confirmation to the empirical findings in Hanson, Mataloni and Slaughter (2001) that earlier research over-estimates the

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existence of horizontal and vertical FDI without taking other multinational strategies such as outsourcing-wholesale trade affiliates into the picture. The separability expands the strategy range for the multinational firms in response to the cross-country variations in production technology, factor endowment, trade and investment policies. Equivalently speaking, firms become more sensitive to those variations in the framework.

The rest of this paper proceeds with next section introducing plant location layouts and projecting conditions each type is likely to arise in. Section 3.3 gives simulation graphs and explanations for experiments with all options. Trade cost issues are included in section 3.4. Section 3.5 provides welfare analysis. The last section concludes.

3.2 PLANT LOCATIONS

There are two countries in the world, home country *i* and foreign country *j*. For a single firm headquartered in home country *i*, all options with intermediate production are listed as follows. Each type of plant location except the first one has two subtypes which are symmetric with respect to home and host country.

1. Full horizontal: Two intermediate plants and two assembly plants
2. National: One intermediate plant and one assembly plant staying together in either country
3. Intermediate vertical – assembly horizontal: One intermediate plant and two assembly plants
4. Full vertical: One intermediate plant and one assembly plant located in different country

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5. Intermediate horizontal – assembly vertical: Two intermediate plants and one assembly plant

The "national" type refers to either domestic or vertical in Markusen (2002). It is also known as vertically integrated in Hanson, Mataloni and Slaughter (2001). Before proceeding to the graphical analysis, I project conditions under which each type of plant location is likely to arise.

Full-horizontal:

1. Total world demand is high.
2. Similar market size.
3. Trade costs are high on intermediates and assembled/final goods.
4. Firm-level fixed costs are large relative to plant-level costs of both intermediate and assembly.
5. Similar marginal costs in intermediate and assembly.
6. Low technology transfer costs.

National:

1. Large difference in market size.
2. Low trade cost on assembled/final goods.
3. Large plant-level fixed costs.
4. Large differences in marginal production costs of intermediates and assembly.
5. High technology transfer costs.

Intermediate vertical – assembly horizontal:

1. High intermediate plant-level fixed cost.

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2. Moderate difference in market size.
3. Low assembly plant-level fixed cost, otherwise switch to “full-vertical” or “national”.
4. Large differences in marginal production costs of intermediates.
5. Similar marginal production costs of assembly.

Full-vertical:

1. Large differences in marginal production costs of intermediates and assembly. (Country *i* highly specialized in intermediates and country *j* highly specialized in assembly, or vice versa.)
2. Low trade costs on both intermediates and assembled/final goods.

Intermediate horizontal – assembly vertical:

1. Plant-level cost of intermediates is low, otherwise switch to “national” or “full-vertical”
2. Plant-level cost of assembly is high, otherwise switch to “horizontal”.
3. Specialization in assembly results in low marginal production cost of assembly in one country.
4. Similar marginal costs of intermediates.

Note that the first two types are the same as in Markusen’s model. The last type is not quite promising as far as the high cost on intermediate plant in the realistic world is concerned. Firm would prefer “national” type given the large difference in country size. Therefore this option will not be considered in the experiments of the study. From this point on, type-h will be used to denote “full horizontal”, type-n “national”, type-iv “intermediate vertical – assembly horizontal” and type-v “full vertical”.

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Following the two-country, two-good, one-factor assumption in Markusen's model where a representative agent maximizes a quasi-linear utility function subject to the budget constraint which is the value of factor endowment plus profits of the national firm,

$$Max\ U_i = \alpha X_{ii} - \left(\frac{\beta}{2}\right)\frac{X_{ii}^2}{L_i} + \gamma L_i + \prod_i - p_i X_{ii}$$

The optimization condition gives an inverse demand function for X_{ii},

$$p_i = \alpha - \beta X_{ii} / L_i$$

This enters firm's profit maximization problem which yields optimal supply of X_{ii},

$$X_{ii} = \frac{\alpha - mc_i - c_i}{2\beta} L_i$$

Thus the corresponding quasi-linear profit functions for all types of location options above are:

$$\prod_H = \beta\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - F - 2G_M - 2G_A$$

$$\prod_{N1} = \beta\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_i - c_i - t_j}{2\beta}\right)^2 L_j - F - G_M - G_A$$

$$\prod_{N2} = \beta\left(\frac{\alpha - mc_j - c_j - t_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - F - G_M - G_A$$

$$\prod_{IV1} = \beta\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j - F - G_M - 2G_A$$

$$\prod_{IV2} = \beta\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - F - G_M - 2G_A$$

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$$\Pi_{V1} = \beta\left(\frac{\alpha - mc_i - c_j - t_j^m - t_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j - F - G_M - G_A$$

$$\Pi_{V2} = \beta\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_i - t_i^m - t_j}{2\beta}\right)^2 L_j - F - G_M - G_A$$

where mc represents marginal production costs of intermediates, c the marginal production costs of assembly. tm and t denote trade costs on intermediate trade and final product trade, respectively. L denotes factor endowment. Subscript i, j denote home country and host country, respectively. mc_i represents marginal production cost of intermediates in home country. tm_i represents trade cost on intermediates from host country to home country. The representation by $c_i, c_j, t_i, t_j, mc_j, tm_j, L_i$ and L_j follow in the similar fashion. F is firm-level fixed cost. GM is plant-level cost of intermediates, and GA is plant-level cost of assembly. Subscript with profit notation $\prod$ is comprised of letter and/or number. Letter part represents type of plant location, and number part represents subtype. Since each type in the analysis except the full horizontal firm carries only one intermediate plant, subtype-1 is used to refer to the location choice with intermediate plant at home, and subtype-2 with intermediate plant in the host country.

3.3 EXPERIMENTS

With single production factor, the interest of this study lies only in how technology characteristics and country characteristics affect the firm's location choices, the same way Markusen conducts his analysis. Following his definition, technology characteristics include firm-level and plant-level scale economies. Country characteristics include total and relative country market sizes, relative marginal cost and trade costs. In

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this study, the plant-level scale economy is split into plant-level of intermediates and plant-level of assembly. Marginal cost is differentiated with respect to production stage, intermediates or assembly. There also exists distinction between trade cost on intermediates and trade cost on assembly (final) products. This realistic assumption introducing complication in the experiments can be very useful in strategic trade policy analysis.

Experiments with the model with technology and country characteristics as determinants of plant location are as follows: (experiments in bold fonts are duplicates of the ones in Markusen's model.)

1. **The Base Case**
2. **Total demand double the base case**
3. Trade costs
   a. Trade costs on intermediates 25% lower than in the base case
   b. Trade costs on final goods 25% lower than in the base case
   c. **Trade costs on both intermediates and final goods 25% lower than in the base case**
4. Composition of fixed costs with $F + GM + GA$ constant
   a. **F increases while holding *GM/GA* and (*F* + *GM* + *GA)* constant**
   b. GM increases while holding F/GA and $(F + GM + GA)$ constant
   c. GM increases while holding F and $(F + GM + GA)$ constant
5. Marginal production costs
   a. Marginal production cost for intermediates 25% lower in country j
   b. Marginal production cost for assembly 25% lower in country j

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c. **Marginal production costs (mc_j, c_j) 25% lower in country *j***

d. Ratio of marginal cost for intermediates in country *i* to country *j* (1.5 – 0.5)

e. Ratio of marginal cost for assembly in country *i* to country *j* (1.5 – 0.5)

f. **Ratio of marginal costs in country *i* to country *j*** (1.5 – 0.5)

6. Technology transfer costs

a. *GM* 50% higher in country *j*

b. *GA* 50% higher in country *j*

c. ***(GM + GA)* 50% higher in country *j***

In an attempt to realistic analysis, all experiments are conducted with certain assumptions of parameters. Plant-level fixed cost of intermediates is assumed twice as much as that of assembly. Trade costs on assembly goods are triple that on intermediates.

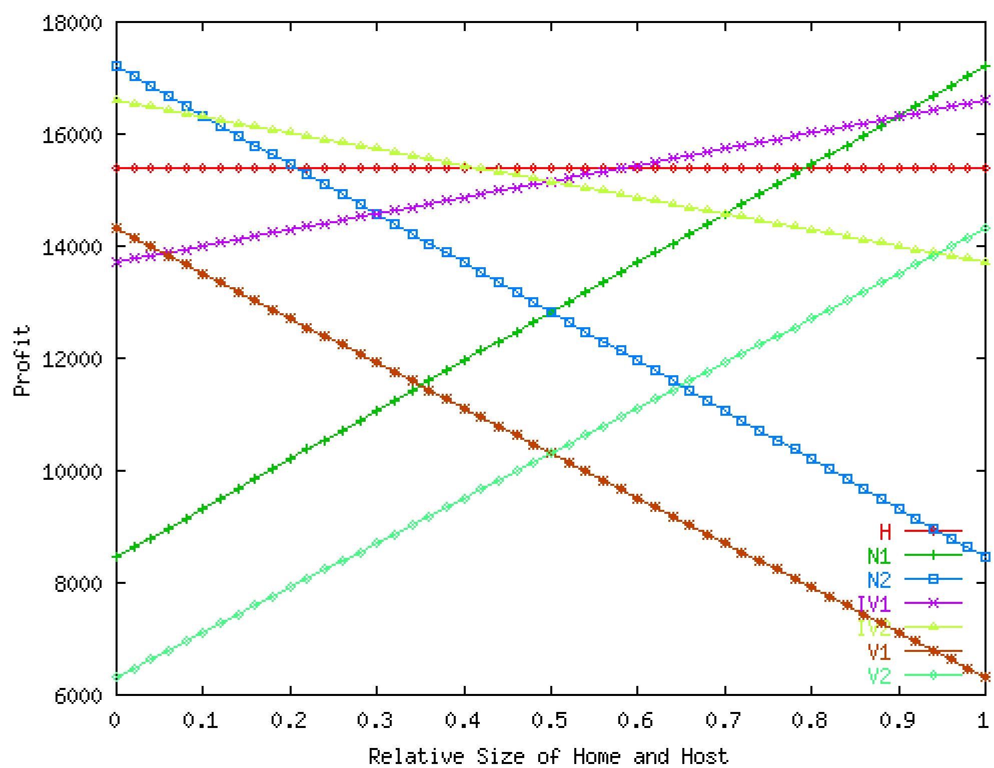

Figure 3.1 The Base Case

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Figure 3.1 presents the base case. With equal marginal costs in intermediates and assembly in both countries, the profit of a type-h firm is not affected by relative demand, and the profit of a type-n, type-iv and type-v firm increases in difference of demand. For type-n and type-iv options, the profit of subtype 1 firm increases in the share of demand at home and vice versa for the profit of subtype 2 firm. As just the opposite, the profit of type-v firm decreases as assembly-importing country becomes bigger due to the high trade costs on assembly goods.

The dominance of the firm type as the countries go from similar to very different in size is in the order of type-h, type-iv and type-n. When countries are very similar in size, a type-h firm is the most profitable given that plant-level fixed costs are low relative to trade costs. The dominance of type-iv over type-h where countries are of intermediate size differences can be explained by the fact that the fixed costs of an intermediate plant is large relative to the variable trade costs on intermediates. The dominance of type-iv over type-n where countries are of more size differences is due to the large trade cost on final products relative to fixed costs of an assembly plant. However, this dominance reverses when the size of one country goes to zero. Given the small demand of the other country, it is more profitable transporting the final products than bearing the fixed costs of an assembly plant.

This base case helps explain the small likelihood of pure horizontal and national firm types (a.k.a. vertical FDI in standard framework) by showing the dominance of new location options over each of these types. The general trend illustrated in the base case is that the firm is more willing to pay for the plant-level fixed costs in assembly and intermediate rather than the variable trade costs as countries becomes similar in size. In

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addition, if one country is small, it is optimal for the firm to set up the intermediate plant in the other country only, and import either intermediates back for assembly (type-iv) or the final products for consumption (type-n). If plant-level costs for intermediates/assembly are sufficiently high or the trade costs on intermediates/assembly are sufficiently low, type-h may not be optimal and can be dominated by type-iv/type-n firm even countries are similar in size.

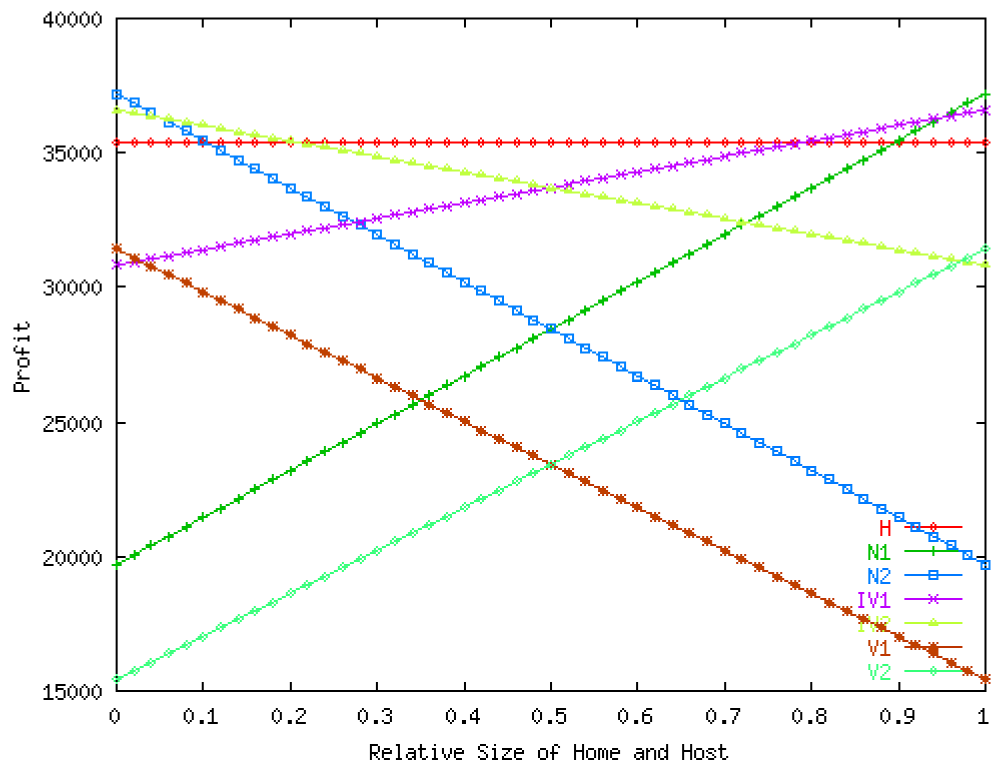

Figure 3.2 Total Demand Double the Base Case

Figure 3.2 illustrates the case where the total demand doubles the base case. The region in which type-h is preferable to all other types becomes larger. Compared to the base case, more demand means more variable trade costs for type-n, type-iv and type-v. Without involving in trade, type-h option costs less to operate than does any of other types. Therefore, increase in total demand will increase the likelihood of type-h location option. The region in which type-iv dominates type-h and type-n becomes smaller, so

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does the region where type-n dominates type-iv and type-h. This mainly is due to the fact that the variable trade costs make any type involved in transportation less favorable when the demand is growing.

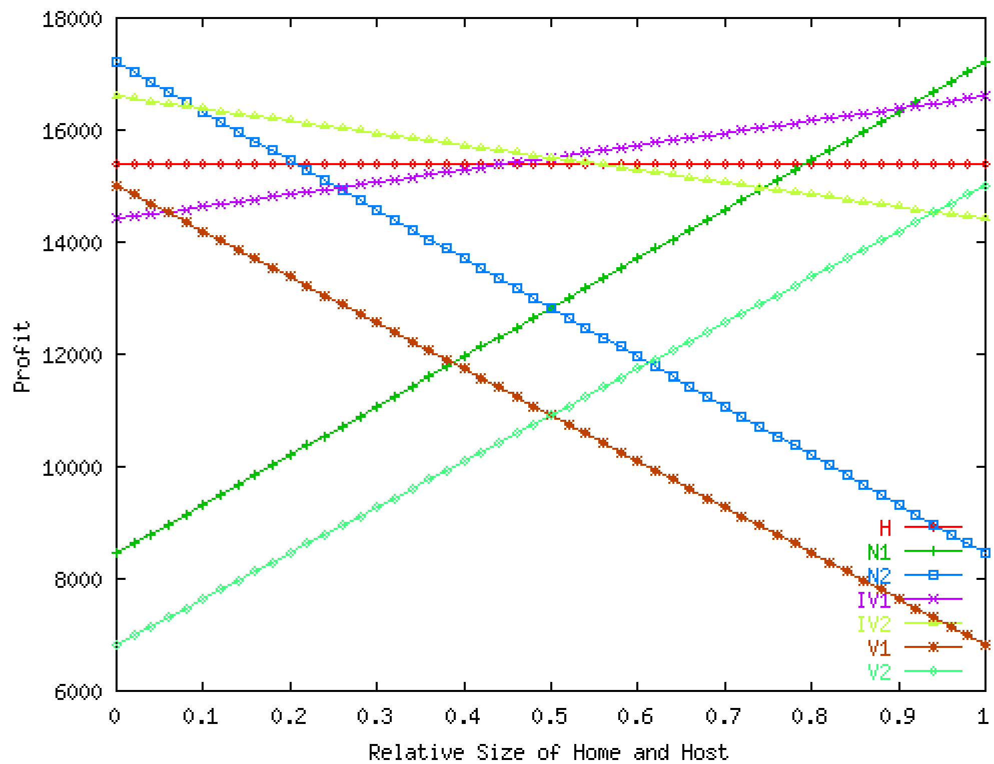

Figure 3.3.1 Trade Costs on Intermediates 25% Lower Than in the Base Case

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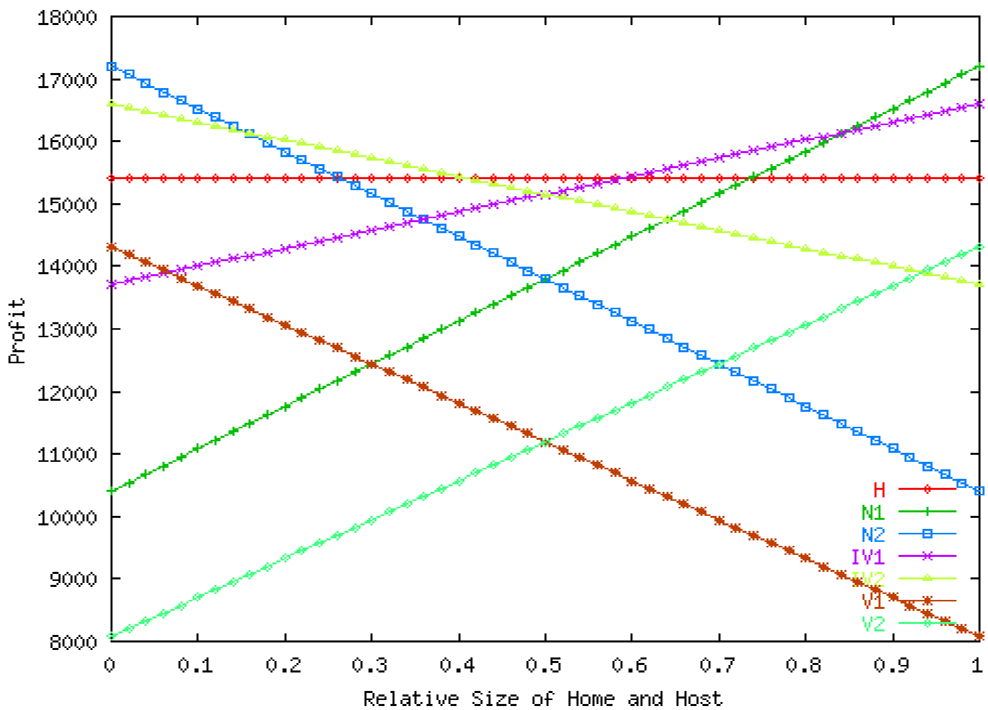

Figure 3.3.2 Trade Costs on Final Goods 25% Lower Than in the Base Case

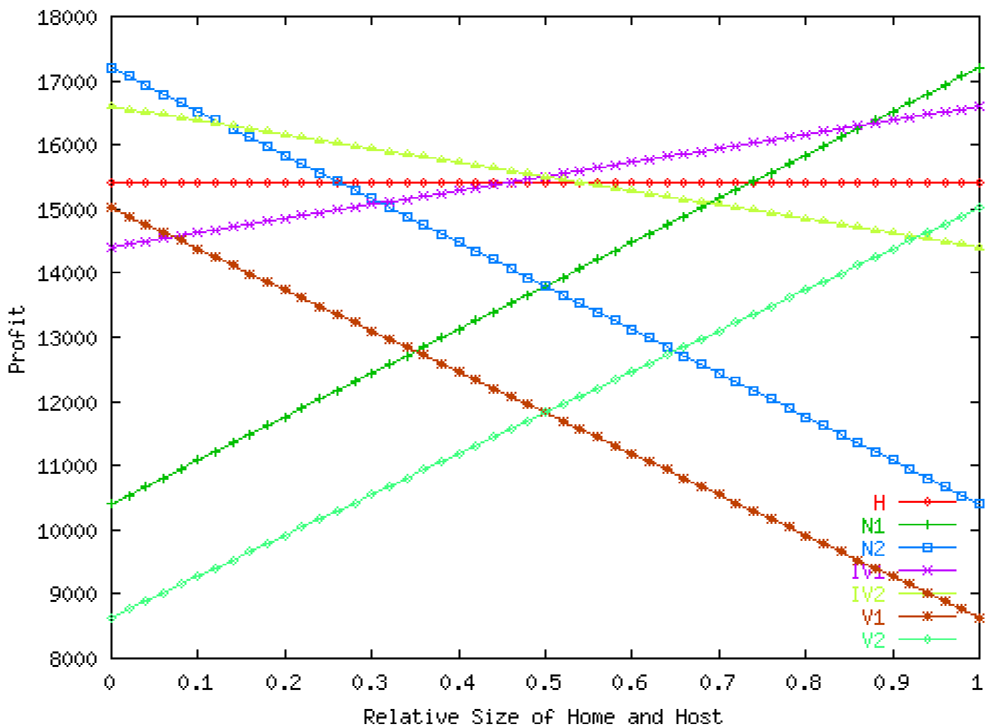

Figure 3.3.3 Trade Costs on Both Intermediates and Final Goods 25% Lower Than in the Base Case

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Figure 3.3.1-3.3.3 show the effects of lowering bilateral trade costs by 25% on intermediates, final goods, and both in turn. The lowering of trade costs makes the type involved in the corresponding trade more preferable than in the base case thus enlarges the dominating region of that type. In figure 3.3.1, a 25% lowering of trade costs on intermediates shifts up type-iv's profit curves, encouraging trade in intermediates rather than a fixed amount spent on a plant producing intermediates. The dominating region of type-iv grows on both sides. On one side, firm is more willing to transport intermediates rather than produce them in the other country (type-h). On the other side, the advantage from lower trade costs on intermediates compensates and gives type-n firm more willingness to pay for fixed cost for an assembly plant. In this particular setting, the 25% lowering of trade costs on intermediates is sufficiently low to make type-iv more favorable than type-h even when countries are identical.

Figure 3.3.2 presents the 25% lowering of trade costs on final goods in which case type-n profit curve shifts up along with a growing dominating region of type-n over type-iv. This is because the lowering of variable trade costs on final goods makes type-n firm more profitable than paying fixed amount in an assembly plant (type-iv). If the trade costs on final goods are sufficiently low, type-n option will be chosen even countries are similar in size. Figure 3.3.3 presents the combination effects of last two cases, in which types involved in trade become more preferable due to the advantage from lower trade costs. The profit of type-h remains the same in all three cases since it is not involved in trades at all.

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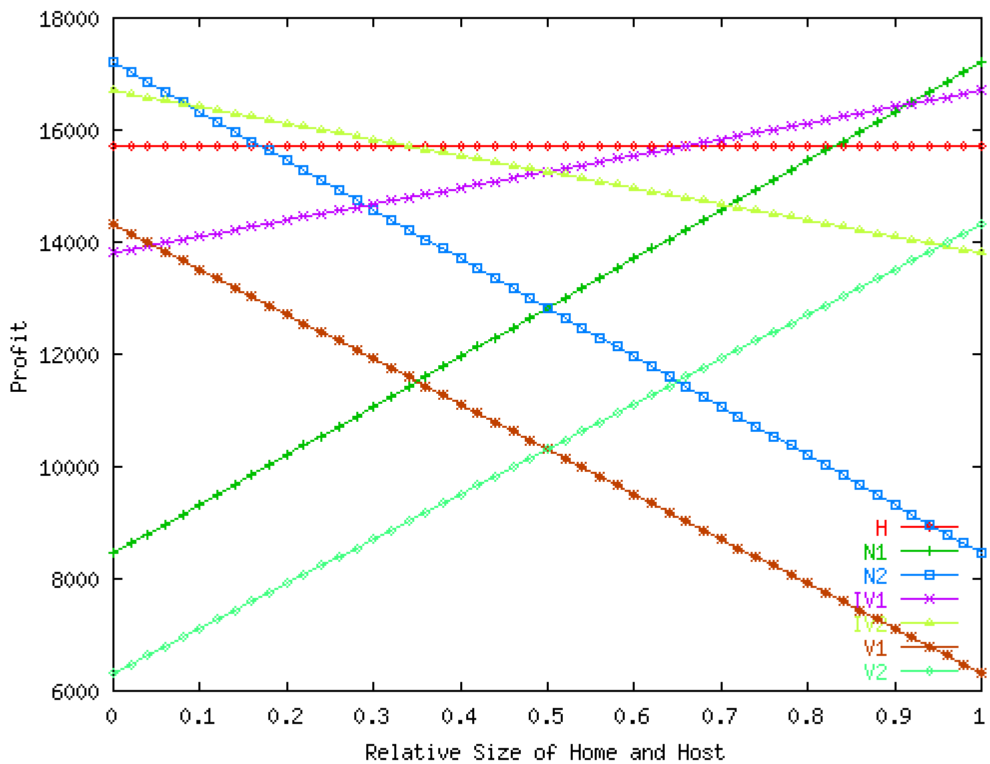

Figure 3.4.1 F Increases While Holding GM/GA and (F + GM + GA) Constant

Figure 3.4.1-3.4.3 illustrate the effects of changes in fixed cost composition. In figure 3.4.1, an increase in firm-level fixed cost (F) while keeping the total fixed costs and ratio of plant-level costs (GM/GA) constant shifts up the profit curves of type-h and type-iv, with more increase on the former type, and has no effect on the profit of type-n or type-v option. Since both plant-level costs are lowered, type-iv firm is more willing to pay for another intermediate plant to become type-h firm, and type-n/type-v firm is more willing to pay for another assembly plant to become type-iv firm. Furthermore, lowering the total plant-level costs while keeping the ratio of plant-level costs constant will lower intermediate plant-level costs more than assembly plant-level costs, as long as an intermediate plant costs more than an assembly plant. This makes the transformation from type-iv to type-h more profitable than that from type-n/type-v to type-iv. Therefore, when firm-level costs are large and important, it is optimal for the firm to become fully or

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partially multinationalized, either from type-n/type-v to type-iv or from type-iv to type-h, depending on the relative size of countries. Given the realistic assumption that an intermediate plant costs more than an assembly plant, more type-iv firms are transformed to type-h than the number of type-n/type-v firms transforming to type-iv. Thus the dominating region of type-iv option is shrinking and moving towards greater differences in country size and the dominating region of type-h option is widened covering more differences in country size. This reaches roughly the same conclusion as in Markusen's model that firms are more likely to be fully/partially multinationalized if firm-level scale economies are more important relative to plant-level scale economies.

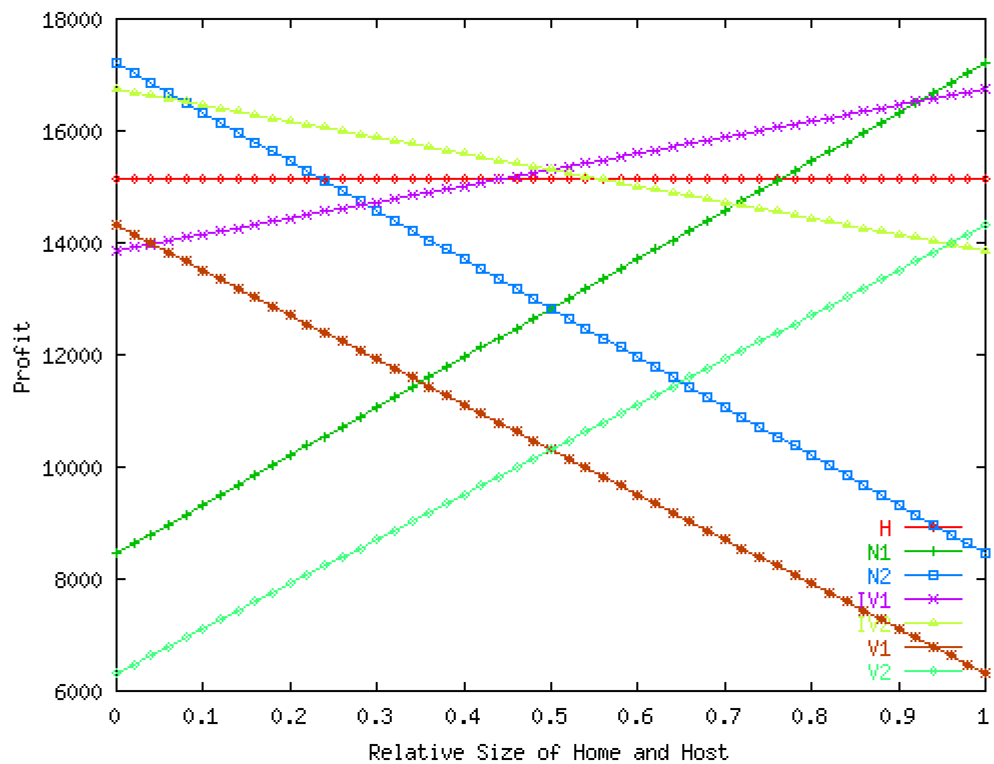

Figure 3.4.2 GM Increases While Holding F/GA and (F + GM + GA) Constant

Figure 3.4.2 presents the result of an increase in intermediate plant-level costs while keeping F/GA and total fixed costs constant. This makes intermediate plant-level costs more important in the total fixed costs. The profit of type-h firm decreases since the

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increase in intermediate plant costs outweighs the decrease in assembly plant costs. It induces type-h firm to shut down one intermediate plant since it is too costly to operate. With the cost for another assembly plant lowered, type-n firm would like to transform to type-iv as long as the variable trade costs can be compensated, depending on the size of the other country. Therefore, the dominating region of type-iv firm grows on both sides. If the plant-level costs for intermediates are sufficiently large, type-iv will be chosen and firm will have only one intermediate plant even countries are similar in size.

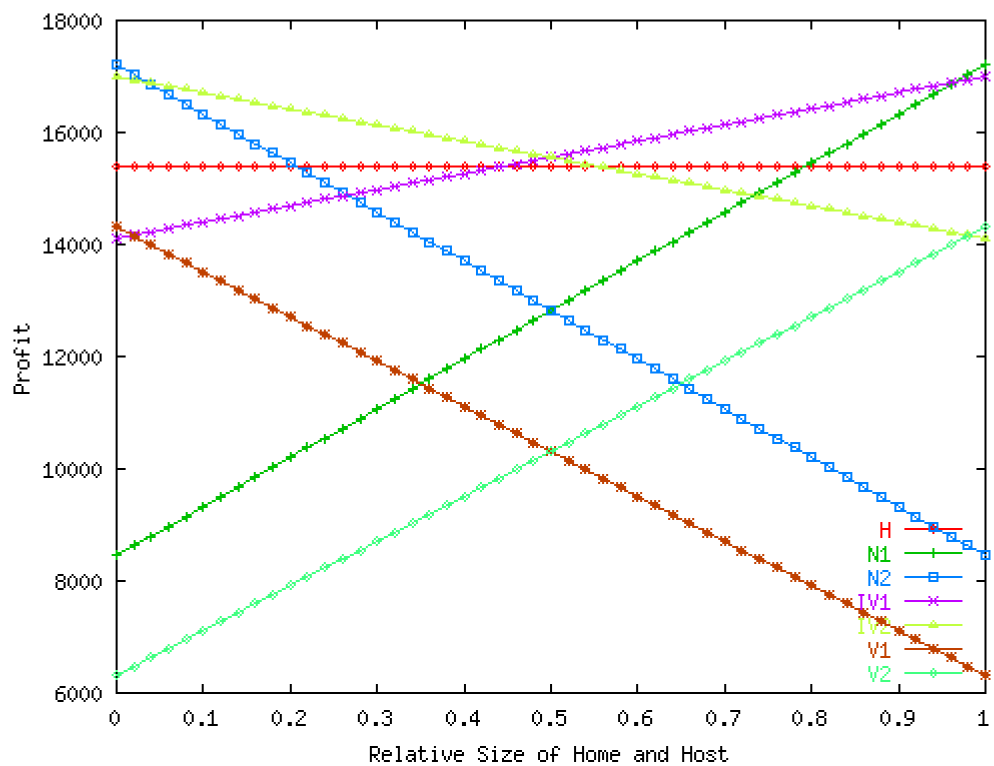

Figure 3.4.3 GM Increases While Holding F and (F + GM + GA) Constant

Figure 3.4.3 illustrates the effects of the relative importance of intermediate plant to assembly plant. For example, if an assembly plant costs marginally to operate, type-n firm would rather switch to type-iv to save variable trade costs. Even though the change in composition of plant-level fixed costs does not affect the profit of type-h firm, the large savings on the intermediate plant will attract type-h firm to transform to type-iv.

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Given that the intermediate plant-level costs are sufficiently large, type-iv will dominate type-h and firm will have only one intermediate plant even when countries are similar in size.

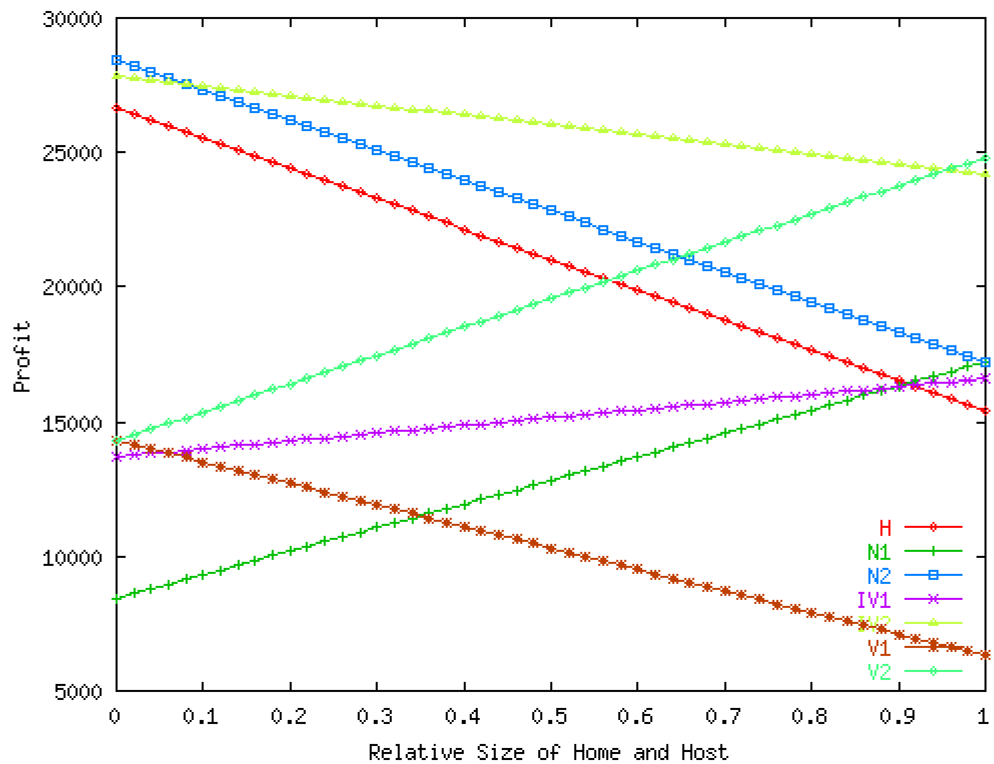

Figure 3.5.1 Marginal Production Cost for Intermediates 25% Lower in Country *j*

Figure 3.5.1-3.5.3 present the effects of different marginal cost across countries. Figure 3.5.1 shows that if marginal production cost for intermediates in country *j* is lowered by 25%, the profit curves of subtype-2 shift up while the profit curves of subtype-1 remain the same level as in the base case since all subtype-1 forms can not take advantage of lower intermediate production costs. Among all subtype-2 options, type-iv will be chosen even when countries are substantially different in size. This is due to the compensating effect that firm has more willingness to pay for an assembly plant when the savings from intermediates production is sufficiently large. If country *i* / *j* is very small,

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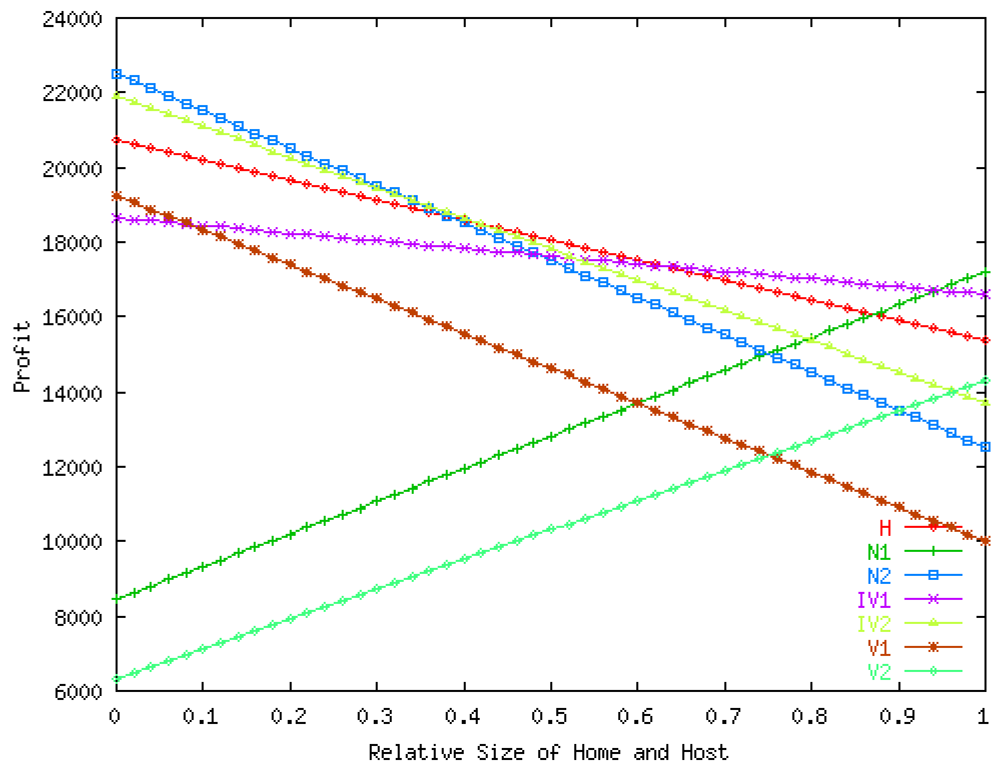

Figure 3.5.2 Marginal Production Cost for Assembly 25% Lower in Country *j*

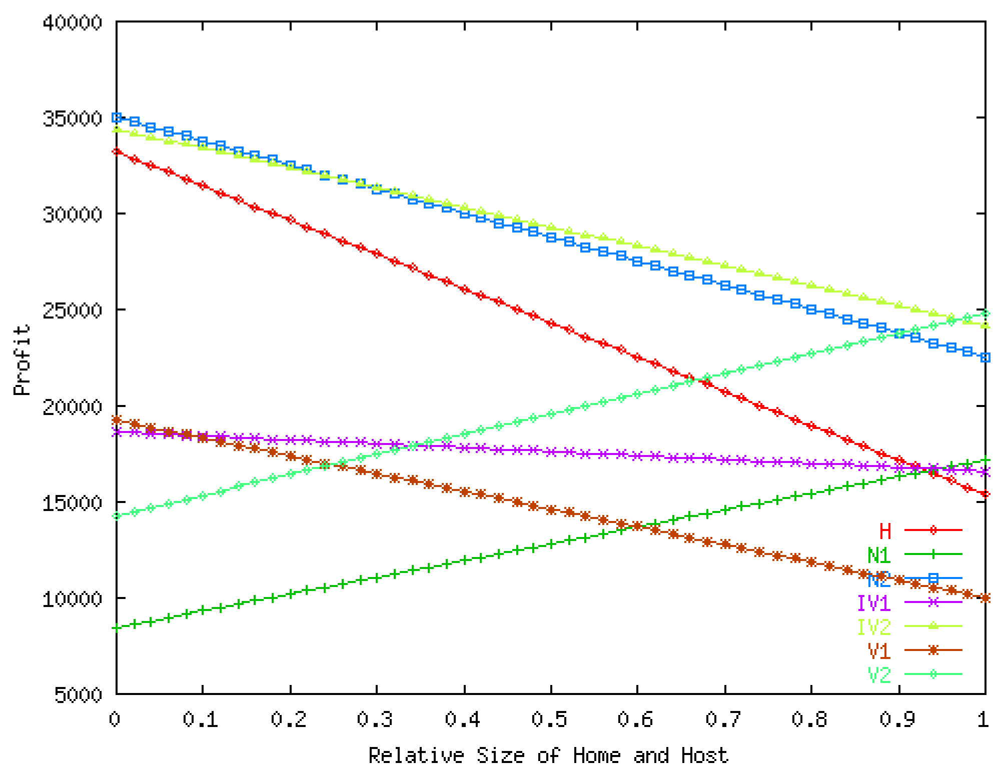

Figure 3.5.3 Marginal Production Costs 25% Lower in Country *j*

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transporting the final goods becomes preferable to setting up an assembly plant in country *i* / *j*, such that type-n / type-v is preferred.

Figure 3.5.2 shows the results with marginal production cost of assembly in country *j* lowered by 25%. When country *i* is relatively small, subtype-2 of type-n and type-iv dominate all other types due to the savings on assembly production in country *j*. Type-iv will dominate type-n when the difference between trade costs on intermediates and on final goods is sufficiently large or the plant-level cost for assembly is sufficiently low. As country *i* grows bigger, increases in trades costs on final goods (type-n) or on intermediates (type-iv) encourages firm to transform to type-h. The dominance of type-h firm remains until country *j* is relatively small when subtype-1 of type-iv and type-n become preferable due to savings on plant-level fixed costs. The dominance of type-iv over type-n follows the same reasoning just mentioned.

Figure 3.5.3 presents the effects of lowering marginal production costs of both intermediates and final goods in country *j* by 25%. The dominance of subtype-2 of type-n and type-iv options is quite obvious since both options fully take the advantage of lower marginal costs. It should be noted that their dominance is independent of relative country sizes. However, when country *i* grows bigger it becomes profitable setting up an assembly plant than bearing growing trade costs on final goods, thus type-iv dominates type-n. When low cost country is extremely small and trade cost on assembly goods are sufficiently high, firm might consider giving up the cost advantage on assembly and operating only one intermediate plant and one assembly plant (subtype-2 of type-v).

Figure 3.5.4-3.5.6 plot the effects of changes in ratio of marginal production costs in country *i* to country *j* keeping the marginal cost in country *j* constant. When marginal

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costs of intermediate/assembly production are quite similar across countries, type-h is preferred; otherwise a single intermediate/assembly plant located in the low marginal cost

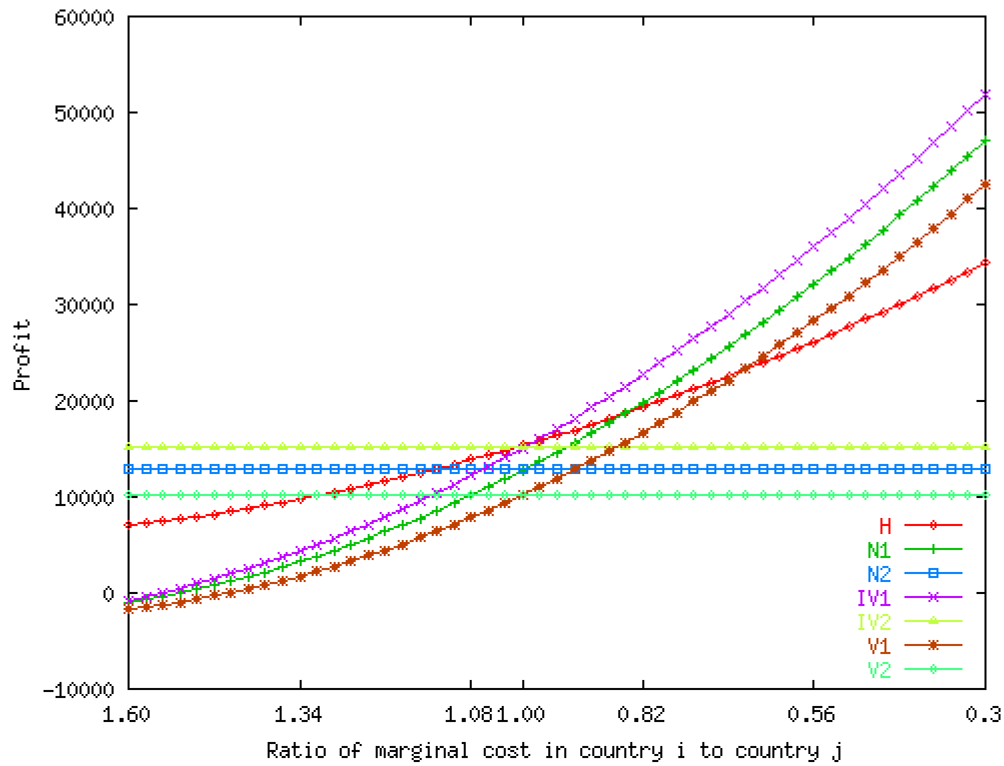

Figure 3.5.4 Ratio of Marginal Production Cost for Intermediates in Country *i* to Country *j*

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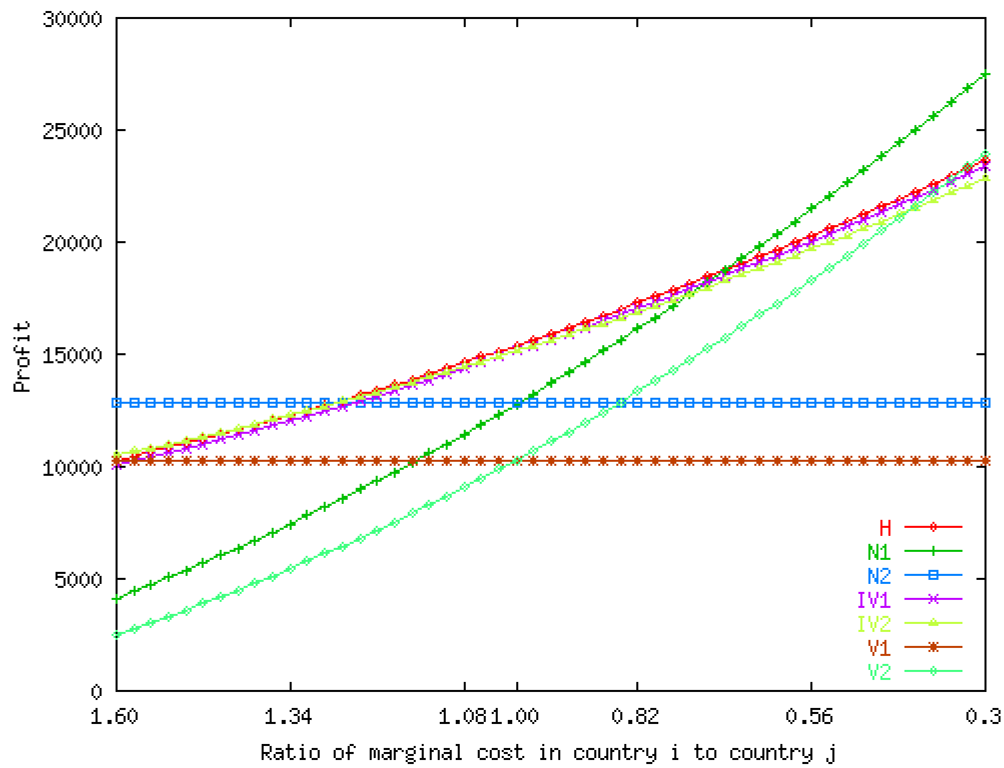

Figure 3.5.5 Ratio of Marginal Production Cost for Assembly in Country *i* to Country *j*

country is chosen. This works the same in 2.5.6, which shows the effects of changes in ratio of marginal costs of both intermediates and assembly in country *i* to country *j*. Firm will choose type-h when marginal costs of intermediates and assembly production are similar across countries. For moderate differences in ratio of marginal costs, type-iv will be chosen and for greater differences, the option with one intermediate and one assembly plant both located in the low cost country is preferred. The dominance of type-iv is due to the compensating effect that the firm is more willing to bear trade costs on intermediates from low cost country to high cost country with the savings from production and one intermediate plant fixed cost. The dominance of type-n will not arise until the savings from production and plant-level fixed costs are large enough to compensate trade costs on final goods.

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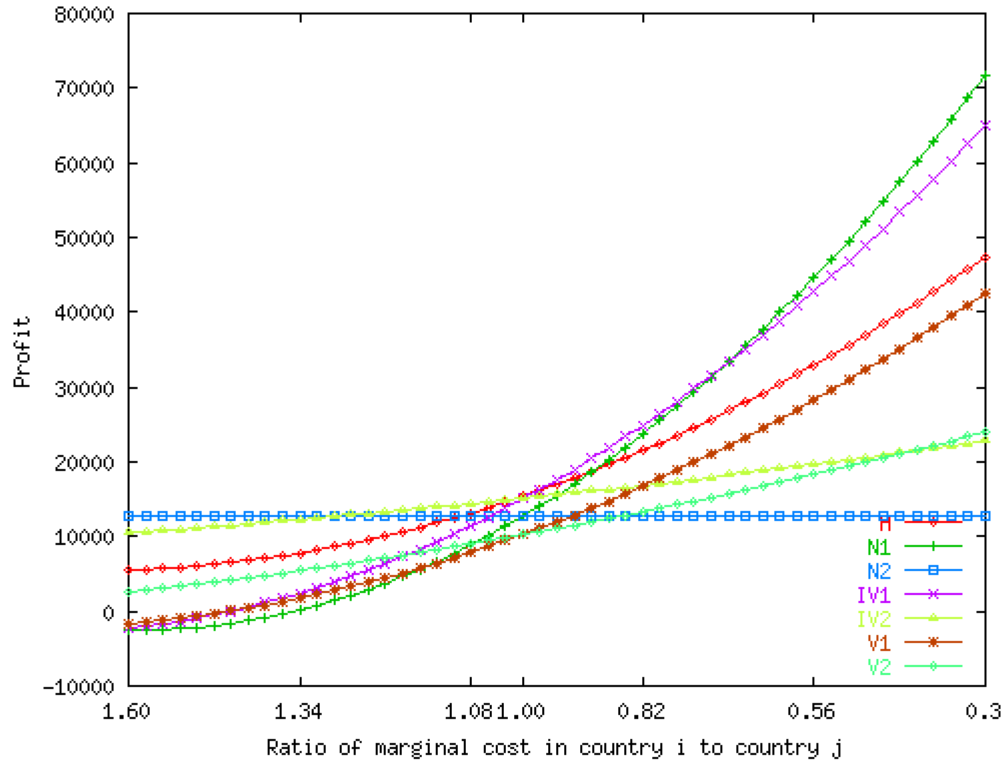

Figure 3.5.6 Ratio of Marginal Production Cost in Country *i* to Country *j*

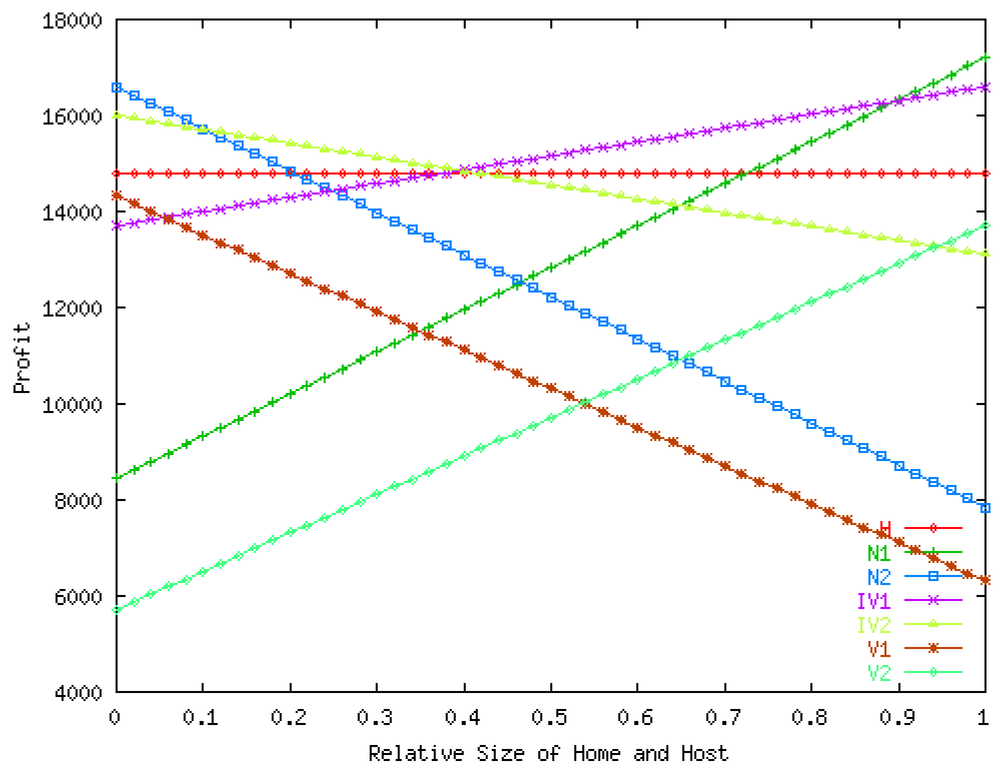

Figure 3.6.1: GM 50% Higher in Country *j*

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Figure 3.6.1-3.6.3 illustrate the effects of technology transfer costs. A firm headquartered in home country *i* usually encounters costs of transferring production technologies or investment barriers in foreign country *j* when the firm setting up plants there. These are added up to plant-level fixed costs. In figure 3.6.1, it costs 50% more to set up an intermediate plant in country *j*. This lowers the profit curves of all types involving in high cost of intermediate plants by the same amounts. Home production of intermediates is preferred since it is cheaper. Figure 3.6.2 presents the results with 50% more costs to establish an assembly plant in foreign country. The profit curves of all options involved in foreign assembly plant shift down by the same amounts. Therefore, home production of assembly becomes more preferable. Figure 3.6.3 considers the case in which all plants cost 50% more to set up in country *j*. The profit of every type of firms is lowered, but by different amounts. Firm is more likely to produce intermediates and

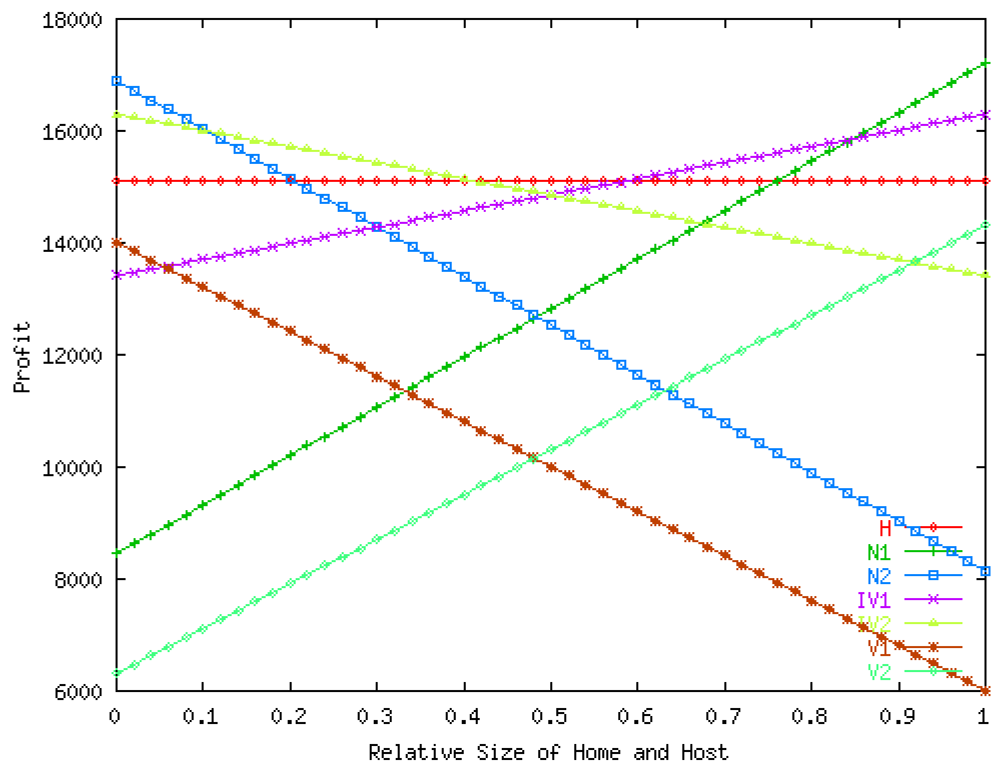

Figure 3.6.2: GA 50% Higher in Country *j*

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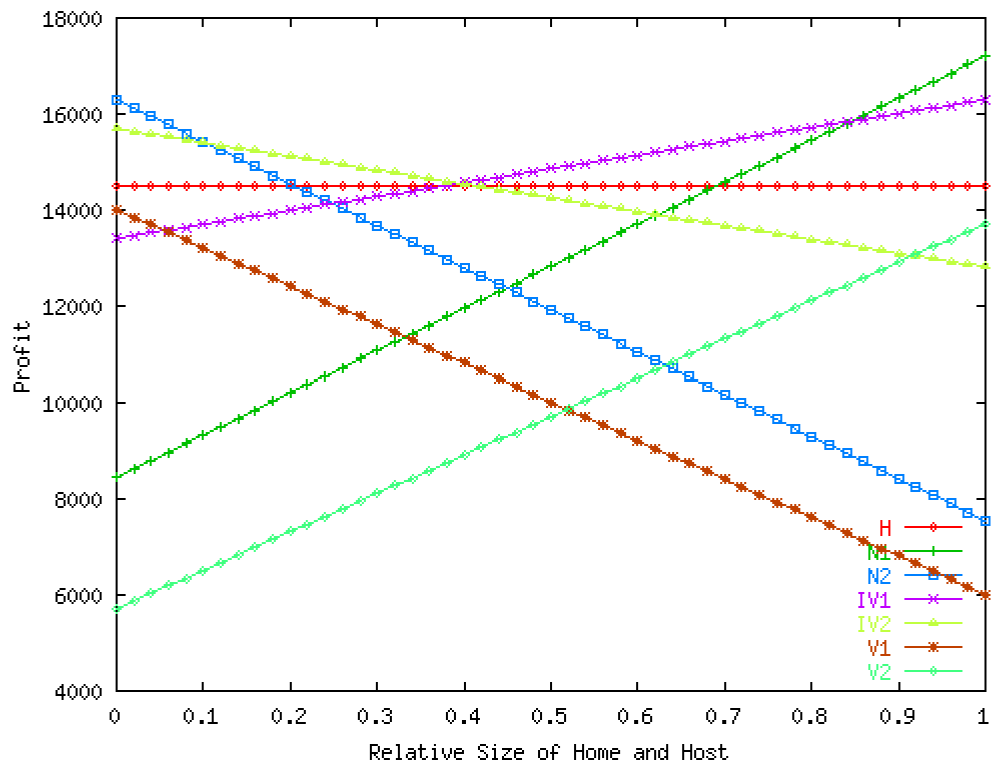

Figure 3.6.3 (GM + GA) 50% Higher in Country *j*

assembly goods in country where there are low set-up costs.

3.4 TRADE COSTS

Besides the market-access motive, factor-price difference motive and firm and plant level scale economies, trade cost differentials in freight, insurance, duties and import/export taxes/subsidies on intermediates and assembly goods gives another explanation for plant location choice.

Compared to intermediates, assembly goods are larger in both size and weight which determine freight costs, and also value more on which insurance rates are based. Thus assembly goods cost more in transportation, one part of trade costs. Duties and taxes/subsidies, imposed by government and composed of mostly the other part of trade costs, vary depending on industry/category, trading partners and the purpose of trade.

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The effect of duty drawback and special import treatment in location choice are demonstrated in the following paragraphs.

Duty drawback is granted to a firm on the imported intermediates which are used in the production of exports. This system is to promote exports by partially or fully compensating exporters for the anti-trade bias imposed by high tariff rates. In context with the fully vertical model, tariffs are waived/rebated on the part of intermediates imported and used in the production for exports, while firm has to bear tariff on intermediates which are used in production for consumption at home. Therefore, duty-drawback advantage is expected to make type-v preferable when market size of the country where intermediates are imported is small.

Some special import treatments give total or partial duty exemptions on imported goods which incorporate domestically produced components and receive further processing and assembly abroad. Even though there exist different methods used for calculating the tariff on re-imported goods, either by value-added or by differential taxation[5], these special treatments provide trade costs alleviation for the corresponding type-v firms. Combining duty-drawback, the full vertical model can be favorable by taking the trade cost advantage beyond production specialization.

3.5 WELFARE ANALYSIS

With a single firm headquartered in home country *i*, country *i*'s welfare is derived from consumption on good *Y*, consumer surplus in consumption on good *X*, and firm's profits in production of *X*. Country *j* gains welfare from consumption on good *Y* and

[5] Yeats (2001) describes the similarity and differences in production sharing provisions compiled by the US International Trade Commission and European Community tariff schedules.

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consumer surplus in consumption on good *X*. Let γ represent the wage rate in terms of the numeraire *Y*. Welfare expressions for country *i* and country *j* under all plant location options are:

$$U_i^H = \frac{3\beta}{2}\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - F - 2G_M - 2G_A + \gamma L_i$$

$$U_i^{N1} = \frac{3\beta}{2}\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_i - c_i - t_j}{2\beta}\right)^2 L_j - F - G_M - G_A + \gamma L_i$$

$$U_i^{N2} = \frac{3\beta}{2}\left(\frac{\alpha - mc_j - c_j - t_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - F - G_M - G_A + \gamma L_i$$

$$U_i^{IV1} = \frac{3\beta}{2}\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j - F - G_M - 2G_A + \gamma L_i$$

$$U_i^{IV2} = \frac{3\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - F - G_M - 2G_A + \gamma L_i$$

$$U_i^{V1} = \frac{3\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m - t_i}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j - F - G_M - G_A + \gamma L_i$$

$$U_i^{V2} = \frac{3\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i + \beta\left(\frac{\alpha - mc_j - c_i - t_i^m - t_j}{2\beta}\right)^2 L_j - F - G_M - G_A + \gamma L_i$$

$$U_j^{N1} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i - t_j}{2\beta}\right)^2 L_j + \gamma L_j$$

$$U_j^{V2} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m - t_j}{2\beta}\right)^2 L_j + \gamma L_j \quad U_j^{IV1} = U_j^{V1} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j + \gamma L_j$$

$$U_j^H = U_j^{N2} = U_j^{IV2} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j + \gamma L_j$$

Country *j* gains equivalent welfare with the same type and number of plants built in country *j*, while country *i* achieves different welfare levels of each type due to the costs and profits associated with the production facilities in country *j*. Given the same marginal production costs of intermediates and assembly goods across countries, country *j*'s

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welfare level depends on the amount of trade costs added up to each unit of products country *j*'s representative agent consumes. Thus, firms with both intermediate and assembly plants located in country *j* (type-h/type-n2/type-iv2) are expected to render the highest welfare/consumer surplus for country *j*. In another word, country *j* prefers local presence of the multinationals. Suppose that the trade cost on intermediates is lower than that on final goods, the type transporting intermediates (type-iv1/type-v1) will yield higher welfare to country *j* than the type shipping final good (type-n1). In the case of duty-drawback, type-v2 is at least equivalent to type-n1 in terms of country *j*'s welfare, and is better when the establishment of intermediate plant in country *j* requires local labors. Otherwise, type-v2 brings the lowest welfare to country *j* since it carries trade costs on both intermediates and assembly goods. Therefore, country *j* is better off with local production unless it is cheaper to import. The greater the trade costs imposed on the goods produced by local production, the more welfare country *j* can gain by shifting from no-local-production option to local-production option.

Even though the firm is indifferent to location options with equal profits, country *i*'s welfare (consumer surplus) can be different. Listed below are comparisons of country *i*'s welfare levels given the equal profits of related options. For example, given that the firm is indifferent between having both intermediate and assembly plants in home country (type-h/type-n1/type-iv1) and having only one assembly plant in home country (type-iv2/type-v2), the representative agent in country *i* can achieve higher welfare level with two plants at home if $mc_i < \left(mc_j + t_i^m\right)$. That is, it is socially optimal to produce at home if it costs more to import, and this applies to both intermediates and finished goods in the following pair-comparisons. In the case of duty-drawback, country *i*'s welfare is

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higher with only one intermediate plant (type-v1) than without any plants (type-n2) as long as the marginal production costs of intermediates in the home country is lower.

$$U_i^{H-N1-IV1} - U_i^{IV2-V2} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i - \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i$$

$$U_i^{H-N1-IV1} - U_i^{V1} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i - \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m - t_i}{2\beta}\right)^2 L_i$$

$$U_i^{H-N1-IV1} - U_i^{N2} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i}{2\beta}\right)^2 L_i - \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j - t_i}{2\beta}\right)^2 L_i$$

$$U_i^{IV2-V2} - U_i^{V1} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i - \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m - t_i}{2\beta}\right)^2 L_i$$

$$U_i^{IV2-V2} - U_i^{N2} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m}{2\beta}\right)^2 L_i - \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j - t_i}{2\beta}\right)^2 L_i$$

$$U_i^{V1} - U_i^{N2} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m - t_i}{2\beta}\right)^2 L_i - \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j - t_i}{2\beta}\right)^2 L_i$$

For country *j*, the pair comparisons of welfare levels under different types of plant locations are listed below. Comparing the firm's type of both intermediate and assembly plants located in country *j* (type-h/type-n2/type-iv2) with that of only a single assembly plant in country *j* (type-iv1/type-v1), country *j*'s representative agent is better off with both plants set up locally as long as $mc_j < \left(mc_i + t_j^m\right)$, assuming the firm has equal profits with all related types. Again, the implication is that country *j*'s welfare will be lower if it has to pay higher costs for imports of intermediates and/or finished goods. Thus it can be inferred that the type(s) with lower costs including marginal production costs and trade

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costs will yield higher welfare level to country *j* no matter how separable those production stages are.

$$U_j^{H-N2-IV2} - U_j^{IV1-V1} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j$$

$$U_j^{H-N2-IV2} - U_j^{V2} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m - t_j}{2\beta}\right)^2 L_j$$

$$U_j^{H-N2-IV2} - U_j^{N1} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_j}{2\beta}\right)^2 L_j - \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i - t_j}{2\beta}\right)^2 L_j$$

$$U_j^{IV1-V1} - U_j^{V2} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j - \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m - t_j}{2\beta}\right)^2 L_j$$

$$U_j^{IV1-V1} - U_j^{N1} = \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_j - t_j^m}{2\beta}\right)^2 L_j - \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i - t_j}{2\beta}\right)^2 L_j$$

$$U_j^{V2} - U_j^{N1} = \frac{\beta}{2}\left(\frac{\alpha - mc_j - c_i - t_i^m - t_j}{2\beta}\right)^2 L_j - \frac{\beta}{2}\left(\frac{\alpha - mc_i - c_i - t_j}{2\beta}\right)^2 L_j$$

Type shift of the multinationals may be induced when host country *j* adjusts trade policies to improve domestic welfare. The mode shift could be either welfare-improving or welfare-worsening for country *j*. For example, given that country *i* is four times the size of country *j*, an increase in trade costs on intermediates to country *j* may induce a mode shift from type-iv1 to either type-h or type-n1, depending on which mode renders higher profits for the firm. Figure 3.7 shows the firm's profits in response to the change in trade costs on intermediates to country *j*. Given the parameter values used in benchmark case, when trade cost on intermediates is higher than 6.1, firm will shift to type-n1, transporting all final products to country *j*. Figure 3.8 is based on the assumption

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that no tariff exists in the benchmark. It shows that country *j*'s welfare decreases in resource using trade cost, but increases if higher trade cost is due to higher tariff collected by country *j*. Since the trade cost higher than 6.1 will induce the multinational firm to shift to type-n1 which is welfare worsening for country *j*, it is optimal for country *j* to keep the trade cost below that level. With combination changes in parameters, cases like this are hardly exhaustible. The fragmentation of production brings in more variables for firms and governments to consider in order to achieve the maximized profits and welfare levels.

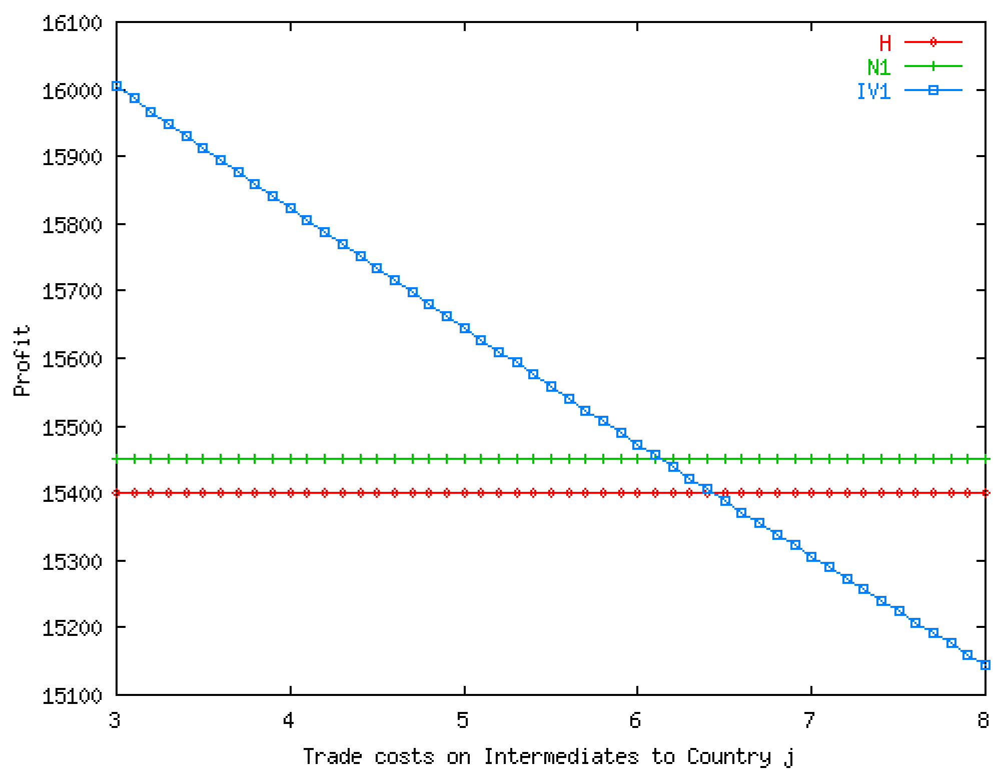

Figure 3.7 Firm's Profit in Response to Change in Trade Costs on Intermediates to Country *j*

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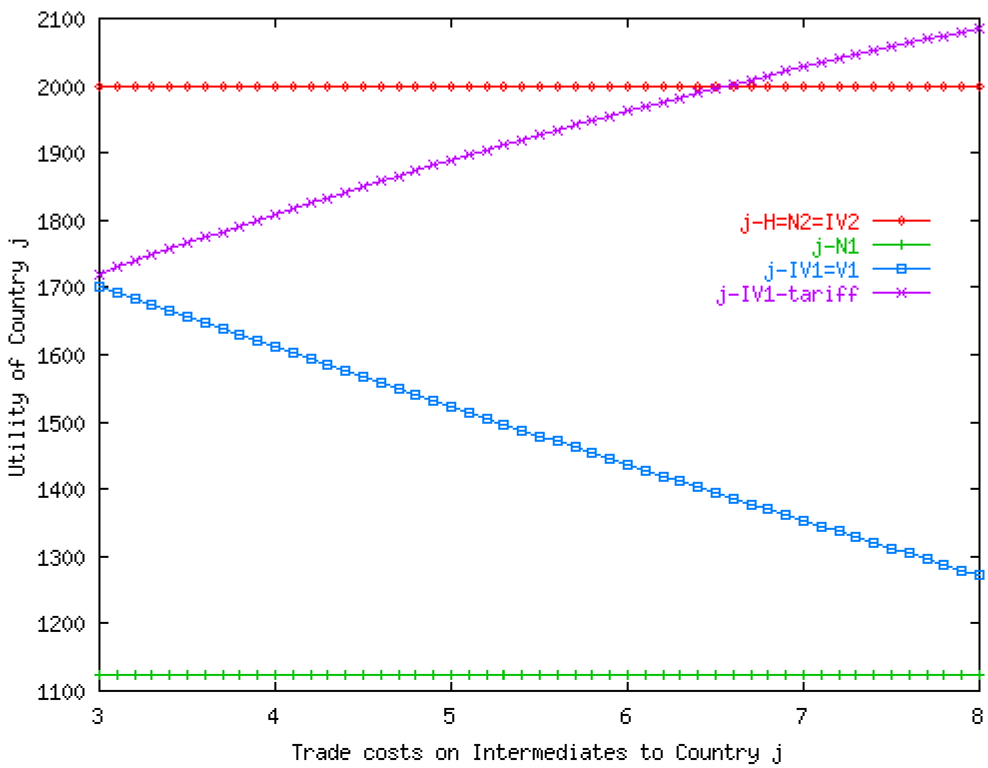

Figure 3.8: Utility in Response to Change in Trade Cost on Intermediates to Country *j*

3.6 SUMMARY

This study follows the principal elements of Markusen's model to further allow separable intermediate production stage. This extension gives firm more plant location options as well as makes the firm more sensitive to the cross-country difference in size, productivity, trade and investment policies and technology. The major contribution is to serve as a theoretical supplement to standard model of pure horizontal and vertical FDI.

Plant location options are categorized into full horizontal (all production stages duplicated in the host country), national (all production stages taking place in one country only), full vertical (intermediate and assembly plant located in different country) and intermediate-vertical assembly-horizontal (single intermediate production plant and duplicate assembly plant). The last two types which are not in the standard model are of

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special interests, and demonstrated to be important when intermediate plant scale economies and trade costs on intermediates are concerned.

The importance of intermediate plant scale economies is fully reflected in the choice of "intermediate-vertical assembly-horizontal" type when countries are of intermediate size differences. This choice is reinforced with low assembly plant-level fixed costs and low trade costs on intermediates. When large across-country difference exists in marginal production costs of intermediates, firm prefers locating intermediate plant in the lower cost country. Whether transporting intermediates for assembly or sending the finished goods to the other country is subject to compensating effect which is whether the firm has willingness to bear the fixed cost of an assembly plant with the savings on the trade costs of transporting intermediates rather than finished goods. This type is also dominant when the firm needs to bear extra costs to transfer intermediate production technology to the host country, thus home production of intermediates is preferred. This effect might become sufficiently large such that the firm prefers single intermediate plant even when the home country is relatively small.

The "full vertical" type is likely to be taken when there exist large cross-country differences in marginal production costs of intermediates and assembled goods along with low trade costs on both. In another word, countries have comparative advantage thus specialize on different production stages, providing factor-price difference motive for the firm. Given a country's comparative disadvantage at assembly production, the firm will consider whether bearing the fixed costs of an assembly plant and higher wage rates for assembly production or bearing the trade costs on intermediates and assembly to supply that country. Some special import treatments such as duty-drawback is discussed and

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shown to favor this location option based on the combination effects of production specialization and trade cost advantage.

Welfare analysis is provided with a simple specific example which could be sensitive to the parameter settings and assumptions yet the main implication remains as in Markusen's study that a country's welfare will be lower if it has to pay higher costs for imports of intermediates and/or finished goods. Consumption of local production is preferred unless it is cheaper to import.

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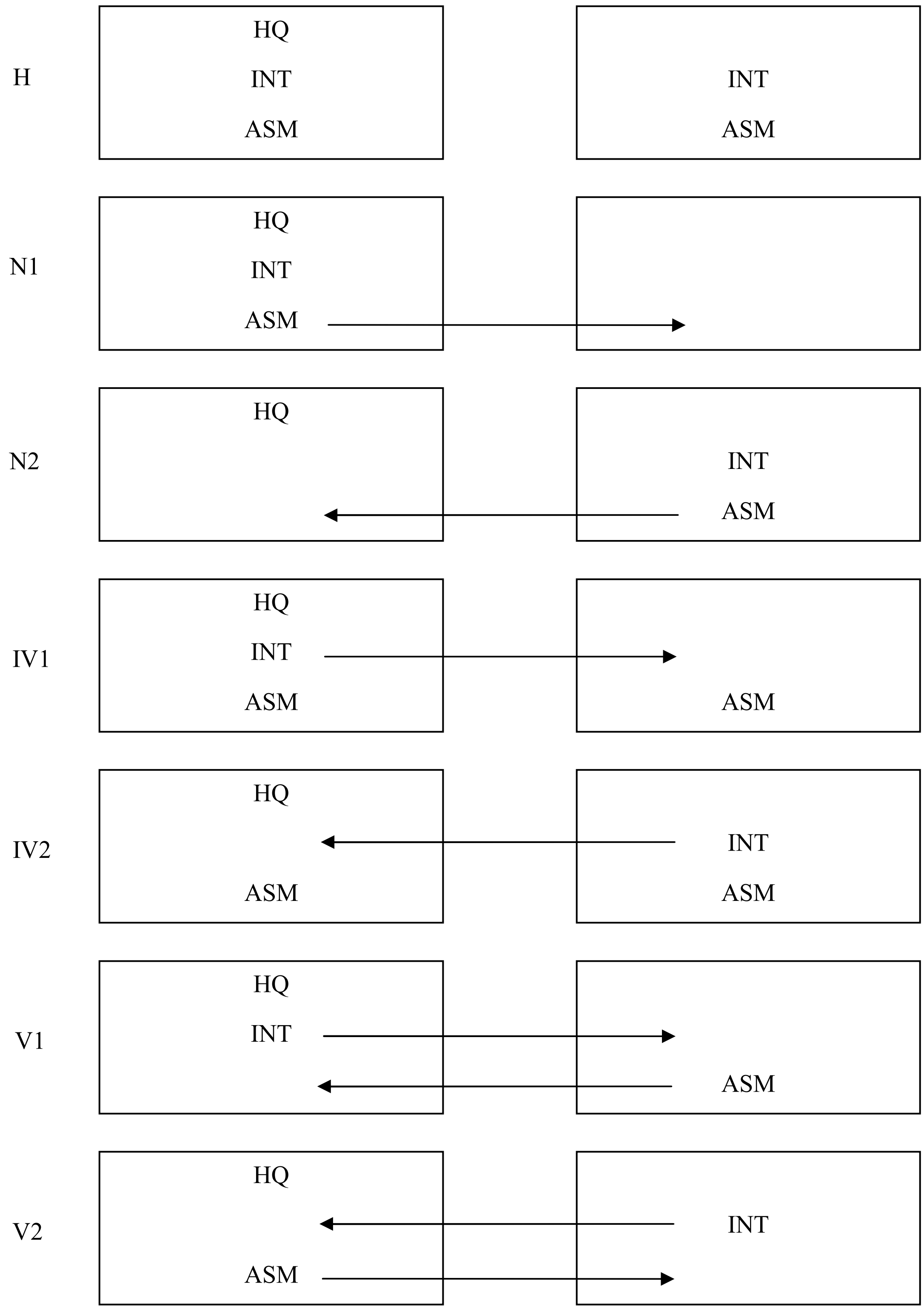

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CHAPTER 4

KNOWLEDGE SPILLOVER FROM FDI

A CGE MONOPOLISTIC-COMPETITION MODEL

4.1 INTRODUCTION

This paper is motivated by a large number of theoretical studies and empirical investigations on knowledge spillover from foreign direct investment (FDI). FDIs combine their advanced production technologies with low factor costs in the host country to conduct second-tier production. Along with the plant establishment in the host country, technical trainings, technology know-how, management skills, marketing techniques and process technologies are provided to the host country in order to maintain the quality level of the production. This increases the knowledge-capital base of the host country, benefiting host country domestic firms when they hire those trained workers to apply higher technology and skills carried with them. Knowledge thus spills over from multinationals to host country domestic firms since they are drawing from the same knowledge pool. Knowledge transmitted in this process is supposed to raise host country domestic firms' productivity and competitiveness with better quality products that consumers are more willing to pay for. Thus the impact of knowledge spillovers can be investigated from consumer's willingness-to-pay (WTP) perspective. That is, as product quality improves, keeping all other things constant, consumers will allocate more budge on that product.

There exist many transmission channels through which knowledge can spill over from one country/firm to another, such as licensing of patented technologies, share

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research projects, scientific publications, international trade and FDI, among which FDI spillover is regarded by many empirical works as an economically important one. Branstetter (2000) bases his work on patent citation and shows FDI as an important channel for knowledge spillover. Estimates from Keller and Yeaple (2002) show approximately 13% of productivity growth in U.S. manufacturing firms over 1987 – 1996 is due to FDI spillover. Their results suggest effect on productivity gains from FDI spillover is stronger than that from imports-related spillovers.

An important assumption of this paper is that productivity growth results in quality improvement. Since knowledge spillover from FDI and domestic firm's productivity gains are positively related, the greater the amount of spillover is received, the more the productivity increases and the more the quality upgrades.

A line of literature on quality argues that product quality affects consumer's WTP. Consumers would like to pay more for better quality. With the quality of one product in the consumption bundle improves relative to other products, consumers are expected to adjust their budget shares accordingly. Therefore, the change in product quality assumed as a result of productivity gain from knowledge spillover can be assessed by consumer's perception to the change, a WTP problem.

The following questions are not of my interests thus not in the scope of this paper. First, how and how much knowledge is transmitted from FDI to host country domestic firms. Second, how and how much productivities are raised. Third, how and how much product quality is improved through productivity gains.

The focus of this study is on the effect of investment liberalization and the effect of knowledge spillover to multinational and domestic firms in both countries in terms of

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factor prices, welfare, trade, affiliate production and domestic production. A computable general equilibrium (CGE) monopolistic-competition model is built to provide quantitative analysis for this purpose. The experiments with the model are based on three scenarios which differ in the existence of multinational firms and the degree of knowledge spillover.

1. NL "no liberalization" multinational firms prohibited.
2. IL "investment liberalization" multinational firms allowed producing in country *j*, no knowledge spillover to domestic firms in country *j*.
3. KS "knowledge spillover" multinational firms allowed producing in country *j*, knowledge spillover available to domestic firms in country *j*.

In all scenarios, the trade in high quality goods from *i* to *j* are allowed and subject to 33 percent trade costs. I consider two types of experiments. First, the effect of investment liberalization can be examined by going from NL to IL. Second, the impact of certain degree of knowledge spillover with the presence of FDI in country *j* is investigated by running from IL to KS. The assumption that trade-related spillover does not exist is made to guarantee all knowledge spillovers are from multinational firms' affiliate production only.

The consumer's perception of local firm's quality improvement through knowledge spillover is modeled with a demand shifter in consumer's utility maximization problem. With no empirical support on the changes in preference with respect to a certain amount of quality improvement, the simulation results are based on the changes in related parameters within an arbitrary range, and are made to provide implications from an illustrative perspective.

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The theoretical framework in this paper does not take heterogeneity of individual perceptions of quality level into consideration. Instead, a representative consumer is employed for each country on the demand side in the analysis. On the supply side, firms headquartered in the home country are potential multinationals with two options only, either being a national firm exporting to the foreign country or being a multinational firm with affiliate production abroad. All domestic firms in the foreign country are assumed identical in quality produced and in absorptive capacity with respect to knowledge spillover from FDI.

The rest of the paper is organized as follows. Section 4.2 provides model formulation and basic equations and inequalities for numeric simulation. Numeric general equilibrium model is presented in section 4.3. Section 4.4 gives base calibration of the simulation model. Section 4.5 considers the effects of investment liberalization and knowledge spillover on the factor prices and welfare in two countries. Section 4.6 considers the effect of fixed cost composition and scale in investment liberalization and knowledge spillover. The world Edgeworth box examinations with respect to the change in real and relative factor prices and the change in welfare are presented in section 4.7. The last section includes summary and policy implications on intellectual property protection.

4.2 MODEL FORMULATION

This is a two-country (home country i and foreign country j), two-good (manufacturing good X and agricultural good Y), two-factor (skilled labor S and unskilled labor L) general equilibrium monopolistic-competition model for an open economy. It is

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assumed that home country and foreign country are identical in size, with home country being relatively skilled-labor abundant and foreign country relatively unskilled-labor abundant. Both agricultural goods and manufacturing goods are produced with skilled and unskilled labors. Agricultural production is unskilled-labor intensive, perfectly competitive and subject to constant return to scale. Agricultural good is homogeneous, and regarded as numeraire. Market for manufacturing goods is characterized as monopolistically competitive. Manufacturing production exhibits increasing return to scale, and is produced intensively with skilled labor. The assumption of large-group monopolistic competition is applied to ensure that individual firms are too small to influence the composite price of the group and output per firm remains constant.

Two quality levels of manufacturing goods are produced. High-quality goods are produced only by firms headquartered in skilled-labor-abundant country i and low-quality goods are produced only by domestic firms in skilled-labor-scarce country j. Each firm in country i has two options in firm type, type-d (domestic) or type-h (horizontal multinational). It is assumed that there are unlimited, identical potential entrants for each firm type. Both types of firm are headquartered in country i, with the domestic type keeping all production facilities along with headquarters in the same location while multinationals duplicating production facilities in country j. All firms headquartered in country j are of type-d. Their products are produced and consumed in country j only.

The perception of local firm's quality improvement through knowledge spillover with the presence of FDI is modeled as a consumer's willingness-to-pay problem. As product quality of local firms in country j upgrades and approaches high quality level

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produced by country *i* firms, consumers in the foreign country are more willing to pay for, thus allocating more budgets on those low-quality products. In this sense, willingness to pay is greater in magnitude the greater local firm's product quality improves. For the simplicity of analysis, welfare functions for country *i* and country *j* can be formulated in Cobb-Douglas form as: (Note that more general CES formulations are allowed and can be easily implemented in the computable model coded in GAMS/MPSGE.)

$$U_i = X_i^{\gamma_i} Y_i^{1-\gamma_i} \quad (1)$$

$$U_j = \left[(\beta X_j)^{\alpha\beta} X_{ij}^{1-\alpha\beta}\right]^{\gamma_j} Y_j^{1-\gamma_j} = \beta^{\alpha\beta\gamma_j} \cdot \left[X_j^{\alpha\beta} X_{ij}^{1-\alpha\beta}\right]^{\gamma_j} Y_j^{1-\gamma_j} \qquad (\beta \geq 1) \quad (2)$$

Where Y_i and Y_j are homogeneous agricultural goods. X_i and X_j represent high-quality and low-quality manufacturing goods produced by firms headquartered in country *i* and country *j*, respectively. X_{ij} is the high-quality manufactures produced by firms headquartered in country *i* and consumed in country *j*. γ_i and γ_j denote value share of manufacturing goods in total consumption in home country *i* and foreign country *j*, respectively. The value share of low-quality and high-quality manufactures in country *j* are represented as $\alpha\beta$ and $1-\alpha\beta$. These utility functions also show that the representative agent in country *i* consumes high-quality manufacturing goods and agricultural products only, while country *j* demands all quality level manufacturing and agricultural goods.

Designed as a demand shifter, β can be interpreted as consumer willingness to pay for low-quality products. It increases as local firms in the foreign country improve product quality with productivity gains through spillovers. β can also be understood as a proxy for the degree of intellectual property protection (IP) in foreign country. A high

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value of β represents low degree of IP protection thus high degree of knowledge spillover to local firms in the foreign country followed by greater quality improvement of low-quality goods which consumers are more willing to pay for. The adjustment of this key variable can bring out two effects. For example, if β increases, first, consumers gain more welfare from manufacturing goods consumption, which is suggested by β as a coefficient term; and secondly, consumers allocate more budgets away from high-quality towards low-quality goods, which is suggested by the value share of low-quality goods in the exponent.

The effect on the welfare of knowledge-spillover receiving country j is illustrated in figure 4.1. All notations follow the definition provided above. Given that β equal to one represents no knowledge spillover, the consumption of one unit of high quality goods and one unit of low quality goods yields one unit of utility. β greater than one indicates consumer preferences shift away from high quality goods towards low quality goods. Thus, the ratio of marginal willingness to pay for low quality and high quality X is higher. Equivalently speaking, this yields a higher marginal rate of substitution (MRS) which is shown in the graph as a steeper MRS line tangent to a steeper indifference curve (the thick black curve) going through one-one consumption point. Even with the same amount of consumption, this thick indifference curve represents higher utility level than the one with no spillover. This is due to scaling effects on manufacturing consumption. Thus the dotted curve is drawn to the left of this new indifference curve to represent unity utility level with knowledge spillover.

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Both countries employ the same production technology in agricultural goods, which are produced from skilled labor S and unskilled labor L and are subject to frictionless trade. [6]

$$Y_c = S_{yc}^{\theta} L_{yc}^{1-\theta} \qquad c = i, j \qquad (3)$$

The value marginal products of S and L are wage rate r and w, respectively:

$$r_c = \theta \left(\frac{S_{yc}}{L_{yc}} \right)^{\theta - 1} \qquad w_c = (1-\theta) \left(\frac{S_{yc}}{L_{yc}} \right)^{\theta} \qquad c = i, j \qquad (4)$$

Manufacturing goods are produced by monopolistic competitive firms, each of which makes a unique variety. All varieties produced by firms headquartered in country i are of high quality, and all varieties by firms headquartered in country j are of low quality. All manufacturing productions have the same markup regardless of product quality level. Assume no price discrimination so that high quality product export price equals local sales price. Further assume that domestic firms and multinationals in country i incur the same marginal cost so they charge the same price in the same country of sales.

In equilibrium, the X sector makes zero profits so country incomes M_i, M_j are given by total factor payments

$$M_c = w_c L_c^* + r_c S_c^* \qquad c = i, j$$

where S_c^* and L_c^* are total factor endowments of country c.

Given the Cobb-Douglas utility from consumption on X and Y in each country, demands for manufacturing and agricultural goods are

$$X_{ii} = \left[N_i^d (x_{ii}^d)^{\rho} + N_i^h (x_{ii}^h)^{\rho} \right]^{1/\rho} = \gamma_i M_i / e_i \qquad 0 < \rho < 1 \qquad (5)$$

---

[6] The derivation onward of zero profit, market clearance and income balance conditions closely follows Markusen (2002).

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$$X_{ij}=\left[N_i^d(x_{ij}^d/t)^\rho+N_i^h(x_{ij}^h)^\rho\right]^{1/\rho}=(1-\alpha\beta)\gamma_j M_j/e_{ij} \qquad i\neq j \qquad (6)$$

$$X_{jj}=\left[N_j^d(x_{jj}^d)^\rho\right]^{1/\rho}=\alpha\beta\gamma_j M_j/e_j \qquad (7)$$

$$Y_c=(1-\gamma_c)M_c \qquad c=i,j \qquad (8)$$

where the first subscript of two-letter subscripts stands for products firm's headquarter country and the second stands for product consuming country. The superscript denotes the firm type, *d* for domestic and *h* for horizontal multinationals. N_c^k (*k*=*d, h, c*=*i* , *j*) represents the number of type-*k* firms headquartered in country *c*. X_{ic} denotes the consumption of high quality *X* in country *c*, and X_{jj} is the consumption of low quality *X* in country *j*. With each firm producing a unique variety, the CES aggregate consumption of each quality level in country *i* and *j* are presented using $1/(1-\rho)$ as elasticity of substitution among varieties. Let e_i denote the price index of high-quality products in country *i*, and e_j denotes the price index of low-quality products in country *j*.

Trade in high-quality *X* is subject to an ice-berg trade cost so that *t* (*t* >1) units need to be shipped in order for one unit ("unmelted") to arrive in country *j*. If x_{ij}^d is shipped for each individual variety of high quality, x_{ij}^d/t is received by country *j*. Exporter in country *i* receives p_i on each unit of traded manufactures, so the total revenue collected is $p_i x_{ij}^d$ per variety which equals the total payment by importer in country *j* on those unmelted units (x_{ij}^d/t). This gives the price per unit of imports as $p_i t$. Under the assumption that multinational firms charge the same price as import in country *j*, hence the consumption price of high-quality goods in country *j* is $e_{ij}=e_i t$. Price of *Y* is

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normalized to unity since it is numeraire. Thus, first-stage budgeting solves the aggregate demands for X and Y in each country in terms of value share, total income and price index.

The second-stage budgeting yields the demand for a given X variety (denoted by lower case x with related sub- and super- scripts) and price indexes by maximizing subutility from manufacturing goods consumption subject to expenditure constraint. In country i,

$$Max \quad X_{ii} = \left[N_i^d (x_{ii}^d)^\rho + N_i^h (x_{ii}^h)^\rho\right]^{1/\rho} + \lambda\left[\gamma_i M_i - p_i (N_i^d x_{ii}^d + N_i^h x_{ii}^h)\right] \qquad (9)$$

Similar formulation applies to X_{ij} and X_{jj}, the consumption of high quality and low quality manufactures in country j, respectively. The standard procedure of first-order condition and substitution leads to

$$x_{ii}^d = x_{ii}^h = p_i^{-\sigma} e_i^{\sigma-1} \gamma_i M_i \qquad \sigma = 1/(1-\rho) \qquad (10)$$

$$x_{ij}^d / t = (p_i t)^{-\sigma} e_{ij}^{\sigma-1} (1-\alpha\beta) \gamma_j M_j \qquad (11)$$

$$x_{ij}^h = (p_{ij})^{-\sigma} e_{ij}^{\sigma-1} (1-\alpha\beta) \gamma_j M_j \qquad p_{ij} = p_i t \qquad (12)$$

$$x_{jj}^d = p_j^{-\sigma} e_j^{\sigma-1} \alpha\beta\gamma_j M_j \qquad (13)$$

where price indexes are expressed in price of individual variety denoted by p, number of supplying firms and elasticity of substitution σ. Note that x_{ij}^d / t is equivalent to x_{ij}^h given the assumption that same quality sells for the same price in each country. Consumption price index for each quality level manufacturing goods in each country can be written as follows,

$$e_i = \left[N_i^d p_i^{1-\sigma} + N_i^h p_i^{1-\sigma}\right]^{1/(1-\sigma)} \qquad (14)$$

$$e_{ij} = \left[N_i^d (p_i t)^{1-\sigma} + N_i^h p_{ij}^{1-\sigma}\right]^{1/(1-\sigma)} = e_i t, \qquad (15)$$

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$$e_j = \left[N_j^d p_j^{1-\sigma}\right]^{1/(1-\sigma)} \quad (16)$$

Each individual variety of manufacturing goods has a cost structure consisting of fixed costs and marginal costs. All fixed costs are spent on skilled labor, and marginal costs are comprised of both factors of production. Cost functions for type-d and type-h firms are written, respectively, as:

$$TC_i^d = f_i^d + mc_i \cdot (x_{ii}^d + x_{ij}^d) \quad (17)$$

$$TC_i^h = f_i^h + mc_i \cdot x_{ii}^h + mc_j \cdot x_{ij}^h \quad (18)$$

$$TC_j^d = f_j^d + mc_j \cdot x_{jj}^d \quad (19)$$

where f_c^k and mc_c are fixed cost function and marginal cost function for type-*k* firm in country *c*, respectively. Total costs of domestic type of firms are comprised of skilled labor and unskilled labor in the local markets. For MNE, the fixed costs consist of skilled labor in both countries, and the marginal costs are expenditures on factors of production in the markets where plants are located.

Assume that fixed costs and marginal costs in X production are of identical fixed-coefficient for all firm types and countries. This implies that the same amount of each factor is required for one unit of production for all firm types and countries. Thus the marginal costs can be written as the sum of product of factor prices and unit factor demands as follows,

$$mc_c(w_c, r_c) = w_c mc_w + r_c mc_r \qquad c = i, j \quad (20)$$

where w_c and r_c are factor prices for unskilled and skilled labors in country *c*, respectively. mc_w and mc_r are unit factor demands derived by Shepard's lemma as the derivatives of

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marginal costs with respect to unskilled and skilled labor. Given the assumption above, these unit factor demands are constant regardless of firm type and country.

$$f_i^d = f(r_i) = r_i F_i^d + r_i G \qquad (21)$$

$$f_i^h = f(r_i, r_j) = r_i F_i^h + r_i G + r_j F_j^h + r_j G \qquad (22)$$

$$f_j^d = f(r_j) = r_j F_j^d + r_j G \qquad (23)$$

Equations (21)-(23) show the compositions of fixed cost for each firm type on headquarters and production plants. Firm-level fixed costs are denoted by *F* measured in units of skilled labor, with subscripts representing headquarters country and superscripts the firm type. Plant-level fixed costs G measured in units of skilled labor are assumed the same for all firm types and countries.

$$F_i^d < F_i^h < F_i^h + F_j^h < 2F_i^d \qquad (24)$$

The fixed-cost assumption presented in equation (24) reflects jointness[7] property which Markusen defines in his knowledge-capital model as "the ability to use the engineer or other headquarters asset in multiple production locations without reducing the services provided in any single location". A high degree of jointness means an additional plant costs relatively small, giving rise to the firm-level scale economies which leads to the horizontal multinationals. Equation (24) shows the jointness assumption that the skilled-labor requirements for a type-h firm are greater than, but less than double, the skilled-labor requirements for a type-d firm. This equation also shows that the total fixed costs of a multinational are comprised of skilled labors from both countries. The first

[7] Markusen defines jointness in his knowledge-capital model and regards jointness as the motive for horizontal multinationals.

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inequality indicates that managerial and coordination activities require some additional home country skilled labor for multinationals.

The total factor endowments in a country are the sum of the factor demands of productions in all sectors. The skilled labor demands in country *i* come from *Y* production, N_i^d domestic firms and N_i^h multinational firms in *X* sector. Let c_{yr} denote unit factor demand for skilled labor in *Y* production. Total skilled labor endowment in country *i* is given by

$$S_i^* = c_{yr} Y_i + N_i^d \left[mc_r (x_{ii}^d + x_{ij}^d) + F_i^d + G \right] + N_i^h (mc_r x_{ii}^h + F_i^h + G) \qquad (25)$$

Similarly, total skilled labor endowment in country *j* is

$$S_j^* = c_{yr} Y_j + N_j^d (mc_r x_{jj}^d + F_j^d + G) + N_i^h (mc_r x_{ij}^h + F_j^h + G) \qquad (26)$$

The trade balance requires that exports of *Y* from country *j* to country *i* equal the imports of high-quality *X* from country *i*. Trade in *Y* is frictionless,

$$N_i^d p_i x_{ij}^d = Y_{ji} = Y_j^p - Y_j^c \qquad (27)$$

where Y_{ji} is the agricultural goods traded from country *j* to country *i*, the difference of country *j*'s production and consumption on *Y*. x_{ij}^d is the manufacturing goods produced by a domestic firm in country *i* and traded to country *j*. N_i^d denotes the number of country *i* domestic firms exporting to country *j*.

Equilibrium in manufacturing sector is determined by pricing equations (marginal revenue equals marginal cost) and free-entry or zero-profit (price equals average cost) conditions. Marginal revenue of an individual type-d firm headquartered in country *i* is

$$MR_{ii}^d = \frac{dTR_{ii}^d}{dx_{ii}^d} = \frac{d\left[p_i \cdot x_{ii}^d\right]}{dx_{ii}^d} = p_i + x_{ii}^d \frac{\partial p_i}{\partial x_{ii}^d} = p_i \left[1 + \frac{x_{ii}^d}{p_i} \frac{\partial p_i}{\partial x_{ii}^d}\right] = p_i \left(1 - \frac{1}{\eta}\right) \qquad (28)$$

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Given the assumption of large-group monopolistic competition, individual firm takes price index and income as constant, thus the elasticity of demand for an individual variety is given by the elasticity of substitution among varieties (σ). The markup is the reciprocal of σ. The output per firm/variety and the number of firms/varieties can be solved from a system of optimization conditions which are formulated as a nonlinear complementary problem – a set of inequalities each associated with a non-negative variable.

$$p_i(1-1/\sigma) \le mc_i \qquad (x_{ii}^d) \qquad (29)$$

$$p_i(1-1/\sigma) \le mc_i \qquad (x_{ij}^d) \qquad (30)$$

$$p_i(1-1/\sigma) \le mc_i \qquad (x_{ii}^h) \qquad (31)$$

$$p_i t(1-1/\sigma) \le mc_j \qquad (x_{ij}^h) \qquad (32)$$

$$p_j(1-1/\sigma) \le mc_j \qquad (x_{jj}^d) \qquad (33)$$

In inequalities (29)-(33), the output is positive if the associated inequality holds as equality in equilibrium, and zero otherwise. Zero-profit conditions require that all profits are spent on fixed costs, thus these free-entry conditions determining the number of active firms of each type are written as markup revenues less than and equal to fixed costs.

$$p_i x_{ii}^d + p_i x_{ij}^d \le mc_i(x_{ii}^d + x_{ij}^d) + r_i(F_i^d + G) \qquad (N_i^d) \qquad (34)$$

$$p_i x_{ii}^h + p_i t x_{ij}^h \le mc_i x_{ii}^h + mc_j x_{ij}^h + r_i(F_i^h + G) + r_j(F_j^h + G) \qquad (N_i^h) \qquad (35)$$

$$p_j x_{jj}^d \le mc_j x_{jj}^d + r_j(F_j^d + G) \qquad (N_j^d) \qquad (36)$$

Multiply both sides of (29) and (30) each by associated output levels, add them up and divide (34) by this sum. This produces an expression for output level of each type-d firm

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in country i. Similar operations are performed on (33) and (36) for type-d firms in country j.

$$x_{ii}^{d} + x_{ij}^{d} \le (\sigma - 1)\frac{r_i(F_i^d + G)}{mc_i} = (\sigma - 1)\frac{(F_i^d + G)}{\frac{w_i}{r_i}mc_w + mc_r} \tag{37}$$

$$x_{jj}^{d} \le (\sigma - 1)\frac{r_j(F_j^d + G)}{mc_j} = (\sigma - 1)\frac{(F_j^d + G)}{\frac{w_j}{r_j}mc_w + mc_r} \tag{38}$$

(37) and (38) show that the output of individual active type-d firm depends on the ratio of fixed costs and marginal costs and increases in elasticity of substitution among varieties. The transformation of the right hand side of inequality further suggests the dependence on the ratio of factor prices. The same operations with inequalities of multinational firms lead to an expression with prices in both countries. As it is not a simple expression, I multiply (31) and (32) each by the associated output, add them up, then subtract this sum from (35) and multiply both sides by σ. Same procedures are done for type-d firms in both countries.

$$p_i x_{ii}^{d} + p_i x_{ij}^{d} \le \sigma \cdot r_i(F_i^d + G) \tag{39}$$

$$p_i x_{ii}^{h} + p_i t x_{ij}^{h} \le \sigma \cdot [\; r_i(F_i^h + G) + r_j(F_j^h + G) \;] \tag{40}$$

$$p_j x_{jj}^{d} \le \sigma \cdot r_j(F_j^d + G) \tag{41}$$

Note that the left hand side of (39) equals to that of (40). Replace all output levels with expressions in (10)-(13). Thus inequalities with number of active firms of each type as complementary variable in (34)-(36) become

$$p_i^{1-\sigma} e_i^{\sigma-1} \gamma_i M_i + p_i^{1-\sigma} t^{1-\sigma} e_{ij}^{\sigma-1}(1-\alpha\beta)\gamma_j M_j \le \sigma \cdot r_i(F_i^d + G) \qquad (N_i^d) \tag{42}$$

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$$p_i^{1-\sigma} e_i^{\sigma-1} \gamma_i M_i + p_i^{1-\sigma} t^{1-\sigma} e_{ij}^{\sigma-1} (1-\alpha\beta) \gamma_j M_j \le \sigma \cdot \left[r_i (F_i^h + G) + r_j (F_j^h + G) \right]$$

$$(N_i^h) \qquad (43)$$

$$p_j^{1-\sigma} e_j^{\sigma-1} \alpha\beta \gamma_j M_j \le \sigma \cdot r_j (F_j^d + G) \qquad (N_j^d) \qquad (44)$$

4.3 THE NUMERIC GENERAL EQUILIBRIUM MODEL

This section provides a complete numeric model characterized by a system of inequalities and equations written in complementary-slackness form with associated non-negative variables. Conditions on pricing, market clearance and income balances are listed with associated complementary variables in goods and factor prices, activity levels and incomes. Twenty inequalities and equations of this nonlinear complementarity problem are coded into computer language and twenty unknown variables are solved by MPSGE (Mathematical Programming System for General Equilibrium), a GAMS (General Algebraic Modeling system) subsystem developed by Rutherford (1995).

The price and unit production cost of *Y* are denoted by p_y ($p_y = 1$) and $c_y(w, r)$, respectively. The derivatives of this cost with respect to the prices of skilled and unskilled labor (c_{yw}, c_{yr}) give, according to Shepard's lemma, factor demands for one unit of *Y* production. These factor demands are constant across countries given the assumed identical factor-intensity of *Y* production.

Inequalities	**Complementary Variable**
$p_y \le c_{yi}$, $p_y \le c_{yj}$	Y_i, Y_j
$e_i = \left[N_i^d p_i^{1-\sigma} + N_i^h p_i^{1-\sigma} \right]^{1/(1-\sigma)}$	e_i
$e_j = \left[N_j^d p_j^{1-\sigma} \right]^{1/(1-\sigma)}$	e_j
$p_i (1 - 1/\sigma) \le mc_i$	p_i

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$$p_j(1-1/\sigma) \le mc_j \qquad p_j$$

$$c_{yw}Y_i + N_i^d mc_w(x_{ii}^d + x_{ij}^d) + N_i^h mc_w x_{ii}^h \le L_i^* \qquad w_i$$

$$c_{yw}Y_j + N_j^d mc_w x_{jj}^d + N_i^h mc_w x_{ij}^h \le L_j^* \qquad w_j$$

$$c_{yr}Y_i + N_i^d\left[mc_r(x_{ii}^d + x_{ij}^d) + F_i^d + G\right] + N_i^h(mc_r x_{ii}^h + F_i^h + G) \le S_i^* \qquad r_i$$

$$c_{yr}Y_j + N_j^d(mc_r x_{jj}^d + F_j^d + G) + N_i^h(mc_r x_{ij}^h + F_j^h + G) \le S_j^* \qquad r_j$$

$$x_{ii}^d = x_{ii}^h = p_i^{-\sigma} e_i^{\sigma-1}\gamma_i M_i \qquad x_{ii}^d,\ x_{ii}^h$$

$$x_{ij}^d = x_{ij}^h = p_i^{-\sigma} e_i^{\sigma-1}(1-\alpha\beta)\gamma_j M_j \qquad x_{ij}^d,\ x_{ij}^h$$

$$x_{jj}^d = p_j^{-\sigma} e_j^{\sigma-1}\alpha\beta\gamma_j M_j \qquad x_{jj}^d$$

$$x_{ii}^d + x_{ij}^d \le (\sigma-1)r_i(F_i^d + G)/mc_i \qquad N_i^d$$

$$p_i x_{ii}^h + p_i t x_{ij}^h \le \sigma\left[r_i(F_i^h + G) + r_j(F_j^h + G)\right] \qquad N_i^h$$

$$x_{jj}^d \le (\sigma-1)r_j(F_j^d + G)/mc_j \qquad N_j^d$$

$$M_i = w_i L_i^* + r_i S_i^*,\ M_j = w_j L_j^* + r_j S_j^* \qquad M_i, M_j$$

4.4 CALIBRATION

Assume the whole world is unskilled labor abundant with the ratio of skilled and unskilled labor as of 2/3. The home country and foreign country are of the same size, and the home country owns 62.5 percent of the world endowment of skilled labor, 41.7 percent of the world endowment of unskilled labor. Calibration of production functions involves determining share parameters and efficiency parameters. In the calibrated form, the cost and demand functions incorporate benchmark values (factor demand, factor prices, cost, output, value shares) and the elasticity of substitution.

Table 4.2 provides the calibration of the model at scenario 1 (NL) equilibrium in which multinational firms are not allowed, and simulation results in scenario 2 and 3. The notation *XHH* and *XHF* represents the high quality manufacturing goods produced by type-d firms in the home country and sold in home country and foreign country, respectively. *NH* is the number of type-d firms headquartered in the home country.

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Similar notations are defined for type-h firms with "*M*" representing multinationals and type-d firms headquartered in the foreign country with "*F*" representing foreign firms. *CXHH* and *CXHF* represents price of high quality goods *X* in the home and the foreign country, respectively. *CXF* is the price of low quality goods *X*. The unit expenditures in the home country and foreign country are denoted by *UTILH* and *UTILF*. *UTILFX* is the unit expenditure on consumption of *X* in the foreign country. These representations are consistent with the notations used in the MPSGE code in the appendix.

4.5 MODEL SIMULATION

This section provides the analysis of simulation results with investment liberalization and different degree of knowledge spillover. Welfare, production quantity, goods prices, factor prices, unit expenditure, multinational's activity in both countries are presented in table 4.2.

4.5.1 INVESTMENT LIBERALIZATION

All prices and quantities are normalized to unity in the scenario 1 (NL). From NL to IL, the investment liberalization transforms some type-d firms to type-h, displacing part of the production for exports with affiliate production of *X* in country *j*. This lowers the home production of *X* and releases more skilled labor relative to unskilled labor. Both factors move to *Y* production, leading to higher output (66 percent increase) of this relatively unskilled-labor intensive activity, which is followed by a fall in the real price of skilled-labor (the nominal price of skilled labor in terms of *Y* divided by unit expenditure), the factor used intensively in *X* production in country *i*, and a rise in that of unskilled

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labor. Because the fall in the price of skilled-labor is more than the rise in that of unskilled-labor, the relative price of skilled labor falls. This is consistent with what Stolper-Samuelson theorem predicts. The entering of multinational firms into country *j* increases the demand for skilled labor more than unskilled labor. Production factors shift out of *Y* production towards *X* production. This bids up the real price of skilled-labor in country *j* and leads to a rise in the price of low quality goods *X*. The movement of factor prices in country *j* conforms to the expectation of Stolper-Samuelson theorem in the similar fashion as in country *i* with an increase in manufacturing production (domestic production of low quality goods and affiliate production of high quality goods) followed by a rise in the real and relative prices of skilled-labor which is intensively used in *X* production and a fall in those of unskilled-labor.

These changes in factor prices lead to lower price of high quality *X* in country *i* since the fall in the price of the factor used intensively in the production outweighs the rise in that of the other factor. Price of low quality *X* in country *j* rises since the rise in the price of the factor used intensively in the production exceeds the fall in that of the other factor. Investment liberalization bids up the price of scarce factor and lowers the price of abundant factor in both countries. Therefore, the skilled-labor-intensive *X* production costs less in skilled-labor-abundant country, more in skilled-labor-scarce country.

Country *i* loses from investment liberalization with a fall in welfare from 1 to 0.9624, and fall in real consumption due to less fall in unit expenditure from 1 to 0.9647. This decrease in welfare can not be attributed to the loss of home-market advantage since the price of high quality *X* relative to *Y* and unit expenditure falls in both countries. The possible explanation can be directed to factor-market effects through investment

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liberalization which unbundles and reallocates production factors across sectors. The liberalization results in a less concentrated increasing-return *X* production in skilled-labor abundant country *i*. This induces a fall in the price of skilled labor which is sufficiently large such that, despite of the rise in the price of unskilled labor, country *i* ends up with lower real factor income (factor income divided by price index). The result also suggests a welfare gain of 5.12 percent in country *j* despite the rise in the price index. This is due to the factor-market effects in unskilled-labor abundant country *j*. The skilled-labor intensive affiliate production bids up the price of skilled-labor, the scarce factor in country *j*. The rise in the price of skilled labor is sufficiently large to outweigh the fall in the price of unskilled labor, thus country *j* ends up with higher factor income relative to price index.

The investment liberalization reduces the number of firms and increases the markup of *X* production in both countries. The factor-market effects through unbundling lower the price of *X* sold in country *i* and the price of *X* exported to country *j*. Even though part of the exports by type-d firms are displaced with the multinational firms' affiliate production in country *j* which has to bear the higher price of skilled labor, the simulation results show a fall in the price of high quality *X* available to country *j*, by export and by affiliate production. The intuition is that the factor-market effects in country *i* combined with savings from trade costs outweigh the rise in factor price in country *j*.

In summary, the investment liberalization makes country *i* less specialized in activities intensively using the abundant factor, and country *j* more specialized in activities intensively using the scarce factor. This bids up the price of scarce factor and

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lowers the price of abundant factor in both countries, thus enlarging the factor-price differences across countries. The factor-market effects are responsible for welfare changes in both countries.

4.5.2 KNOWLEDGE SPILLOVER

This section examines the changes in variables with respect to the change in knowledge spillover, the degree of which is represented by parameter 'beta' in column heading under scenario 3 in table 4.2. Recall the model formulation in section 4.2, beta is a demand shifter affecting the preference for low quality goods *X*. The larger the value of beta, the more knowledge spillover is received by domestic firms in country *j*. Another interpretation of beta is that it increases as the intellectual property protection becomes less stringent. The simulation results suggest beta larger than 1.65 leads to no existence of multinational firms in country *j*, even though beta is bounded from 1 to 2 based on the numeric model set-up.

From IL to KS and as beta increases, consumers in country *j* shift manufactures consumption away from high quality goods towards low quality goods. The stronger preferences for low quality goods leads to an increase in low quality goods production and more low quality producing firms in country *j*. Correspondingly, this decreases country *j*'s total consumption of high quality goods produced by type-d and type-h firms headquartered in country *i*. With less demand for high quality goods, the variable trade-cost mode is preferred to the fixed-cost affiliate production mode, leading to less multinational firms' affiliate production and fewer multinational firms in country *j*. Thus, more high quality goods are supplied through transportation, and type-h firms are

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displaced by type-d firms. This reverses the direction of changes in almost all variables of country *i* which took place during the transition from NL to IL. The fall in skilled-labor demand by multinational firms in country *j* is less than the rise in skilled-labor demand by country *j*'s domestic firms, thus a rise in the real price of skilled labor in country *j* is resulted. As the production of high quality *X* shifts back to country *i*, greater output of high quality *X* leads to a higher price of skilled labor and lower price of unskilled labor. Production factors shifting towards *X* production results in less output of *Y* in country *i*.

As a recipient of knowledge spillover from multinational firms, country *j* has a substantial gain in welfare. This gain ranges from 5.12 percent in IL with no spillover to 46.61 percent when multinational firms exit country *j* completely. The home-market effect is responsible for this welfare gain. More preference for low quality goods leads to higher demand and increased supply with more firms producing with lower markup at lower prices. The decrease in the price of low quality *X* is large enough leading to an outweighing fall in price index, along which real factor price of skilled and unskilled labor both rises, and real factor income (factor income divided by price index) rises as well. The marginal gain in welfare in country *i* results mostly from lower consumption of expensive *X* with rising real factor income.

In summary, knowledge spillover results in less demand for high quality goods in both countries. Compared to the case of investment liberalization with no knowledge spillover, the real price of skilled labor rises and that of unskilled labor falls in country *i*, while the real price of both factors rises in country *j*. When the degree of spillover runs above $\beta = 1.25$, the real prices of country *j*'s factors rise above the level under NL. There is marginal gain in welfare in FDI-exporting country along with higher price of high

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quality products. The FDI-importing (knowledge-spillover receiving) country has substantial gain in welfare due to the increased consumption at lower prices and the rise in real factor income.

4.6 FIXED COST COMPOSITION AND SCALE

This section considers the effect of changes in multinational firm's fixed costs in two dimensions, the composition and the scale. I first alter the composition of fixed costs away from plant-level costs towards firm-level costs holding the total fixed costs constant. This makes firm-level scale economies more important relative to plant-level scale economies. Given the assumption in expression (24) that type-h firm incurs more firm-level costs in country *i* due to the managerial and coordination activities, and incurs less in country *j*, additional assumption is necessary that the more than half of the decrease in total plant-level fixed costs transforms to be firm-level fixed costs incurred in country *i*. This leads to an increase in fixed-cost expenditure on skilled labor in country *i* and a decrease in that in country *j*. It implies that affiliate production incurs less fixed costs, inducing more type-d firms transforming to type-h in IL. This change in fixed-cost composition along with increasing number of multinational firms yields higher demand for skilled labor, leading to a rise in the real price of skilled labor and higher price of goods *X* in country *i*. In other words, as the high quality goods production becomes less concentrated in skilled-labor-abundant country *i*, country *i* loses the home-market advantage. That is, country *i* will experience a fall in local production, higher markup on local production and higher real price of goods *X*.

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As the affiliate production requires less skilled labor in country *j*, the price of skilled labor falls, which leads to higher production of manufacturing goods of both quality levels, and lower price index. Country *j* gains in welfare due to the higher consumption of *X* at lower prices. Country *i* could gain a little in welfare if the firm-level fixed costs are sufficiently important relative to plant-level costs such that the rise in the real price of skilled labor leads to higher real factor income, offsetting the effect of lower consumption of expensive goods. An examination of the simulation results from IL to KS shows that changing fixed-cost composition renders the same qualitative effects.

Next, I change the scale of total fixed costs of multinational firm keeping the composition of fixed cost. Lowering firm-level and plant-level fixed costs multinational firms incur in both countries lowers the scale economies, making it cheaper to become multinational to avoid the trade costs on exports to country *j*. Since the fixed costs consist of skilled labor only, demand for skilled labor falls in both countries. The fall in demand for skilled labor in country *i* is bigger relative to that in country *j*, and it leads to lower skilled labor price, higher domestic production of *X* and lower price index. However, the welfare falls due to the factor-market effects: the real factor incomes decreases large enough to outweigh the increased consumption of goods at lower price. In country *j*, the relative small fall in multinational firm's demand for skilled labor may be outweighed by the increase in number of multinational firms transformed from type-d during investment liberalization. If this is true, the total demand for country *j*'s skilled labor by multinational firms will increase. This renders all variable changes in the same direction as in the base case yet in larger magnitude.

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When it comes to knowledge spillover with smaller scale economies, all variable changes preserve the sign as in the base case except that country *i* experiences welfare loss with lower real factor income. The knowledge spillover shifts *X* production concentration back to country *i* which drives up the price index more than in the base case due to the larger differences of fixed costs. This effect can be large enough to result in a decrease in real factor income despite of the rise in real price of skilled labor. Thus, with lower real factor income for lower consumption at higher prices, welfare decreases in country *i*.

4.7 EDGEWORTH BOX EXAMINATION

Figure 4.2-4.4 presents the change in real and relative factor prices and change in welfare in a world Edgeworth box when it moves from investment liberalization with no knowledge spillover to a case with some degree of spillover ($\beta = 1.35$). This case with beta value equal to 1.35 is to serve as an illustrative purpose. Since country *i* is the home country of high quality goods, it makes more sense to just examine the area to the left of the SW-NE diagonal, where country *i* is skilled-labor-abundant relative to country *j*.

Figure 4.2 shows the effect of knowledge spillover on the real price of skilled labor. The dark shaded region on the top represents no multinational activities in IL, thus no spillover and no change in the real factor prices in both countries. In the presence of spillover, multinational affiliate production decreases in the rest area of the triangle. Note that this is followed by a rise in real price of skilled labor in country *j* in all those points. Since the spillover helps improve low quality goods, consumers in country *j* allocating more budget share towards low quality goods and lowers the consumption of expensive

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high quality goods. This leads to, first, a fall in price index; second, a fall in demand for high quality goods outweighed by the rise in demand for quality-improving low quality goods. Given the same factor intensity of manufacturing production, this increases the demand for skilled labor in country *j*, bidding up the real price of skilled labor.

The real price of skilled labor falls when country *i* is either skilled-labor-abundant and relatively small or marginally skilled-labor-abundant and relatively small. The intuition is that in either case, country *i* has larger concentration of affiliate production, thus will have more reduction in total production induced by knowledge spillover. The lower production transforms into higher price index in country *i*. Even though the price of skilled labor rises due to higher concentration of domestic production, the rise in the price index exceeds the rise in nominal price of skilled labor, resulting in a fall in the real price of skilled labor. Applying this line of reasoning to those grey shade points where real price of skilled labor rises in country *i*, that is the rise in the price of skilled labor due to the higher domestic production outweighs the rise in the price index from the fall in total production.

Figure 4.3 presents the effect of knowledge spillover on the relative factor price of skilled to unskilled labor. Same as in figure 4.2, the dark shaded region on the top represents no multinational activities in IL, thus no spillover and no change in the relative factor prices in both countries. The large portion of the rest area of the triangle indicates that factor price ratio rises in country *i*, and falls in country *j*. This is mostly the region with rising real price of skilled labor in both countries. It implies that the real price of unskilled labor in country *j* rises. For those blank points where the factor price ratios move in the same direction as the real price of skilled labor, the direction of change in

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real price of unskilled labor is uncertain. There are a few points with fall in real price of skilled labor but rise in factor price ratio in country *i*, implying a fall in the real price of unskilled labor. Some other points note a rise in real price of skilled labor but fall in the price ratio in country *j*, indicating a rise in the real price of unskilled labor.

In figure 4.4, the dark shaded region on the top represents no multinational activities in IL, thus no spillover and no change in welfare in both countries. It suggests that county *j* be above certain relative endowment of skilled-labor to attract multinational affiliate production. The adjacent points of this region indicate that multinational firms with marginal activity will exit country *j* in the presence of the given amount of the spillover. Multinational activities are reduced in the rest of the triangle area, and welfare falls in country *i* when it is relatively small and rises when it is relatively large. Country *j*'s welfare rises in every point where multinationals and knowledge spillovers are present.

From the analysis in section 4.5, the endogenous firm location decision shifts fixed-cost affiliate production mode to variable-cost export production mode, and the fall in affiliate production outweighs the rise in export production in the home country. In addition, local production for local consumption falls as well. Even though the knowledge spillover restores the production concentration back to country *i*, the effect of fall in total production outweighs the restored home market effect, thus resulting in higher real price of *X*. Therefore, the welfare loss in country *i* is associated with a fall in the total production of high quality goods, followed by higher price and higher markup for local production of *X*. This is what happened in the benchmark case calibrated with both countries identical in size but country *i* relatively skilled-labor-abundant. The northeast striped region in figure 4.4 attempts to show that when country *i* is large in size,

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there is less fall in total production, and the effect of lower production is outweighed by the restored home market effect, leading to a gain in welfare. This region shrinks in the presence of higher degree of knowledge spillover.

4.8 CONCLUSION

This paper assumes that product quality improves in the host country as a result of productivity growth induced by knowledge spillover from foreign direct investment. The impact of knowledge spillover from FDI is investigated from the change in consumer's willingness to pay with respect to the change in quality. A computable general equilibrium monopolistic-competition model is built to provide quantitative analysis for illustrative purpose. The effects on real and relative factor prices, welfare and multinational activities are examined by changing degree of knowledge spillover, composition and scale of fixed costs. An edgeworth-box examination with change in relative endowment of production factors is also provided. Results show that FDI-exporting country will have a gain in welfare only when it is large in size; otherwise incur lower domestic production of manufacturing goods along with welfare loss, higher price index and higher markup. FDI-importing country will have substantial gain in welfare along with higher production of domestic firms and lower price index.

This analysis also provides policy implications on intellectual property rights protection in the sense that stringent IP protection results in low degree of knowledge spillover. This can help explain the observation of relative more multinational activities in countries with strict IP protection and of relative more supply through imports in countries with weak protection.

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Figure 4.1 Welfare Level of FDI-Importing (knowledge-spillover receiving) Country *j*

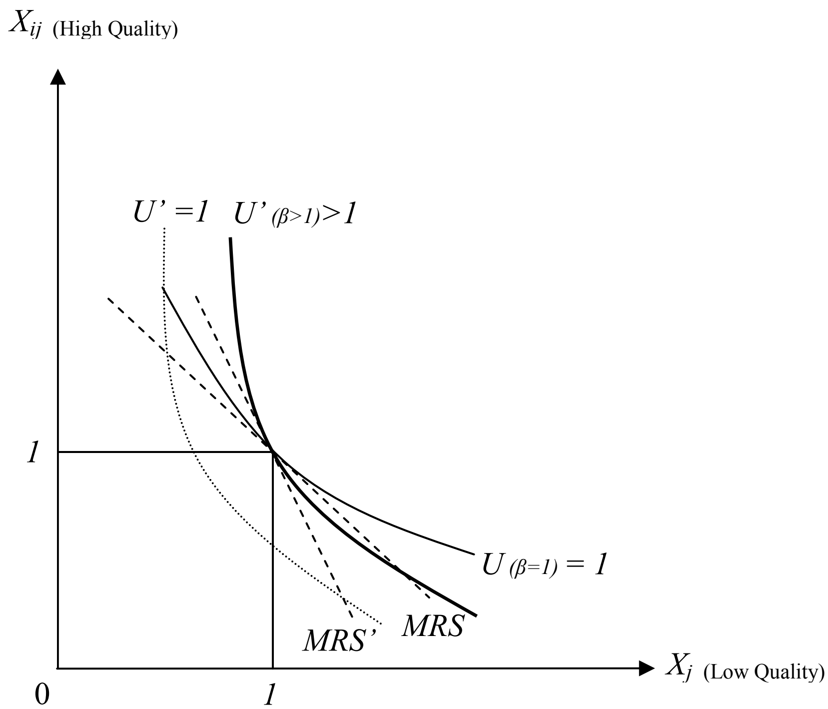

Figure 4.2 Change in Real Price of Skilled Labor from IL to KS ($\beta = 1.35$)

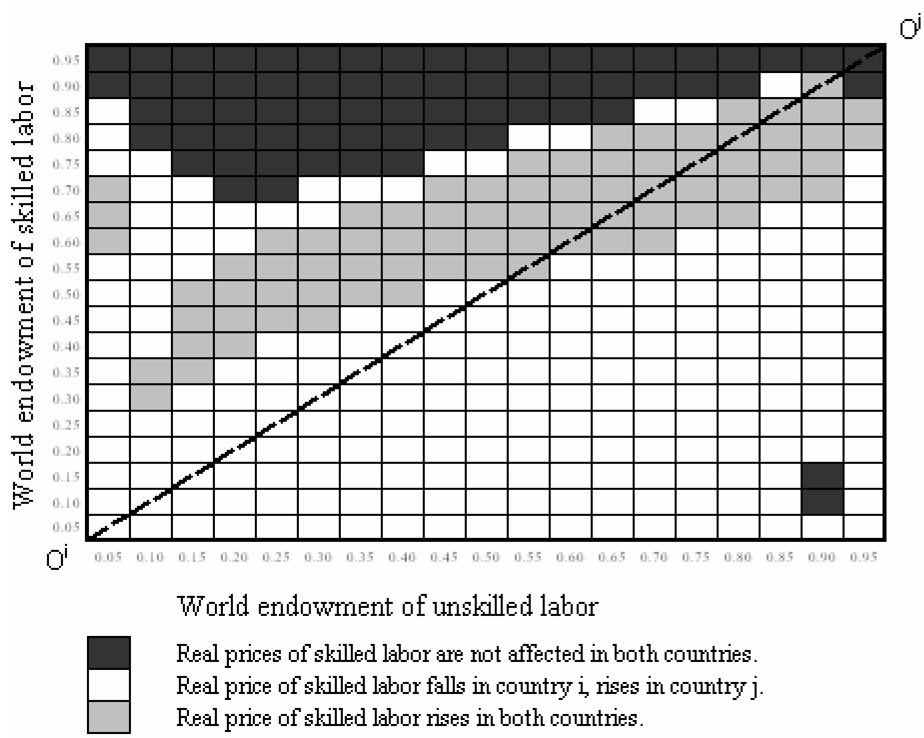

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Figure 4.3 Change in Factor Price Ratio from IL to KS ($\beta = 1.35$)

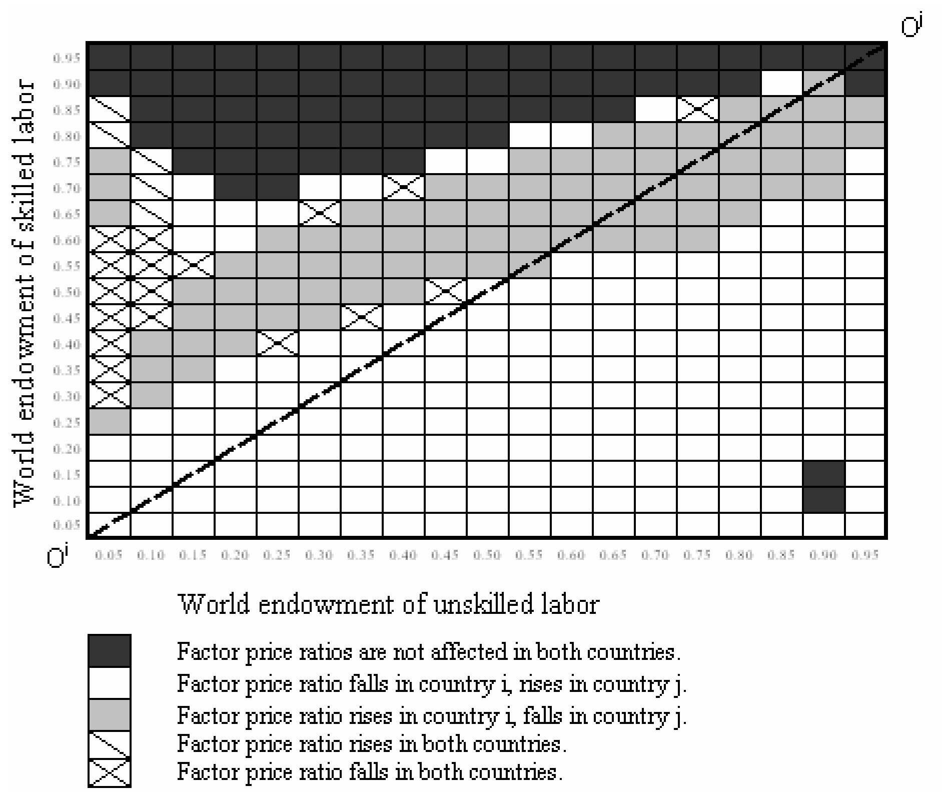

Figure 4.4 Change in Welfare from IL to KS ($\beta = 1.35$)

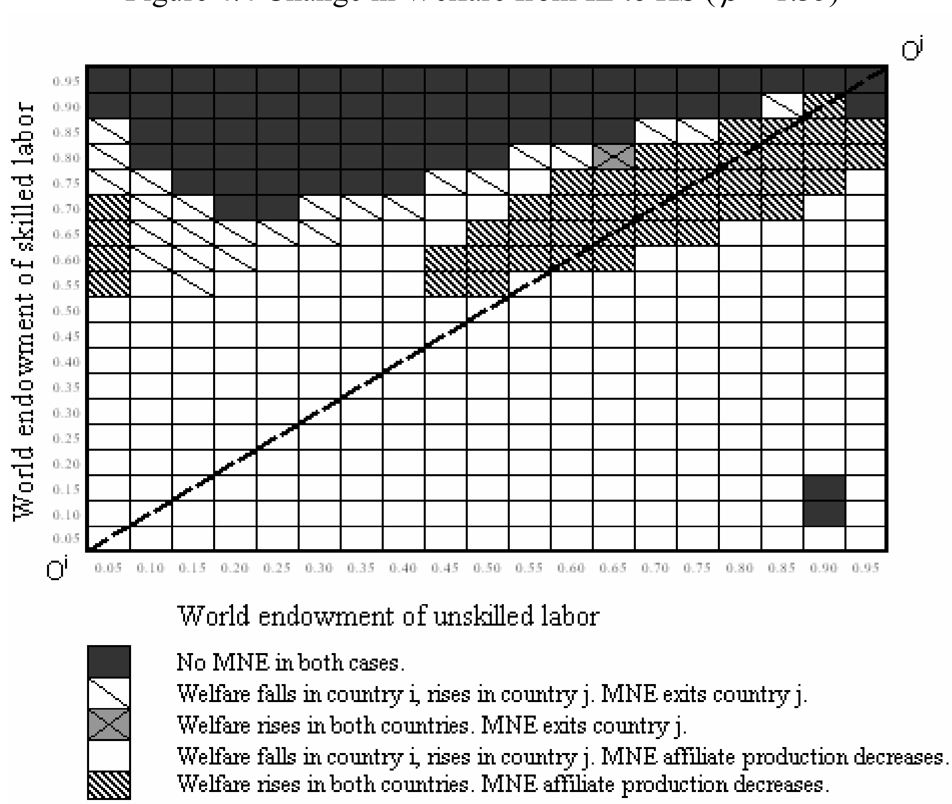

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Table 4.1: Model Calibration

	YH	YF	XH	XHH	XHF	XMH	XMF	XF	NH	MH	NF	WH	WF	CONH	CONF	ENTDH	ENTMH	ENTF	SUM
CY	50	150										-100	-100						0
CXH			120	-80	-40														0
CXHH				100								-100							0
CXHF					50								-50						0
CXF								50					-50						0
FCH									30							-30			0
FCM																			0
FCF											10							-10	0
LH	-40		-60											100					0
LHE	-10		-60						-30					100					0
LF		-120						-20							140				0
LFE		-30						-20			-10				60				0
UITILH												200		-200					0
UTILF													200		-200				0
MDHH				-20												20			0
MDHF					-10											10			0
MMHH																			0
MMHF																			0
MDFF								-10										10	0
COL SUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$PROD:XMH
O: CXHH Q:80 A:ENTM N:MMHH
I: LH Q:40
I: LHE Q:40

$PROD:XMF
O: CXHF Q:80 A:ENTM N:MMHF
I: LF Q:40
I: LFE Q:40

$PROD:NM
O:FCM Q:(40/5)
I:LHE Q:(32/5)
I:LHF Q:(8/5)

$DEMAND:ENTM
D: FCM

Row sums equal zero are market clearing conditions (e.g., supply equal demand)
Column sums equal zero are product exhaustion conditions (e.g., zero profits)
Positive entries are receipts (e.g., sales revenues)
Negative entries are payments (e.g., payments to factors or markup revenues paid to entrepreneurs)

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Table 4.2: Model Simulation Results

		Scenario 1 NL	Scenario 2 IL	Scenario 3 KS beta (1.10)	beta (1.20)	beta (1.30)	beta (1.40)	beta (1.50)	beta (1.60)	beta (1.65)	beta (1.70)
country i	***Welfare***	1.000	0.9624	0.9625	0.9626	0.9627	0.9629	0.9631	0.9634	0.9636	0.9631
	Y(production)	1.000	1.6594	1.6425	1.6258	1.6092	1.5927	1.5763	1.5599	1.5517	1.5567
	XHH + XMH	1.000	0.9976	0.9966	0.9957	0.9949	0.9942	0.9937	0.9933	0.9931	0.9930
	XHH	1.000	0.2910	0.3678	0.4509	0.5416	0.6412	0.7513	0.8741	0.9411	0.9930
	XHF	1.000	0.1466	0.1765	0.2059	0.2349	0.2636	0.2921	0.3205	0.3346	0.3311
	NH	5.000	1.3912	1.7554	2.1496	2.5794	3.0513	3.5739	4.1579	4.4770	4.7176
	XMH	0.000	0.7066	0.6288	0.5447	0.4532	0.3530	0.2423	0.1191	0.0520	0.0000
	XMF	0.000	0.3979	0.3379	0.2785	0.2197	0.1616	0.1043	0.0479	0.0202	0.0000
	MH	0.000	3.3781	3.0016	2.5967	2.1584	1.6798	1.1527	0.5666	0.2473	0.0001
	CXHH	1.250	1.1634	1.1659	1.1683	1.1705	1.1725	1.1744	1.1761	1.1768	1.1759
	CXHF	1.667	1.4518	1.4622	1.4741	1.4880	1.5042	1.5234	1.5462	1.5593	1.5678
	UTILH	1.000	0.9647	0.9658	0.9668	0.9677	0.9685	0.9693	0.9700	0.9703	0.9699
	r_i	1.000	0.7993	0.8025	0.8056	0.8086	0.8116	0.8145	0.8173	0.8187	0.8161
	w_i	1.000	1.0576	1.0566	1.0555	1.0545	1.0536	1.0526	1.0517	1.0513	1.0521
	real r_i	1.000	0.8286	0.8309	0.8333	0.8356	0.8380	0.8403	0.8426	0.8437	0.8414
	real w_i	1.000	1.0963	1.0940	1.0918	1.0898	1.0878	1.0860	1.0843	1.0835	1.0848
	r_i/w_i	1.000	0.7558	0.7595	0.7632	0.7668	0.7703	0.7738	0.7771	0.7787	0.7757
	real factor income	200	192.482	192.493	192.512	192.540	192.579	192.628	192.688	192.723	192.621
country j	***Welfare***	1.000	1.0512	1.0759	1.1096	1.1533	1.2083	1.2764	1.3607	1.4102	1.4661
	Welfare(X)	1.000	1.0504	1.0457	1.0525	1.0716	1.1043	1.1533	1.2227	1.2670	1.3187
	Y(production)	1.000	0.7673	0.7725	0.7775	0.7824	0.7872	0.7918	0.7962	0.7984	0.7960
	XF	1.000	0.9135	1.0203	1.1281	1.2371	1.3473	1.4586	1.5712	1.6281	1.6828
	NF	5.000	4.4352	4.6644	4.8865	5.1029	5.3150	5.5240	5.7310	5.8342	5.9235
	CXF	1.250	1.4397	1.4157	1.3943	1.3748	1.3568	1.3398	1.3235	1.3155	1.3111
	UTILF	1.000	1.0008	0.9763	0.9450	0.9075	0.8645	0.8165	0.7641	0.7364	0.7082
	UTILFX	1.000	1.0017	0.9532	0.8931	0.8236	0.7474	0.6668	0.5839	0.5422	0.5015
	r_j	1.000	1.3371	1.3277	1.3175	1.3063	1.2942	1.2809	1.2663	1.2585	1.2577
	w_j	1.000	0.9299	0.9316	0.9334	0.9354	0.9376	0.9400	0.9427	0.9441	0.9443
	real r_j	1.000	1.3360	1.3599	1.3941	1.4394	1.4970	1.5686	1.6572	1.7090	1.7759
	real w_j	1.000	0.9292	0.9542	0.9877	1.0307	1.0845	1.1512	1.2337	1.2822	1.3334
	r_j/w_j	1.000	1.4379	1.4252	1.4115	1.3966	1.3803	1.3626	1.3433	1.3329	1.3318
	real factor income	200	210.246	215.176	221.926	230.662	241.650	255.283	272.144	282.046	293.226
	r_i/r_j	1.000	0.5978	0.6044	0.6115	0.6190	0.6271	0.6359	0.6454	0.6505	0.6489
	w_i/w_j	1.000	1.1373	1.1341	1.1309	1.1274	1.1237	1.1198	1.1157	1.1135	1.1142

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Bibliography

Branstetter, Lee. “Is Foreign Direct Investment a Channel of Knowledge Spillovers? Evidence from Japan’s FDI in the United States.” *NBER Working Paper 8015 (2000)*

Broda, Christian and David E. Weinstein, “Globalization and the Gains from Variety.” *NBER Working Paper 10314 (2004)*

Brooks, Eileen, “Why Don’t Firms Export More? Product Quality and Colombian Plants.” *Journal of Development Economics (2006), forthcoming*

Ekholm, Karolina, *Multinational Production and Trade in Technological Knowledge*, *Lund Economic Studies (1995), number 58.*

Ethier, Wilfred J. and James R. Markusen, “Multinational firms, technology diffusion and trade.” *Journal of International Economics (1996), Vol. 41, pp. 1-28.*

Falvey, Rodney E. and Kierzkowski, Henryk. “Product Quality, Intra-industry Trade and (Im)perfect Competition.” *Protection and Competition in International Trade. (1987)*

Funke, Michael and Ralf Ruhwedel, “Export Variety and Export Performance: Empirical Evidence from East Asia.” *Journal of Asian Economics 12 (2001) pp. 493-505*

Grant, Robert M., Shani, Rami B. and R. Krishnan, "TQM′s Challenge to Management Theory and Practice." *Sloan Management Review (1994), Vol. 35 No.2, pp. 25-35*

Hallak, Juan-Carlos. “Product Quality and the Direction of Trade.” *Journal of International Economics, (2006), 68 (1), pp. 238-265*

Hallak, Juan-Carlos and Peter K. Schott. “ Estimating Cross-Country Differences in Product Quality.” *University of Michigan (2005)*

Hanson, Gordon H., “Market Potential, Increasing Returns and Geographic Concentration.” *NBER working paper 6429. (1998)*

Hanson, Gordon H., Raymond J. Mataloni, Jr., and Matthew J. Slaughter. “Expansion Strategies of U.S. Multinational Firms.” in D. Rodrik and S. Collins (eds.) *Brookings Trade Forum (2001), pp. 245-294.*

Helpman, E. and P. Krugman, *Market Structure and Foreign Trade*, Cambridge MA: MITPress. *(1985)*

Hummels, David and Peter J. Klenow, “The Variety and Quality of a Nation’s Trade.” *NBER Working Paper 8712 (2002)*

المنارة للاستشارات

www.manaraa.com

Hummels, David and Peter J. Klenow, "The Variety and Quality of a Nation's Exports." *American Economic Review (1995), pp. 704-723*

Hummels, David and Volodymyr Lugovskyy, "Usable Data? Matched Partner Trade Statistics as a Measure of International Transportation Costs." *Review of International Economics (2006), Vol. 14, No. 1, pp. 69-86*

Hummels, David, Jun Ishii, and Kei-Mu Yi. "The Nature and Growth of Vertical Specialization in World Trade." *Journal of International Economics (2001), Vol. 54, pp. 75-96*

Keller, Wolfgang, "Are international R&D spillovers trade-related? Analyzing spillovers among randomly matched trade partners." *European Economic Review (1998), Vol. 42, pp.1469-1481.*

Keller, Wolfgang, "Do trade patterns and technology flows affect productivity growth?" *World Bank Economic Review (2000), Vol. 14, pp. 17-47.*

Keller, Wolfgang and Stephen Yeaple, "Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the US." *NBER Working Paper 9504 (2004)*

Kontoghiorghes, Constantine. "Examining the Association Between Quality and Productivity Performance in a Service Organization." *Quality Management Journal,(2003),Vol. 10, Number 1*

Lopez-de-Silane, Florencio, James R. Markusen, and Thomas F. Rutherford. "Complementarity and Increasing Returns in Intermediate Inputs." *Journal of Development Economics (1994), Vol. l 45, pp. 101-119.*

Markusen, James R. *Multinational Firms and the Theory of International Trade*. Cambridge, MA: MIT Press. (*2002)*

Markusen, James R., "Trade versus Investment Liberalization." NBER working paper *6231, (1998)*

Markusen, James R., "Multinationals, Multi-Plant Economies, and the Gains from Trade." *Journal of International Economics (1984), Vol. 16, pp. 205-226.*

Markusen, James R., and Anthony Venables. "The Theory of Endowment, Intra-Industry and Multinational Trade." *Journal of International Economics (2000), Vol. 52, pp. 209-234.*

Markusen, James R. and Anthony J. Venables, "Multinational Firms and the New Trade Theory." *Journal of International Economics (1998), Vol. 46, pp. 183-203*

www.manaraa.com

Markusen, James R. and Keith Maskus. "Multinational Firms: Reconciling Theory and Evidence." In Magnus Blomstrom and Linda Goldberg (eds.) *Topics in International Economics: A Festschrift in Honor of Robert E. Lipsey*. Chicago: University of Chicago Press *(2001), pp. 71-95.*

Markusen, James R. and Keith Maskus. "Discriminating among Alternative Theories of the Multinational Enterprise." *National Bureau of Economic Research Working Paper No. 7164. (1999)*

Markusen, James R. and Rutherford, Thomas F. "Learning on the Quick and Cheap: Gains from Trade through Imported Expertise." *NBER working paper 10603 (2004)*

Markusen, James R., Tarr David and Rutherfod, Thomas F. "Trade and Foreign Direct Investment in Producer Services and the Market for Domestic Expertise." *Canadian Journal of Economics (2005), Vol. 38, pp. 758-777*

Ng, F. and A. Yeats, "Production sharing in East Asia; who does what for whom and why." *World Bank Policy Research Working Paper 2197. (1999)*
Keller, Wolfgang, "Geographic localization of international technology diffusion." *American Economic Review (2002), Vol. 92, pp.120-142.*

Rodrik, Dani "What's So Special about China's Exports?" *NBER Working Paper 11947 (2006)*

Roson, Roberto. "Introducing Imperfect Competition in CGE Models: Technical Aspects and Implications." *FEEM Working Paper No. 3. (2006)*

Rutherford, Thomas F., "Lecture Notes on Constant Elasticity Functions." http://www.gamsworld.org/mpsge *(2002)*

Rutherford, Thomas F. "Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax." *Computational Economics (1999)*

Schott, Peter K. "The Relative Sophistication of Chinese Exports." *NBER Working Paper 12173 (2006)*

Schott, Peter K. "Across-Product versus Within-Product Specialization in International Trade." *Quarterly Journal of Economics (2004) 119(2):647-678.*

Venables, A.J. "Fragmentation and multinational production." *European Economic Review (1999), Vol. 43, pp. 935-945.*

Yeats, Alexander J. "Just How Big is Global Production Sharing?" in Sven W. Arndt and Henryk Kierzkowski (eds.), *Fragmentation: New Production Patterns in the World Economy*, Oxford: Oxford University Press. *(2001)*

المنارة للاستشارات
www.manaraa.com

Yi, Kei-Mu. "Can Vertical Specialization Explain the Growth of World Trade?" *Journal of Political Economy (2003), Vol. 111(1), pp. 52-102.*

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Appendix MPSGE Code for Numeric General Equilibrium Model

```
PARAMETERS

SHIFT
ALPHA
BETA
ENDOWHL
ENDOWHS
ENDOWFL
ENDOWFS
ROW
COL
QM   /80/
FC   /40/
FCI  /32/

SHIFT = 1;
ALPHA = 1/2;
BETA = 1;
ENDOWHL = 1;
ENDOWHS = 1;
ENDOWFL = 1;
ENDOWFS = 1;

$ONTEXT
$MODEL:BASIC

$SECTORS:
YH YF
XH XHH XHF XMH XMF
XF
NH MH NF
WH WF WFX

$COMMODITIES:
CY
CXH CXHH CXHF
CXF
FCH FCM FCF
LH LHE LF LFE
UTILH UTILF UTILFX

$CONSUMERS:
CONH CONF ENTDH ENTMH ENTF

$AUXILIARY:
MDHH MDHF MMHH MMHF MDFF
MHT NHT NFT

$PROD:YH  S:1
O:CY   Q:50
I:LH   Q:40
I:LHE  Q:10

$PROD:YF  S:1
O:CY   Q:150
I:LF   Q:120
I:LFE  Q:30

$PROD:XH  S:1
O:CXH  Q:120
I:LH   Q:60
I:LHE  Q:60

$PROD:XHH S:1
O:CXHH Q:80   A:ENTDH  N:MDHH
I:CXH  Q:80

$PROD:XHF S:1
```

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```
O:CXHF Q:30   A:ENTDH  N:MDHF
I:CXH  Q:40

$PROD:XMH  S:1
O:CXHH Q:QM   A:ENTMH  N:MMHH
I:LH   Q:(0.5*QM*SHIFT)
I:LHE  Q:(0.5*QM*SHIFT)

$PROD:XMF  S:1
O:CXHF Q:QM   A:ENTMH  N:MMHF
I:LF   Q:(0.5*QM*SHIFT)
I:LFE  Q:(0.5*QM*SHIFT)

$PROD:XF   S:1
O:CXF  Q:40   A:ENTF   N:MDFF
I:LF   Q:20
I:LFE  Q:20

$PROD:NH
O:FCH  Q:(30/5)
I:LHE  Q:(30/5)

$PROD:MH
O:FCM  Q:(FC/5)
I:LHE  Q:(FCI/5*SHIFT)
I:LFE  Q:((FC-FCI)/5*SHIFT)

$PROD:NF
O:FCF  Q:(10/5)
I:LFE  Q:(10/5)

$PROD:WH S:1
O:UTILH  Q:200
I:CY     Q:100
I:CXHH   Q:80   P:1.25

$PROD:WF S:1
O:UTILF  Q:200
I:CY     Q:100
I:UTILFX Q:100

$PROD:WFX S:1
O:UTILFX Q:(100*BETA**(ALPHA*BETA))
I:CXHF   Q:30  P:(5/3*(2-BETA))
I:CXF    Q:40  P:(5/4*BETA)

$DEMAND:CONH
D:UTILH  Q:200
E:LH     Q:(100*ENDOWHL)
E:LHE    Q:(100*ENDOWHS)

$DEMAND:CONF
D:UTILF  Q:200
E:LF     Q:(140*ENDOWFL)
E:LFE    Q:(60*ENDOWFS)

$DEMAND:ENTDH
D:FCH

$DEMAND:ENTMH
D:FCM

$DEMAND:ENTF
D:FCF

$CONSTRAINT:MDHH
 MDHH*NHT*(XHH + XMH) =G= XHH;

$CONSTRAINT:MDHF
 MDHF*NHT*(XHF*30 + XMF*40) =G= XHF*30;
```

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```
$CONSTRAINT:MMHH
 MMHH*MHT*(XHH + XMH) =G= XMH;

$CONSTRAINT:MMHF
 MMHF*MHT*(XHF*30 + XMF*40) =G= XMF*40;

$CONSTRAINT:MDFF
 MDFF*NFT =G= 1;

$CONSTRAINT:MHT
 MHT =G= MH;

$CONSTRAINT:NHT
 NHT =G= NH;

$CONSTRAINT:NFT
 NFT =G= NF;

$OFFTEXT
$SYSINCLUDE MPSGESET BASIC

MHT.LO = 0.0001;
NHT.LO = 0.0001;
NFT.LO = 0.0001;
XMH.L = 0;
XMF.L = 0;
FCM.L = 0;
CXHH.L = 1.25;
CXHF.L = (5/3);
CXF.L = 1.25;
NH.L = 5.0;
NF.L = 5.0;
MH.L = 0;
MDHH.L = 0.2;
MDHF.L = 0.2;
MDFF.L = 0.2;
NHT.L = 5.0;
NFT.L = 5.0;

CY.FX = 1.0;

SHIFT = 25;

BASIC.ITERLIM = 0;
$INCLUDE BASIC.GEN
SOLVE BASIC USING MCP;

FCH.L = MAX(FCH.L, 0.0001);
FCF.L = MAX(FCF.L, 0.0001);
FCM.L = MAX(FCM.L, 0.0001);
BASIC.ITERLIM = 2000;

SHIFT = 1.;
$INCLUDE BASIC.GEN
SOLVE BASIC USING MCP;
```

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