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ESSAYS ON INTERNATIONAL TRADE AND INDUSTRIAL AGGLOMERATION

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ABSTRACT

After thirty years of economic development, the spatial distribution of China's economic activities, such as industrial production and international trade now displays significant spatial concentration. This dissertation studies the spatial distribution of China's economic activities from the New Economic Geography (NEG) perspective.

Chapter 1 briefly introduces the economic background and the structure of this dissertation. It also summarizes the main conclusions and contributions of this work.

Chapter 2 adds capital as a variable input for the final manufacturing production into the NEG model. The new model indicates that the thorough agglomeration of all industries does not happen. Only the labor-intensive industries completely agglomerate into the labor abundant countries and this only occurs under some extreme conditions. The simulation results also show that with immobile capital, the economy with the greater labor endowment will have a lower real wage level. For countries with strict capital controls, capital liberalization can help reduce wage difference between countries.

Chapter 3 is an empirical application of a NEG model similar to the one developed in Chapter 2. It seeks to explain the regional wage disparity within China from the NEG perspective. The nonlinear regression based on pooled data from 237 cities (1990-2000) shows that regions with larger markets and labor endowments tend to have higher wage levels. This is consistent with most NEG studies' predictions. The estimation results also show that the estimated product elasticity of substitution for intermediate inputs in China roughly decreased during the studied period. This indicates that agglomeration has made the sub-regions of China lose their diversification in intermediate inputs.

The last chapter (coauthored with Christopher Edmonds) introduces the Gravity Model Adjusted Trade Intensity Index to measure and compare the geographical intensity of China's bilateral trade with the world average level. We also make some comparisons between China and Japan, the other big economy in Asia which experienced a similar trade boom in the early period of its development.

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CHAPTER 1
INTRODUCTION

Since the beginning of its open door policy in 1978, China's trade with the rest of the world has expanded rapidly over three decades. From 1978 to 2005, China's exports and imports increased at an average annual rate of 12.6% and 13.3%, respectively. With the associated liberalization of foreign direct investment (FDI) restrictions, there has also been a remarkable surge of FDI inflows into China during the same period. China approved 594,427 foreign projects by the end of 2006, with yearly realized FDI increasing from US$1.96 billion in 1985 to US$69.47 billion in 2006.[1] Thanks in part to its outward-oriented economic development, China's Gross Domestic Product (GDP) rose from $157.7 billion in 1978 to $1,889.9 billion in 2005,[2] giving an average annual GDP growth rate of 9.6%. However, the economic development, the origins of exports and the destinations of FDI inflows have displayed significant spatial concentration in China. In 2006, approximately 53% of China's GDP is contributed by its coastal regions, over 31% of China's exports are from Guangdong province and more than 75% of FDI flowed into its coastal regions.[3] At the same time, the problem of sharp disparities in wages and income levels of households between coastal areas, where most business activities are located, and inland provinces has been serious.[4] This has induced the "floating" population of internal migrants seeking improved income, and the associated severe congestion and environmental problems. All these problems have been threatening

[1] NBSC, China Statistical Yearbook (2007).
[2] Values are in constant 2000 US$. *World Development Indicators*, World Bank (2007).
[3] Values are calculated from data in NBSC China Statistical Yearbook (2007). Please see Van Huffel, Luo and Catin (2005) for more detailed review on the concentration of economic activities in China.
[4] The role of trade opening in altering economic disparities in China is assessed in Anderson et al. (2003).

China's ability to sustain its remarkable achievements in terms of economic and social development.

The agglomeration of economic activities within China has been accompanied by a significant shift in China's bilateral trade pattern. Before liberalization, China's foreign trade was primarily oriented toward other Eastern Bloc countries, and it displayed patterns typical of Eastern Bloc trade. Over the course of the 1980s and 1990s, China's trade refocused dramatically toward large market economies (Europe and North America), Asian economies, and countries with large endowments of natural resources. China's exports to both Europe and North America expanded by more than 300% over the period of 1995-2003, while its imports from natural resource abundant countries grew even more rapidly (Edmonds et al., 2005). The growth of bilateral trade between China and different trading partners also displayed significant spatial concentration.

China's rapid growth of exports to some countries has raised tensions with its major trading partners, many of whom have initiated anti-dumping actions and imposed safeguard quotas on imports from China. The spectacular economic development in China has also raised the specter of its increasing imports on scarce oil and other natural resources. Policymakers in some of China's largest trading partners appear increasingly preoccupied by the implications of China's emergence as a leading regional and global trading power for their economies and the global economy as a whole.

It is in the above economic context that I write the following three essays to study the spatial distribution of economic activities within China, as well as the international exchange between China and its trading partners.

Regional economic researchers have been interested in the relationships between markets, production, and distance since the early 19^{th} century [Von Thünen (1826) and Harris (1954)]. In the 1990s, theorists developed a new approach to understanding the spatial concentration of economic activity: "New Economic Geography" (NEG). NEG approaches economic geography with a perspective adapted from "new trade theory" rather than regional economics. Most of the NEG models predict that a larger economy (i.e., one has both a greater labor endowment and a larger local market) tends to be more attractive to manufactures and to offer higher real wage levels. NEG models successfully explain the geographical distribution of economic activities among countries within the European Union as well as counties within the United States (Henderson, J. V. and Thisse, J. 2004). However, the stylized facts of China seem to run contrary to the predictions of NEG models. The economy of China is larger than most of its trading partners. The country also has the largest labor endowment in the world. But the labor costs (real wage level) of China are lower than most of its trading partners. This is consistent with the prediction of the traditional Hecksher-Olin trade theory. The H-O theory is based on an important assumption, diminishing marginal returns. The law of diminishing returns states that in a production system with fixed and variable inputs, beyond some point, each additional unit of variable input yields less and less additional output. Most of the NEG models have only one factor, labor, as a variable input.[5] Therefore, they cannot reflect the effect of diminishing marginal returns on the spatial distribution of economic activities.

[5] The variable input means that the producer can change the share of the input in the total costs of the production. The variable input can be mobile or immobile between countries.

In Chapter 2, I add a second variable input, capital, into the NEG model. The numerical simulation of my model shows that with immobile capital, the effect of diminishing marginal return will be stronger than the effect of agglomeration. An economy with a larger labor endowment will have a lower real wage level. Comparing with the original NEG models, this model turns out to be more appropriate in explaining the case of China. My simulation results also indicate that for the country with strict capital controls, capital liberalization can help reduce wage difference between countries in both nominal and real terms.

On the other hand, previous NEG models predict catastrophic agglomeration [Baldwin (1999)] of manufactures when the trade costs are sufficiently low. This does not seem to find empirical support at a broad. As a "world factory", China is attractive to the labor-intensive industries. However, it is unlikely that China will attract a relocation of all labor-intensive industries, much less a relocation of all manufacturing industries, into China. In the labor-involved production, the shift of production can lead to the shift of both labor and expenditure, which followed by further production shifting. This kind of circular causality finally causes the catastrophic agglomeration. By introducing capital as a specific factor for the final manufacturing production, my model divides the manufacturing sector into labor- and capital- intensive industries and completely rules out the circular causality from the capital-intensive industry. As a result, my simulation results show that only if the distribution of labor endowments is highly concentrated and the trade costs are extremely low, the labor-intensive industries agglomerate into the labor abundant countries. The catastrophic agglomeration does not occur in the capital-intensive industries.

Chapter 3 studies the interaction between China's regional labor endowments, market size and wage level. It is an empirical application of a NEG model similar to the one developed in Chapter 2 and seeks to explain the regional wage disparity within China from the NEGperspective. The nonlinear regression based on pooled data of 237 cities from 1990 to 2000 shows that the regions with larger markets and labor endowments tend to have higher wage levels. This is consistent with the predictions from most previous NEG studies on industrial agglomeration. My estimates of China's product elasticity of substitution are smaller than those of other countries studied in previous research. The regression results also show a roughly decreasing trend of estimated elasticity of substitution for China in the period studied. This could be explained by the increasing specialization of the sub-regional production within China.

To study the spatial distribution of economic activities across countries and the implications for China's international trade, a similar NEG approach can be applied. However, due to the characteristic differences across countries, the measurement of the spatial distribution of the international economic activities is much more complicated than that of the domestic economic activities. Chapter 4, coauthored with Christopher Edmonds, examines China's bilateral trade pattern and investigates if China intensively trades with some regions comparing with the world average level. The traditional trade intensity index measures the world average level based only on countries' economic sizes. However, with all other factors equal, countries that are near to each other, or share a common border, or have a close cultural relationship, tend to have more intense trade relationships than those that are geographically or culturally distant. The trade values estimated by gravity models can reflect the effect of each country's specific characteristics, such as distances to the markets, geographic factors and the cultural relationships, etc. Nevertheless, the gravity model approach cannot perform a complete cross country comparison on trade. To study whether a country is trading more intensively than another country with similar characteristics, we introduce the gravity model adjusted trade intensity (GMATI) index and utilize it to measure and analyze China's international trade pattern.

The GMATI index indicates that China does trade more actively than the world average level. While trading with North America, Europe and Oceania countries, China is more active in exporting than in importing. Our index also reveals that China has increasing interests in trading with Africa. Comparisons between China and Japan, the other big economy in Asia which experienced a similar trade boom in the early period of its development, show that Japan is even more active than China in the world market in the periods studied. But Japan is more active in importing than in exporting, which is contrary to China. Finally, China's imports from Middle East have become more intensive. But its GMATI index remains around 1, i.e., its import from oil suppliers does not seriously intensive, comparing to the world average level.

CHAPTER 2
INTERNATIONAL TRADE AND INDUSTRIAL AGGLOMERATION

2.1 Introduction

Since the early 19th century, regional economic researchers have been interested in the relationships between markets, production, regional development and distance [Von Thünen (1826) and Harris (1954)]. In the 1990s, theorists developed a new approach to understanding the spatial concentration of economic activities: "New Economic Geography" (NEG). NEG approaches economic geography with a perspective developed from "new trade theory" instead of regional economics.

In one of the initial papers that popularized NEG study,[6] Krugman (1991) sets up a Core-Periphery (CP) model which emphasizes the interaction between trade costs and scale economies as a cause of agglomeration. The CP model is a general equilibrium model with monopolistic competition. With labor mobility, the CP model shows that a larger economy[7] tends to be more attractive to manufactures and may agglomerate all industrial activities due to the existence of economies of scale and trade costs. However, the "catastrophic agglomeration" [Baldwin (1999)], in which all industries move to a single region, does not exist in the real world. At the same time, empirical papers have shown that Krugman's basic CP model might not capture all reasons for agglomeration, such as intra-industry externalities [Head and Mayer (2002)], natural advantages [Ellison and Glaeser (1997, 1999), Davis and Weinstein (2002) and Redding and Venables (2004)], human capital externalities [Moretti (2004)], technological externalities

[6] There are other two papers which are considered as the initiation of NEG: Fujita (1988) and Venables (1996)

[7] The larger economy has both a greater labor endowment and a larger local market.

[Audretsch and Feldman (1996)], and vertical linkages [Redding and Venables (2004)]. Thus, economists try to extend the original CP model according to empirical indications.

Krugman and Venables (1995) incorporate the input-output linkages between firms into the model. Venables (1996) relaxes Krugman's assumption of cross-regional labor mobility and sets up the so-called Core-Periphery model with Vertical Linkage (CPVL model). The CPVL model presents that even without labor mobility, agglomeration can be generated by the interplay between the location decisions of firms that are linked through an input-output structure. In another version of CPVL model, Puga (1999) employs a specific production function for the agricultural sector and assumes immobile land. Ricci (1999) adds ingredients of traditional trade theory into the CPVL model and checks the interaction between agglomeration and specialization.

A very important assumption for all above NEG models is that only trade of differentiated goods involves trade costs. But empirical work [Rauch (1996), Hellilll (1995), McCallum (1995), Harrigan (1993) and Ii (1996)] shows that conventional trade costs are higher for homogeneous goods than for differentiated goods. Davis (1998) finds that unless the trade cost is unusually higher for differentiated goods; agglomeration will not be the economic equilibrium. Therefore, he concludes, if the industries have identical trade costs, the home market effect predicted by the CP model disappears and the market size is irrelevant to the industrial structure. This criticism is obviously crucial to the CP models.

Another problem is that only one factor, labor, is used as an input for the industrial production in previous models. However, there is another factor that is essential for the industrial production in the real world, capital. In fact, when doing cross-country analysis, capital is more likely to be mobile than labor since movement of labor across countries usually is restricted. Empirical studies have also found much stronger effects of FDI flows in the industrial concentration process than any other factors [Tuan and Ng (2003, 2004)]. In addition, the single factor model cannot reflect the effect of diminishing marginal returns, which is a law followed by most production systems. The law of diminishing marginal returns states that in a production system with fixed and variable inputs, beyond some point, each additional unit of variable input yields less and less additional output. The existence of diminishing marginal returns affects the equilibrium factor returns and location of production materials. It will impede the use of inputs that exceeds the optimal level indicated by the given technology. In other words, it can impede the agglomeration of factors and economic activities to some extent. Therefore, it is necessary to include the second factor, capital, into the NEG models when analyzing the causes of agglomeration and the resulting equilibrium factor returns. Some theorists have set up NEG models involving both labor and capital (either physical or human capital) in industrial production, such as Martin and Rogers's (1995) Footloose Capital (FC) model, Ottaviano (1996) and Forslid's (1999) Footloose Entrepreneurs (FE) model and Baldwin's (1999) Constructed Capital (CC) Model. However, all of these models add capital as a fixed input for intermediate manufacturing producers and they still get the catastrophic agglomeration of all manufactures.

In this chapter, I incorporate capital as a variable input for the final industrial production into Puga (1999)'s CPVL model and check the interaction between the agglomeration effects and the diminishing marginal return effect. My model produces the agglomeration of only the labor-intensive industries instead of the catastrophic agglomeration of all manufactures. The remainder of the paper is organized as follows. In the second section, I incorporate a capital endowment into Puga's CPVL model and set up an autarky model with three factors and two sectors. In the third section, the model is expanded to include two countries and international trade. Numerical simulations are used to analyze the general equilibrium. I also check the robustness of the model to the introduction of trade costs for agricultural goods. Conclusions and remarks are in section four.

2.2 Model of Autarky Economy

To set up a model with international trade, I need to start from a model of an autarky economy. Consider a model similar to Puga (1999)'s model, with two sectors, agriculture and manufacturing, but three factors, arable land (A), labor (L) and capital (K), instead of two factors (land and labor).[8] Labor is assumed to be mobile between the agricultural sector and manufacturing sector which is the assumption also used by Puga. I assume land and capital are specific factors for agriculture and manufacturing respectively.

2.2.1 Consumer Side

As in the CPVL model, the representative consumer maximizes utility:

$$U = C_A^{1-\mu} C_M^{\mu}, \; 0 < \mu < 1 \tag{2.1}$$

$$\text{s.t } P_A C_A + P_M C_M = Y \tag{2.2}$$

[8] Actually, L, K can be just labor, capital or Cobb-Douglas combinations of labor, capital or other endowments (human capital), but I consider them as labor and physical capital respectively here.

where C_A and C_M denote the consumption of agricultural products and final manufactures. P_A and P_M are prices of agricultural products and final manufactures and Y is the income.

The utility function implies that μ share of a representative consumer's income will be spent on manufactures and $1-\mu$ share of the income will be spent on agricultural products. Assume everybody in the economy has the same utility function. The share of manufactures in the total consumption of the economy will be μ.

2.2.2 Producer Side

Agriculture is perfectly competitive and produces a homogenous output with a constant return to scale (CRS) technology as in the CPVL model. I use the specific production function that Puga (1999) uses for the agricultural sector: $X_A = A^{1-\theta} L_A^{\theta}$. X_A, A and L_A denote the agricultural output, the amount of arable land and the labor employed in the agricultural sector respectively. Since the land endowment is fixed, the representative land owner will choose the amount of labor to maximize the return to land (g) according to the prevailing wage level (w) and agricultural commodity price (P_A). Same as all other NEG models, the price of the agricultural product is set to be the *numeraire*: $P_A = 1$. So the maximization problem for a representative land owner is:

$$\text{Max } Ag(w) = X_A P_A - wL_A \text{, s.t. } X_A \le A^{1-\theta} L_A^{\theta}. \tag{2.3}$$

Solving the maximization problem, I can get the labor employed by the agricultural sector:

$$L_A = A\left(\frac{w}{\theta}\right)^{1/(\theta-1)}, \tag{2.4}$$

the agricultural production:

$$X_A = A(\frac{w}{\theta})^{\theta/(\theta-1)}, \tag{2.5}$$

and the price of land:

$$g = (1-\theta)(\frac{w}{\theta})^{\theta/(\theta-1)}. \tag{2.6}$$

From (2.4) – (2.6), I can see that the labor employed by the agricultural sector (L_A), the agricultural production (X_A) and the price of land (g) are all based on the prevailing wage level w.

The manufacturing sector displays increasing return to scale (IRS) in a two-stage production process: As in the CPVL model, the first stage products are differentiated intermediate manufactures that will be used as inputs in the second stage of production. The number of varieties of the first stage manufactures is endogenous. The second stage, however, involves a Cobb-Douglas combination of the intermediate manufactures (C_L) and capital which is not considered in the CP and most related models.

Following Krugman (1991) and all other NEG models, I use Dixit and Stiglitz (1977)'s framework to model the intermediate manufacturing production, which implies that each variety can be produced by only one firm. The production of an individual variety involves a fixed cost and a constant marginal cost: to produce x_i of good *i*, I need $L_i = \alpha + \beta x_i$ ($\alpha > 0, \beta > 0$), where L_i is the amount of labor employed to produce good *i*.

The total cost of producing good *i* is $E_i = wL_i = w(\alpha + \beta x_i)$, so the marginal cost is $MC_i = \frac{\partial E_i}{\partial x_i} = w\beta$. Therefore the IRS of first stage manufactures comes from the scale of a single firm's production.

Following Krugman (1991), the aggregation of intermediate manufactures is defined by

$$C_L = \left(\sum_{i=1}^{n} c_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{2.7}$$

where n is the number of varieties of intermediate manufactures and $\sigma > 1$ is the elasticity of substitution among the varieties.[9]

The price index of intermediate manufactures can be defined as [Krugman et.al. (1999)]:

$$P_L = \left(\sum_{i=1}^{n} p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{2.8}$$

The production function of final manufactures is defined as:

$$X_M = C_L^b K^{1-b} = \left[\left(\sum_{i=1}^{n} c_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right]^b K^{1-b} \tag{2.9}$$

where $0 < b < 1$.

By now, I have set up a model of an autarky economy with two sectors and three factors. The inclusion of both labor and capital as variable input for industrial production enables the model to reflect the effect of diminishing marginal returns for both labor and capital. At the same time, since the capital input is specific for the final manufacturing production, we can certainly consider this industry as the capital-intensive industry while the intermediate manufacturing production is labor-intensive. This division strengthens the difference of the two vertically linked industries and further help in analyzing the

[9] I follow Ethier's (1982) assumption that the work of aggregating varieties can also be considered as a variety, so there is no extra labor needed in the aggregation production.

special distribution of labor- and capital-intensive industries separately. In the following section, I solve the general equilibrium and do some comparative static analysis.

2.2.3 General Equilibrium and Comparative Static Analysis

Same as the standard Dixit-Stiglitz (1977) framework, I assume the producer of each variety acts as though his behavior does not influence that of other varieties' producers. By solving the production maximization problem, I can get the optimized price for each variety of the intermediate manufacture:

$$p_i = \left(\frac{C_L}{nc_i}\right)^{\frac{1}{\sigma}} \tag{2.10}$$

and the optimized production for each variety:

$$x_i = \frac{\alpha}{\beta}(\sigma - 1). \tag{2.11}$$

(It is the same with most NEG models.)

Therefore, the price index is

$$P_L = \left(\sum_{i=1}^{n} p_i^{1-\sigma}\right)^{\frac{1}{1-\sigma}} = n^{\frac{1}{1-\sigma}} p_i = n^{\frac{1}{1-\sigma}} w\beta \frac{\sigma}{\sigma - 1}. \tag{2.12}$$

The number of varieties:

$$n = \frac{L - L_A}{L_i} = \frac{L - Ag_w}{\alpha + \beta x_i} = \frac{L - Ag_w}{\alpha\sigma} = \frac{L - A\left(\frac{w}{\theta}\right)^{\frac{1}{\theta-1}}}{\alpha\sigma}. \tag{2.13}$$

Total production of intermediate manufacture is:

$$X_L = \sum_{i=1}^{n} x_i = n * x_i = n\frac{\alpha}{\beta}(\sigma - 1) = \frac{L - Ag_w}{\beta\sigma}(\sigma - 1). \tag{2.14}$$

Total output of intermediate manufacture is:

$$P_L X_L = (L - Ag_w)w \,. \tag{2.15}$$

Assume that the market for final manufactures is perfectly competitive. The zero profit condition is:

$$P_M X_M = P_L C_L + rK = \frac{P_L C_L}{b} = \frac{rK}{1-b}. \tag{2.16}$$

Market clearing in autarky implies

$$X_A = C_A, \tag{2.17}$$

$$c_i = x_i, \tag{2.18}$$

$$C_M = X_M \,. \tag{2.19}$$

Full employment implies:

$$L = L_A + \sum_{i=1}^{n} L_i \,. \tag{2.20}$$

Balance of payment gives us:

$$P_A C_A + P_M C_M = Ag(w) + Lw + Kr \,. \tag{2.21}$$

Solving the system (2.17) - (2.21) [10], I get the equilibrium factor returns, commodity prices and the number of varieties.

The equilibrium wage rate:

$$w = \theta \left(\frac{A}{L} \right)^{1-\theta} \left[\left(\frac{1}{1-\mu} - 1 \right) \frac{b}{\theta} + 1 \right]^{1-\theta}. \tag{2.22}$$

The equilibrium land price:

$$g(w) = (1-\theta)\left(\frac{w}{\theta}\right)^{\theta/(\theta-1)} = (1-\theta)\left[\left(\frac{1}{1-\mu} - 1 \right) \frac{b}{\theta} + 1 \right]^{-\theta} \left(\frac{L}{A} \right)^{\theta}. \tag{2.23}$$

[10] Please see Appendix 1.

The equilibrium capital rent:

$$r = \frac{\mu(1-b)\theta^{\theta}(\mu b + \theta - \mu\theta)^{-\theta} L^{\theta} A^{1-\theta}}{(1-\mu)^{1-\theta} K}. \tag{2.24}$$

The price and price index of intermediate manufactures:

$$P_L = n^{\frac{1}{1-\sigma}} p_i = (b\mu + \theta - \mu\theta)^{(1-\theta+\frac{1}{\sigma-1})} \left(\frac{\alpha\sigma}{b\mu}\right)^{\frac{1}{\sigma-1}} \theta^{\theta}(1-\mu)^{(\theta-1)} \beta \frac{\sigma}{\sigma-1} A^{1-\theta} L^{\frac{1}{1-\sigma}+\theta-1} \tag{2.25}$$

The equilibrium price of final manufactures:

$$P_M = \xi A^{1-\theta} L^{\theta - \frac{\sigma b}{\sigma-1}} K^{b-1} \tag{2.26}$$

where $\xi = \mu\theta^{\theta}(1-\mu)^{\theta-1}\left(\frac{\alpha\sigma}{\mu b}\right)^{\frac{\sigma b}{\sigma-1}}\left(\frac{\beta}{\alpha(\sigma-1)}\right)^{b}(\mu b + \theta - \mu\theta)^{\frac{\sigma b}{\sigma-1}-\theta}$

And the number of varieties of intermediate manufactures:

$$n = \frac{Lb\mu}{(b\mu + \theta - \mu\theta)\alpha\sigma} \tag{2.27}$$

From the comparative static analysis, I can get some standard results of traditional trade theories:

i) The price of a factor decreases in the factor's endowment ($\frac{\partial g(w)}{\partial A} < 0$, $\frac{\partial w}{\partial L} < 0$, $\frac{\partial r}{\partial K} < 0$) and increases in other factors' endowments ($\frac{\partial g(w)}{\partial L} > 0$, $\frac{\partial w}{\partial A} > 0$, $\frac{\partial r}{\partial A} > 0$, $\frac{\partial r}{\partial L} > 0$). ii) The price of a product decreases in the supply of its inputs

($\frac{\partial P_L}{\partial L} < 0$, $\frac{\partial P_M}{\partial K} < 0$, $\frac{\partial P_M}{\partial L} < 0$ if $\theta < b$ [11]) and increases in the supply of other products' inputs ($\frac{\partial P_L}{\partial A} > 0$, $\frac{\partial P_M}{\partial A} > 0$).

I can also get some results that are consistent with previous CPVL model:

i) The equilibrium wage and the number of varieties increase in the share of industry in the economy ($\frac{\partial w}{\partial \mu}$>0, $\frac{\partial n}{\partial \mu} > 0$). But the land rent decreases in the share of industry in the economy ($\frac{\partial g(w)}{\partial \mu} < 0$).

ii) The number of varieties increases in the labor endowment ($\frac{\partial n}{\partial L} > 0$) and decreases in the firm-level economies of scale (α).

At the same time, due to the involvement of capital in the model, I also get some new results:

Proposition 1. As the share of intermediate manufactures in the cost of final manufacturing production increase, the equilibrium wage rate increase ($\frac{\partial w}{\partial b} > 0$), while the equilibrium land and capital rent decreases ($\frac{\partial g(w)}{\partial b} < 0$, $\frac{\partial r}{\partial b} < 0$)[12].

Holding all else equal, as the cost share of intermediate manufactures increases, the labor needed in manufacturing production will increase. Therefore, the return to labor increases, while the return to other factors (arable land and capital) decrease.

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[11] I only consider regular manufactures, not those needing special high technology or rare materials in production. For regular manufactures, the country with more labor usually has a lower price since labor is a necessary factor for all regular manufactures, no matter if they are labor-intensive or capital-intensive. Therefore, I assume this condition always holds through the paper.

[12] Please see Appendix 1 for proof.

From (2.25) and (2.26), I can have the price ratio of final and intermediate manufactures:

$$\frac{P_M}{p_i} = \left[\sigma(b + \frac{\theta}{\mu} - \theta)\right]^{\frac{\sigma b}{\sigma-1}-1} \left(\frac{\sigma-1}{\beta}\right)^{1-b} \alpha^{\frac{b}{\sigma-1}} b^{\frac{-\sigma b}{\sigma-1}} L^{1-\frac{\sigma b}{\sigma-1}} K^{b-1} \tag{2.28}$$

Therefore $\frac{\partial \frac{P_M}{p_i}}{\partial L} \begin{cases} > 0, if & \sigma(1-b) > 1 \\ < 0, if & \sigma(1-b) < 1 \end{cases}$ and $\frac{\partial \frac{P_M}{p_i}}{\partial K} < 0$. (2.29)

Equation (2.29) indicates that the increase of capital endowment will decrease the relative prices of final manufacturing products (based on the price of intermediate manufactures). However, the relationship between labor endowment and the relative prices of final manufacturing products is uncertain and depends on the elasticity of substitution among varieties (σ) and the cost share of capital in industrial production ($1-b$). If $\sigma(1-b) > 1$, the increase of labor endowment will increase the relative prices of final manufacturing products. In other words, if the elasticity of substitution or the costs share of capital in industrial production is sufficiently large, the increase of labor endowment will increase final manufactures' relative price.

Proposition 2. Keeping other conditions unchanged, if $\sigma(1-b) > 1$, a country with more labor will have higher relative prices of final manufactures (based on the price of intermediate manufactures) than if the country would have a less labor endowment.

In this section, I set up a model of an autarky economy based on the framework of Puga (1999)'s CPVL model. I introduce a second factor, capital, as variable input for manufactures which makes my model different from the NEG models with only one industrial input. Therefore, besides the results similar with that of traditional trade theories and previous CPVL model, my model also presents the effects of capital and diminishing marginal returns on the economy.

2.3 The Two-Country Model

2.3.1 The Two-Country Model with Immobile Factors

Now consider a two-country (x, y) model. Assume country y has more labor than country x. Other endowments and technology are the same for these two countries. Also assume that all products can be traded across countries but all factors cannot. Labor is still mobile across agriculture and manufacturing. Land and capital are specific factors for agriculture and manufacturing respectively.

From the previous section, I know that in autarky, country y will have a lower wage rate and manufacture prices,[13] but higher prices of capital and land. Use subscript x, y to distinguish each variable for different countries. From (2.25), (2.28) and (2.29), I know that in autarky, if $\sigma(1-b)>1$, I have $\frac{p_y}{p_x}<\frac{P_{My}}{P_{Mx}}<\frac{P_{Ay}}{P_{Ax}}$. Thus the order of comparative advantage of country y's products will be intermediate manufactures > final manufactures > agricultural products. Therefore, country y will be a net exporter of intermediate manufactures and a net importer of agricultural products if the two countries trade with each other. The trade direction of final manufactures is uncertain. On the other hand, if $\sigma(1-b)<1$, I have $\frac{P_{My}}{P_{Mx}}<\frac{p_y}{p_x}<\frac{P_{Ay}}{P_{Ax}}$. Then country y will be a net exporter of final manufactures and still a net importer of agricultural products in trade. The trade direction of intermediate manufactures is uncertain. So, besides the endowment, both the

[13] Both intermediate and final manufactures.

elasticity of substitution among varieties and the utilization of capital in industrial production can affect a country's trade pattern.

Let L_k, w_k, K_k, r_k denote the endowments and factor prices in country k ($k = x, y$). Following the standard CP model, agricultural products can be traded costlessly, so I use their price as the numeraire again: $P_A = 1$. All manufactures can trade at "iceberg" trade costs. Only τ ($0<\tau<1$) share of shipped goods can be delivered from one country to the other country. The production of the agricultural and manufacturing sectors and the utility function are the same with the autarky economy.

The number of varieties of the first stage manufactures produced in country k is n_k. The assumption of monopolistic competition implies that one variety can only be produced in one region and by one firm [Dixit and Stiglitz (1977)], so the total number of intermediate manufacturing varieties is $n = n_x + n_y$.

Similarly with the autarky economy, the price index of intermediate manufactures in country x is:

$$P_{Ix} = \left(\sum_{i=1}^{n_x} p_{xi}^{1-\sigma} + \sum_{j=1}^{n_y}\left(\frac{p_{yj}}{\tau}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{2.30}$$

where p_{xi} is the producer price of variety i produced in country x and p_{yj} is the producer price of variety j produced in country y. Symmetrically, the price index of intermediate manufactures in country y can be expressed as:

$$P_{Iy} = \left(\sum_{i=1}^{n_y} p_{yi}^{1-\sigma} + \sum_{j=1}^{n_x}\left(\frac{p_{xj}}{\tau}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{2.31}$$

2.3.1.1 Producer Side

Similarly with the autarky economy and the CPVL model,[14] I can have the optimal price of variety i produced in country x

$$p_{xi} = w_x \beta \frac{\sigma}{\sigma - 1}. \tag{2.32}$$

The optimal price of variety i produced in country y:

$$p_{yi} = w_y \beta \frac{\sigma}{\sigma - 1}. \tag{2.33}$$

Monopolistic competition implies that each firm earns zero profit, so $E_{ki} = p_{ki} x_{ki}$ and thus $w_k(\alpha + \beta x_{ki}) = w_{Lk} \beta \frac{\sigma}{\sigma - 1} c_{ki}$, where E_{ki} is the cost of producing x_{ki} of variety i in country k. Therefore, I can get the optimal output for each factory:

$$x_{xi} = \frac{\alpha}{\beta}(\sigma - 1) = x_{yi} = x. \tag{2.34}$$

It is again the same as the result in all other NEG models. Since output is the same for any variety, I ignore the subscript i or j from now on.

From (2.34), the number of varieties in country k is:

$$n_k = \frac{L_k - L_{Ak}}{L_i} = \frac{L_k - A_k g_{kw}}{\alpha + \beta x}$$

$$= \frac{L_k - A_k g_{kw}}{\alpha\sigma} = \frac{L_k - A_k \left(\frac{w_k}{\theta}\right)^{1/(\theta-1)}}{\alpha\sigma}. \tag{2.35}$$

Total production of intermediate manufactures in country k is:

[14] Please see Appendix 2.

$$X_{Lk} = n_k * x_k = \frac{L_k - A_k\left(\frac{w_k}{\theta}\right)^{1/(\theta-1)}}{\alpha\sigma} * \frac{\alpha}{\beta}(\sigma-1) = \frac{L_k - A_k\left(\frac{w_k}{\theta}\right)^{1/(\theta-1)}}{\beta\sigma}(\sigma-1). \quad (2.36)$$

The output of final manufactures in country k is

$$P_{Mk}X_{Mk} = P_{Mk}C_{Lk}^{b}K_{k}^{1-b} = \frac{P_{Lk}C_{Lk}}{b} = \frac{K_k r_k}{1-b}, \quad (2.37)$$

where K_x is the capital endowment in country x.

The price of final manufacturing products is: $P_{Mk} = \frac{P_{Lk}^{b}(P_{Lk}C_{Lk})^{1-b}}{K_k^{1-b}b}$. (2.38)

Total capital income in country k is:

$$r_k K_k = \frac{1-b}{b}P_{Lk}C_{Lk} \quad (2.39)$$

2.3.1.2 Consumer Side

A representative consumer in country k solves the same utility maximization problem as equation (2.1), (2.2). Therefore, $P_{Mk}C_{Mk} = \frac{\mu}{1-\mu}P_{Ak}C_{Ak} = \mu Y_k$ (2.40)

The consumer price index of country k is $P_k = P_{Ak}^{1-\mu}P_{Mk}^{\mu}$, (2.41)

where C_{Ak}, C_{Mk} are the consumption of agriculture and manufactures in country k, respectively. P_{Mx}, Y_k are the price of final manufactures and the total output, respectively.

2.3.1.3 General Equilibrium

In equilibrium, I have:

A. Balance of production and consumption:

Each variety of intermediate manufactures produced in country x:

$$c_x = x_x = c_{xx} + c_{xy} \tag{2.42}$$

Each variety of intermediate manufactures produced in country *y*:

$$c_y = x_y = c_{yx} + c_{yy} \tag{2.43}$$

Agricultural products:

$$C_{Ax} + C_{Ay} = X_{Ax} + X_{Ay} \tag{2.44}$$

Final manufactures:

$$C_{Mx} + C_{My} = X_{Mx} + X_{My} \tag{2.45}$$

B. Balance of payments, total income equals total consumption:

$$A_x g(w_x) + w_x L_x + r_x K_x = C_{Ax} P_{Ax} + P_{Mx} C_{Mx} \tag{2.46}$$

$$A_y g(w_y) + w_y L_y + r_y K_y = C_{Ay} P_{Ay} + P_{My} C_{My} \tag{2.47}$$

Solving the system (2.42)-(2.47),[15] I find that $P_{Lx}C_{Lx}$, $P_{Ly}C_{Ly}$ and P_{Mk} are all functions of wages and I can have:

$$P_{Lx} C_{Lx} = bX_{Mx} P_{Mx} \tag{2.48}$$

$$P_{Ly} C_{Ly} = bX_{My} P_{My} \tag{2.49}$$

$$\mu\left(\frac{A_x g(w_x) + w_x L_x + r_x K_x}{P_{Mx}} + \frac{A_y g(w_y) + w_y L_y + r_y K_y}{P_{My}}\right) = X_{Mx} + X_{My} \tag{2.50}$$

$$(1-\mu)(A_x g(w_x) + w_x L_x + r_x K_x + A_y g(w_y) + w_y L_y + r_y K_y) = X_{Ax} + X_{Ay} \tag{2.51}$$

Equations (2.48) — (2.51) form a nonlinear equation system from which I can solve four unknowns: w_x, w_y, r_x and r_y. Then starting from w_x, w_y, r_x and r_y, I can solve all

[15] Please see the Appendix 3.

other unknowns of the economy: $g(w_x)$ and $g(w_y)$ (by (2.6)), L_{Ax} and L_{Ay} (by (2.5)), n_x and n_y (by (2.13)) P_{Mx} and P_{My} (by (2.26)), etc.

After setting up the system above, I start the numerical analysis here. Set b = 0.4, $\alpha = \beta = 0.05$, $\theta = 0.5$, $\sigma = 6$, $\mu = 0.6$,[16] $A_x = A_y = 0.5$, $K_x = K_y = 2$, $L = L_x + L_y = 8$, $L_y \in [4.1, 7]$. Assuming capital is evenly distributed between the two countries, I keep the total labor endowment of the whole economy to be constant. But the distribution of labor changes from almost evenly distributed between country *x* and *y* to highly concentrated in country *y*. Then, I change the value of τ to see its effect on economies with different labor endowment concentration.

Figure 1 and Figure 2 show the change of trade patterns and income ratios of the two countries with three different values of τ : 0.1, 0.5, 0.9. The horizontal axis presents country *y*'s share of labor (L_y / L). The greater country *y*'s share of labor is, the more concentrated labor endowment in country *y* is. In Figure 1, vertical axis presents share of country *y*'s output (or consumption) in world output (or consumption). In Figure 2, vertical axis presents share of country *y*'s income in world income:

$$\left(\frac{country\ y's\ income}{country\ x's\ income + country\ y's\ income}\right).$$

According to classic Heckscher-Olin (H-O) theory, when two countries producing homogeneous goods have different endowments, they will have comparative advantages in different products and trade will be Pareto-improving in the world without trading cost. In our simulation, I assume country *y* has more labor than country *x* and final

[16]The values of parameters (α , β , θ, σ , μ) follow Venables (1996).

manufactures and agricultural products are homogeneous. Therefore trade of final manufactures and agricultural products will occur when there is no trade cost. However, I assume trade costs exist for final manufactures. In this case, unless one country's comparative advantage is sufficiently strong to compensate for the trade cost, trade of final manufactures will not happen. With a specific trade cost, there should be a critical labor share of country y (L_y / L). When the labor ratio is greater than the critical value, trade of final manufactures will occur, otherwise, there will be no trade of final manufactures.

On the other hand, trade theories of differentiated products indicate that trade of differentiated products is Pareto-improving if it increases varieties within the consumption bundle while keeps all other things unchanged. Price can only affect the amount of traded varieties but not the trade pattern. Therefore, unless the trading cost is infinitely high ($\tau = 0$), the trade of intermediate manufactures will always exist in our simulation.

From Figure 1, I can see that when $\tau = 0.1$, there is no trade of final manufactures if L_y / L <0.75[17], since the curve for output and consumption are overlapped. When $\tau = 0.5$ or $\tau = 0.9$, country y is the net exporter of final manufactures since the output curve for final manufactures is always above the corresponding consumption curve. Country y has abundant labor endowment, thus lower labor cost and cheaper intermediate input. Therefore, it has comparative advantage in the production of final manufactures. Country y is always the net importer of agricultural products. When $\tau = 0.9$, I find that

[17] In fact, the simulation data shows that there is no trade of final manufactures when L_y / L <0.79

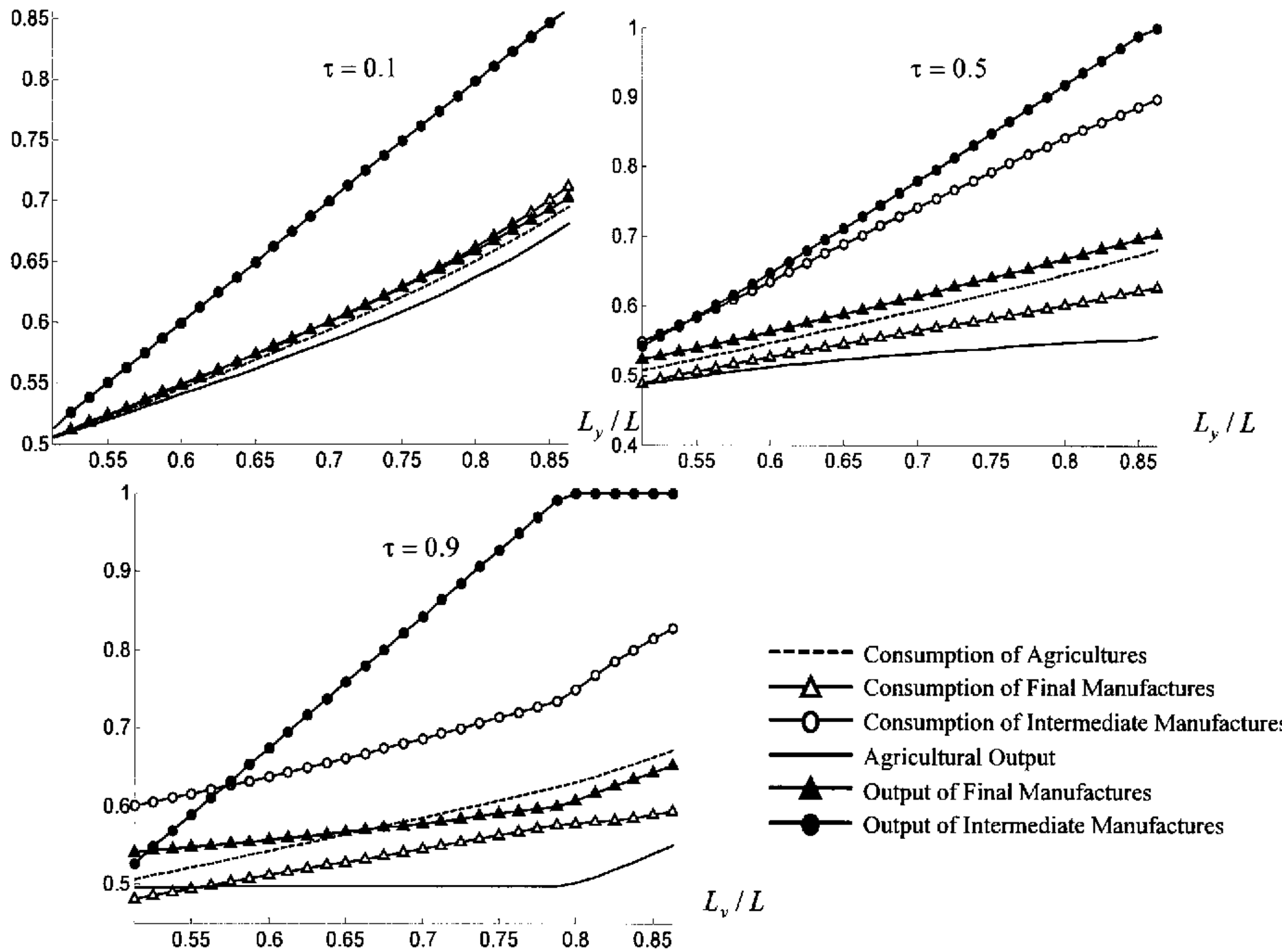

Figure 1. Trade Patterns of Two Countries with Immobile Factors

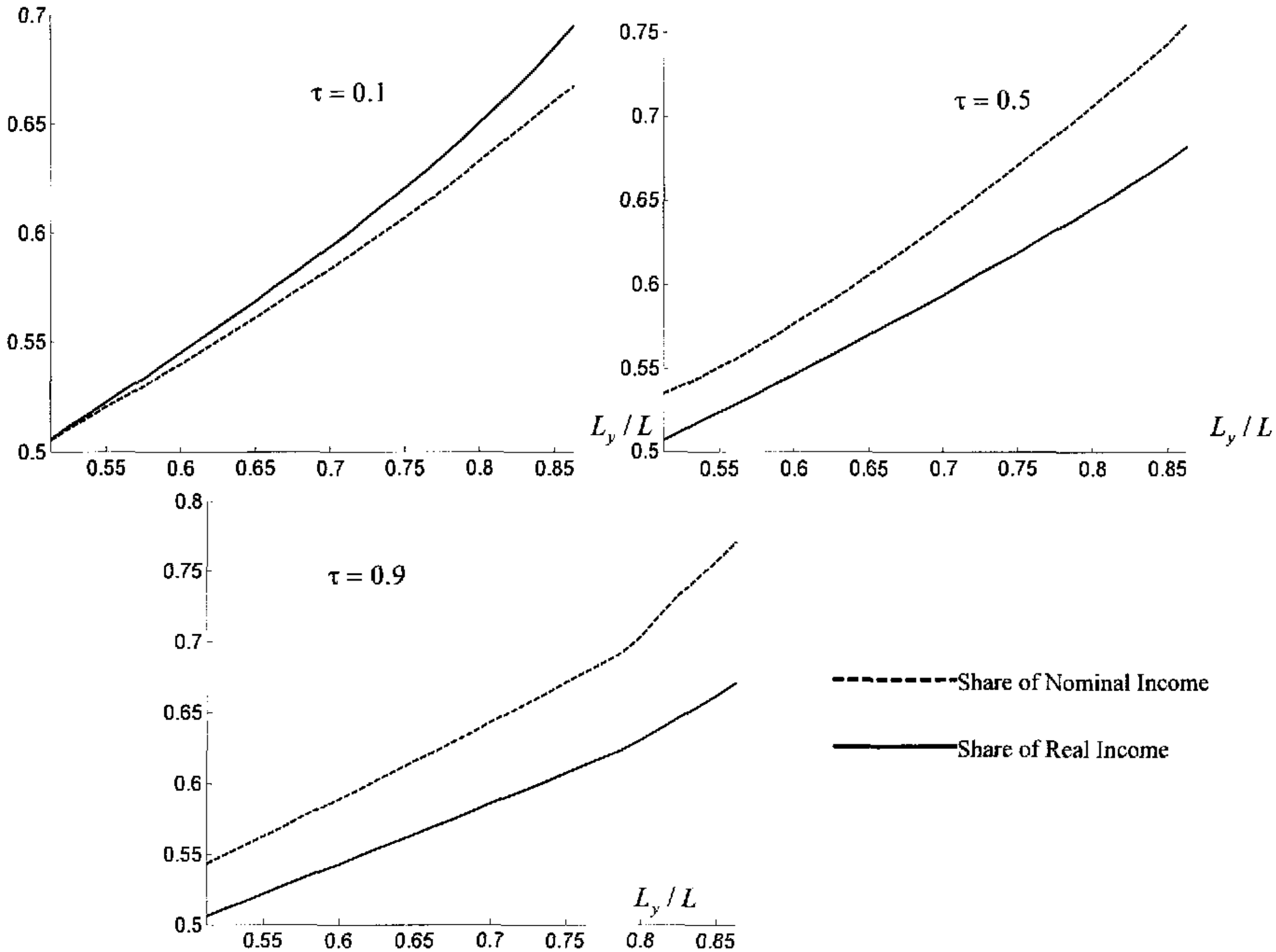

Figure 2. Income Ratios of Two Countries with Immobile Factors

country y changes from net importer of intermediate manufactures to net exporter of intermediate manufactures as its share of labor increases. This can be explained by the opposing effects of comparative advantage effect and increased varieties. Country y has comparative advantage in labor-intensive products, which indicates that this country will export intermediate manufactures. On the other hand, Country y needs to import intermediate manufactures from country x to increase its varieties. When country y's share of labor is sufficiently large, the effect of comparative advantage dominates the effect of increased varieties. As a result, country y has a disproportionately larger share of production in the labor-intensive industry and becomes a net exporter of intermediate manufactures, or even produces all intermediate manufactures the world needs. [18] However, if the comparative advantage is not sufficiently strong (when $\tau = 0.9$ and $0.5 < L_y / L < 0.57$); country y does not have a disproportionately larger share of production in the labor intensive industry and becomes a net importer of intermediate manufactures. This is different from Venables (1996)'s prediction that the larger market will have a disproportionately larger share of production. On the other hand, country y has greater market of agricultural product compared with country x. But country x has the comparative advantage in agricultural. Therefore, agricultural production does not concentrate in the country with the larger market (country y) either.

Proposition 3. Based on simulations, when factors are immobile across countries and countries trade with each other, if both the comparative advantage effect and the increase

[18] Country y produces all intermediate manufactures the economy needs when $\tau = 0.9$ and $L_y / L > 0.79$ in our simulations.

in varieties effect exist, production does not necessarily concentrate in the country which has a comparative advantage nor does it necessarily concentrate in the larger market.

From Figure 2, I can see that both shares of nominal and real income increase as country y's share of labor increases. However, almost all shares of income are smaller than corresponding shares of labor. The higher country y's labor share is, the greater the difference between income share and labor share is. This means that the welfare for a representative consumer in country x is higher than that in country y and the gap increases with the increase of labor endowment difference between the two countries. This is inconsistent with the prediction of the CP and most related models that the country with abundant labor will have higher personal real income. To see it in more detail, I decompose income to factor returns and show the change of factor returns to the change of labor endowment distribution in Figure 3. Again, I simulated with three different values of τ : 0.1, 0.5, 0.9. The horizontal axis still presents country y's share of labor (L_y / L). The vertical axis presents the ratio of country y's factor returns to country x's factor returns. Similarly, in Figure 4, the vertical axis presents total real income of the whole economy (sum of two countries' real incomes), total manufacturing outputs or total agricultural outputs.

From Figure 3, I can see that both nominal and real capital returns in country y are greater than those in country x since the curves for nominal and real capital return ratios are always above 1. However, the real wage in country y is always lower than that in country x. With higher value of τ, i.e., lower trading cost, trade between two countries increases and the wage (and other factor returns) difference between two countries decreases. This is consistent with the trade theory of factor price equalization. But real

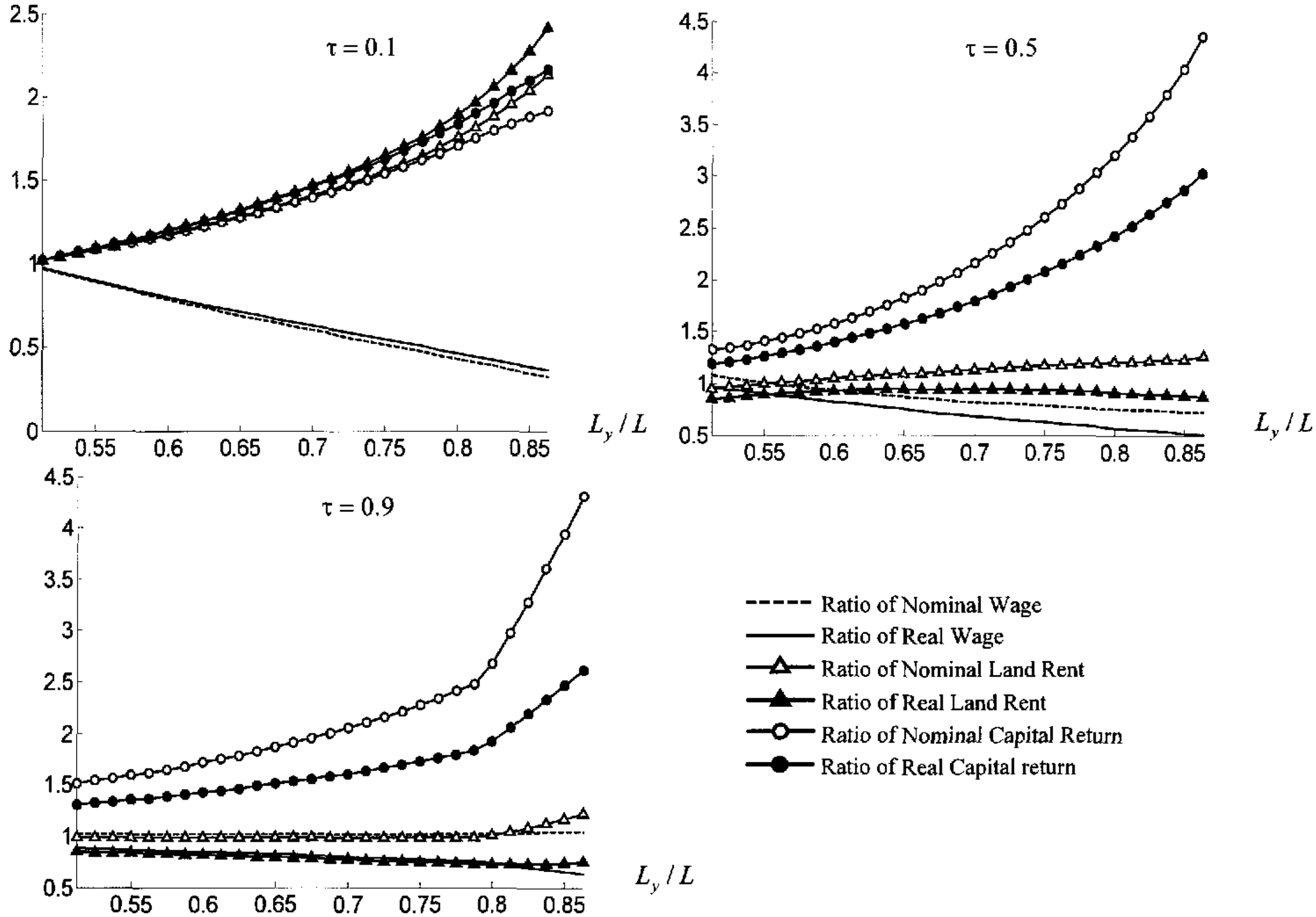

Figure 3. Factor Returns of Two Countries with Immobile Factors

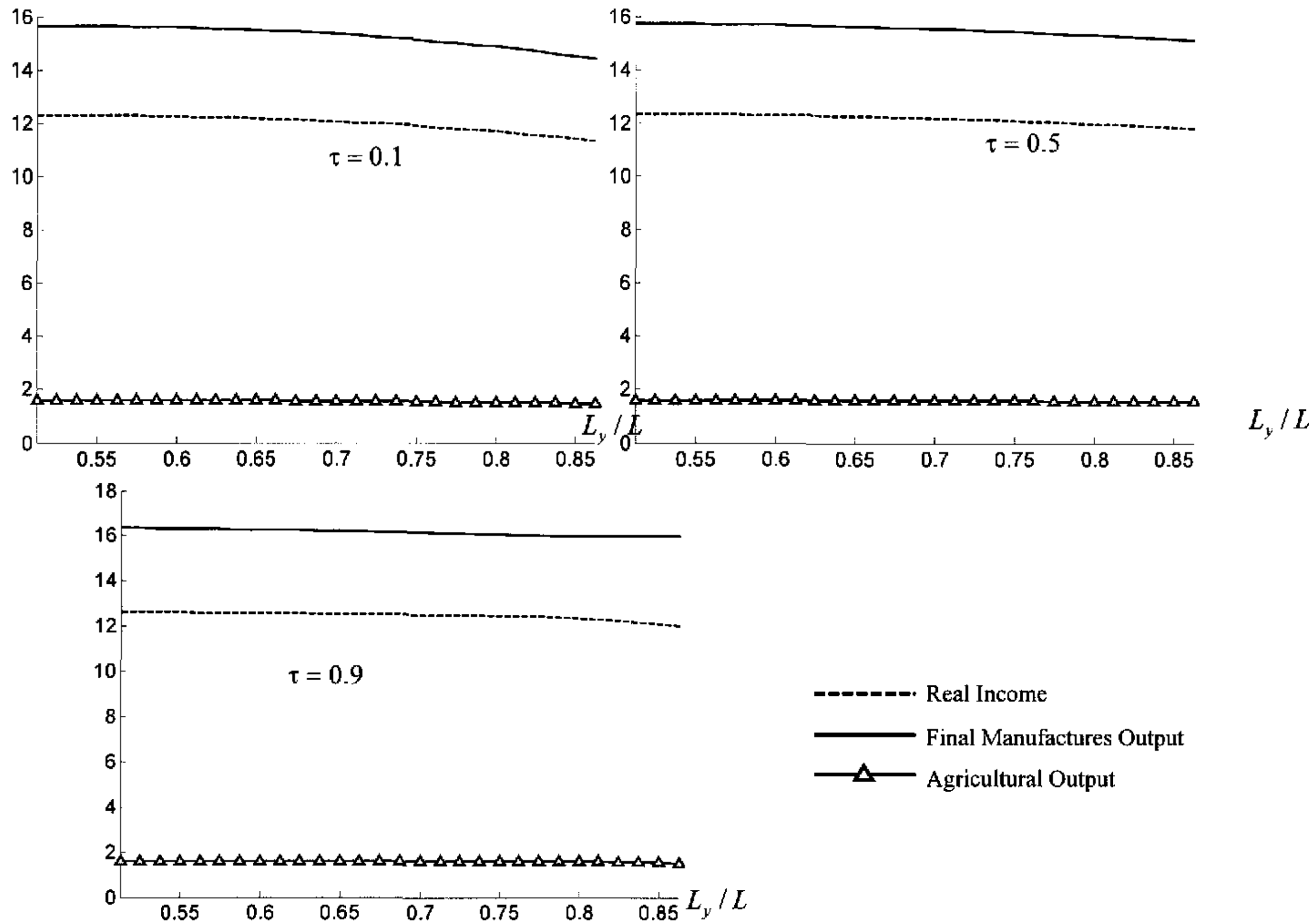

Figure 4. Output of Two Countries with Immobile Factors

wage in country y decreases when country y's labor share increases. There are two reasons: 1. The labor price (wage) cannot be completely equalized by trade due to the existence of trade cost and the labor immobility. 2. The law of diminishing marginal returns, i.e., the value of marginal product of labor is decreasing. When trading cost is very high, there is no trade and no trading costs are incurred. Therefore, the real wage ratio is very close to the nominal wage ratio. When trading cost decreases and trade starts, the factor equalization effect will decrease the wage difference between the two countries, thus increase the wage ratio towards 1. However, the real wage ratio will increase less than the nominal wage ratio due to the existence of trade costs. At the same time, the nominal and real wage ratios still decrease in labor ratio due to the decreasing marginal return to labor. However, most other NEG models show that when transportation cost is sufficiently low, the real wage ratio will increase in the labor ratio. Most NEG models include only one factor---labor, as a variable input in manufacturing production. As a result, they cannot reflect the effect of decreasing value of marginal product of labor.

Figure 4 shows that the total real income and final manufacturing production of the two countries increase in value of τ while decrease in country y's labor share. It indicates that the decrease of trading cost and thus the increase of trade improves the whole economy's welfare. But the economy with labor concentrated in one country is worse than the economy with more evenly distributed labor in the simulated case.

Proposition 4. Based on simulations, both countries gain from trade when factors are not mobile, but the per capita income of the labor abundant country is less than that of the other country and the gap increases in the labor endowment difference. The cross-country wage difference (either real or nominal) is reduced through trade. But it will not be eliminated as in factor price equalization as long as the trading costs are positive. Between trading countries, the wage difference is larger the larger the labor endowment difference.

2.3.2 The Two-Country Model with Mobile Capital and Immobile Labor

Now keep all other conditions unchanged but assume that capital (K) can move freely across countries, so the nominal equilibrium return for capital will be r for both countries and the capital used by one country does not necessarily equal to the country's capital endowments. In the NEG models without capital input, the shift of production can lead to the shift of labor and expenditure followed by further production shifting. This kind of circular causality finally causes the catastrophic agglomeration. The involvement of mobile capital and immobile labor rules out this kind of demand linkage because all capital income is repatriated, by assumption. At the same time, since the capital return is the same between countries while there are "iceberg" trading costs for any trade of manufactures, the trade of final manufactures will actually not happen.[19] Thus, each country will only consume the final manufactures produced domestically and the complete agglomeration of manufacturing production in one country will not exist. Therefore, I have: $C_{Mk} = X_{Mk}$. (2.52)

This is different from other capital-involved NEG models which get the catastrophic agglomeration of all manufactures. In those models, capital is involved only as a fixed input for the intermediate manufactures. Low labor costs attract capital and the

[19] Consider if it is profitable for a firm to produce the final manufactures in country x and sell them in country y. A $(1-\tau)$ share of capital-added value will be lost as trading costs. In addition, the varieties produced in country y will be transported to country x as intermediate inputs and then shipped back to country y as part of the final manufactures. A $(1-\tau)^2$ share of this part of varieties will be lost as trading costs again. If the firm just ships the varieties produced by country x to country y and produce the final manufactures consumed by country y locally, all above trading costs will be avoided.

intermediate manufacturing production together to the labor-abundant country. The concentration of the intermediate manufacturing production lowers the cost of intermediate input and further attracts final manufacturing production. Therefore, both intermediate and final manufacturing productions agglomerate to the labor-abundant country.

From (2.52), I can get $P_{Mk}X_{Mk} = P_{Mk}C_{Mk}$ (2.53)

Again, I can solve w_x, w_y, r_x and r_y from a nonlinear equation system: (2.48), (2.49) and (2.53). And solve all other variables of the economy after I have the values of w_x, w_y, r_x and r_y. Let K_{xc} and K_{yc} denote capital used by country x and country y respectively, I can have

$$\frac{P_{My}X_{My}}{P_{Mx}X_{Mx}} = \frac{K_{yc}}{K_{xc}} = \frac{P_{Ly}C_{Ly}}{P_{Lx}C_{Lx}} \tag{2.54}$$

So, the country with a larger market for intermediate manufactures will use more capital and have larger production and consumption of final manufactures.

In the following part of this section, I will do the numerical analysis. I can get the results shown in Figure 5 by using the same parameters used in section 2.3.1. With mobile capital, I can see that when $\tau = 0.1$, the varieties increasing effect is stronger than comparative advantage effect, thus country y is net importer of intermediate manufactures and a net exporter of agricultural products. But when trading cost decreases and $\tau = 0.9$, country y becomes a net exporter of intermediate manufactures. In this case, country y has the larger market in intermediate manufactures and disproportionately larger share of intermediate manufacturing production. Based on the same set of simulations, Figure 6

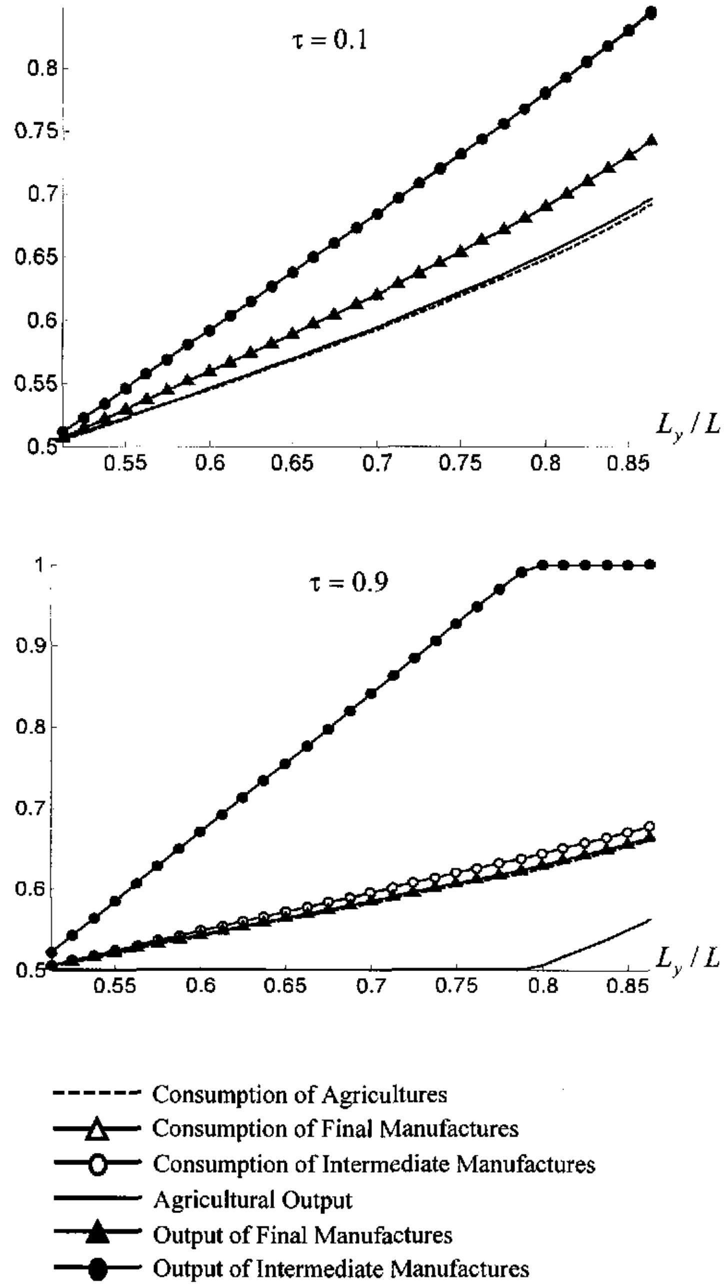

Figure 5. Trade Patterns of Two Countries with Mobile Capital and Immobile Labor

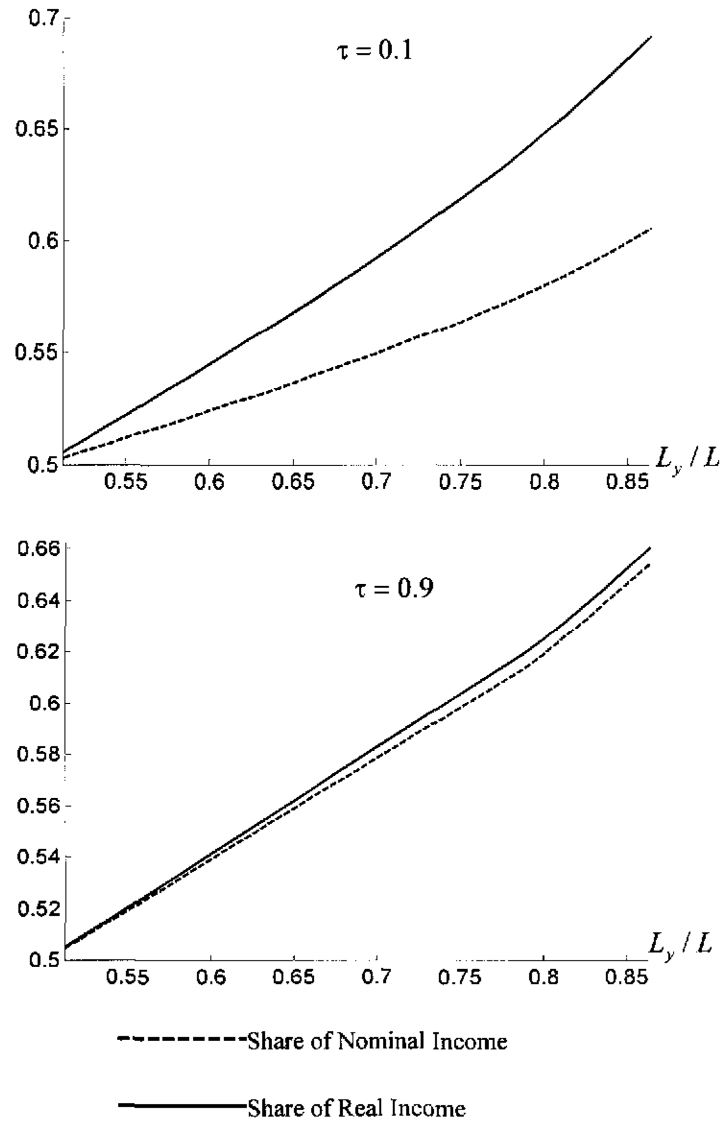

Figure 6. Income of Two Countries with Mobile Capital and Immobile Labor

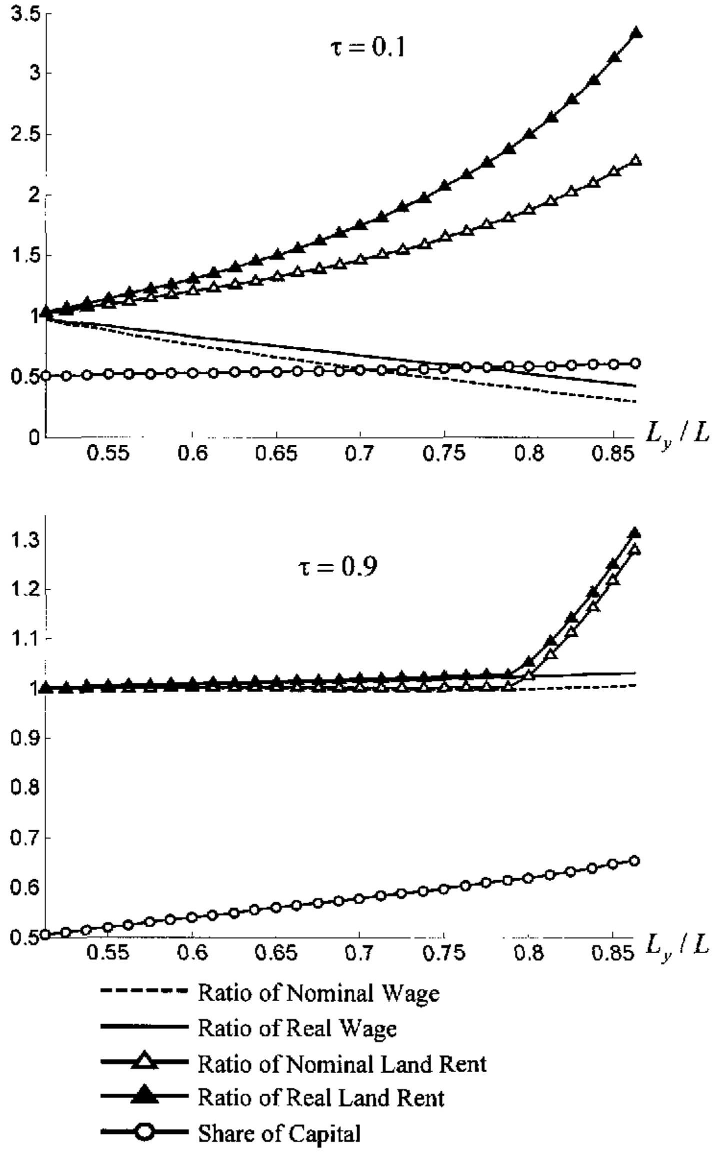

Figure 7. Factor Returns of Two Countries with Mobile Capital and Immobile Labor

shows that country y's shares of nominal income are still smaller than its corresponding shares of labor. However, country y's share of real income is higher than its share of nominal income. And the higher the trading cost is, the higher country y's share of real income is. Combining the simulation results in section 2.3.1 and 2.3.2, it indicates that trade increases the real per capita income difference between the two countries while capital mobility alleviates it. Therefore, liberalization of capital mobility can help reduce income inequality across countries.

In Figure 7, I decompose income into factor returns again. I can see that both country y's nominal and real land rents are higher than those of country x's. When trading cost is high ($\tau = 0.1$) and there is not much trade, both nominal and real wage ratios are smaller than 1, i.e., both country y's nominal and real wages are lower than those of country x's. The difference increases in labor concentration in country y. This result is similar with the case in section 3.1. However, when trading cost is low (e.g., $\tau = 0.9$) and trade increases, the ratio of real wage becomes higher than 1 and the factor return differences between the two countries are much smaller than those in Figure 3. I can also see that the share of capital used by country y increases in country y's labor share and value of τ. It means that both the increase of trade between the two countries and the increase of labor concentration help country y attract more capital. This can be explained intuitively. Without capital mobility, due to the abundant labor endowment, country y has lower labor cost, and cheaper intermediate manufacturing input than country x. Once the capital can freely move across countries, the low price of country y's intermediate manufactures attracts capital from country x. On the other hand, the lower trading costs can further decrease country y's intermediate manufacturing cost and increase the capital inflow. The inflow of capital increases country y's marginal product of labor, which offsets the decrease of country y's marginal product of labor due to the increase of labor. Therefore, I see that country y's real wage is higher than that of country x's. These results can be summarized in the following proposition:

Proposition 5. Based on our simulation, when capital is mobile across countries, production concentration caused by the vertical linkage of industries occurs. The capital mobility also reduces the wage gap exists between the two countries due to the labor endowment differences.

2.3.3 The Two-Country Model with Transportation Cost for All Sectors

Davis (1998) finds that the transportation assumption is crucial to Krugman's CP model and unless the trade cost is unusually higher for differentiated goods (more than 28 times of homogeneous goods' trade cost), each economy will remain in the proportional equilibrium. However, he does not incorporate Venables (1996)'s model with two vertically linked manufacturing sectors. Following Venables's model, define

$$v_L = \frac{n_y p_y (c_{yx} + c_{yy})}{n_x p_x (c_{xx} + c_{xy})} = \frac{p_y X_{Ly}}{p_x X_{Lx}}, \tag{2.55}$$

$$\rho_L = \frac{p_y}{p_x} = \frac{w_y}{w_x}, \tag{2.56}$$

and $\eta_L = \dfrac{P_{Ly} C_{Ly}}{P_{Lx} C_{Lx}}$, as ratio of two countries' first stage manufacture output, price level and consumption respectively.

Let v_H, ρ_H and η_H denote the ratios of the two regions' second stage manufacturing output, price level and consumption respectively.

From (A.1.5), (2.32) $v_M = \frac{P_{My}X_{My}}{P_{Mx}X_{Mx}} = \frac{K_y r_y}{K_x r_x} = \frac{P_{Ly}C_{Ly}}{P_{Lx}C_{Lx}} = \eta_L$ (2.57)

From (2.40), $\eta_M = \frac{Y_y}{Y_x} = \frac{X_{Ay}P_{Ay} + w_y(L_y - L_{Ay}) + r_y K_y}{X_{Ax}P_{Ax} + w_x(L_x - L_{Ax}) + r_x K_x}$ (2.58)

Taking (2.31)/(2.30), $\left(\frac{P_{Ly}}{P_{Lx}}\right)^{1-\sigma} = \frac{\tau^{\sigma-1} + v_L \rho_L^{-\sigma}}{1+\tau^{\sigma-1}\rho_L^{-\sigma} v_L}$ (2.59)

From (A.1.5), (2.34), $\frac{c_y}{c_x} = 1 = \left(\frac{p_y}{p_x}\right)^{-\sigma} \frac{P_{Ly}^{\sigma-1}P_{Ly}C_{Ly} + \tau^{\sigma} P_{Lx}^{\sigma-1}P_{Lx}C_{Lx}}{P_{Lx}^{\sigma-1}P_{Lx}C_{Lx} + \tau^{\sigma} P_{Ly}^{\sigma-1}P_{Ly}C_{Ly}}$

$$= \rho_L^{-\sigma} \frac{\eta_L (P_{Ly}/P_{Lx})^{\sigma-1} + \tau^{\sigma}}{1+\tau^{\sigma}\eta_L (P_{Ly}/P_{Lx})^{\sigma-1}} \quad (2.60)$$

Substituting (2.38) into (2.60), $v_L = \frac{\eta_L(\tau^{-\sigma} - \rho_L^{\sigma}) - \tau^{-1}(\rho_L^{\sigma} - \tau^{\sigma})}{\tau^{-\sigma} - \rho_L^{-\sigma} - \eta_L \tau^{-1}(\rho_L^{-\sigma} - \tau^{\sigma})}$ (2.61)

So, $\frac{\partial v_L}{\partial \rho_L}$ >0, and $\frac{\partial v_L}{\partial \eta_L} . \frac{\eta_L}{v_L}$ >1. Therefore, for the intermediate manufacturing sector, the larger market will have higher price and wage and disproporationately larger share of production. However, it is easy to show that when there is no transportation cost, i.e., $\tau = 1$, this statement will not hold. In this section, I will examine the case when agriculture has the same trade cost as manufactures.

Assume that all conditions stay the same as in section 2.3.2, except that agriculture now has the same trade cost as manufactures. Use the price of agricultural products in country *x* as numeraire: P_Ax = 1. I can have:

$$(1-\mu)\left(A_x g(w_x) + w_x L_x + r_x K_x + \frac{A_y g(w_y) + w_y L_y + r_y K_y}{P_{Ay}} \right) = X_{Ax} + X_{Ay} \quad (2.62)$$

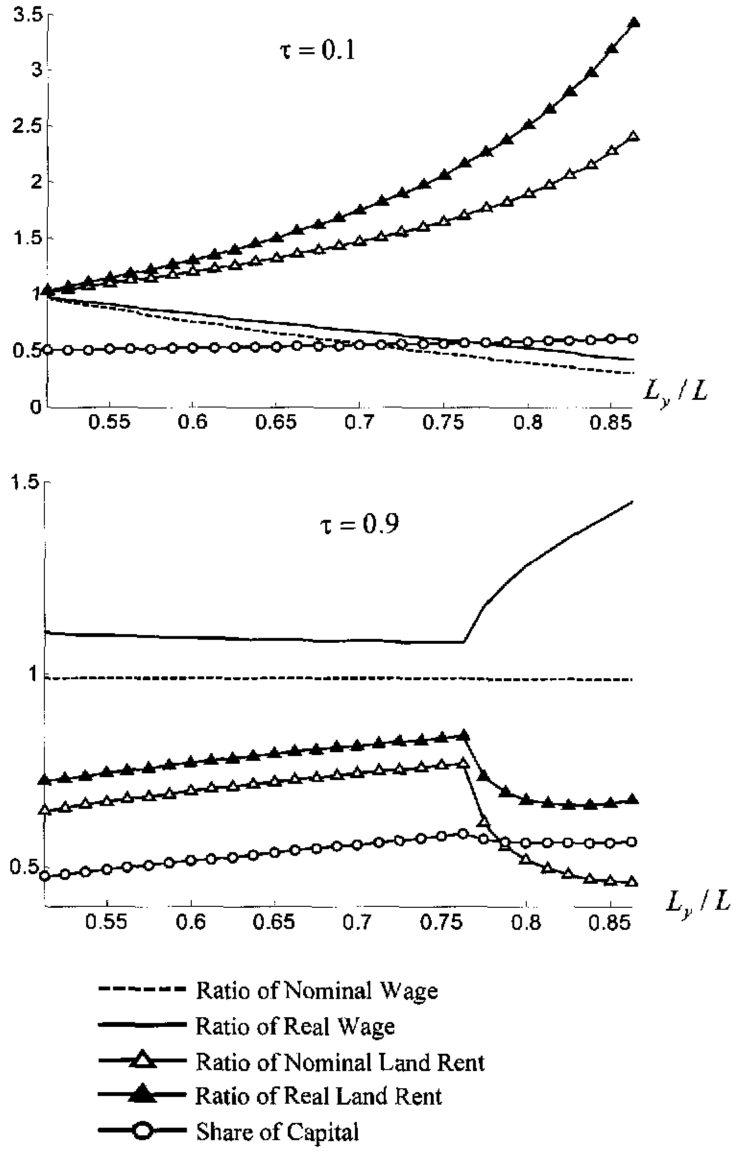

Figure 8. Factor Returns of Two Countries with Transportation Cost for All Sectors

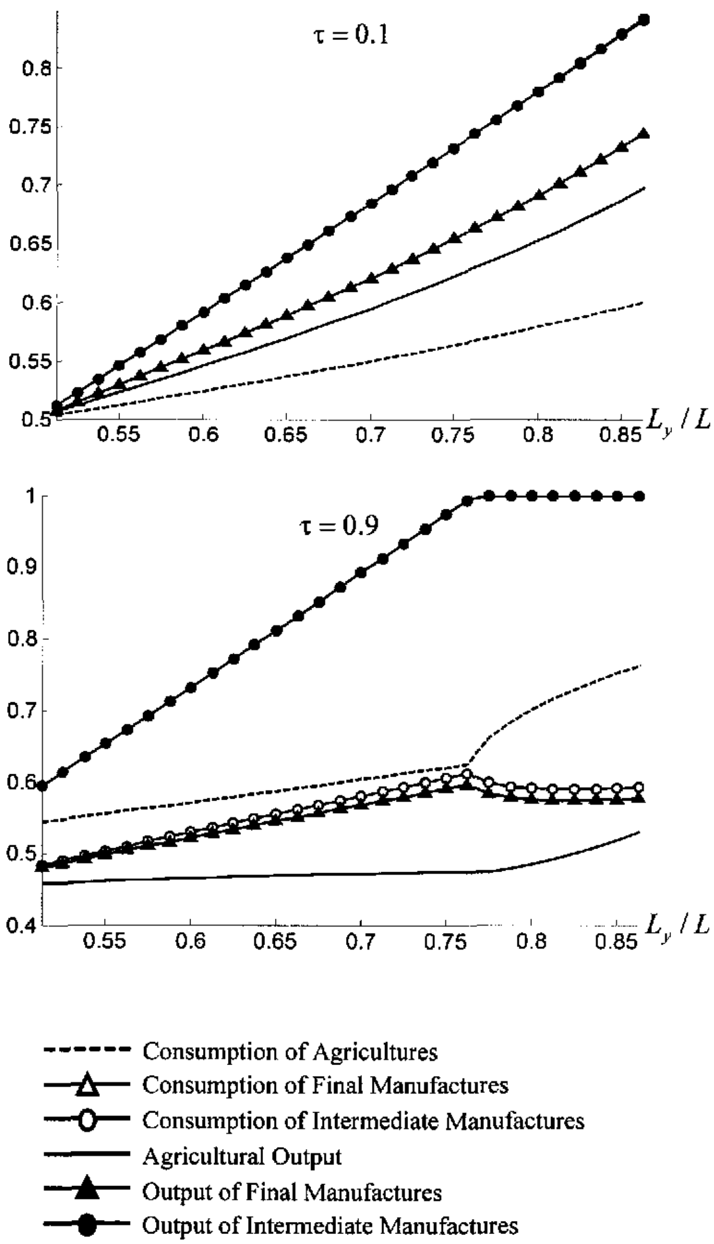

Figure 9. Trade Patterns of Two Countries with Transportation Cost for All Sectors

Equations of w_x, w_y, r_x and r_y can be derived through the nonlinear equation system (2.48), (2.49), (2.53) and (2.62). Figure 8 and Figure 9 display our simulation results. When $\tau = 0.1$, I can see that Figure 8 is quite similar to Figure 7. However, when $\tau = 0.9$, Figure 9 shows that the ratio of real wage becomes much greater than 1. When country y's share of labor is greater than 0.77, country *x* stops producing intermediate manufactures and the country *y*'s real wage increases dramatically relative to that of country *x*'s. This can be explained by the involvement of trade costs for agricultures. Country *y*'s labor endowment is so abundant that it has absolute advantages in both manufacture and agricultural sectors. But its comparative advantage is still in the manufactures sector. Therefore, it is a net exporter of intermediate manufactures and net importer of agricultural products when trading cost is very low ($\tau = 0.9$). In this situation, the involvement of trading costs for agricultural products will increase the price of country *x*'s exports, i.e., agricultural products, thus decrease its comparative advantage in that sector and its gain from trade. This will further decrease country *x*'s factor returns, including real wage. Therefore, the involvement of trading costs for agricultural products increases the gap of real wage between the two countries from another direction. It increases the relative real wage of country *y*, which has comparative advantage in the manufactures sector. In other words, the involvement of trading costs for agricultural products augments the agglomeration effect in the manufactures sector.

Proposition 6. Based on the simulations, when there are trade costs for agricultural products, the agglomeration effect in manufacturing increases and capital mobility still can help reduce the inequality across countries.

2.4 Conclusions

This paper studies how the existence of economies of scale and the trading cost affect the industrial distribution, the trade pattern and the wage difference of two countries. I set up a two-country general equilibrium model by incorporating a capital factor into the NEG model.[20] I simulate the effects of capital mobility and diminishing marginal returns on the economy. Based on Davis (1998)'s comments on Krugman's CP model, I also check the robustness of my results to the introduction of trade costs for agricultural goods.

From the numerical simulation, I find that agglomeration of labor-intensive industries occurs in the labor-abundant country if the trading cost is sufficiently low. The agglomeration occurs regardless of whether or not there are trading costs for agriculture and capital mobility across countries. But a larger market does not necessarily have a disproporationately larger share of production in all industries as previous NEG models predicted. The effect of comparative advantage impedes the agglomeration of industries when the country with a smaller market has the comparative advantage in the same industries. This is consistent with Ricci (1999)'s conclusion that the agglomeration effect weakens the specialization degree. On the other hand, when comparative advantage is not sufficiently strong and trading cost is high, the varieties increasing effect can also impede the agglomeration of labor-intensive industries in the labor abundant country.

In the case of immobile capital, trade occurs when comparative advantage is sufficiently strong to compensate for the trade cost and both countries gain from trade. There is a gap between the two countries' wages in both nominal and real terms. Both

[20] If a country can attract resources and consumers of its rivals', it can surely win the competition in the third country market. I therefore only analyze the two-country model in this paper.

nominal and real wages are lower in the labor abundant country. This is caused by the endowment difference and the existence of trading costs. The gap is reduced by trade, but still increases in the labor endowment difference due to the effect of diminishing marginal returns. This result differs from most previous NEG models' simulation results which show that the wage level is higher in the labor abundant country when the trading cost is sufficiently low. This is because those models do not have capital as an input in manufacturing production. They do not reflect the effect of diminishing marginal returns of labor.

My simulation results show that capital mobility narrows the wage (either nominal or real) difference across countries. The real wage in the labor abundant country is even slightly higher than that in the other country when the trading cost is sufficiently low. When both mobile capital and agricultural trade costs are involved in the model, the simulation results show that the countries with abundant labor have much higher real wage than the other country. This suggests that for the country with strict capital controls, capital liberalization can help reduce wage difference between countries in both nominal and real terms.

The simulation results of this chapter indicate that with economies of scale technology and labor immobile across countries, as long as the trade pattern follows what comparative advantages indicate, low trading costs will not cause the catastrophic agglomeration in the country with the larger market as most other NEG models predict. This is because of the involvement of capital as a variable input in the final manufacturing production. By introducing capital, I have completely ruled out the demand and cost linkage associated with the labor-involved production from the capital-intensive industry. As a result, only the labor-intensive industries agglomerate into the labor abundant countries. The catastrophic agglomeration does not happen in the capital-intensive industries. This is different from other capital-involved NEG models which have capital as a fixed input for the intermediate manufactures and still get the catastrophic agglomeration for all industries. At the same time, the inclusion of both labor and capital as variable manufacturing inputs enables the model to reflect the effects of comparative advantages and the diminishing marginal returns to labor and capital, which work to counter to the agglomeration effect. The simulation results show that when labor is not the only variable input in manufacturing production, the labor abundant country does not necessarily have a higher wage rate as other NEG models predict.

With labor immobile across countries, my model predicts that capital mobility will increase the return to labor in the labor abundant region relative to the other region. However, labor is more likely to be mobile across sub-regions within a country. How will labor mobility together with capital mobility affect an economy? This is an important topic for my further study.

CHAPTER 3
EMPIRICAL STUDY ON INDUSTRIAL AGGLOMERATION WITHIN CHINA

3.1 Introduction

Since the beginning of its open door policy in 1978, China's economy has grown spectacularly for 30 years. From then to 2005, China's Gross Domestic Product (GDP) rose, in constant 2000 US$, from US $157.7 billion to US $1,889.9 billion,[21] giving an average annual GDP growth rate of 9.6%. China's exports and imports have grown even faster during the same period, with average annual growth rates of 12.6% and 13.3% respectively.

Along with China's rapid economic and trade expansion, the world prices of products in which China has comparative advantage, mostly labor-intensive products, have dropped significantly due to the cheap supply from China.[22] Consumers benefit from the price drop and their consumption of labor-intensive products shifts to those made in China, which increases the world market share of China's exports in labor-intensive industries. At the same time, the production of labor-intensive industries tends to agglomerate in China. To save the labor cost, multinational companies continue to move their labor-intensive production to China, which induces the huge flow of foreign direct investment (FDI) into China. However, the locations of China's exporting industries and the destinations of FDI flowing into China have displayed significant spatial concentration in China. In 2006, over 31 percent of China's exports were from

[21] *World Development Indicators*, World Bank (2007).
[22] Please see IMF (2004) for more detail.

Guangdong province and more than 75% of FDI flowed into its coastal regions. [23] It seems that it is China's coastal regions that hold comparative advantage over many other countries as well as other regions of China, gain large world market share of labor-intensive products and absorb a huge amount of the world's production resources [Tuan and Ng (2004)]. Economic activity is agglomerating in China's coastal regions.

One of the most important reasons that caused this agglomeration is believed to be the Chinese government's reform strategy------ "let some people and some regions get rich first; the rich people and regions should then pull the rest of the country to get rich" [Deng, (1994)] and the corresponding economic policies[24]. Some preferential policies were implemented in China's coastal region which sped up the development of those regions and made them more competitive and wealthier than the rest of the country. [25] Tuan and Ng's (2004) research indicates that the process of legal modernization and policy reforms via institutionalization, which has significantly lowered both domestic and international trade costs of China, has strong effects on China's development distribution.

Tuan and Ng's (2004) study is based on Krugman's (1991) well-known NEG model----- the Core-Periphery (CP) model. The CP model shows that a larger economy, which has both a larger labor endowment and a larger local market, tends to be more attractive to manufactures due to the existence of economies of scale and trade costs. The concentration of manufactures in the larger economy increases the demand for labor which lifts its wage level to be higher than other regions. The higher wage level attract

[23] Values are calculated from data in NBSC (2007). Please see Van Huffel, Luo and Catin (2005) for more detailed review on the concentration of economic activities in China.
[24] The role of China's trade policies on firm location is discussed in Batisse and Poncet (2004) and Jin (2004).
[25] In general, preferential policies include preferential tax treatment and direct local authorization for approval of FDI utilization. Please see Tuan and Ng (2001) for more detail.

more labor to the larger economy which further increase the larger economy's labor endowment and local market size. The process will continue until all manufactures agglomerates to the larger economy. Tuan and Ng's conclusion supports the argument that institutional changes affected the distribution of economic activities in China. However, their study did not tell us whether the labor endowment and market size affected the distribution of economic activities as well as the regional wage levels in China as CP model predicted.

In reality, the large population, and thus large potential market size and labor supply, is the most important reason that China's development attracts extra attention and raises concerns. At the same time, the problem of sharp disparities in wages and income levels of households between coastal areas—where most business activities are located—and inland provinces has been serious.[26] This has induced the "floating" population of internal migrants seeking improved income, and the associated severe congestion and environmental problems. All these problems have threatened the continuance of China's economic development. To solve the regional inequality and the associated problems within China as well as release world's concerns on China's development, we need to understand the agglomeration patterns of economic activities within China. Therefore, an important question must be answered: How do China's regional labor endowment, market size and wage level interact with each other?

Much NEG empirical work has been done to study the effect of agglomeration on wage levels and the regional income (market size). Two methods that are widely used are the market-potential method [Brakman, Garretsen and schramm (2003),Hanson (2005)]

[26] The role of trade opening in altering economic disparities in China is assessed in Anderson et al. (2003).

and the market-access method [Redding and Venables's (2004)]. Hanson derives a full structural equation of wage based on Helpman's (1998) NEG model and estimates the wage equation with US data on employment, income, and housing stocks as right-hand side variables. On the other hand, Redding and Venables (2004) estimate the cross-country correlation between per capita income and the proximity to demand and supply markets, where the latter is constructed from estimated parameters of a gravity model of trade. Due to the lack of data on sub-regional trade within China, in this paper, I use Hanson's method to check the relationship between the sub-regional wage levels and market size within China.

3.2 Literature Review

Hanson (2005) classifies empirical researches on the NEG models into three strands: 1) studies examining Krugman's (1980) home-market effect [Davis and Weinstein (1999, 2003), Head and Reis (2001), Hanson and Xiang (2004)], i.e., whether production or exports tend to concentrate near larger markets; 2) studies examining technology diffusion across space and its effects on trade and industry location [Eaton and Kortum (1999, 2002), Keller (2002)]; 3) studies examining whether income or nominal wages are higher in countries or regions with access to larger markets for their goods [Hanson (1996, 1997), Redding and Venables (2004), Head and Mayer (2004), Brakman et al (2003,2005)]. I focus on the third strand since my purpose is to examine the income or nominal wage differences among different regions.

Based on Helpman's (1998) economic geography model, Hanson (2005) set up a full structural approach to consider wages inequalities in the economic geography framework. Basically, Helpman's model is very close to Krugman (1991)'s CP model and the functional equilibrium relationships look very similar for the two models. However, there is still an essential difference, as mentioned by Hanson, which makes the Helpman model more favorable for empirical work: Helpman uses housing, a sector with non-tradable products and exogenously fixed endowment to replace the agricultural sector in Krugman's CP model. As industrialization continues, the share of expenditure on agricultural products decreases, which weakens the importance of the agricultural sector to the economy substantially. However, the effect of housing on the economy will be relatively more stable across time, thus reduce the disturbance caused by factors other than the agglomeration effect. To be more comparable with Hanson's study, I use Helpman's model rather than Krugman's basic CP model in the following estimations.

Based on US county-level data, Hanson estimates both the simple market-potential function based on Harris (1954) and the augmented market potential function based on Helpman's (1998) model of economic geography. His results reject the simple market-potential function in favor of the augmented market-potential function and provide confirmation for his version of the Helpman model, but the results are of limited geographical scope. At the same time, Hanson's study still cannot rule out the possibility that other factors also contribute to spatial agglomeration as shown in other empirical studies of agglomeration.[27]

Redding and Venables (2004) apply a very different empirical strategy to study the agglomeration effects on regional wage level. They estimate the cross-country correlation between per capita income and the proximity to demand and supply markets,

[27] Empirical work shows that the basic CP model might not capture all reasons for agglomeration. Alternative explanations can be natural advantages [Ellison and Glaeser (1997, 1999) and Davis and Weinstein (2002)], human capital externalities [Moretti (2004) and Head and Mayer (2004)], technological externalities [Audretsch and Feldman (1996) and vertical linkages among industries [Redding and Venables (2004)]

where the latter is constructed from estimated parameters of a gravity model of trade. They find that market access is positively correlated with per capita income, which is consistent with Hanson's (2005) finding that county wage growth is positively correlated with growth in a county's market-potential index. Thus, market access appears to be strongly associated with wages whether one looks across countries or across regions within a country.

The advantage of Hanson's approach is that the spatial distribution of economy activities can be studied at a highly disaggregated level and the model's structural parameters can be estimated. Compared with Hanson's method, the advantage of the Redding-Venables method is that by starting with a gravity model we are able to account for the importance of proximity to both demand and supply, thus permitting both consumers and firms to be sources of industrial demand. Due to the lack of data on China's internal trade, I use Hanson's method in this paper.

There are also other empirical works on spatial distribution of economic activities within China. Catin and Van Huffel (2003) divide the development of a transition economy into three stages: 1) pre-industrial, which is characterized by low per capita income and weak urban concentration; 2) economic take-off, where the industrialization process pushes the concentration of activities; 3) specialization in high-tech industries, where the regional inequalities increases and the concentration in labor-intensive industries decelerates or even decreases, while a concentration in technological industries starts. Based on this classification and the provincial level panel data of the period 1988-97, they test two hypotheses: 1) whether the openness has reinforced a polarization process that characterized the second stage of development, 2) whether the progressive specialization in high-tech industries leads to a diffusion of the labor intensive activities to the inland provinces.

Van Huffel, Luo and Catin (2005)'s results show that high-tech industries are concentrated highly in the coastal provinces. At the same time, the concentration in labor-intensive industries decelerates or even decreases in the coastal region. But this movement is just from the more developed coastal provinces to the less developed coastal provinces and does not significantly modify the major trends of the location and specialization of industries in the inland region. Van Huffel, Luo and Catin's study provides strong support for the importance of my study. First of all, their study confirms that the concentration of economic activities does exist in the different development stages of China at both sub-regional and national levels. Secondly, their empirical tests focus on the effects of the gradual open-door policies and the inflow of FDI on the spatial distribution of the Chinese economy. They do not analyze the detailed market potential or market access; how well the NEG framework can work for the case of China still needs to be tested. Finally, the data they use is at the provincial level for the period 1988-97. However, the rural-urban disparity and the hierarchy of cities may make the welfare effect of the concentration more significant [Brakman et. al. (2005)]. At the same time, their study is based on an immobile labor assumption, but the extent of labor mobility in China has increased since 1990s.[28] This suggests that their conclusions may change substantially with a data update.

Au and Henderson (2002) estimate the relationship between city-level per capita output in the non-agricultural sector and several determinants: capital stock to labor ratio,

[28] Please see Huang and Zhan (2005) for detail.

share of accumulated FDI in capital stock, distance to the coast, education and scale measures (city employment, employment squared, and employment interacted with the manufacturing to service ratio). They divide the data into the 1990-92 "planning" period and the 1995-97 "market" period and regress separately. Their results confirm that worker productivity is shown to be an inverted U-shape function of the city employment level, with the peak point shifting out as industrial composition moves from the manufacturing sector to the service sector as predicted by urban theory. They also argue that the majority of Chinese cities are shown to be potentially undersized – below the lower bound on the 95% confidence interval of the size where their output per worker peaks – and so there could be large gains from increased agglomeration in both the rural industrial and urban sectors. The purpose of Au and Henderson's study is close to my empirical study. I want to test the effect of agglomeration on wage levels at the city level. However, our methods will be quite different since I will use the nonlinear structural model derived from the NEG models. Instead of just estimating the linear relationships between per capita output and its determinants, I can estimate the structural parameters such as elasticity of substitution, share of industrial production in national production, share of capital in the industrial production and the trading cost parameter.

According to the above literature, China continues to face regional disparity problems caused by the concentration of economic activities. The factors that affect the spatial distribution and regional wage disparity of the Chinese economy are economic openness, industrialization, agglomeration, other factors or the combination of these factors. The effect of agglomeration has not yet been checked. Therefore, I try to explain the regional wage disparity in China from the NEG perspective in this paper.

3.3 The Model

3.3.1 The Wage Equation:

This section derives a wage equation based on my NEG model developed in Chapter 2. As Hanson (2005) has mentioned, Helpman (1998)'s extension on the Krugman (1991) model is more tractable for empirical work due to the introduction of a non-tradable housing sector in place of the agricultural sector. Therefore, I assume that all consumers have identical Cobb–Douglas preferences over two bundles of goods, tradable manufacturing goods and housing services. A representative consumer in region k solves the problem:

$$\text{Max } U_k = C_{Hk}^{1-\mu} C_{Mk}^{\mu} \tag{3.1}$$

$$\text{s.t. } P_{Hk} C_{Hk} + P_{Mk} C_{Mk} = Y_k, \tag{3.2}$$

where C_{Hk} , C_{Mk} are consumption of non-tradable housing services and traded manufactures in country k respectively. P_{Mx}, P_{Hk}, Y_k are the price of manufactures, the housing price and the total output in country k.

The production function of manufactures is defined as:

$$X_{Mk} = C_{Lk}^{b} K_k^{1-b} = \left[\left(\sum_{i=1}^{n} c_{ik}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right]^{b} K_k^{1-b}, \tag{3.3}$$

where $C_{Lk} = \left(\sum_{i=1}^{n} c_{ik}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$ is the CES (Constant Elasticity of Substitution) aggregation of intermediate manufactures used in region k, K_k is the capital used by region k,[29] n is the

[29] The NEG model in this paper includes both labor and capital as manufacturing inputs. For detailed reason, please see Chapter 2.

number of varieties of intermediate manufactures consumed by region k and $\sigma > 1$ is the elasticity of substitution[30] among varieties. Here, the production of manufactures needs two inputs: labor and capital. It is different from Helpman's model which only includes labor in manufacture production.

The production of an intermediate variety involves a fixed cost and a constant marginal cost: to produce x_i of good i, we need $L_i = \alpha + \beta x_i$ ($\alpha > 0, \beta > 0$), where L_i is the amount of labor employed to produce good i. Therefore, there are increasing returns in production of each intermediate manufacturing variety. In equilibrium, each variety is produced by a single monopolistically competitive firm and the f.o.b price of variety i produced in region j is $p_{ij} = \left(\frac{\sigma}{\sigma-1}\right)\beta w_j$, where w_j is the nominal wage in region j.

There are J regions, K capital and L laborers in total, where laborers and capital are mobile across regions. With iceberg transportation costs in shipping goods between regions, the c.i.f price of good i produced by region j and sold in region k is

$$p_{ijk} = p_{ij} e^{\tau d_{jk}} \tag{3.4}$$

where τ is the unit transportation cost and d_{jk} is the distance between region j and k. Given the symmetry of intermediate manufactures in production and the mobile capital, the total sales of manufacturing goods by region j are[31]

$$\sum_k \sum_i p_{ijk} c_{ijk} = n_j r^{\frac{(b-1)(\sigma-1)}{b}} \sum_k \mu b Y_k \left[\frac{\sigma}{\sigma-1}\beta w_j e^{\tau d_{jk}}\right]^{1-\sigma} P_{Mk}^{\frac{\sigma-1}{b}} \text{ [32]} \tag{3.5}$$

[30] I follow Ethier's (1982) assumption that the work of aggregating varieties can also be considered as a variety, so there is no extra labor needed in the aggregation production.

[31] Since the capital return is the same between regions but we have "iceberg" trade costs for any trade of manufactures, the trade of final manufactures will actually not happen. Please see Chapter 2 for details.

where c_{ijk} is the amount of variety i that region k purchases from region j, r is the nominal return to capital. Monopolistically competitive firms earn zero profits. Therefore, the manufacturing sales in region j equal wages paid to labor in j, which is $w_j n_j a\sigma$. We then can get the following function for wage:

$$w_j = \theta r^{\frac{(b-1)(\sigma-1)}{b\sigma}} \left[\sum_k Y_k e^{-\tau(\sigma-1)d_{jk}} P_{Mk}^{\frac{\sigma-1}{b}} \right]^{1/\sigma}, \quad \theta = \left(\frac{\mu b}{\alpha\sigma} \right)^{1/\sigma} \left(\frac{\sigma\beta}{\sigma-1} \right)^{1-\sigma} \tag{3.6}$$

where θ is a function of fixed parameters. This equation indicates that wages in a region are increasing in the income of surrounding locations, decreasing in capital return, decreasing in transportation costs to these locations, and increasing in the price of competing traded goods in these locations. The summation term measures the market potential of the region.

Since labor can move freely across regions, real wages are equalized. Thus we have

$$\frac{w_j}{P_{Hj}^{1-\mu} P_{Mj}^{\mu}} = \frac{w_k}{P_{Hk}^{1-\mu} P_{Mk}^{\mu}} = \delta, \quad \forall j \neq k \tag{3.7}$$

where δ is the equalized real wage.

In equilibrium, we also have housing payments equal housing expenditure,

$$P_{Hk} C_{Hk} = (1-\mu) Y_k. \tag{3.8}$$

[32] $c_{ijk} = C_{Lk} \left(\frac{P_{Lk}}{p_{ijk}} \right)^{\sigma}$.

From equation (3.6)-(3.8), We can derive a wage equation similar to Hanson's wage equation:[33]

$$\ln(w_j) = \phi + \frac{(b-1)(\sigma-1)}{b\sigma}\ln r + \frac{1-\sigma}{b\mu\sigma}\ln\delta + \sigma^{-1}\ln\left(\sum_k Y_k^{\frac{(\sigma-1)(\mu-1)+b\mu}{b\mu}} C_{Hk}^{\frac{(\sigma-1)(1-\mu)}{b\mu}} w_k^{\frac{\sigma-1}{b\mu}} e^{-\tau(\sigma-1)d_{ik}}\right) \quad (3.9)$$

where $\phi = \ln\theta + \frac{(\mu-1)(\sigma-1)}{b\mu}\ln(1-\mu)$.

It can be rewritten in reduced form:

$$\ln(w_j) = \phi + B5\ln r + B6\ln\delta + \sigma^{-1}\ln\left(\sum_k Y_k^{B1} C_{Hk}^{B2} w_k^{B3} e^{B4 d_{ik}}\right) \quad (3.10)$$

Parameters $B1$-$B6$ are reduced form coefficients to measure the effects of nearby region income, housing stock, wages, distance, capital return and real wage levels.

From equation (3.9), we can see that an increase in the return to capital will decrease the nominal wage. At the same time, higher income in nearby regions raises demand for traded goods produced in j (as long as $(\sigma-1)(\mu-1)+b\mu>0$ is satisfied)[34], and higher wages in nearby regions raise the relative price of traded goods produced in these regions, which also increases the demand for goods produced in *j*. The higher demand further increases the production in region *j* and raises the region's demand for labor and its nominal wages. In addition, larger housing stocks in nearby regions imply lower housing prices and higher employment in these regions and so higher nominal

[33] Hanson's (2005) wage equation is

$$\ln(w_j) = \phi + \sigma^{-1}\ln\left(\sum_k Y_k^{\frac{\sigma\mu-\sigma+1}{\mu}} C_{Hk}^{\frac{(\sigma-1)(1-\mu)}{\mu}} w_k^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)$$, where ϕ is also a constant.

[34] All my estimations satisfy this inequation.

wage needed for region j to attract more labor. Finally, the summation expression measures the market potential of region j. The greater market potential a region has, the higher its wage level is.

3.4 Data and Estimation Issues

3.4.1 Data Sources

I take cities in China as the geographic unit of analysis. The data required are wages, population, regional income, housing stocks and distance between cities. Data on distance between cities are driving distances in thousand kilometers downloaded from www.hua2.com (China Map Online). I measure a city's wage level by its average annual wage (in RMB yuan). The regional income is measured by each city's GDP in hundred million RMB yuan. Total personal housing area in square meter is used as proxy of housing stock. City-level data on average annual wage, population, GDP and per capita housing area are available in the China City Statistical Yearbook from 1990 to 2001 (They have stopped reporting the per capita housing area since 2002). Table 1 gives summary statistics on the variables. There are 327 cities. But data for some cities are missing in some years.

Table 1. Statistical Summary of Variables

Variables	GDP	GDP	GDP	Population	Population	Population
Year	2000	1995	1990	2000	1995	1990
Obs.	262.00	262.00	209.00	262.00	261.00	210.00
Mean	190.24	101.20	35.63	124.13	104.76	104.05
Standard Deviation	409.28	212.27	72.29	244.79	168.01	167.67
Skewness	6.48	7.05	6.77	8.62	6.55	5.94
Variables	housing	housing	housing	Wage	Wage	Wage
Year	2000	1995	1990	2000	1995	1990
Obs.	260.00	219.00	203.00	262.00	262.00	209.00
Mean	1,706.23	861.12	681.91	8,986.40	5,325.81	2,259.39
Standard Deviation	2,690.98	1,255.49	990.86	2,729.91	1,520.76	433.35
Skewness	7.10	6.13	6.10	1.60	1.41	1.57

Source: Author's calculations based on data in *China City Statistical Yearbook* (1990-2000)

Table 1 shows that the Pearson Index for GDP, Population and Housing Stock are far greater than 1, i.e., the distributions of these variables are positively skewed. Therefore, for the majority of the cities, the values of these variables are below average. It means that the population and economic activities are concentrated in a small number of the cities.

To further check the concentration and agglomeration of economic activities in China, I calculate the Concentration and Agglomeration Theil indices (Theil, 1967) with city level data of 30 Provincial Capitals and Separate Planning Cities in 2004. The Concentration index is defined as follows [Brakman, et al. (2005)]:

$$T^f = \sum_{r=1}^{R} T_r^f = \sum_{r=1}^{R} \frac{x_r^f}{x^f}\left(\log\frac{x_r^f}{x^f} - \log\frac{n_r}{n}\right) \tag{3.11}$$

where f is an industry index,

r is a region index,

R is the total number of regions,

x_r^f is the economic activity of industry f in region r,

x^f is total economic activity of industry f, $\sum_r x_r^f$,

n_r is the number of basic units of region r and

n is the total number of basic units, $\sum_r n_r$.

T^f compares each region r's relative economic activity of industry f (x_r^f / x^f) with what it should have been on the basis of the relative number of basic units (n_r / n). The basic units can be land area, population, economic activity, sub-regions, etc. If the industry is proportionally represented, $x_r^f / x^f = n_r / n$, T^f will be 0; if the industry is over represented, $x_r^f / x^f > n_r / n$, T_r^f will be a positive number; if the industry is under represented, $x_r^f / x^f < n_r / n$, T_r^f will be a negative number. The logarithmic transformation and the weights guarantee that T^f increases in the inequality of the distribution of x^f with respect to n.

The agglomeration Theil index is:

$$T = \sum_{r=1}^{R} \frac{x_r}{x} \left(\log \frac{x_r}{x} - \log \frac{n_r}{n} \right) \tag{3.12}$$

where, x_r is total economic activity of region r, x is the total economic activity of the whole nation $\sum_{r=1}^{R} x_r$, n_r is the number of basic units of region r and n is the total number of basic units, $\sum_r n_r$. Here, the basic unit can only be regions, population or area.

There are three kinds of indices shown inTable 2. The Economic Agglomeration indices use Regional GDP to measure the economic activities. The Industrial Concentration indices use regional industrial output to measure the industrial activities. The Employment Agglomeration indices use regional employment to measure the regional economic activities. All three indices use population as the basic unit. The city level data of the provincial capitals and the separate planning cities are used in calculation.

From the table we can see that the spatial concentration of economic activities is very significant in China. All three indices are greater than 10 at the national level. In

Table 2. Agglomeration and Concentration Indices in 2004 China
(Based on city-level data of Provincial Capitals and Separate Planning Cities)

Region	City	Economic Agglomeration based on regional GDP	Industrial Concentration	Agglomeration of Employment
North	Beijing	3.79	5.48	13.54
	Tianjin	1.66	6.57	1.24
	Shijiazhuang	-1.06	-1.37	-1.27
	Taiyuan	-0.27	-0.32	0.97
	Hohhot	0.00	-0.33	-0.03
Northeast	Shenyang	0.55	-0.68	-0.24
	Changchun	-0.35	-0.51	-0.55
	Harbin	-1.07	-1.70	0.56
East	Shanghai	12.64	26.75	2.52
	Nanjing	1.23	3.88	-0.03
	Hangzhou	2.46	5.77	-0.60
	Hefei	-0.69	-0.72	-0.69
	Fuzhou	0.21	-0.07	-0.37
	Nanchang	-0.55	-0.81	-0.48
	Jinan	0.47	0.16	-0.27
Middle	Zhengzhou	-0.41	-0.89	-0.42
	Wuhan	0.18	-0.79	0.69
	Changsha	-0.56	-1.07	-0.74
	Guangzhou	7.09	7.63	3.22
	Nanning	-1.14	-0.87	-1.01
	Haikou	-0.15	-0.23	0.10
Southwest	Chongqing	-5.54	-5.18	-5.45
	Chengdu	-0.62	-1.86	-0.98
	Guiyang	-0.56	-0.60	0.20
	Kunming	-0.45	-0.81	-0.15
West	Xi'an	-1.00	-1.28	0.22
	Lanzhou	-0.38	-0.32	0.30
	Xining	-0.36	-0.36	-0.28
	Yinchuan	-0.21	-0.23	0.32
	Urumqi	0.09	-0.16	0.78
	Agglomeration/ Concentration Index	14.99	35.11	11.10

Source: Author's calculations based on data in China Statistical Yearbook (2005) general, more economic production (GDP) is located in Shanghai, Guangzhou and Beijing compared with other cities. Industrial activities are mostly concentrated in Shanghai, while employment is agglomerated mostly in Beijing.

Table 1 also shows that the distribution of average annual wage level is positively skewed, although it is not as significant as the distribution of the other three variables. According to the NEG model, a few cities, which have concentrated population and labor supply, will have higher than national average wages. The rest, majority of the cities will have lower than national average wages. Therefore, the skewness of wage level's distribution is consistent with NEG model's prediction.

3.4.2 Estimation Issues

The first issue is the measurement error problem. The desired city wage measure is for a worker with some constant level of skill. According to the NEG theory, the variation in the constant skill wage across locations reflects the regional variation in nominal wages caused by the spatial variation in industry location. However, the available wage measure is the average annual wage per worker of each city. The variation in city average wages may be due either to the variation in the constant skill wage or to variation in worker characteristics. At the same time, the city with favorable characteristics, such as convenient transportation, the presence of universities or preferential policies, may attract both industrial firms and more-skilled labor, therefore any correlation between wages and the market-potential may be a byproduct of a correlation between the city's labor skill level and the market-potential. For instance, a city with more universities may have relatively large supplies of skilled workers (because college graduates tend to look for jobs near their place of education) and relatively large concentrations of production (because students and faculty are a captive local market).To reduce the effect of measurement error mentioned above, Hanson (2005) took time differences of the estimating equations. I follow his method and get the following specification for Eq. (3.9),

$$
\begin{aligned}
\Delta \ln(w_i) &= \frac{(b-1)(\sigma-1)}{b\sigma}(\ln r_t - \ln r_{t-1}) + \frac{1-\sigma}{b\mu\sigma}(\ln \delta_t - \ln \delta_{t-1}) \\
&+ \sigma^{-1}\left[\ln\left(\sum_k Y_{kt}^{\frac{(\sigma-1)(\mu-1)+b\mu}{b\mu}} C_{Hkt}^{\frac{(\sigma-1)(1-\mu)}{b\mu}} w_{kt}^{\frac{\sigma-1}{b\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\right. \\
&\left. - \ln\left(\sum_k Y_{kt-1}^{\frac{(\sigma-1)(\mu-1)+b\mu}{b\mu}} C_{Hkt-1}^{\frac{(\sigma-1)(1-\mu)}{b\mu}} w_{kt-1}^{\frac{\sigma-1}{b\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\right] + \Delta v_{it}
\end{aligned} \tag{3.13}
$$

It can be written in reduced form:

$$
\begin{aligned}
\Delta \ln(w_i) &= B5(\ln r_t - \ln r_{t-1}) + B6(\ln \delta_t - \ln \delta_{t-1}) \\
&+ \sigma^{-1}\left[\ln\left(\sum_k Y_{kt}^{B1} C_{Hkt}^{B2} w_{kt}^{B3} e^{B4d_{ik}}\right) - \ln\left(\sum_k Y_{kt-1}^{B1} C_{Hkt-1}^{B2} w_{kt-1}^{B4} e^{B4d_{ik}}\right)\right] + \Delta v_{it}
\end{aligned} \tag{3.14}
$$

The time difference removes the effect of city characteristics that vary little over time, such as the availability of agricultural land, convenient transportation, the presence of universities or preferential policies. Equation (3.13) should still be able to reflect the effects of economic activities, such as the factor movement, international trade and production relocation.

In Hanson's paper, the real wage is implicitly treated as constant and canceled out when taking the time difference. He gets the following wage equation:

$$
\begin{aligned}
\Delta \ln(w_i) = \sigma^{-1}&\left[\ln\left(\sum_k Y_{kt}^{\frac{(\sigma-1)(\mu-1)+\mu}{\mu}} C_{Hkt}^{\frac{(\sigma-1)(1-\mu)}{\mu}} w_{kt}^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\right. \\
&\left. - \ln\left(\sum_k Y_{kt-1}^{\frac{(\sigma-1)(\mu-1)+\mu}{\mu}} C_{Hkt-1}^{\frac{(\sigma-1)(1-\mu)}{\mu}} w_{kt-1}^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\right] + \Delta v_{it}
\end{aligned} \tag{3.15}
$$

The corresponding reduced form is:

$$\Delta \ln(w_i) = \sigma^{-1}\left[\ln\left(\sum_k Y_{kt}^{B1} C_{Hkt}^{B2} w_{kt}^{B3} e^{B4d_{ik}}\right) - \ln\left(\sum_k Y_{kt-1}^{B1} C_{Hkt-1}^{B2} w_{kt-1}^{B3} e^{B4d_{ik}}\right)\right] + \Delta v_{it} \quad (3.16)$$

Due to the complete labor mobility assumption, real wage (δ) is equalized across regions. However, it is not necessarily constant across time. From equation (3.7), we can have

$$\ln \delta_t - \ln \delta_{t-1} = (\ln w_t - \ln w_{t-1}) - \left(\ln\left(P_{Ht}^{1-\mu} P_{Mt}^{\mu}\right) - \ln\left(P_{Ht-1}^{1-\mu} P_{Mt-1}^{\mu}\right)\right) \quad (3.17)$$

From equation (3.17) we can see that the time difference of $\ln \delta$ is the difference between the nominal wage inflation and the price index inflation. These two inflations can be different for the same year and the term $\ln \delta_t - \ln \delta_{t-1}$ can have non-zero value. Therefore, the term with real wage should be kept in the time difference equation. Since δ is constant across cities, $\ln \delta_t - \ln \delta_{t-1}$ is also constant across cities. Therefore, I use national real wage level to calculate the time difference of real wage. Similarly, I use the national nominal lending interest rate to calculate the time difference of $\ln r$[35].

The remaining error term, Δv_{it}, is the change in the deviation of city average wages from city constant-skill wages. Hanson mentioned that this error term may be correlated with the change in the summation expression in equation (3.9), if regions that experience growth in demand for locally produced traded goods tend to attract workers with above average skills. To account for the possible correlation between the error term and the change in the summation expression, Hanson uses a GMM estimator with historical data on regional population growth lagged by 10 years or more as the

[35] The data for real wage and nominal lending interest rate are available in *China Statistical Yearbook* (1990-2001).

instrument for the change in the summation. Due to the limit of data availability, I use nonlinear least square estimator in Stata 9.1 with the city population growth data lagged only 5 years as the instrument.[36]

The second estimation issue is that other factors that influence spatial agglomeration, such as supplies of FDI (Tuan and Ng, 2003, 2004), or the available exogenous amenities (Roback, 1982) or localized human-capital externalities (Rauch, 1993), may also influence the spatial distribution of nominal wages. I deal with this issue by including three control variables in the estimation: annual utilized FDI, changes in the share of the tertiary industry in a city's GDP and higher educated population.[37] Due to the data limitation, I cannot use measures of exogenous amenities mentioned by Roback (1982), such as heating-degree days, cooling-degree days, average possible sunshine, etc. The amenities can be very important advantages for the development of the service industry in a city. Therefore, I use the changes in the share of the service industry in a city's GDP as proxy for the exogenous amenities. By regressing city average wage growth on city education, the specification captures the impact of both individual education and average city education on wages, which implicitly controls for human-capital externalities across workers within a city (Rauch, 1993). The city level data for utilized FDI, share of third industry in GDP and the higher educated population are also available in the China City Statistical Yearbook.

[36] Stata does not have nonlinear GMM estimator. But it provides a more general nonlinear estimator, nl, which can fit an arbitrary nonlinear function to the dependent variable by least squares.

[37] According to *China Statistical Yearbook*, economic activities are categorized into the following three strata of industry: Primary industry refers to agriculture, forestry, animal husbandry and fishery and services in support of these industries. Secondary industry refers to mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction. Tertiary industry refers to all other economic activities not included in the primary or secondary industries.

Other factors, such as technological spillovers, may also contribute to spatial agglomeration. Using external economies to explain spatial agglomeration has a long history in urban economics (Fujita and Thisse, 1996). However, spillovers tend to be assumed rather than derived in these models. As Hanson (2005) has mentioned, although spillovers between firms could certainly contribute to spatial agglomeration, the absence of microfoundations for this explanation perhaps makes it less compelling. Part of the appeal of the NEG models is that the pecuniary externalities arise endogenously through the incorporated scale economies at the firm level.

As China is an economy in transition, the structures of its production and consumption are both changing. This implies that the parameters in my structural wage equations, such as the elasticity of substitution, the share of housing expenditure in annual living expenses and the share of labor cost in industrial production, may not be the same for different years. Therefore, I estimate the equation for each individual year and check if there is any trend for the change of these parameters.

3.5 Estimation Results

Hanson estimated the reduced-form regression coefficient of the wage equation first. Then he derived the implied structural parameter. When I performed the nonlinear regression following Hanson's strategy, the R^2 values are smaller than 0.3 in most years, which are similar to Hanson's results.[38] But if I estimate the structural parameter directly, the R^2 increases to more than 0.5 in most cases, which means a great improvement in the fit of the regression. Table 3 and Table 4 report the direct nonlinear least squares estimation results for wage equations (3.15) and (3.13) respectively. The dependent

[38] Please see APPENDIX 4 for Hanson (2005)'s results.

variable is the log change in average annual wage. I report both the structural parameter estimates and the values of the reduced-form regression coefficient implied by these estimates. Consider first the fit of the regression. In Table 4, all structural parameters for my wage equation are precisely estimated with values within the theoretical range. However, Table 3 shows that for some years, Hanson's equation does not converge to the significant estimates with theoretically correct values. For the years 1993, 1996 and 1999, Hanson's method does not produce significant estimates for μ, the share of industrial consumption in total consumption, between 0 and 1. For the years 1991 and 1995, I find insignificant estimates for τ(>0), the unit transportation cost. As a result, the implied estimates for some of the reduced-form regression coefficients in equation (3.15) are not significant in these years. For the years 1990 and 1992, although the structural parameter estimates are significant within the theoretical value region, the implied reduced-form regression coefficients for regional personal income have the wrong sign. The reduced-form effects of personal income, wages and housing on market potential implied by my wage equation, however, are broadly consistent with the Krugman model in all 11 years. Higher personal income, higher wages and higher housing stocks in surrounding locations are all associated with higher wages in a given city. Comparing values of the Akaike's information criterion (AIC), Schwarz criterion (BIC) and R^2 in Table 3 and Table 4, we see that my wage equation improves the fit of the regression in 6 of the 11 years. Therefore, in the following analysis, I focus only on results in Table 4. In unreported results, I performed the estimation with data excluding Provincial Capitals and Separate Planning Cities. The results are very similar to those for the full sample. Table 5 and Table 6 report results including controls for used FDI, human capital and exogenous amenities for the year 1991 and 1995-2001 (Time difference data for 1992 - 1994 are not available). These results are qualitatively similar to those without controls.

Consider next the value of the structural parameter estimates in Table 4. Consistent with theory, estimates of σ, the elasticity of substitution, are greater than 1. It ranges in value between 1 and 3 in most cases. This is roughly in line with Hanson's estimates based on Helpman's model (range between 2 and 4) but far below his estimates based on Krugman's model (range between 4 and 8). As Hanson has mentioned, recent estimates of σ in the empirical literature are concentrated between 4.0 and 9.0 (e.g., Feenstra 1994, Head and Ries, 2001), which is a range above the estimates in Table 4. The lower is the value of σ, the lower in absolute value is the own-price elasticity of demand for any individual good and the less competitive is the market for that good. Therefore, my estimation results indicate that the Chinese market is less competitive than the markets in the countries studied in previous research (such as the U.S. market). At the same time, the change of the estimated σ is not monotonic. This can be explained with two opposite effects of the trade across sub-regions. First, the trade diversifies varieties available in each region. As the number of varieties increases, the elasticity of substitution among varieties increase and the market is more competitive. On the other hand, as trade continues, each region will specialize in the industries that they have comparative advantage. For example, in the early years, almost every Chinese city had cloth producers. After years of trade and specialization, the cloth production concentrated in only a few cities now. The concentration of production decreases the market competition and the elasticity of substitution. I also find that the estimated σ for the years after 1997 are smaller than those for the years before 1997. It indicates that the specialization in specific industry may have made the sub-regions of China lose their diversification in intermediate inputs in the period of 1998-2001.

The estimates of μ, the expenditure share on traded goods, are between 0 and 1. This is also consistent with theory. With the ongoing urban housing reform and the associated increasing housing price and expenditure for Chinese household, the estimated values for μ of 0.82–0.99 may seem too high. This may be due to the restricted categorization of goods as either traded consumables or housing services as Hanson suggested. On the other hand, before the launch of China's urban housing reform, housing expenditure comprised less than 1 percent of a Chinese urban resident's annual salary or living expenses (Chen, 1996). After more than two decades' privatization and marketization, China's housing market today is still far from mature (Li and Yi, 2007). The 2000 Population Census of China shows that 41% of the owned homes were so called "fanggai fang", referring to homes bought from "work units" (most are state-owned enterprises or institutions) or the municipal housing bureau at subsidized prices. Nine percent were "jingji shiyong fang", which is a special kind of commodity housing that developers are asked to build for low- and middle-income households. Only 13% of the owned homes were bought in the open market by individual households. The remaining 37% were self-built housing found mostly in middle-sized and small cities. Therefore, the low share of housing expenditure in Chinese household's living expense is reasonable to some extent. We can also see that the estimated values of μ after 1997 are lower than those before 1997.[39] This decreasing trend reflects the Chinese government's effort at further reforming the housing market.[40]

Estimated values of b, the share of labor cost in manufacturing production are between 0.7 and 1, which is consistent with the fact that the Chinese economy is labor intensive. There is also a rough decreasing trend for estimated values of b, especially when comparing the values after the year 1997 with those before 1997. China is transitioning towards a more capital intensive economy. If there are more data available for years after 2000, we may be able to see this decreasing trend clearer. Finally, the estimated values of τ, the unit transport costs, are much lower than those in Hanson's estimations. It may be caused by the Chinese government's heavy subsidy on gas consumption before 2000.

Table 4 also shows that the implied reduced-form coefficient estimates for market potential and neighbor cities' regional income increased during the studied period while those for distance, neighbor cities' wage level and housing stock, the national capital return and wage level decreased during the same period. It indicates that the effect of market potential and neighbor cities' regional income on a city's wage level is increasing, which is consistent with the Krugman model's prediction. If there are no other factors to impede this effect, it will continue until all economic activities agglomerate into one big city. Capital return and real wage level have negative effects on a city's wage level. But their effects are decreasing in China as shown in Table 4.

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[39] The estimation based on 1997's data appears abnormal when comparing with estimations for other years. The estimated values for structural function parameters are much higher than those for other years. The R^2 value is very low (lower than 0.05). The reason can be the low quality of data or the effect of a shock such as 1997 crisis, or something else. It needs further study in future. Therefore, I do not count the estimation results for 1997 when doing trend analysis in this paper.

[40] In 1997, Chinese government launched a series of new policies for further urban housing reform. For more details, please see Li and Yi (2007).

In unreported results, I estimate equation (3.13) with data on regional population growth lagged by 3-5 years as the instrument for the change in the summation. The including of instruments does not improve the estimates of structural parameters much. But the values of R2 decrease dramatically to around 0.1. It may be caused by the low quality instruments since I do not have data of city population growth lagged by a longer period (10 or more years) as Hanson used.

3.6 Conclusions and Discussion

In this chapter, I use data on 327 cities in China to estimate nonlinear wage equations derived from NEG models. These models attribute the geographic concentration of economic activities to product-market linkages between regions that result from scale economies and transport costs. My estimation results are broadly consistent with this hypothesis. Regional variation in wages is associated with proximity to large markets.

One contribution of the paper is estimation of a structural wage equation and the parameters such as the elasticity of substitution, the share of housing expenditure in a Chinese urban resident' s annual living expenses and the share of labor cost in industrial production in China. Estimates of the model's parameters are broadly consistent with theory. The estimated elasticity of substitution of China is smaller than those of the other countries studied in previous research. It indicates that the effect of market potential, and therefore the agglomeration effect, is greater in China than in other countries. Thus, with the same amount of national market size increase, China may suffer more serious regional inequality problems. The estimation results also show that the estimated values of elasticity of substitution for the years after 1997 are smaller than those for the years before 1997. The reason could be that most small and middle-sized cities specialize in just a few industries with specific technology. Each city obtains strong market power in their specialized industries. But at the same time, each city loses its diversity of production. As a result, the elasticity of substitution on intermediate products decreases in these small and middle sized cities, which indicates a stronger market potential effect. This further accelerates the increase of wage difference between cities and the agglomeration of each industry into the city with the strongest technology and market power in that industry. Therefore, increasing small cities' economic sizes and diversifying their industry composition may help decrease the wage inequality between cities in China. Au and Henderson (2002) also argue that the majority of Chinese cities should increase their economic size to reach the output per worker peaks. They further state that there could be large gains from increased agglomeration in both the rural industrial and urban sectors. However, my estimation shows that although increased agglomeration can increase each city's wage level, it may also increase the wage gap between large and small cities.

Similar to Hanson's study, my estimations, of course, do not rule out the possibility that other factors also contribute to spatial agglomeration. My estimation results are not qualitatively affected by introducing controls for FDI, human capital externalities or exogenous amenities or by instrumenting for the market-potential term. But there are still other factors, such as the technology spillovers between firms, for which I do not control and which could have important effects on industry location.

My estimation results also show that the share of housing expenditure in a Chinese urban resident's annual living expenses is still very low, although the housing prices in some major Chinese cities such as Beijing and Shanghai now exceed those in many US cities. This share will increase in the near future, as China's urban housing reform is going on and the share of the population who obtain homes at lower than market price from the old housing institution is decreasing. The estimated share of capital cost in industrial production is also very low, which is consistent with the fact that the Chinese economy is labor intensive. But the roughly increasing trend shows that China is transitioning towards a more capital intensive economy.

There are still some of the concerns about the empirical results. They can conceivably be remedied through improving data quality or generalizing the NEG model, such as by introducing more heterogeneity in industry production and trade costs or by allowing for other motivations for spatial agglomeration.

Table 3. Nonlinear Least Square Estimation Results for Hanson's Wage Equation without Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	4.54	3.20	2.96	2.17	5.48	2.15	2.21	1.46	1.14	2.81	4.24
	(0.116)	(0.288)	(0.149)	(0.072)	(0.200)	(0.056)	(0.348)	(0.079)	(0.124)	(0.272)	(0.382)
τ	0.45	0.00	0.90	0.17	0.16	0.00	0.08	3.22	4.91	0.05	0.18
	(0.021)	(0.034)	(0.083)	(0.052)	(0.014)	(0.053)	(0.138)	(0.580)	(3.778)	(0.042)	(0.029)
μ	0.70	0.70	0.57	1.00	0.93	0.96	1.00	0.52	0.35	1.00	0.93
	(0.006)	(0.043)	(0.017)	(0.027)	(0.007)	(0.021)	(0.015)	(0.041)	(0.183)	(0.010)	(0.005)
Implied values											
Market potential	0.22	0.31	0.34	0.46	0.18	0.47	0.45	0.68	0.88	0.36	0.24
	(0.006)	(0.028)	(0.017)	(0.015)	(0.007)	(0.012)	(0.071)	(0.037)	(0.095)	(0.034)	(0.021)
Regional income (B1)	-0.51	0.06	-0.50	1.00	0.65	0.96	1.00	0.58	0.73	1.00	0.74
	(0.029)	(0.099)	(0.045)	(0.032)	(0.032)	(0.026)	(0.018)	(0.008)	(0.023)	(0.018)	(0.038)
Housing stock (B2)	1.51	0.94	1.50	0.00	0.35	0.04	0.00	0.42	0.27	0.00	0.26
	(0.029)	(0.099)	(0.045)	(0.032)	(0.032)	(0.026)	(0.018)	(0.008)	(0.023)	(0.018)	(0.038)
wages (B3)	5.04	3.14	3.46	1.17	4.83	1.19	1.21	0.88	0.41	1.81	3.50
	(0.130)	(0.258)	(0.174)	(0.073)	(0.203)	(0.057)	(0.365)	(0.083)	(0.144)	(0.272)	(0.417)
distance (B4)	-1.59	0.00	-1.77	-0.20	-0.71	0.00	-0.09	-1.49	-0.69	-0.09	-0.60
	(0.051)	(0.074)	(0.080)	(0.062)	(0.070)	(0.060)	(0.169)	(0.071)	(0.154)	(0.071)	(0.072)
Obs.	29975	30691	31099	31099	38322	38322	33489	33141	34053	37069	33447
Adj. R^2	0.78	0.34	0.62	0.88	0.76	0.50	0.00	0.50	0.30	0.59	0.52
Log likelihood	50542	11404	9812	27349	38273	32499	6493	18300	13381	35874	15883
AIC	-101077	-22803	-19619	-54692	-76541	-64992	-12980	-36594	-26756	-71743	-31761
BIC	-101052	-22778	-19594	-54667	-76515	-64967	-12955	-36569	-26730	-71717	-31735

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

Table 4. Nonlinear Least Square Estimation Results for My Wage Equation without Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	2.41	3.07	2.73	2.99	2.23	2.31	5.24	1.50	1.03	1.37	1.03
	(0.008)	(0.045)	(0.032)	(0.027)	(0.012)	(0.015)	(0.162)	(0.006)	(0.000)	(0.002)	(0.000)
τ	0.10	0.06	1.10	0.08	0.10	0.11	2.56	0.02	0.20	0.13	0.16
	(0.001)	(0.002)	(0.029)	(0.001)	(0.001)	(0.001)	(0.096)	(0.000)	(0.003)	(0.001)	(0.002)
μ	0.91	0.82	0.97	0.89	0.90	0.92	1.00	0.46	0.88	0.89	0.84
	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.003)	(0.001)	(0.001)	(0.002)
b	0.93	0.95	0.97	0.95	0.92	0.94	0.99	0.72	0.80	0.89	0.84
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)	(0.002)	(0.001)	(0.002)
Implied values											
Market potential	0.41	0.33	0.37	0.33	0.45	0.43	0.19	0.67	0.97	0.73	0.97
	(0.001)	(0.005)	(0.004)	(0.003)	(0.002)	(0.003)	(0.006)	(0.002)	(0.000)	(0.001)	(0.000)
Regional income (B1)	0.84	0.52	0.94	0.75	0.86	0.88	0.99	0.19	0.99	0.95	0.99
	(0.001)	(0.012)	(0.002)	(0.004)	(0.002)	(0.002)	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)
Housing stock (B2)	0.16	0.48	0.06	0.25	0.14	0.12	0.01	0.81	0.01	0.05	0.01
	(0.001)	(0.012)	(0.002)	(0.004)	(0.002)	(0.002)	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)
wages (B3)	1.68	2.65	1.84	2.34	1.48	1.52	4.28	1.50	0.05	0.47	0.05
	(0.009)	(0.053)	(0.034)	(0.031)	(0.014)	(0.016)	(0.164)	(0.014)	(0.000)	(0.003)	(0.000)
distance (B4)	-0.14	-0.13	-1.91	-0.17	-0.12	-0.14	-10.87	-0.01	-0.01	-0.05	-0.01
	(0.001)	(0.004)	(0.049)	(0.003)	(0.001)	(0.002)	(0.358)	(0.000)	(0.000)	(0.000)	(0.000)
Capital return (B5)	-0.05	-0.03	-0.02	-0.04	-0.05	-0.04	-0.01	-0.13	-0.01	-0.04	-0.01
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
Real wage (B6)	-0.70	-0.86	-0.67	-0.79	-0.66	-0.66	-0.82	-1.00	-0.05	-0.34	-0.04
	(0.002)	(0.006)	(0.004)	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.000)	(0.001)	(0.000)
Obs.	29975	30691	31099	31099	38322	38322	33489	33141	34053	37069	33447
Adj. R^2	0.77	0.39	0.62	0.90	0.76	0.52	0.05	0.48	0.27	0.61	0.51
Log likelihood	50289	12545	9778	30776	38388	33448	7341	17868	12630	36868	15417
AIC	-100570	-25082	-19548	-61543	-76769	-66887	-14675	-35728	-25253	-73727	-30825
BIC	-100537	-25049	-19515	-61510	-76734	-66853	-14641	-35695	-25219	-73693	-30792

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

Table 5. Nonlinear Least Square Estimation Results for Hanson's Wage Equation with Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	3.58				5.95	3.02	4.95	1.57	6.24	8.68	4.12
	(0.045)				(0.116)	(0.091)	(0.274)	(0.032)	(0.399)	(0.191)	(0.209)
τ	0.84				0.35	0.01	2.27	3.24	0.00	0.11	0.20
	(0.020)				(0.011)	(0.005)	(0.151)	(0.192)	(0.001)	(0.005)	(0.015)
μ	0.73				0.93	1.00	1.00	0.61	0.93	1.00	0.91
	(0.004)				(0.003)	.	.	(0.013)	(0.008)	.	(0.004)
Implied values											
Market potential	0.28				0.17	0.33	0.20	0.64	0.16	0.12	0.24
	(0.003)				(0.003)	(0.010)	(0.011)	(0.013)	(0.010)	(0.003)	(0.012)
Regional income (B1)	0.06				0.65	1.00	1.00	0.63	0.63	1.00	0.70
	(0.017)				(0.016)	(0.000)	(0.000)	(0.010)	(0.041)	(0.000)	(0.020)
Housing stock (B2)	0.94				0.35	0.00	0.00	0.37	0.37	0.00	0.30
	(0.017)				(0.016)	(0.000)	(0.000)	(0.010)	(0.041)	(0.000)	(0.020)
wages (B3)	3.52				5.29	2.02	3.95	0.94	5.62	7.68	3.42
	(0.054)				(0.123)	(0.091)	(0.274)	(0.036)	(0.404)	(0.191)	(0.223)
distance (B4)	-2.17				-1.75	-0.03	-8.97	-1.85	0.00	-0.83	-0.63
	(0.048)				(0.051)	(0.010)	(0.419)	(0.088)	(0.004)	(0.040)	(0.053)
Obs.	18696				26345	29853	27945	27294	27160	30518	27847
Adj. R^2	0.903				0.806	0.511	0.019	0.496	0.308	0.636	0.507
Log likelihood	39226.3				29752.1	25642.7	4035.75	14396.4	8781.74	31168.4	11598.1
AIC	-78440.6				-59492.3	-51275.4	-8061.49	-28780.8	-17551.5	-62326.7	-23184.2
BIC	-78393.6				-59443.2	-51233.9	-8020.3	-28731.5	-17502.2	-62285.1	-23134.8

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

Table 6. Nonlinear Least Square Estimation Results for My Wage Equation with Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	1.97				2.10	2.44	4.92	1.53	1.07	1.48	1.05
	(0.004)				(0.011)	(0.019)	(0.175)	(0.007)	(0.001)	(0.003)	(0.001)
τ	0.10				0.10	0.10	2.25	0.02	0.18	0.13	0.15
	(0.000)				(0.001)	(0.001)	(0.098)	(0.000)	(0.003)	(0.001)	(0.002)
μ	0.91				0.90	0.92	1.00	0.61	0.88	0.90	0.85
	(0.000)				(0.001)	(0.001)	(0.000)	(0.003)	(0.002)	(0.001)	(0.002)
b	0.91				0.92	0.94	0.99	0.65	0.85	0.89	0.81
	(0.000)				(0.001)	(0.001)	(0.000)	(0.003)	(0.003)	(0.001)	(0.003)
Implied values											
Market potential	0.51				0.48	0.41	0.20	0.65	0.93	0.68	0.95
	(0.001)				(0.002)	(0.003)	(0.007)	(0.003)	(0.001)	(0.002)	(0.000)
distance (B4)	-0.10				-0.11	-0.15	-8.82	-0.01	-0.01	-0.06	-0.01
	(0.000)				(0.001)	(0.002)	(0.351)	(0.000)	(0.000)	(0.000)	(0.000)
Regional income (B1)	0.89				0.87	0.86	0.99	0.47	0.99	0.94	0.99
	(0.001)				(0.001)	(0.002)	(0.001)	(0.007)	(0.000)	(0.001)	(0.000)
wages (B3)	1.18				1.33	1.66	3.95	1.35	0.10	0.60	0.08
	(0.005)				(0.012)	(0.021)	(0.176)	(0.014)	(0.001)	(0.004)	(0.001)
Housing stock (B2)	0.11				0.13	0.14	0.01	0.53	0.01	0.06	0.01
	(0.001)				(0.001)	(0.002)	(0.001)	(0.007)	(0.000)	(0.001)	(0.000)
Capital return (B5)	-0.05				-0.05	-0.04	0.00	-0.19	-0.01	-0.04	-0.01
	(0.000)				(0.000)	(0.001)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
Real wage (B6)	-0.60				-0.63	-0.68	-0.80	-0.88	-0.09	-0.40	-0.07
	(0.001)				(0.003)	(0.003)	(0.007)	(0.006)	(0.001)	(0.002)	(0.001)
Obs.	18696				26345	29853	27945	27294	27160	30518	27847
Adj. R^2	0.89				0.81	0.53	0.03	0.48	0.28	0.64	0.49
Log likelihood	38139				29738	26218	4192	14067	8163	31446	11224
AIC	-76264				-59461	-52422	-8369	-28120	-16312	-62879	-22434
BIC	-76209				-59404	-52364	-8312	-28063	-16255	-62820	-22376

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

CHAPTER 4
CHINA'S TRADE INTENSITY[41]

4.1 Introduction

Since China reopened its door to the world in the late 1970s, its international trade policies have rapidly liberalized from the prohibition of trade in all but a few products with a few countries to a relatively liberal stance towards both imports and exports in the world market. During the same period, China's exports and imports have increased at an average annual rate of 12.6 percent and 13.3 percent, respectively.[42] China's bilateral trade pattern has also shifted. Before liberalization, China's foreign trade was oriented primarily toward other Eastern Bloc countries, and it displayed patterns typical of Eastern Bloc trade. During the 1980s and 1990s, China's trade refocused dramatically towards large market economies (Europe and North America), Asian economies, and countries with large endowments of natural resources. From 1980 to 2003, China's trading partners increased from 87 to 160 out of 190 countries and regions reported by the International Monetary Fund (2005). China's exports to both Europe and North America expanded by more than 300 percent over the period of 1995-2003, while its imports from natural resource abundant countries grew even more rapidly (Edmonds et al., 2006).

In this chapter, we introduce a new index, the Gravity Model Adjusted Trade Intensity (GMATI) index, to measure and compare China's bilateral trade with the world average level. Our index indicates a more active trade of China than the world average level during the period from 1985 to 2002. When trading with North America, Europe and Oceania, China is more active in exporting than in importing. Our index also reveals

[41] Coauthored with Christopher Edmonds.

[42] Values are calculated from data (in constant 2000 US$) in *World Development Indicators*, World Bank (2007).

that China has increasing interest in trading with Africa. We also make comparisons between China and Japan, another big economy in Asia which experienced a similar trade boom in the early period of its development. It is found that both China and Japan are very active in the world market, whereas the two countries have different regional focuses in trade.

To secure trade liberalization and to further the access of Chinese firms to important foreign markets, China has shown increasing interest in preferential trade agreements (PTA) since its WTO accession.[43] As of July 2005, China was negotiating or had proposed PTAs with Australia, Chile, India, Indonesia, New Zealand, Pakistan, Singapore, South Africa, Thailand, and four regional groupings—the Association of South East Asian Nations (ASEAN), the Gulf Cooperation Council, Mercosur, and the Shanghai Cooperation Organization (SCO).[44] It seems that China tries to use PTAs to improve its bilateral trade with some regions. Another application of the GMATI index is to examine the regional emphases of China's efforts in the world market. Our analysis shows that during the studied period China imports more actively than exports when trading with East and Southeast Asian countries. It should be noted that East and Southeast Asia was not the region that China most intensively trades with and its importance to China had even declined over that period. A similar decrease in trade intensity can also be observed in the South American market. These may be due to the delay of the PTA effects.

[43] PTAs are agreements between two or more countries in which tariffs imposed on goods produced in the member countries are lower than on goods produced outside (Panagariya 2000).
Before 2001, China was not party to any PTAs as its political energy was consumed with the massive negotiating efforts required to gain WTO entry and wishing to avoid the perception of going against the principal of non-PTAs that underpins WTO.

[44] The Mercosur PTA includes Argentina, Uruguay, Brazil, and Paraguay. The SCO—founded in 2001—is composed of China, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, and Uzbekistan.

This chapter is organized as follows. In the second section, we review the definition and applications of the trade intensity index. The third section describes our regression model and data sources. Section four presents the regression results and the GMATI index. Conclusions and remarks are included in section five.

4.2 Introduction to the Trade Intensity Index

There is a large body of literature on the measurement and analysis of bilateral trade. In a literature survey, Drysdale and Garnaut (1982) identified two approaches for systematic studies of bilateral trade: the gravity model of bilateral trade introduced by Linder (1961), Tinbergen (1962) and Linnemann (1966), and the intensity approach developed by Brown (1949) and Kojima (1964).

The gravity model approach seeks to explain each bilateral trade flow independently. It claims that trade between two economies is proportional to their economic sizes (as measured by GDP, population, per capita GDP, area, etc.) and inversely related to the distance (both geographical and cultural distance) between them. The name comes from an analogy between key factors explaining gravitation under Newton's theory (mass and distance) and the analogous roles that economy size (GDP) and distance play in explaining trade flows under the gravity model of international trade. The gravity equation is referred to as "one of the most empirically successful in economics," although the essential assumption of independent bilateral trade flow is too extreme [Anderson and Wincoop (2003)]. Intuitively, the more resistant to trade with all others an economy is, the more it is pushed to trade with a given bilateral partner. This is known as "multilateral resistance." Both theoretical [Anderson (1979)] and empirical [Anderson and Wincoop (2003), Subramanian and Wei (2003)] studies have shown the effects of multilateral resistances on bilateral trade flows. Hence, due to the omitted variables, the simple gravity model approach may have a misspecification problem. Economists are still trying to improve the gravity model and have suggested several methods to address the problem of multilateral resistance.[45]

In contrast, the intensity approach [Kunimoto (1977), Vollrath (1991)] which takes each country's total imports and exports as given, divides the determinants of international trade into two categories: those which influence the levels of total imports and exports of the countries in the world and those which influence their geographical distribution. It then assumes a hypothetical world in which the second category of trade determinants is absent, or in other words, that the hypothetical world consists of countries with no "geographic specialization" in international trade. A country's total trade is distributed among countries according to the partner country's share in world trade. Symbolically, the hypothetical trade flows from country i to country j ($\bar{x}_{ij}$) would be:

$$\bar{x}_{ij} = x_{iW} \frac{x_{Wj}}{x_{ww}} \text{ [46]} \tag{4.1}$$

where $\bar{x}_{ij}$ is country i's exports to country j in the hypothetical world, x_{iW} is country i's total exports, x_{Wj} is country j's total imports and x_{WW} is the total world imports.

However, the actual trade flows from country i to country j are usually different from the hypothetical value derived by equation (4.1). This is because of the presence of

[45] Such as country specific dummies (Anderson and Wincoop, 2003), country pair specific dummies (Baldwin and Taglioni, 2006).

[46] Brown (1949) and Kunimoto (1977) also defined an adjusted version of this formula: $\bar{x}_{ij} = x_{iW} \cdot x_{Wj} / (x_{ww} - x_{Wi})$, because a country cannot trade internationally with itself and its trade can only be distributed among all other countries. The adjusted version is superior to the one we use in this chapter. However, the two definitions yield similar results in terms of comparing the intensities of one country's export to its trading partners. In this chapter, formula (4.1) is used to simplify the calculations. Also refer to Yamazawa (1970) for detailed information.

the factors that distort the direction of international trade flows, i.e., the second category of trade determinants. When the deviation is expressed by their ratio, we obtain the geographic trade intensity index (I_{ij}):

$$I_{ij} = \frac{x_{ij}}{\bar{x}_{ij}} = \frac{x_{ij}}{x_{iW}} \bigg/ \frac{x_{Wj}}{x_{ww}} \tag{4.2}$$

where x_{ij} is country i's actual exports to country j. If the trade intensity index equals 1, trade partners are trading with each other at the same intensity as found in the hypothetical world, whereas value above (below) 1 indicates the trade between two countries is more (less) intensive than expected.

The intensity approach is convenient for describing the geographic distribution of a country's trade and comparing the bilateral trade tendencies across countries. In fact, a number of indicators have been widely used in empirical examinations of international trade to measure the tendency of trade between countries. These indicators gauge the level of trade against the size of economies, and other structural characteristics important in determining trade levels (e.g., distance between the countries). The simplest measures are the deflated value of exports or trade volume and the trade share: $S_{ij} = x_{ij}^T / x_{iW}^T$, where S_{ij} is the share of exports from country i to country j to country i's total exports to the world; x_{ij}^T is exports from country i to country j, and x_{iW}^T is the total exports of country i to the world. Exports, imports, or trade volumes (exports plus imports) can be used when calculating this summary statistic. The trade share highlights the importance of trade between two countries and is useful for comparisons of trade flows over time between two countries. However, its usefulness is limited in cross-country comparisons as economies of different sizes can be expected to trade in proportion to the overall size of their economies. The trade intensity index gauges trade levels between country *i* and *j* in relation to country *j*'s average trade share across all countries of the world. It thereby overcomes the economy-size problem encountered in cross-country comparisons of trade shares.

The gravity model approach can also measure and compare bilateral trade. For example, if country *i* and country *j* have an actual trade value greater than the estimate by the gravity model, we can conclude that the trade between country *i* and *j* is above the world average level given by the gravity model. To compare bilateral trade levels across countries, the intensity approach is however more desirable than the gravity model. Nevertheless, in determining the intensity of trade between countries, the trade Intensity Index cannot reflect the effects of any of a country's characteristics other than economy size. It cannot detect whether a country is trading more than another has similar characteristics. Empirical and theoretical studies [Deardorff (1995), Frankel (1997), Rose (2003)] have revealed that similar countries that are near to each other, share a common border, or have a close cultural relationship, should be expected to have more "intense" trade relations than those that are geographically or culturally distant. These factors are known as objective resistance [Drysdale and Garnaut (1982)]. To account for the effects of countries' characteristics on bilateral trade, the gravity model seems to be a better choice.

Ng and Yeats (2003) introduced a distance adjusted trade intensity index in their analysis of East Asia trade, which accounted for geographic distance while measuring each country's trade intensities to different trading partners. This approach first estimates the following equation:

$$\ln(I_{ij}) = \alpha + \beta \ln(distance) \tag{4.3}$$

where I_{ij} represents the intensity of country *i*'s export to country *j*, given *distance* between the capitals of the two trading countries. The coefficient $\hat{\beta}$ is estimated based on cross-sectional time series data and thus captures the average effect of distance on trade intensities between pairs of countries worldwide. The estimated coefficient $\hat{\beta}$ is then used to predict $\hat{I}_{ij}$, which is the expected trade intensity assuming no geographic specialization factors other than distance exist. The distance adjusted trade intensity index is defined as $I_{ij} / \hat{I}_{ij}$ It measures the trade intensity caused by geographic specialization factors other than distance. Again, a value greater (less) than 1 suggests the trade intensity is above (below) expected after considering the effect of distance between them. Ng and Yeats obtain a nice regression result. The sign of coefficient of distance is consistent with the expected (negative) and the R square is acceptable (0.672).

However, the trade intensity index is defined as the ratio of trade values while the gravity model explains just the trade values. The theoretical foundation underneath the gravity model is therefore not appropriate for Ng and Yeats's approach. Actually, our regressions in section 4.4 show that the independent variables of the gravity model perform very well in explaining trade value, but not for the intensity index.[47]

Our approach is designed to take advantage of both the gravity model and the intensity index to describe a country's bilateral trade. We first estimate each country's

[47] To analyze the determinants of trade intensity, Yamazawa(1971) regresses trade intensity index on distance and the complementary degree between two countries, economy sizes, inter-governmental loans and several dummy variables. The R squares resulted from his regressions are better than Ng and Yeats'. However, the estimated coefficient for economy size is not significant and has an incorrect sign. Furthermore, Yamazawa's equation also lacks of theoretical foundation.

expected exports and imports ($\hat{x}_{ij}$) according to the gravity model. The estimated exports and imports are then used to calculate the expected trade intensity between two countries, given that all countries trade as predicted by the gravity model:

$$\hat{T}_{ij} = \frac{\hat{x}_{ij}}{\hat{x}_{iW}} \bigg/ \frac{\hat{x}_{Wj}}{\hat{x}_{ww}} \tag{4.4}$$

where $\hat{x}_{iW} = \sum_j \hat{x}_{ij}$, $\hat{x}_{Wj} = \sum_i \hat{x}_{ij}$ and $\hat{x}_{ww} = \sum_i \sum_j \hat{x}_{ij}$.

The GMATI index is defined as $T_{ij} / \hat{T}_{ij}$. This index gauges the bilateral trade intensities based on countries' characteristics as included in the gravity model. We can use the GMATI index to investigate whether China has traded more intensively with some regions and countries in its trade expansion or is just approaching the world average level. The difference between Ng and Yeats' approach and ours is that the variable we estimated is the trade value instead of the intensity index. This is in line with the general gravity model and thus has a solid theoretical foundation. In the following sections, we attempt to include all important independent variables in the gravity model given the data availability, though some determinants may still be omitted. Future study can improve the results by adding more effective determinants into the gravity model.

4.3 Regressions and Data Sources

In this section we estimate a full gravity model and adjust the original trade intensity index by each of the statistically significant parameters from the model. Accordingly, our GMATI index adjusts for several factors found to systematically affect trade between countries. Our specification of the gravity equation follows the specification in Clarete et al. (2003), and is as follows:

$$
\begin{aligned}
\ln(I_{i,jt}) = [&\beta_0 + \beta_1 \ln D_{i,j} + \beta_2 \ln(Y_i)_{t-1} + \beta_3 \ln(Y_j)_{t-1} + \beta_4 \ln(Y_i / Pop_i)_t \\
&+ \beta_5 \ln(Y_j / Pop_j)_t + \beta_6 \ln(Area_i) + \beta_7 \ln(Area_j) + \beta_8 \ln Smctry_{i,j}] \\
&+ [\beta_9 Landl_i + \beta_{10} Landl_j + \beta_{11} Cont_{i,j} + \beta_{12} Island_i + \beta_{13} Island_j] \\
&+ [\beta_{14} Lang_{i,j} + \beta_{15} Colony_{i,j} + \beta_{16} ComCol_{i,j} + \beta_{17} Col45_{i,j}] + \varepsilon_{i,jt} \quad (4.5)
\end{aligned}
$$

where i and j denotes trading partners (country i is the exporting country and j is the importing country), and t denotes time. The variables on the left hand side are divided into three groups denoted by the square brackets. The first group contains the basic variables of the gravity model and captures notions of economy size and country size which are considered fundamental in driving trade flows under the gravity model. All the models estimated include these variables, so it is also referred to as the base gravity model. The second group of variables captures geographic characteristics, besides the distance between the trading countries that is expected to influence their level of trade. The third group of variables captures shared historical and linguistic ties between countries that may be expected to strengthen trade relationships.

Notation of the variables in the model, and the expectation regarding the relationship between the level of trade and each variable, are as follows:[48]

$I_{i,jt}$ denotes the value exports (or imports) of country i to country j at time t.

$D_{i,j}$ is the linear distance between capital cities of the trading countries. Distance is expected to have a negative association with trade level since it proxies transport and transaction costs.

[48] The rationale for the inclusion of particular variables and expectations regarding their relationship to trade levels is widely discussed in the literature developing and applying the gravity model of trade, for example see discussions in Linneman (1966), Krugman (1991), and Frankel (op. cit.).

Y is real GDP of country *i* or *j* in year *t*-1 (in constant year 2000 dollars). The variable enters the model with a one year lag to address potential endogeneity between trade levels and GDP. Larger economies are expected to trade more.

Pop is the population of country *i* or *j* in year *t*. Countries with larger populations are generally expected to trade less because of their larger domestic markets.

Area is the land area (in square kilometers) of country *i* or *j*. Countries with large land areas are expected to trade less because greater land area is associated with larger internal markets and greater availability of resources domestically.

Smctry is a binary variable which is unity if both country *i* and *j* had constant boundaries between 1985 and 2002 (with the break up of the Former Soviet Union, Yugoslavia, and other countries, several new countries were formed after 1985 resulting in interrupted time series data). Countries with steady borders are expected to have higher trade due to their greater stability and cultivation of trading relationships over time.

Landl is a binary variable which is unity if country *i* or *j* is landlocked (no sea ports of direct sea access). Landlocked status is expected to be associated with lower trade due to higher trade costs.

Cont is a binary variable which is unity if country *i* and *j* border one another. Countries sharing a common land border are expected to trade more due to proximity and ease of overland transport.

Island is a binary variable which is unity if country *i* or *j* is a small island country. Small island countries are expected to trade at a higher rate due to limited domestic market and natural resources.

Lang is a binary variable which equals 1 if i and j share a common language (zero otherwise). Shared language and historical ties through colonialism are expected to increase trade links between countries.

Colony is a binary variable which equals 1 if country i established a colony in country j or vice versa.

Comcol is a binary variable which is unity if i and j were colonies of the same colonial power.

Col45 is a binary variable which is unity if i and j had a colonial relationship after 1945.

$\varepsilon_{i,jt}$ represents model error and the effect of other influences on bilateral trade that are omitted.

The coefficients in equation (4.5) can be interpreted as measuring the elasticity of exports with respect to changes in the explanatory variables. Following established practice, continuous variables in the model are estimated in log-linear form. Because of potential endogeneity between trade levels and GDP, we estimate the model using real GDP with a 1 year lag. Country specific dummies are introduced into the regression as suggested by Anderson and Wincoop (2003) to address the multilateral resistance problem.[49]

Data on exports used in the estimates are drawn from World Trade Analyzer (WTA), a trade database provided by the International Trade Division of Statistics

[49] As Baldwin and Taglioni (2006) have argued, country pair dummies are superior to country dummies in panel data regression due to the existence of time-series bias. However, inclusion of the country pair dummies makes it impossible to estimate the coefficients of the time-invariant variables, such as distance. Since our study does not focus on the effect of time-variant policies, country dummies are used in our regressions. Each country has two specific dummies (e.g., Chinaex and Chinaim for China). The value of Chinaex (Chinaim) equals 1 if the exporter (importer) is China, and otherwise equals 0.

Canada. It contains adjusted United Nations Conference on Trade and Development (UNCTAD) source data on over 180 countries' international trade activities at a four-digit level of Standard International Trade Classification (Rev. 2) from 1985. An important feature of this data is that recorded imports and exports of trading countries are rectified so that exports reported by the exporting country are consistent with the imports reported by the importing country, which is not the case in the original UN-COMTRADE data upon which the WTA data is based. Since the WTA cleans and corrects data to ensure concordance between exports to country B reported by country A and imports from country A reported by country B, regressions run on exports or imports can produce equivalent results. We estimate our models for exports, which follows standard practice.

Data on distance between trading countries and related geographic characteristics are obtained from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) database.[50] The database incorporates geographical variables for 225 countries, including information on distance between the capital and largest cities of each pair of countries, and dummy variables indicating whether a country is landlocked, and whether pairs of countries are contiguous or share a common language or post-WWII colonizer. Combining the CEPII data with detailed data on trade from the WTA yields a panel of 24,492 country pairs (across 157 countries) during the period 1985 to 2002. Other sources of data informing variables used in our gravity model estimates include: the World Bank's World Development Indicators (WDI 2005), the Asian Development Bank's Key Indicators (KI 2005), and data available on Jon Haveman's international

[50] Available online at http://www.cepii.fr/anglaisgraph/bdd/distances.htm(last accessed on February 14, 2006)

trade data website.[51] Unfortunately, some economies that have had close trade relationships with China historically, such as Russia, North Korea, do not have GDP data in the WDI, so have to be dropped from the analysis. However, most Asian countries and all OECD (Organisation for Economic Cooperation and Development) member economies are included. Ultimately, missing data for selected countries and years result in the loss of some observations.

The gravity model is estimated using the standard generalized log-linear least squares regression on cross-section data of selected individual years, as well as using the random effects panel estimator (sometimes referred to as the random error components panel estimator) on the full dataset. The random effects estimator breaks up the standard regression residual into two components: one captures the systematic error observed in estimated trade for each country-pair and the other captures the regular residual (technical details on the random effects estimator are available in Greene (2003)). The panel estimator is expected to be more efficient since it makes use of the complete cross-sectional time series of observations of country-pair exports. The cross-sectional estimation results, in contrast, offer somewhat easier interpretation. In addition, the evolution of results over time can yield useful insights into how trade and the factors driving trade flows have evolved over time.

There are many observations with zero bilateral trade flows. Since the WTA database records the values of bilateral trade flows to a high degree of accuracy, these

[51] Data of development indicators for Taiwan are obtained from ADB (2005), while data for other countries are drawn from WDI 2005. Haveman's trade data available at http://www.macalester.edu/research/economics/PAGE/HAVEMAN/ Trade.Resources/TradeData.html (last accessed on February 14, 2006)

zeros are not missing values. When we take logarithms of trade flows, the zero observations are excluded from our regression. As a result, our regressions are actually based on the sample left censored at zero. To keep the information embedded in zero-trade observations, we add $1 to all trade flows before taking logarithms and run the Tobit regression.

The software we use, Stata 8.0, estimates random-effects models, including the panel data Tobit model, with Gauss–Hermite quadrature and adaptive quadrature to approximate the high-dimension integrals that are part of the likelihood for these models. Quadrature is one of the most accepted approaches to estimate these models, but the quadrature approximation can be poor in some cases: (1) data with large panel sizes, (2) data with high within-panel correlation.[52] To examine the numerical soundness of the quadrature approximation, two more regressions are performed with two different numbers of quadrature points. Then the regression results are compared against the original. If the coefficient estimates are sensitive to the different numbers of quadrature points (namely, the two estimations yield two values of the same coefficient with a relative difference greater than 1%), then the polynomial approximation is poor, all coefficient estimates are unreliable and nothing can be gained by simply increasing the number of quadrature points. In this case, we can only use the GLS regression to estimate the model for country-pairs with positive trade, omitting country-pairs with zero trade. Accordingly, the model will explain the trade levels across countries rather than trade per se (i.e., the decision of whether to trade and the level of trade). This treatment of observed cases of zero trade also alleviates the issue of transforming zero cases into

[52] Refer to Stata Corp. (2003) for details.

logarithms, which is typically handled by addition of an arbitrary small constant (for instance, $1) to such cases before they are transformed into logarithms.

To examine whether China has special interest in trading with some regions such as East and Southeast Asian countries, African countries, or Middle East countries, we introduce binary dummy variables to the gravity model. For example, a dummy variable ChinaexESA equals 1 if the exporter is China and the importer is an East or Southeast Asian country, and otherwise equals 0. The detail list of the dummy variables will be introduced in the next section.

4.4 Regression Results

Table 7 presents the regression results from the Random-effect panel data Tobit model[53]. We can see that almost all estimates are statistically significant with their expected sign. However, when the number of quadrature points changes, the relative changes in estimated coefficients, except for $Ln(D_{ij})$, are greater than 1%. Additionally, in our unreported regressions, we also find that small changes in the scale of exports generate regression results with great discrepancies. Therefore, in our case, the estimates from the Random-effect panel data Tobit model are not trustworthy and cannot be used to adjust the trade intensity index.

Table 8 summarizes the estimates of Random-effect GLS regression. Since observations with zero export are omitted, only two thirds of the total observations are used in the regressions. The dependent variables for regressions (1)–(4) are the logarithms of exports between each country pair in constant (year 2000) US dollars. The

[53] This regression does not include country dummies as independent variables, otherwise the regression is extremely time-consuming. Limited by the capability of current personal computers, we are not able to examine the results from the Random-effect panel data Tobit model with country dummies.

dependent variables for regressions (5) and (6) are the logarithms of the original export intensity index. We find that the R-squares for regressions (1)–(4) are much higher than regressions (5) and (6), though the significance of the estimated coefficient of each variable is similar in almost all regressions. In addition, in regression (6), the estimated coefficients of GDP per capita, area of land and area dummies are significant but with signs inconsistent with theoretical expectations. It implies that the explanatory variables of the gravity model perform very well in explaining the trade value, but not for the trade intensity index. In the following analyses, we use the estimated coefficients from regression (4) in Table 8 to adjust the trade intensity index.

The regression presented in Table 9 investigates the activities of China and Japan's trade with East and Southeast Asian countries. [54] The dummy variable ChinaexESA (ChinaimESA) equals 1 if the exporter (importer) is China and the importer (exporter) is an East or Southeast Asian country, and otherwise equals 0. Values of dummy variables JapanexESA and JapanimESA are defined in a similar way. Table 9 also presents the estimated coefficients for China and Japan's country dummies: Chinaex, Chinaim, Japanex and Japanim. They are all significantly positive at 5% level and their values are greater than that of most of other country dummies. However, the estimated coefficients of the four new dummies are all negative and not statistically significant. It indicates that, after considering the effects of economy sizes and distances to the markets, China and Japan's trade with ESA countries is not significantly more active than their trade with other regions, whereas the two countries are active in trading with the rest of the world on average.

[54] The East and Southeast Asian countries consist of Japan, Brunei, Myanmar, Cambodia, Hongkong, Korea, Malaysia, Lao, Indonesia, Philippines, Singapore, Thailand, Taiwan, China, Mongolia, Viet Nam.

The Random-effects GLS Regression in Table 10 is performed to examine if China has special interests in some regions among its trading partners. This regression introduces 14 more dummies into regression (4): ChinaexESA, ChinaimESA, ChinaexAfr, ChinaimAfr, ChinaexNA, ChinaimNA, ChinaexSA, ChinaimSA, ChinaexEU, ChinaimEU, ChinaexME, ChinaimME, ChinaexOCN and ChinaimOCN, where Afr, NA, SA, EU, ME and OCN refer to Africa, North America, South America, Europe, Middle East and Oceania, respectively.[55] Definitions of these dummies are similar to ChinaimESA in regression (9).

It is found in Table 10 that the estimated coefficients for export dummies are all positive, but only significant for ChinaexAfr at 5% level and ChinaexME at 10% level. It is also noticed that the estimated coefficients for ChinaexAfr and ChinaexME are greater than that of most other export dummies. This indicates that, after considering the effects of factors defined by the gravity model, China's exports to Africa and Middle East are more active than other selected regions. On the import side, the estimated coefficients for ChinaAfr, ChinaimNA, ChinaimEU and ChinaimME are significantly positive at 5% level with values greater than other import dummies'. This can be explained by China's large demands for crude oil and other scarce natural resources from Africa and the Middle East as well as high technology products from the North America and Europe.

Table 11 presents the estimated coefficients and their standard errors for OLS regressions using cross-section data of selected years between 1985 and 2002. Most of the estimates are significant at 5% level with expected sign. The exports increase in trading partners' GDP and decrease in their area and distance. The GDP per capita

[55] Lists of countries for each region are included in Appendix 5.

variables are significantly negative in most years. Countries that are landlocked typically trade less than those not landlocked. Island countries, on the other hand, tend to trade more with other countries. Two countries that have a common language, the same colonizer or the same colonial history will trade more with each other. Country pairs that share borders or remain as part of the same nation also trade more than others. We find that the absolute value of the distance coefficient increases from nearly 1.2 to almost 1.5 during the period. It indicates that the effect of distance has become stronger.

From the above analyses based on the gravity model, we seem to be able to draw a few conclusions as follows: After considering the effects of economy sizes and distances to markets,

1. Both China and Japan are active in trading with the rest of the world on average.

2. China and Japan's trade with ESA countries is not significantly more active than with other regions.

3. China's exports to Africa and Middle East are more active than other selected regions.

4. China is very active in importing from Africa, Middle East, North America and Europe.

As we have mentioned in Section 4.2, the intensity index method is superior to the gravity model method in performing cross-country comparison analyses of bilateral trade. Cross-country comparison can be made with the gravity model by introducing additional dummy variables as we have done for Table 9 and Table 10. However, all time-invariant variables must be dropped if a full list of country-pair dummies is used. In addition, some of the estimated coefficients may not be significant. Therefore, this is not a complete comparison.

We compute the original intensity index and the GMATI index for all available country pairs over the period of 1985-2002. Some of the results are selected for China and Japan and listed in Table 12. The table shows that the original intensity index is less than 1 for China's trade with all the selected regions except East and Southeast Asia. This implies first that China's trade with these regions is below the world average level, and second that East and Southeast Asia is the region China trade most intensively with. These implications contradict our previous analyses based on the gravity model. In contrast, the table also shows the GMATI index for China and Japan, which is quite different from the original intensity index. The GMATI index shows that China's trade intensities are greater than 1, the world average level, with all the selected regions and in most years. This is in good agreement with our previous gravity model analysis that suggests China trades actively with rest of the world. In addition, the GMATI index shows that China's trade with East and Southeast Asia is not the most intensive among its trading partners. This is again in line with our previous gravity model analysis. Therefore the GMATI index provides better agreement with the gravity model analysis than the original trade intensity index.

Table 12 also shows that the GMATI index of China's exports to East and Southeast Asia decreases from close to 1.7 to below 0.9 during the studied period. In contrast, the GMATI index of China's imports from the same region increases from around 0.8 to nearly 1.5. This implies that the importance of the East and Southeast Asia market to China's exports has declined while China has increasing interests in importing from this region. The GMATI index also indicates that East and Southeast Asia is not the region Japan most intensively trades with. Japan's trade with this region is always less intensive than China's and even below the world average level.

We find that Japan's trade intensity with Africa, as described by the GMATI index, remains relatively stable during the period of 1985 and 2002. However, China shows an increasing interest in the Africa Market during that period. The GMATI index for China's exports and imports with Africa increases dramatically and becomes the highest among the selected regions. Furthermore, the GMATI index for China's imports from Africa becomes especially high (topped at 3.83) after 2000. This may be explained by China's increasing direct investment in Africa most of which are resource-oriented [Chan-Fishel (2007)].

The Middle East is another interesting region. Yergin and Roberts (2004) argue that, "China accounted for 40% of total growth in world oil demand during 2000-04. In a decade, China has gone from self-sufficiency to being the most dynamic factor in the world oil market and one of the main elements in today's $40-plus per barrel price." According to their argument, one should expect a big increase in the import intensity of China with Middle East Countries during the decade and a significantly active import of China from the Middle East, the primary oil supplier of the world.

In our gravity model estimations (Table 10), the coefficient for ChinaexME is greater than that of ChinaimME and they are both significantly positive. This indicates that both China's export and import with Middle East Countries are very active. However, the time trend of China's trade intensity with the Middle East is not clearly reflected by the gravity model estimations. The GMATI index in Table 12 shows an increasing trend of China's export intensity to the Middle East. Additionally, the intensity indices are greater than 1 for China's export to the Middle East in all years except 1985. The intensity index also increases significantly for China's import from the Middle East, from a fairly low 0.09 in 1985 to 1.76 in 1997, hitting a peak at 2.48 in 2000 and then decreasing to 1.45 in 2002. In comparison, the intensity index is greater than 10 for Japan's imports from Middle East in most of the selected years, which is much greater than that of China. Thus it is the specter of China's huge expected future consumption that makes the world oil market more sensitive than ever. In fact, after considering the effect of economy sizes and distances to the markets, China's import from oil suppliers is not seriously intensive compared with the world average level.

Table 12 also shows increasing intensities for China's exports to North America, Europe and the Oceania over the studied period, and on the contrary, decreasing intensities for China's imports. This indicates that China emphasizes export more than import in its trade expansion. The gravity model analysis, however, can not provide this kind of information.

4.5 Conclusions

In this chapter, we investigate if China has certain geographical specialization in trade compared with the world average level and its neighbor, Japan. The original trade intensity index gauges bilateral trade levels based only upon countries' economic sizes. However, with all other things being equal, countries that are near to each other, share a common border, or have a close cultural relationship, should be expected to have more "intense" trade relations than those that are geographically or culturally distant. The gravity model-estimated trade values reflect the effect of each country's specific characteristics such as distances to the markets, geographic factors and the cultural relationships, etc. But the gravity model approach cannot perform a complete cross country comparison of trade. To examine if a country is trading more intensively than another possessing similar characteristics, we introduce the GMATI index and use it to measure and compare the spatial distribution of China and Japan's international trade.

After controlling for the effects of distance and economy size, the GMATI index indicates that both China and Japan trade more actively than the world average level the effects of distance and economy size. We also find that China emphasizes more in exporting than in importing in its trade expansion. It is found that China imports more actively than exports when trading with East and Southeast Asia. This region is not the one that China or Japan most intensively trades with and its importance to China has even decreased.

The GMATI index also shows that China has increasing import and export intensities with African countries, but decreasing intensities with South America. Though the intensity of China's imports from Middle East also increases, China's imports from oil suppliers is not considerably intensive compared with the world average level.

In the above analyses, the GMATI index can measure and compare China's bilateral trade intensity with different trading partners while considering the effects of economy sizes and distances to markets both geographical and cultural. However, to better understand China's trade expansion and its impact on the world economy, we should analyze other factors that affect China's trading patterns, including economic and political factors, such as comparative advantages and control over specific regions or countries, etc. It is expected that these more detailed analyses can be performed on a case-by-case basis in the future.

Table 7. Estimates of Random-effects Panel Data Tobit Model

Estimated Coefficient
(Standard Error of Estimated)

Regression	(1)'	(2)'	(3)'	(4)'
Ln(Dij)	-1.881 **	-1.899 **	-1.759 **	-1.775 **
	(0.034)	(0.038)	(0.037)	(0.038)
Ln(Yi)(t-1)	1.891 **	1.865 **	1.886 **	1.884 **
	(0.016)	(0.016)	(0.016)	(0.016)
Ln(Yj)(t-1)	1.496 **	1.447 **	1.466 **	1.465 **
	(0.016)	(0.016)	(0.016)	(0.016)
Ln(popi)	0.099 **	0.112 **	0.098 **	0.099 **
	(0.027)	(0.027)	(0.026)	(0.026)
Ln(popj)	0.111 **	0.137 **	0.126 **	0.127 **
	(0.027)	(0.027)	(0.026)	(0.027)
Ln(Areai)	-0.261 **	-0.235 **	-0.235 **	-0.221 **
	(0.017)	(0.019)	(0.018)	(0.018)
Ln(Areaj)	-0.254 **	-0.229 **	-0.223 **	-0.221 **
	(0.017)	(0.018)	(0.017)	(0.018)
Smctryij	2.711 **	2.459 **	1.720 **	1.721 **
	(0.252)	(0.259)	(0.272)	(0.273)
Landli		-0.381 **	-0.375 **	-0.342 **
		(0.083)	(0.081)	(0.082)
Landlj		-0.939 **	-0.917 **	-0.909 **
		(0.083)	(0.080)	(0.081)
Islandli		0.272 **		0.176 **
		(0.074)		(0.073)
Islandlj		0.139 *		0.024
		(0.075)		(0.073)
Contij		0.493 **	0.427 **	0.414 **
		(0.186)	(0.190)	(0.191)
Langij			1.164 **	1.154 **
			(0.073)	(0.073)
Colonyij			0.482 *	0.481 *
			(0.285)	(0.291)
ComColij			0.483 **	0.480 **
			(0.098)	(0.099)
col45			1.732 **	1.690 **
			(0.349)	(0.357)

Note: * denotes significant at the 90% level. ** denotes significant at the 95% level.
Source: Statistics Canada Trade Analyzer (2005).

Table 7. (Continued) Estimates of Random-effects Panel Data Tobit Model

Estimated Coefficient
(Standard Error of Estimated Coefficient)

Regression	(1)'	(2)'	(3)'	(4)'
Intercept	-84.163 **	-83.373 **	-85.377 **	-85.447 **
	(0.508)	(0.525)	(0.535)	(0.537)
df_m	8	13	15	17
sigma_u	2.852	2.837	2.762	2.761
	(0.024)	(0.024)	(0.023)	(0.023)
sigma_e	3.572	3.572	3.572	3.572
rho	0.389	0.387	0.374	0.374
Log likehood	-320,462	-320,363	-320,126	-320,121
Number of Observations:	312,196	312,196	312,196	312,196
Number ofGroups	18,090	18,090	18,090	18,090
Wald Chi-square	37,609	37,799	39,712	39,829

Note: * denotes significant at the 90% level. ** denotes significant at the 95% level.
Source: Statistics Canada Trade Analyzer (2005).

Table 8. Estimates of Random-effects GLS Regression

Estimated Coefficient
(Standard Error of Estimated Coefficient)

Regression	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Exports	Exports	Exports	Exports	Trade intensity index	Trade intensity index
$Ln(D_{ij})$	-1.423 **	-1.427 **	-1.382 **	-1.322 **	-1.455 **	-1.340 **
	(0.016)	(0.018)	(0.019)	(0.019)	(0.016)	(0.019)
$Ln(Y_i)_{(t-1)}$		0.719 **	0.718 **	0.719 **		0.332 **
		(0.033)	(0.033)	(0.033)		(0.032)
$Ln(Y_j)_{(t-1)}$		0.297 **	0.296 **	0.297 **		0.128 **
		(0.032)	(0.032)	(0.032)		(0.031)
$Ln(Y/pop)_i$		0.585 **	0.586 **	0.585 **		-0.175 **
		(0.038)	(0.038)	(0.038)		(0.037)
$Ln(Y/pop)_j$		0.442 **	0.443 **	0.442 **		-0.210 **
		(0.036)	(0.036)	(0.036)		(0.036)
$Ln(Area_i)$		0.179 **	0.055 *	0.074 **		-0.317 **
		(0.035)	(0.031)	(0.031)		(0.031)
$Ln(Area_j)$		0.346 **	0.316 **	0.334 **		-0.142 **
		(0.042)	(0.041)	(0.041)		(0.041)
$Smctry_{ij}$		1.327 **	1.122 **	0.751 **		0.770 **
		(0.117)	(0.122)	(0.121)		(0.122)
$Landl_i$			0.347	0.433 **		3.160 **
			(0.215)	(0.212)		(0.213)
$Landl_j$			-0.847 **	-0.995 **		0.649 **
			(0.187)	(0.185)		(0.186)
$Islandl_i$			-0.376	-0.338		0.292
			(0.297)	(0.292)		(0.294)
$Islandl_j$			-2.697 **	-0.807 **		0.449 *
			(0.242)	(0.233)		(0.234)
$Cont_{ij}$			0.564 **	0.508 **		0.501 **
			(0.090)	(0.088)		(0.089)
$Lang_{ij}$				0.532 **		0.551 **
				(0.038)		(0.038)
$Colony_{ij}$				0.649 **		0.653 **
				(0.145)		(0.147)
$ComCol_{ij}$				0.406 **		0.401 **
				(0.049)		(0.049)
col45				0.809 **		0.800 **
				(0.183)		(0.185)

Note:a. * denotes significant at the 90% level. ** denotes significant at the 95% level.

b. Coefficients for country dummies and intercept are not reported.

Source: Statistics Canada Trade Analyzer (2005).

Table 8. (Continued) Estimates of Random-effects GLS Regression

Estimated Coefficient
(Standard Error of Estimated)

Regression	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Exports	Exports	Exports	Exports	Trade intensity index	Trade intensity index
df_m	1	8	13	17	1	17
sigma_u	1.41	1.358	1.355	1.328	1.460	1.345
sigma_e	1.23	1.123	1.123	1.123	1.157	1.096
rho	0.57	0.594	0.593	0.583	0.614	0.601
Theta(minimum)	0.344	0.363	0.362	0.354	0.379	0.368
Theta(median)	0.766	0.784	0.784	0.780	0.785	0.787
Theta(maximum)	0.799	0.809	0.808	0.805	0.816	0.811
Number of Observations	215,407	179,919	179,919	179,919	215,407	179,919
Number ofGroups	19,154	15,333	15,333	15,333	19,154	15,333
R-sq(within)	0	0.076	0.076	0.076	0	0.003
R-sq(between)	0.791	0.818	0.818	0.825	0.427	0.474
R-sq(overal)	0.705	0.739	0.740	0.748	0.327	0.371
Breuch-Pagan LM Test	3.E+05	3.E+05	3.E+05	3.E+05	4.E+05	3.E+05
Wald Chi-square	72,814	82,975	83,229	86,449	14,272	14,639

Note:a. * denotes significant at the 90% level. ** denotes significant at the 95% level.

b. Coefficients for country dummies and intercept are not reported.

Source: Statistics Canada Trade Analyzer (2005).

Table 9. Estimates of Random-effects GLS Regression

Variables	Estimated Coefficient	Standard Errors	Variables	Estimated Coefficient	Standard Errors
$Ln(D_{ij})$	-1.326 **	0.019	Chinaex	3.026 **	0.264
$Ln(Y_i)_{(t-1)}$	0.719 **	0.033	Chinaim	0.786 **	0.259
$Ln(Y_j)_{(t-1)}$	0.297 **	0.032	Japanex	1.671 **	0.372
$Ln(Y/pop)_i$	0.585 **	0.038	Japanim	0.799 **	0.333
$Ln(Y/pop)_j$	0.442 **	0.036	ChinaexESA	-0.497	0.401
$Ln(Area_i)$	0.074 **	0.031	ChinaimESA	-0.040	0.401
$Ln(Area_j)$	0.336 **	0.041	JapanexESA	-0.477	0.400
$Smctry_{ij}$	0.433 **	0.212	JapanimESA	-0.624	0.400
$Landl_i$	-1.002 **	0.185			
$Landl_j$	-0.340 **	0.292			
$Islandl_i$	0.810	0.233			
$Islandl_j$	0.754 **	0.121			
$Cont_{ij}$	0.531 **	0.038			
$Lang_{ij}$	0.504 **	0.088			
$Colony_{ij}$	0.657 **	0.145			
$ComCol_{ij}$	0.406 **	0.049			
col45	0.819 **	0.184			
df_m		31	Number of Observations:		179,919
sigma_u		1.328	Number ofGroups		15,333
sigma_e		1.123	R-sq(within)		0.08
rho		0.583	R-sq(between)		0.82
Theta(minimum)		0.3544	R-sq(overal)		0.75
Theta(median)		0.7796	Breuch-Pagan LM Test		310,000
Theta(maximum)		0.8046	Wald Chi-square		86,457

Note:a. * denotes significant at the 90% level. ** denotes significant at the 95% level.

b. Coefficients for country dummies and intercept are not reported.

Source: Statistics Canada Trade Analyzer (2005).

Table 10. Estimates of Random-effects GLS Regression

Variables	Estimated Coefficient	Standard Errors	Variables	Estimated Coefficient	Standard Errors
$Ln(D_{ij})$	-1.322 **	0.019	ChinaexESA	0.399	0.517
$Ln(Y_i)_{(t-1)}$	0.719 **	0.033	ChinaimESA	1.267 *	0.049
$Ln(Y_j)_{(t-1)}$	0.297 **	0.032	ChinaexAfr	1.487 **	0.005
$Ln(Y/pop)_i$	0.584 **	0.038	ChinaimAfr	1.465 **	0.009
$Ln(Y/pop)_j$	0.442 **	0.036	ChinaexNA	1.282	0.234
$Ln(Area_i)$	0.074 **	0.031	ChinaimNA	2.647 **	0.015
$Ln(Area_j)$	0.336 **	0.041	ChinaexSA	0.573	0.302
$Smctry_{ij}$	0.455 **	0.212	ChinaimSA	0.864	0.141
$Landl_i$	-1.006 **	0.185	ChinaexEU	0.532	0.347
$Landl_j$	-0.333 **	0.292	ChinaimEU	1.590 **	0.008
$Islandl_i$	0.813	0.233	ChinaexME	1.147 *	0.067
$Islandl_j$	0.741 **	0.121	ChinaimME	2.061 **	0.002
$Cont_{ij}$	0.534 **	0.038	ChinaexOCN	0.726	0.306
$Lang_{ij}$	0.544 **	0.089	ChinaimOCN	1.191	0.107
$Colony_{ij}$	0.648 **	0.145			
$ComCol_{ij}$	0.405 **	0.049			
col45	0.810 **	0.183			
df_m		31	Number of Observations:		179,919
sigma_u		1.328	Number ofGroups		15,333
sigma_e		1.123	R-sq(within)		0.08
rho		0.583	R-sq(between)		0.83
Theta(minimum)		0.3542	R-sq(overal)		0.75
Theta(median)		0.7795	Breuch-Pagan LM Test		310,000
Theta(maximum)		0.8045	Wald Chi-square		86,550

Note:a. * denotes significant at the 90% level. ** denotes significant at the 95% level.

b. Coefficients for country dummies and intercept are not reported.

Source: Statistics Canada Trade Analyzer (2005).

Table 11. OLS Regression Results for Cross Section Data in Selected Years

Estimated Coefficient — Dependent variable: Exports
(Standard Error of Estimated oefficient)

Year	1985	1990	1995	1997	1998	2000	2001	2002
$Ln(D_{ij})$	-1.224 **	-1.295 **	-1.353 **	-1.386 **	-1.417 **	-1.456 **	-1.428 **	-1.489 **
	(0.033)	(0.030)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
$Ln(Y_i)_{(t-1)}$	0.927 **	0.991 **	1.261 **	1.277 **	1.262 **	1.064 **	1.379 **	0.244 **
	(0.058)	(0.065)	(0.067)	(0.039)	(0.039)	(0.078)	(0.040)	(0.075)
$Ln(Y_j)_{(t-1)}$	0.835 **	0.862 **	1.079 **	1.064 **	1.000 **	0.792 **	1.135 **	0.001
	(0.058)	(0.065)	(0.067)	(0.039)	(0.038)	(0.077)	(0.040)	(0.075)
$Ln(Y/pop)_i$	-0.297 **	0.082	-0.656 **	-0.573 **	-0.419 **	-0.341 **	-0.200 **	0.212 **
	(0.074)	(0.095)	(0.094)	(0.056)	(0.058)	(0.067)	(0.050)	(0.057)
$Ln(Y/pop)_j$	-0.431 **	0.007	-0.695 **	-0.590 **	-0.354 **	-0.268 **	-0.203 **	0.207 **
	(0.074)	(0.095)	(0.094)	(0.056)	(0.058)	(0.066)	(0.050)	(0.057)
$Ln(Area_i)$	-0.202 **	-0.161 **	-0.057	-0.400 **	-0.371 **	-0.331 **	-0.257 **	-0.014
	(0.045)	(0.061)	(0.051)	(0.033)	(0.035)	(0.039)	(0.032)	(0.038)
$Ln(Area_j)$	-0.222 **	-0.172 **	-0.060	-0.393 **	-0.339 **	-0.300 **	-0.247 **	-0.014
	(0.045)	(0.061)	(0.050)	(0.033)	(0.035)	(0.040)	(0.032)	(0.038)
$Smctry_{ij}$	1.103 **	0.868 **	0.939 **	0.907 **	0.607 **	0.888 **	0.820 **	0.658 **
	(0.215)	(0.201)	(0.193)	(0.170)	(0.167)	(0.160)	(0.159)	(0.167)
$Landl_i$	-2.007 **	-0.137	-2.110 **	-1.114 **	1.576 **	-0.872 **	-0.782 **	-1.498 **
	(0.417)	(0.265)	(0.215)	(0.236)	(0.278)	(0.238)	(0.233)	(0.227)
$Landl_j$	-2.579 **	-0.648 **	-2.464 **	-1.406 **	1.216 **	-1.040 **	-1.088 **	-1.862 **
	(0.414)	(0.263)	(0.213)	(0.235)	(0.277)	(0.235)	(0.228)	(0.223)
$Islandl_i$	0.030	1.396 **	0.616 **	1.806 **	1.480 **	1.112 **	0.693 **	-0.723 **
	(0.271)	(0.186)	(0.193)	(0.166)	(0.175)	(0.214)	(0.158)	(0.191)
$Islandl_j$	0.008	1.512 **	0.522 **	1.797 **	1.365 **	1.046 **	0.489 **	-0.897 **
	(0.270)	(0.186)	(0.193)	(0.166)	(0.176)	(0.213)	(0.157)	(0.190)
$Cont_{ij}$	-0.005	0.162	0.269 **	0.290 **	0.259 **	0.464 **	0.396 **	0.292 **
	(0.147)	(0.139)	(0.127)	(0.121)	(0.119)	(0.116)	(0.116)	(0.119)
$Lang_{ij}$	0.287 **	0.419 **	0.520 **	0.610 **	0.603 **	0.541 **	0.643 **	0.506 **
	(0.067)	(0.061)	(0.056)	(0.055)	(0.055)	(0.054)	(0.054)	(0.054)
$Colony_{ij}$	1.405 **	1.278 **	1.111 **	1.001 **	1.029 **	1.070 **	0.895 **	0.982 **
	(0.139)	(0.129)	(0.123)	(0.124)	(0.126)	(0.127)	(0.126)	(0.126)
$ComCol_{ij}$	0.417 **	0.586 **	0.398 **	0.432 **	0.467 **	0.510 **	0.371 **	0.407 **
	(0.096)	(0.086)	(0.077)	(0.073)	(0.074)	(0.072)	(0.071)	(0.072)
Intercept	-26.495 **	-36.565 **	-36.259 **	-33.298 **	-35.209 **	-27.516 **	-45.766 **	-4.647 *
	(1.830)	(1.545)	(1.455)	(1.192)	(1.402)	(2.234)	(1.414)	(2.372)
n	8,144	9,045	10,406	10,994	11,206	11,627	11,707	11,472
Adjusted R-Square	0.682	0.729	0.756	0.753	0.742	0.748	0.752	0.752

Note: a. * denotes significant at the 90% level. ** denotes significant at the 95% level.

b. n is the number of Observations

c. Coefficients for country dummies and intercept are not reported.

Source: Statistics Canada *Trade Analyzer* (2005).

Table 12. Original and Gravity Model Adjusted Export Intensity Index of China and Japan to selected Regions

Export Intensity Index
(Gravity model Adjusted Export Intensity Index)

exporter	importer	1985	1990	1995	1997	1998	2000	2001	2002
China	East and Southeast Asia	3.80	3.61	2.05	2.10	2.35	2.05	2.04	2.09
		(1.67)	(1.63)	(0.90)	(0.92)	(1.02)	(0.87)	(0.86)	(0.89)
	Africa	0.16	0.25	0.42	0.47	0.53	0.59	0.63	0.59
		(0.98)	(1.42)	(2.18)	(2.31)	(2.60)	(2.94)	(3.11)	(2.90)
	North America	0.42	0.41	0.79	0.82	0.86	0.84	0.84	0.87
		(1.19)	(1.10)	(2.01)	(2.01)	(2.12)	(2.06)	(2.05)	(2.11)
	South America	0.38	0.13	0.15	0.18	0.20	0.22	0.26	0.26
		(1.74)	(0.54)	(0.60)	(0.71)	(0.77)	(0.87)	(0.99)	(1.01)
	Middle East	0.17	0.41	0.51	0.44	0.44	0.58	0.55	0.60
		(0.45)	(1.05)	(1.22)	(1.03)	(1.04)	(1.36)	(1.28)	(1.38)
	Europe	0.62	0.48	0.76	0.82	0.87	0.95	0.96	0.98
		(1.01)	(0.77)	(1.18)	(1.27)	(1.36)	(1.48)	(1.48)	(1.50)
	Oceania	0.40	0.47	0.59	0.62	0.66	0.78	0.82	0.86
		(0.62)	(0.73)	(0.93)	(0.96)	(1.01)	(1.19)	(1.24)	(1.29)
Japan	East and Southeast Asia	1.76	1.85	1.97	1.98	2.00	2.12	2.00	2.06
		(0.54)	(0.60)	(0.65)	(0.65)	(0.65)	(0.68)	(0.64)	(0.67)
	Africa	0.41	0.42	0.42	0.35	0.35	0.33	0.32	0.33
		(2.12)	(2.10)	(2.06)	(1.65)	(1.68)	(1.62)	(1.57)	(1.64)
	North America	1.42	1.37	1.23	1.21	1.21	1.11	1.14	1.08
		(2.68)	(2.60)	(2.32)	(2.25)	(2.25)	(2.11)	(2.15)	(2.04)
	South America	0.66	0.50	0.50	0.52	0.52	0.47	0.49	0.49
		(1.96)	(1.44)	(1.42)	(1.46)	(1.46)	(1.38)	(1.43)	(1.42)
	Middle East	0.89	0.69	0.47	0.54	0.60	0.48	0.58	0.58
		(2.25)	(1.82)	(1.22)	(1.41)	(1.56)	(1.27)	(1.53)	(1.55)
	Europe	0.71	0.94	0.89	0.90	0.99	0.92	0.91	0.89
		(1.00)	(1.36)	(1.32)	(1.35)	(1.49)	(1.42)	(1.41)	(1.37)
	Oceania	1.34	1.14	1.00	1.02	1.03	1.01	1.10	1.08
		(1.18)	(1.07)	(0.98)	(1.01)	(1.01)	(1.00)	(1.10)	(1.08)

Source: Statistics Canada *Trade Analyzer* (2005).

Table 12. (Continued) Original and Gravity Model Adjusted Import Intensity Index of China and Japan to selected Regions

Import Intensity Index
(Gravity model Adjusted Import Intensity Index)

importer	exporter	1985	1990	1995	1997	1998	2000	2001	2002
China	East and Southeast Asia	1.78	3.15	2.95	3.14	2.95	2.74	2.72	2.75
		(0.82)	(1.62)	(1.61)	(1.73)	(1.60)	(1.46)	(1.46)	(1.48)
	Africa	0.09	0.15	0.18	0.35	0.21	0.56	0.50	0.48
		(0.61)	(1.02)	(1.26)	(2.42)	(1.44)	(3.83)	(3.39)	(3.23)
	North America	0.81	0.67	0.51	0.43	0.48	0.46	0.54	0.54
		(3.15)	(2.74)	(2.06)	(1.70)	(1.89)	(1.76)	(2.06)	(2.01)
	South America	0.45	0.29	0.24	0.25	0.19	0.21	0.25	0.26
		(2.78)	(1.86)	(1.48)	(1.52)	(1.16)	(1.27)	(1.53)	(1.53)
	Middle East	0.02	0.13	0.28	0.43	0.52	0.63	0.46	0.38
		(0.09)	(0.55)	(1.13)	(1.76)	(2.12)	(2.48)	(1.79)	(1.45)
	Europe	0.80	0.78	0.64	0.53	0.58	0.61	0.67	0.63
		(2.04)	(2.10)	(1.73)	(1.41)	(1.53)	(1.60)	(1.73)	(1.60)
	Oceania	1.06	0.87	0.76	0.88	0.78	0.94	0.90	0.92
		(2.09)	(1.84)	(1.63)	(1.85)	(1.62)	(1.91)	(1.83)	(1.81)
Japan	East and Southeast Asia	1.85	1.55	1.49	1.45	1.41	1.58	1.59	1.48
		(0.55)	(0.55)	(0.61)	(0.61)	(0.58)	(0.65)	(0.66)	(0.61)
	Africa	0.45	0.38	0.40	0.37	0.45	0.25	0.31	0.44
		(2.56)	(2.57)	(3.10)	(2.99)	(3.53)	(2.09)	(2.58)	(3.75)
	North America	1.43	1.34	1.31	1.26	1.32	1.17	1.15	1.17
		(3.81)	(4.22)	(4.68)	(4.61)	(4.79)	(4.32)	(4.30)	(4.43)
	South America	0.61	0.59	0.46	0.42	0.37	0.29	0.27	0.24
		(2.60)	(2.94)	(2.61)	(2.41)	(2.12)	(1.70)	(1.63)	(1.48)
	Middle East	3.24	2.11	2.01	2.20	2.13	2.17	1.67	2.18
		(11.88)	(9.85)	(10.61)	(12.09)	(11.68)	(12.04)	(9.32)	(12.26)
	Europe	0.41	0.79	0.77	0.74	0.76	0.74	0.74	0.73
		(0.94)	(2.11)	(2.38)	(2.35)	(2.41)	(2.42)	(2.44)	(2.43)
	Oceania	2.71	2.29	2.39	2.21	2.49	2.27	2.26	2.25
		(3.13)	(3.16)	(3.83)	(3.67)	(4.07)	(3.78)	(3.82)	(3.85)

Source: Statistics Canada *Trade Analyzer* (2005).

APPENDIX 1
SOLVE THE GENERAL EQUILIBRIUM FOR AUTARKY MODEL

Solve the utility maximization problem for consumers:

Max $U = C_A^{1-\mu} C_M^{\mu}$, $0 < \mu < 1$

s.t $P_A C_A + P_M C_M = Y$

F.O.C.: $\frac{\partial U}{\partial C_A} = \lambda \frac{\partial Y}{\partial C_A} \Rightarrow (1-\mu) C_A^{-1} U = \lambda P_A$ (A.1.1)

$$\frac{\partial U}{\partial C_M} = \lambda \frac{\partial Y}{\partial C_M} \Rightarrow \mu C_M^{-1} U = \lambda P_M \quad \text{(A.1.2)}$$

Taking (A.1.1)/(A.1.2): $P_M C_M = \mu \frac{C_A}{(1-\mu)}$ (A.1.3)

Substituting (2.4), (2.6), (2.15) and (2.16) into (A.1.3), I get:

$$\frac{\mu A}{(1-\mu)} \left(\frac{w}{\theta} \right)^{\frac{\theta}{\theta-1}} = \frac{w}{b} [L - A (\frac{w}{\theta})^{\frac{1}{\theta-1}}]$$

So, the equilibrium wage is $w = \theta \left(\frac{A}{L} \right)^{1-\theta} \left[\left(\frac{1}{1-\mu} - 1 \right) \frac{b}{\theta} + 1 \right]^{1-\theta}$ (A.1.4)

Since $0 < \theta < 1$, I can easily get $\frac{\partial w}{\partial b} > 0$.

From (2.6), (A.1.4) the equilibrium land price is

$$g(w) = (1-\theta)(\frac{w}{\theta})^{\theta/(\theta-1)} = (1-\theta) \left[\left(\frac{1}{1-\mu} - 1 \right) \frac{b}{\theta} + 1 \right]^{-\theta} \left(\frac{L}{A} \right)^{\theta} \quad \text{(A.1.5)}$$

Therefore, $\frac{\partial g(w)}{\partial b} < 0$.

From (2.13) and (A.1.4): $n = \frac{L - A \left(\frac{w}{\theta} \right)^{1/(\theta-1)}}{\alpha\sigma} = \frac{Lb\mu}{(b\mu + \theta - \mu\theta)\alpha\sigma}$ (A.1.6)

From (2.12) and (A.1.4), I have

$$P_L = n^{\frac{1}{1-\sigma}} p_i = \left(b\mu + \theta - \mu\theta\right)^{(1-\theta+\frac{1}{\sigma-1})} \left(\frac{\alpha\sigma}{b\mu}\right)^{\frac{1}{\sigma-1}} \theta^{\theta} (1-\mu)^{(\theta-1)} \beta \frac{\sigma}{\sigma-1} A^{1-\theta} L^{\frac{1}{1-\sigma}+\theta-1} \quad \text{(A.1.7)}$$

Substituting (A.1.7) into (2.16): $P_M C_M = \frac{P_L C_L}{b} = P_M C_L^b K^{1-b}$

So, $P_M = C_L^{1-b} K^{b-1} \frac{P_L}{b} = n^{1-b} c_i^{1-b} K^{b-1} \frac{P_L}{b} = \xi A^{1-\theta} L^{\theta - \frac{\sigma b}{\sigma-1}} K^{b-1}$ (A.1.8)

Where $\xi = \mu\theta^{\theta}(1-\mu)^{\theta-1} \left(\frac{\alpha\sigma}{\mu b}\right)^{\frac{\sigma b}{\sigma-1}} \left(\frac{\beta}{\alpha(\sigma-1)}\right)^{b} \left(\mu b + \theta - \mu\theta\right)^{\frac{\sigma b}{\sigma-1}-\theta}$

Substituting (2.11) into (2.16): $rK = \frac{1-b}{b} P_L C_L = \frac{(1-b)np_i c_i}{b} = \frac{(1-b)\alpha\sigma n w}{b}$.

Therefore, $r = \frac{wn(1-b)\alpha\sigma}{bK} = \frac{\mu(1-b)\theta^{\theta}(\mu b + \theta - \mu\theta)^{-\theta} L^{\theta} A^{1-\theta}}{(1-\mu)^{1-\theta} K}$ (A.1.9)

From (A.1.9), I can have $\frac{\partial r}{\partial b} < 0$.

APPENDIX 2
OUTPUT MAXIMIZATION IN TWO-COUNTRY MODEL

Similarly with autarky economy (A.1.8), I can have the optimal country x produced intermediate manufacturing product i as input for the final manufactures production of country x[56]:

$$c_{xxi} = C_{Lx}\left(\frac{P_{Lx}}{p_{xi}}\right)^{\sigma} \tag{A.2.1}$$

The optimal country y produced intermediate manufactures i as input for the final manufactures production of country x:

$$c_{yxj} = C_{Lx}\left(\frac{\tau P_{Lx}}{p_{yj}}\right)^{\sigma} \tag{A.2.2}$$

Symmetrically,

$$c_{xyi} = C_{Ly}\left(\frac{\tau P_{Ly}}{p_{xi}}\right)^{\sigma} \tag{A.2.3}$$

$$c_{yyj} = C_{Ly}\left(\frac{P_{Ly}}{p_{yj}}\right)^{\sigma} \tag{A.2.4}$$

So, variety i of intermediate manufactures produced in country x as input for the final manufactures is:

$$c_{xi} = c_{xyi} + c_{xxi} = C_{Ly}\left(\frac{\tau P_{Ly}}{p_{xi}}\right)^{\sigma} + C_{Lx}\left(\frac{P_{Lx}}{p_{xi}}\right)^{\sigma} \tag{A.2.5}$$

The optimal price of variety i for the final manufactures producers is:

$$p_{xi} = c_{xi}^{\frac{-1}{\sigma}}\left[C_{Ly}\left(\tau P_{Ly}\right)^{\sigma} + C_{Lx}P_{Lx}^{\sigma}\right]^{1/\sigma}.$$

[56] Solve the production maximization problem for final manufactures producers in country x.

Thus, $p_{xi} c_{xi} = c_{xi}^{\frac{-1}{\sigma}} \left[C_{Ly} \left(\tau P_{Ly} \right)^{\sigma} + C_{Lx} P_{Ix}^{\sigma} \right]^{1/\sigma} c_{xi}$ and $MP_{xi} = \dfrac{\partial p_{xi} c_{xi}}{\partial c_{xi}} = \dfrac{\sigma - 1}{\sigma} p_{xi}$

Maximize profit in monopoly competitive market, each firm must satisfy $MP_{xi} = MC_{xi}$, i.e., $\dfrac{\sigma - 1}{\sigma} p_{xi} = w_x \beta$. Therefore,

$$p_{xi} = w_x \beta \frac{\sigma}{\sigma - 1} \tag{A.2.6}$$

APPENDIX 3
DERIVATION OF EQUATIONS FOR SIMULATION

From (A.2.1) and (A.2.2), $\dfrac{c_{xx}}{c_{yx}} = \left(\dfrac{\tau p_x}{p_y}\right)^{-\sigma} = \left(\dfrac{\tau w_x}{w_y}\right)^{-\sigma}$,

thus $c_{xx} = \left(\dfrac{\tau w_x}{w_y}\right)^{-\sigma} c_{yx}$ (A.3.1)

Similarly, $c_{xy} = \left(\dfrac{w_x}{\tau w_y}\right)^{-\sigma} c_{yy}$. (A.3.2)

Substituting (A.3.1) and (A.3.2) into (2.42),

$$c_{xx} + c_{xy} = \left(\frac{\tau w_x}{w_y}\right)^{-\sigma} c_{yx} + \left(\frac{w_x}{\tau w_y}\right)^{-\sigma} c_{yy} = c_{yx} + c_{yy} = \frac{\alpha}{\beta}(\sigma - 1)$$

So, $c_{yy} = \dfrac{\alpha}{\beta}(\sigma-1)\dfrac{\tau^{-\sigma} - \left(\dfrac{w_y}{w_x}\right)^{-\sigma}}{\tau^{-\sigma} - \tau^{\sigma}}$, (A.3.3)

$$c_{yx} = \frac{\alpha}{\beta}(\sigma-1)\frac{\left(\dfrac{w_y}{w_x}\right)^{-\sigma} - \tau^{\sigma}}{\tau^{-\sigma} - \tau^{\sigma}}, \quad \text{(A.3.4)}$$

$$c_{xy} = \frac{\alpha}{\beta}(\sigma-1)\frac{\left(\dfrac{w_y}{w_x}\right)^{\sigma} - \tau^{\sigma}}{\tau^{-\sigma} - \tau^{\sigma}}, \quad \text{(A.3.5)}$$

$$c_{xx} = \frac{\alpha}{\beta}(\sigma-1)\frac{\tau^{-\sigma} - \left(\dfrac{w_y}{w_x}\right)^{\sigma}}{\tau^{-\sigma} - \tau^{\sigma}}, \quad \text{(A.3.6)}$$

Therefore, country x's total expenditure on intermediate manufactures is:

$$P_{Lx}C_{Lx} = n_x c_{xx} p_x + n_y c_{yx} \frac{p_y}{\tau} = \xi(w_x, w_y) \quad \text{(A.3.7)}$$

According to (2.33), (2.35), (A.3.4) and (A.3.6), $P_{Lx}C_{Lx}$ can be a function of wages, $\xi_x(w_x, w_y)$. Similarly, $P_{Ly}C_{Ly}$ can be a function of wages, $\xi_y(w_x, w_y)$.

From (2.30), (2.32) and (2.35), the price of intermediate manufactures aggregation in country x is: $P_{Lx} = (\frac{n_x p_x^{1-\sigma}}{n} + \frac{n_y (p_y/\tau)^{1-\sigma}}{n})^{1/(1-\sigma)}$

$$= \frac{\sigma\beta}{\sigma - 1}\left[\frac{\left[L_x - A_x\left(\frac{w_x}{\theta}\right)^{\frac{1}{\theta-1}}\right]w_x^{1-\sigma} + \left[L_y - A_y\left(\frac{w_y}{\theta}\right)^{\frac{1}{\theta-1}}\right]\left(\frac{w_y}{\tau}\right)^{1-\sigma}}{L_x + L_y - A_x\left(\frac{w_x}{\theta}\right)^{\frac{1}{\theta-1}} - A_y\left(\frac{w_y}{\theta}\right)^{\frac{1}{\theta-1}}}\right]^{\frac{1}{1-\sigma}} \qquad \text{(A.3.8)}$$

From (2.38), (A.3.7) and (A.3.8), I know that P_{Hk} can also be expressed by a function of wages, $\lambda_k(w_x, w_y)$.

Since there is no trading cost for agricultural products, I have:

$$X_{Ax} + X_{Ay} = C_{Ax} + C_{Ay} = \frac{1-\mu}{\mu}(P_{Hx}C_{Hx} + P_{Hx}C_{Hx}).$$

Subtracting agricultural income and expenditure from (2.46) + (2.47):

$$w_x(L_x - L_{Ax}) + w_y(L_y - L_{Ay}) + r_xK_x + r_yK_y = \frac{\mu}{1-\mu}(X_{Ax} + X_{Ay}) \qquad \text{(A.3.9)}$$

Substituting (2.44) into (2.48) + (2.49):

$$\left(\frac{1}{\tau} - 1\right)(n_y c_{yx} p_y + n_x c_{xy} p_x) + \frac{\mu}{1-\mu}(X_{Ax} + X_{Ay}) - \frac{P_{Lx}C_{Lx} + P_{Ly}C_{Ly}}{b} = 0 \qquad \text{(A.3.10)}$$

APPENDIX 4
HANSON (2005)'S REGRESSION RESULTS

Hanson's estimation of the wage equation based on Krugman's model

Time period	1970–1980 (1)	1980–1990 (2)	1970–1980 (3)	1980–1990 (4)	1980–1990 (5)	1980–1990 (6)
Market potential	0.132	0.152	0.132	0.147	0.203	0.203
	(0.022)	(0.020)	(0.258)	(0.021)	(0.056)	(0.056)
Distance	−12.993	−17.907	−11.580	−17.561	−6.430	−6.429
	(1.071)	(0.906)	(1.006)	(0.953)	(0.520)	(0.520)
Personal income	0.394	0.802	0.381	0.805	0.931	0.931
	(0.076)	(0.068)	(0.095)	(0.084)	(0.128)	(0.128)
Wages	7.202	5.760	6.997	5.974	4.004	4.006
	(1.271)	(0.823)	(1.439)	(0.953)	(1.313)	(1.314)
Housing stock	0.606	0.198	0.619	0.196	0.069	0.068
	(0.076)	(0.068)	(0.095)	(0.084)	(0.128)	(0.128)
Implied values						
σ	7.597	6.562	7.377	6.779	4.935	4.937
	(1.250)	(0.838)	(1.402)	(0.973)	(1.372)	(1.372)
τ	1.970	3.219	1.816	3.039	1.634	1.633
	(0.328)	(0.416)	(0.351)	(0.440)	(0.523)	(0.523)
μ	0.916	0.956	0.911	0.967	0.982	0.983
	(0.015)	(0.013)	(0.018)	(0.016)	(0.035)	(0.035)
$\sigma/(\sigma-1)$	1.152	1.180	1.157	1.173	1.254	1.254
	(0.029)	(0.030)	(0.034)	(0.029)	(0.089)	(0.089)
$\sigma(1-\mu)$	0.639	0.226	0.653	0.221	0.085	0.084
	(0.072)	(0.075)	(0.089)	(0.094)	(0.158)	(0.158)
Adj. R^2	0.256	0.347	0.217	0.296	0.376	0.376
Log likelihood	−16,698.1	−16,576.9	−14,699.4	−14,662.2	−16,479.9	−14,573.0
Schwarz criterion	−16,714.0	−16,592.9	−14,715.0	−14,677.9	−16,575.5	−14,667.1
Wald test (p-value)	0.000	0.000	0.000	0.000	0.001	0.001
Counties	All	All	Low pop.	Low pop.	All	Low pop.
Wage controls	No	No	No	No	Yes	Yes

Hanson's estimation of the wage equation based on Helpman's model

Time period	1970–1980 (1)	1980–1990 (2)	1970–1980 (3)	1980–1990 (4)	1980–1990 (5)	1980–1990 (6)
(α_1) market potential	0.487	0.393	0.492	0.488	0.467	0.573
	(0.119)	(0.164)	(0.119)	(0.207)	(0.372)	(0.271)
(α_2) distance	−11.163	−15.400	−11.145	−16.597	−16.175	−15.108
	(2.081)	(2.054)	(2.082)	(3.312)	(3.453)	(2.366)
(α_3) personal income	0.120	0.664	0.121	0.615	0.834	0.754
	(0.046)	(0.138)	(0.046)	(0.127)	(0.338)	(0.169)
(α_4) wages	1.934	1.882	1.908	1.435	1.306	0.992
	(0.519)	(0.957)	(0.509)	(0.770)	(1.398)	(0.703)
(α_5) housing stock	0.880	0.336	0.879	0.385	0.166	0.246
	(0.046)	(0.138)	(0.046)	(0.127)	(0.338)	(0.169)
Implied values						
σ	2.053	2.546	2.028	2.050	2.140	1.745
	(0.500)	(1.064)	(0.490)	(0.869)	(1.705)	(0.827)
τ	10.593	9.964	10.836	15.800	14.188	20.272
	(5.585)	(7.129)	(5.737)	(14.901)	(18.875)	(20.626)
μ	0.545	0.821	0.539	0.732	0.873	0.752
	(0.113)	(0.154)	(0.114)	0.218	(0.385)	(0.317)
$\sigma/(\sigma-1)$	1.934	1.647	1.972	1.950	1.877	2.341
	(0.519)	(0.446)	(0.463)	(0.787)	(1.312)	(1.488)
$\sigma(1-\mu)$	0.935	0.456	0.935	0.550	0.272	0.433
	(0.025)	(0.210)	(0.025)	(0.221)	(0.614)	(0.359)
Adj. R^2	0.160	0.314	0.159	0.298	0.327	0.309
Wald test (p-value)	0.000	0.000	0.000	0.000	0.015	0.002
Chi-square (p-value)	0.343	0.200	0.254	0.167	0.206	0.327
Instrument set	Narrow	Narrow	Broad	Broad	Narrow	Broad
Wages controls	No	No	No	No	Yes	Yes

APPENDIX 5
LIST OF COUNTRIES

ESA: Brunei, Cambodia, Hong Kong, Indonesia, Japan, Korea Rp, Laos P Dem R, Malaysia, Mongolia, Myanmar, Philippines, Singapore, Taiwan, Thailand, Vietnam.

Afr: Angola, Burkina Faso, Burundi, Cameroon, Algeria, Central Afr Rep, Chad, Comoros, Egypt, Benin, Congo, Congo Dem Rep, Djibouti, Cote D'Ivoire, Eq Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Nigeria, Reunion, Rwanda, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia, Zimbabwe.

NA: USA, Canada

SA: Bahamas, Belize, Bermuda, Bolivia, Argentina, Brazil, Cayman islds, Chile, Ecuador, Barbados, Colombia, Costa Rica, Dominican Rp, Cuba, El Salvador, Falkland Isl, French Guiana, Greenland, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Neth Antilles, Nicaragua, Panama, Paraguay, Peru, St Pierre Miqu, Suriname, Trinidad Tbg, Turks Caicos Isl, Uruguay, Venezuela.

EU: Austria, Bulgaria, Denmark, Finland, Albania, France, Germany, Gibraltar, Italy, Belgium-Lux, Greece, Hungary, Ireland, Iceland, Malta, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, UK,

ME: Cyprus, Iraq, Israel, Jordan, Bahrain, Kuwait, Lebanon, Oman, Iran, Qatar, Saudi Arabia, Untd, Arab Em, Syrn Arab Rp.

OCN: Australia, Fiji, Kiribati, New Caledonia, New Zealand, Papua N Guinea, Solomon Islds

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