Capital liberalization, industrial agglomeration and wage inequality

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Abstract: This paper sets up a new economic geography model with diminishing marginal returns and examines the effect of capital liberalization on industrial agglomeration and wage inequality. The simulation results indicate that for the country with strict capital controls, capital liberalization can help reduce wage difference between countries in both nominal and real terms. It is also shown that when both comparative advantage and agglomeration are in effect, low trading costs does not necessarily cause the catastrophic agglomeration in the country with the larger market as most other NEG models predict.

Key Words: New Economic Geography, Capital Liberalization, Trade Costs

JEL Classification: F12, O24, R12

1. Introduction

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. 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 [Baldwin et. al. (2003), Henderson and Thisse (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, which is a law followed by most production systems. 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. 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, none of these studies focus on the interaction between agglomeration and diminishing marginal returns. In this paper, I set up a NEG model with diminishing marginal returns and examine the effect of capital liberalization on industrial agglomeration and wage inequality. Amiti (2005) also embed a NEG model with vertical linkages within a Heckscher-Ohlin framework to analyze the interaction between agglomeration and comparative advantage.

But her study focuses on the effects of reducing trade costs rather than the capital mobility on the location of manufacturing firms.

On the other hand, most 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.

The remainder of the paper is organized as follows. In the second section, I incorporate a capital endowment into Puga (1999) 's Core-Periphery model with Vertical Linkage (CPVL) 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. Model of Autarky Economy

To set up a model with international trade, I 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).[1] 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.

1. Consumer Side

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

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

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

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. Producer Side

[1] 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.

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:

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

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 CPVL 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

$$C_L = \left(\sum_{i=1}^{n} c_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{2.4}$$

where n is the number of varieties of intermediate manufactures and $\sigma > 1$ is the elasticity of substitution among the varieties. [2]

The price index of intermediate manufactures can be defined as [Fujita et.al. (1999)]: $P_L = \left(\sum_{i=1}^{n} p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ (2.5)

The production function of final manufactures is defined as:

$$X_M = C_L^b K^{1-b} = \left[\left(\sum_{i=1}^{n} c_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right]^b K^{1-b} \tag{2.6}$$

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

[2] 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.

the intermediate manufacturing production is labor-intensive. This division strengthens the difference of the two vertically linked industries and further help in analyzing the special distribution of labor- and capital-intensive industries separately. In the following section, I solve the general equilibrium and do some comparative static analysis.

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 profit maximization price for each variety of the intermediate manufacture:

$$p_i = \left(\frac{C_L}{nc_i} \right)^{\frac{1}{\sigma}} \tag{2.7}$$

and the optimized production for each variety: $x_i = \frac{\alpha}{\beta}(\sigma - 1)$. (2.8)

(It is the same with most NEG models.)

Therefore, the number of varieties:

$$n = \frac{L - L_A}{L_i} = \frac{L - Ag_w}{\alpha + \beta x_i} = \frac{L - Ag_w}{\alpha\sigma} = \frac{L - A\left(\frac{w}{\theta}\right)^{\frac{1}{\theta - 1}}}{\alpha\sigma}. \tag{2.9}$$

Assume that the market for final manufactures is perfectly competitive. The zero profit condition is: $P_M X_M = P_L C_L + rK = \frac{P_L C_L}{b} = \frac{rK}{1-b}$. (2.10)

Market clearing in autarky implies

$$X_A = C_A, \tag{2.11}$$

$$c_i = x_i, \tag{2.12}$$

$$C_M = X_M . \tag{2.13}$$

Full employment implies: $L = L_A + \sum_{i=1}^{n} L_i$. (2.14)

Balance of payment gives us: $P_A C_A + P_M C_M = Ag(w) + Lw + Kr$. (2.15)

Solving the system (2.11) - (2.15), I get the equilibrium factor returns, commodity prices and the number of varieties.

The equilibrium wage rate: $w = \theta\left(\frac{A}{L}\right)^{1-\theta}\left[\left(\frac{1}{1-\mu}-1\right)\frac{b}{\theta}+1\right]^{1-\theta}$. (2.16)

The equilibrium land price:

$$g(w) = (1-\theta)(\frac{w}{\theta})^{\theta/(\theta-1)} = (1-\theta)\left[\left(\frac{1}{1-\mu}-1\right)\frac{b}{\theta}+1\right]^{-\theta}\left(\frac{L}{A}\right)^{\theta} . \tag{2.17}$$

The equilibrium capital rent: $r = \frac{\mu(1-b)\theta^{\theta}(\mu b+\theta-\mu\theta)^{-\theta}L^{\theta}A^{1-\theta}}{(1-\mu)^{1-\theta}K}$. (2.18)

The price and price index of intermediate manufactures:

$$P_L = n^{\frac{1}{1-\sigma}}p_i = \left(b\mu+\theta-\mu\theta\right)^{(1-\theta+\frac{1}{\sigma-1})}\left(\frac{\alpha\sigma}{b\mu}\right)^{\frac{1}{\sigma-1}}\theta^{\theta}(1-\mu)^{(\theta-1)}\beta\frac{\sigma}{\sigma-1}A^{1-\theta}L^{\frac{1}{1-\sigma}+\theta-1} \tag{2.19}$$

The equilibrium price of final manufactures: $P_M = \xi A^{1-\theta}L^{\theta-\frac{\sigma b}{\sigma-1}}K^{b-1}$ (2.20)

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

And the number of varieties of intermediate manufactures:

$$n = \frac{Lb\mu}{(b\mu+\theta-\mu\theta)\alpha\sigma} \tag{2.21}$$

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 $\theta < b$) and increases in the supply of other products' inputs ($\frac{\partial P_L}{\partial A} > 0$, $\frac{\partial P_M}{\partial A} > 0$).[3]

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:

[3] 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.

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

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.

From (2.19) and (2.20), I can have the price ratio of final and intermediate manufactures:

$$\frac{P_M}{p_i} = \left[\sigma(b + \frac{\theta}{\mu} - \theta)\right]^{\frac{\sigma b}{\sigma-1}-1} \left(\frac{\sigma - 1}{\beta}\right)^{1-b} \alpha^{\frac{b}{\sigma-1}} b^{\frac{-\sigma b}{\sigma-1}} L^{1-\frac{\sigma b}{\sigma-1}} K^{b-1} \tag{2.22}$$

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 $\frac{\partial \frac{P_M}{p_i}}{\partial K} < 0$. (2.23)

Equation (2.23) 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.

3. The Two-Country Model

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,[4] but higher prices of capital and land. Use subscript x, y to distinguish each variable for different countries. From (2.19), (2.22) and (2.23), 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

[4] Both intermediate and final manufactures.

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 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< τ <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:

$$P_{Lx} = (\sum_{i=1}^{n_x} p_{xi}^{1-\sigma} + \sum_{j=1}^{n_y} \left(\frac{p_{yj}}{\tau} \right)^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{3.1}$$

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:

$$P_{Ly} = (\sum_{i=1}^{n_y} p_{yi}^{1-\sigma} + \sum_{j=1}^{n_x} \left(\frac{p_{xj}}{\tau} \right)^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{3.2}$$

Producer Side

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

$$p_{xi} = w_x \beta \frac{\sigma}{\sigma - 1}. \tag{3.3}$$

The optimal price of variety *i* produced in country *y*:

$$p_{yi} = w_y \beta \frac{\sigma}{\sigma - 1}. \tag{3.4}$$

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:

$$x_{xi} = \frac{\alpha}{\beta}(\sigma - 1) = x_{yi} = x\ . \tag{3. 5}$$

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 (3.5), the number of varieties in country *k* is:

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

$$= \frac{L_k - A_k g_{kw}}{\alpha\sigma} = \frac{L_k - A_k \left(\frac{w_k}{\theta}\right)^{1/(\theta-1)}}{\alpha\sigma}. \tag{3. 6}$$

Total production of intermediate manufactures in country k is:

$$X_{Lk} = n_k * x_k = \frac{L_k - A_k \left(\frac{w_k}{\theta}\right)^{1/(\theta-1)}}{\alpha\sigma} * \frac{\alpha}{\beta}(\sigma - 1) = \frac{L_k - A_k \left(\frac{w_k}{\theta}\right)^{1/(\theta-1)}}{\beta\sigma}(\sigma - 1). \tag{3. 7}$$

The output of final manufactures in country k is

$$P_{Mk} X_{Mk} = P_{Mk} C_{Lk}^{b} K_k^{1-b} = \frac{P_{Lk} C_{Lk}}{b} = \frac{K_k r_k}{1-b}, \tag{3. 8}$$

where K_x is the capital endowment in country x.

The price of final manufacturing products is: $P_{Mk} = \dfrac{P_{Lk}^{b} (P_{Lk} C_{Lk})^{1-b}}{K_k^{1-b} b}$. (3. 9)

Total capital income in country k is:

$$r_k K_k = \frac{1-b}{b} P_{Lk} C_{Lk} \tag{3. 10}$$

Consumer Side

A representative consumer in country k solves the same utility maximization problem as equation (2.1), (2.2). Therefore, $P_{Mk} C_{Mk} = \dfrac{\mu}{1-\mu} P_{Ak} C_{Ak} = \mu Y_k$ (3. 11)

The consumer price index of country k is $P_k = P_{Ak}^{1-\mu} P_{Mk}^{\mu}$, (3. 12)

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.

General Equilibrium

In equilibrium, I have:

A. Balance of production and consumption:

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

$$c_x = x_x = c_{xx} + c_{xy} \tag{3. 13}$$

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

$$c_y = x_y = c_{yx} + c_{yy} \tag{3. 14}$$

Agricultural products:

$$C_{Ax} + C_{Ay} = X_{Ax} + X_{Ay} \tag{3. 15}$$

Final manufactures:

$$C_{Mx} + C_{My} = X_{Mx} + X_{My} \tag{3. 16}$$

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

$$A_x g(w_x) + w_x L_x + r_x K_x = C_{Ax} P_{Ax} + P_{Mx} C_{Mx} \tag{3. 17}$$

$$A_y g(w_y) + w_y L_y + r_y K_y = C_{Ay} P_{Ay} + P_{My} C_{My} \tag{3. 18}$$

Solving the system (3.13)-(3.18), I find that $P_{Lx} C_{Lx}$, $P_{Ly} C_{Ly}$ and P_{Mk} are all functions of wages and I can have:

$$P_{Lx} C_{Lx} = b X_{Mx} P_{Mx} \tag{3. 19}$$

$$P_{Ly} C_{Ly} = b X_{My} P_{My} \tag{3. 20}$$

$$\mu\left(\frac{A_x g(w_x) + w_x L_x + r_x K_x}{P_{Mx}} + \frac{A_y g(w_y) + w_y L_y + r_y K_y}{P_{My}}\right) = X_{Mx} + X_{My} \tag{3. 21}$$

$$(1-\mu)(A_x g(w_x) + w_x L_x + r_x K_x + A_y g(w_y) + w_y L_y + r_y K_y) = X_{Ax} + X_{Ay} \tag{3. 22}$$

Equations (3.19) — (3.22) 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 other unknowns of the economy: $g(w_x)$ and $g(w_y)$ (by (2.3)), L_{Ax} and L_{Ay} (by (2.3)), n_x and n_y (by (2.9)) P_{Mx} and P_{My} (by (2.20)), etc.

After setting up the system above, I start the numerical analysis here. Set b = 0.4, $\alpha = \beta = 0.05$, $\theta = 0.5$, $\sigma = 6$, $\mu = 0.6$,[5] $A_x = A_y = 0.5$, $K_x = K_y = 2$, $L = L_x + L_y = 8$, $L_y \in [4.1, 7]$. 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

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

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 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[6], 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.

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

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 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.[7] 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.

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

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 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 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.

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.[8] 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: $C_{Mk} = X_{Mk}$. (3. 23)

[8] 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.

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 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 (3. 23), I can get $P_{Mk}X_{Mk} = P_{Mk}C_{Mk}$ (3. 24)

Again, I can solve w_x, w_y, r_x and r_y from a nonlinear equation system: (3. 19), (3. 20) and (3. 24). 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

$$\frac{P_{My}X_{My}}{P_{Mx}X_{Mx}} = \frac{K_{yc}}{K_{xc}} = \frac{P_{Ly}C_{Ly}}{P_{Lx}C_{Lx}} \tag{3. 25}$$

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 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 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 3.1 and 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.

3.3. The Two-Country Model with Transportation Cost for All Sectors

A very important assumption for the above NEG models is that only trade of differentiated goods involves trade costs. But empirical work [Rauch (1996), HelliIll (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 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.

In this section, I examine the robustness of my model by assuming agriculture has the same trade cost as manufactures.

Assume that all conditions stay the same as in section 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:

$$(1-\mu)\left(A_x g(w_x) + w_x L_x + r_x K_x + \frac{A_y g(w_y) + w_y L_y + r_y K_y}{P_{Ay}} \right) = X_{Ax} + X_{Ay} \qquad (3.\ 26)$$

Equations of w_x, w_y, r_x and r_y can be derived through the nonlinear equation system (3. 19), (3. 20), (3. 24) and (3. 26). 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.

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. 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 disproportionately 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 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 paper 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 further study.

REFERENCES

Amiti, Mary, 2005. "Location of vertically linked industries: agglomeration versus comparative advantage," *European Economic Review*, Elsevier, vol. 49(4), pages 809-832.

Baldwin, Richard E., 1999. “Agglomeration and endogenous capital.” *European Economic Review*, 43(2), 253-280.

Baldwin, R., R. Forslid, P. Martin, G. Ottaviano and F. Robert-Nicoud, 2003. *Economic Geography and Public Policy*, Princeton University Press.

Davis, D.R. 1998 “The Home Market Effect, Trade and Industrial Structure.” *American Economic Review*, 88(5), 1264-1276.

Dixit, Avinash K and Stiglitz, Joseph E, 1977. “Monopolistic Competition and Optimum Product Diversity.” *American Economic Review*, 67(3), 297-308.

Ethier, Wilfred J, 1982. “National and International Returns to Scale in the Modern Theory of International Trade.” *American Economic Review*, 72(3), 389-405.

Forslid, Rikard, 1999. “Agglomeration with Human and Physical Capital: an Analytically Solvable Case.” CEPR Discussion Papers 2102, C.E.P.R. Discussion Papers

Fujita, Masahisa and Krugman, Paul and Venables, Anthony J. 1999. *The spatial economy : cities, regions and international trade.* MIT Press, Cambridge, Mass..

Harris, C.D., 1954. “The market as a factor in the localization of industry in the United States.” *Annals of the Association of American Geographers*, 44, 315– 348.

Henderson, J. V., and Thisse, J. 2004. *Handbook of Regional and Urban Economics*. volume 4. *Cities and Geography*. Amsterdam; San Diego and Oxford: Elsevier.

Krugman, Paul. 1991. "Increasing Returns and Economic Geography." *Journal of Political Economy*, 99(3), 483-99.

Martin, Philippe & Rogers, Carol Ann, 1995. "Industrial location and public infrastructure," *Journal of International Economics*, Elsevier, 39(3-4), 335-351.

Ottaviano, Gianmarco I P, 1996. "Monopolistic Competition, Trade, and Endogenous Spatial Fluctuations." CEPR Discussion Papers 1327, C.E.P.R. Discussion Papers.

Puga, D. 1999. "The Rise and Fall of Regional Inequalities." *Europe Economic Review*, 43, 303-334

Ricci, Luca, 1999. "Economic geography and comparative advantage: Agglomeration versus specialization," *European Economic Review*, 43(2), 357-377

Venables, Anthony J, 1996. "Equilibrium Locations of Vertically Linked Industries." *International Economic Review*, 37(2), 341-59

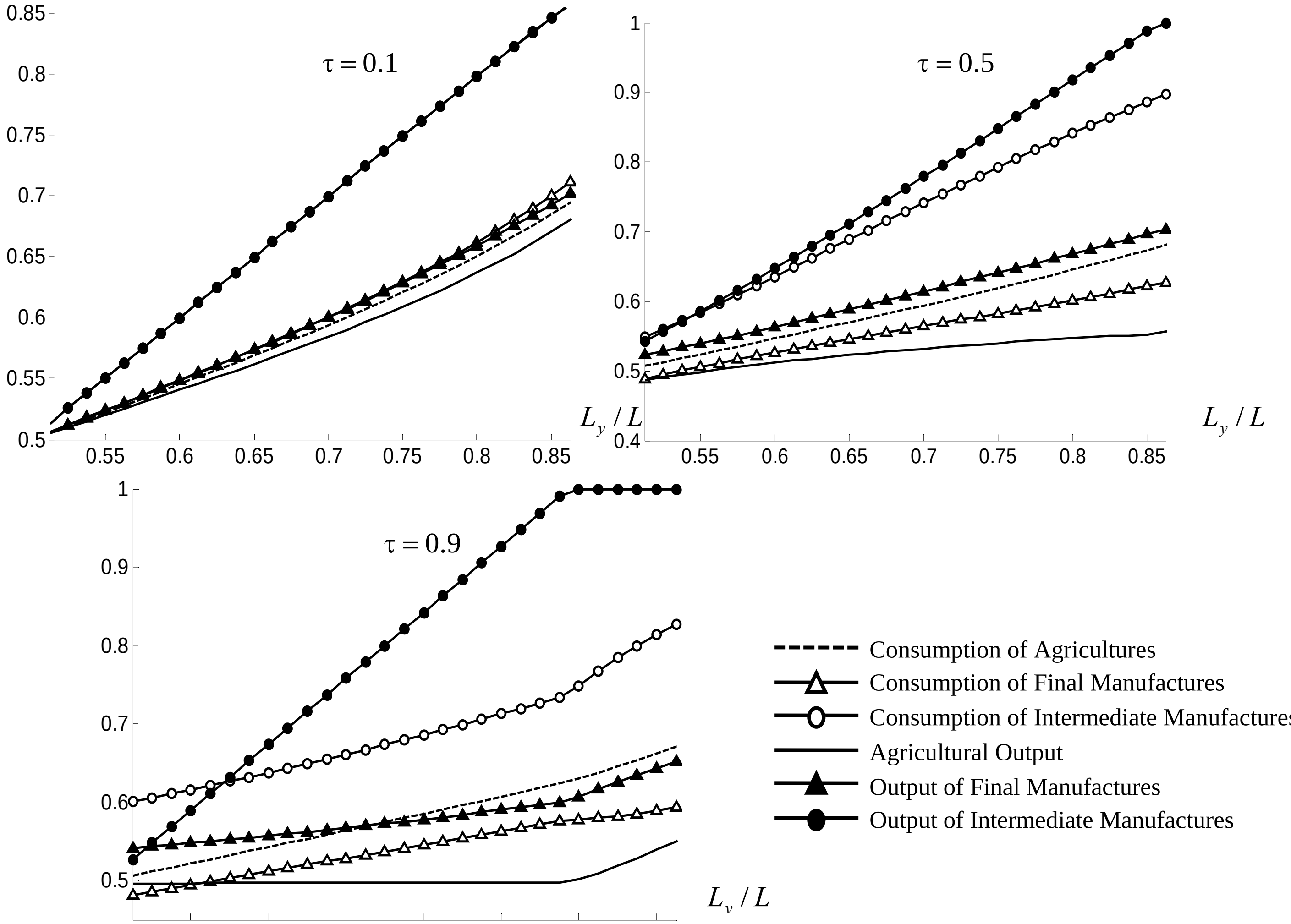

Figure 1. Trade Patterns of Two Countries with Immobile Factors

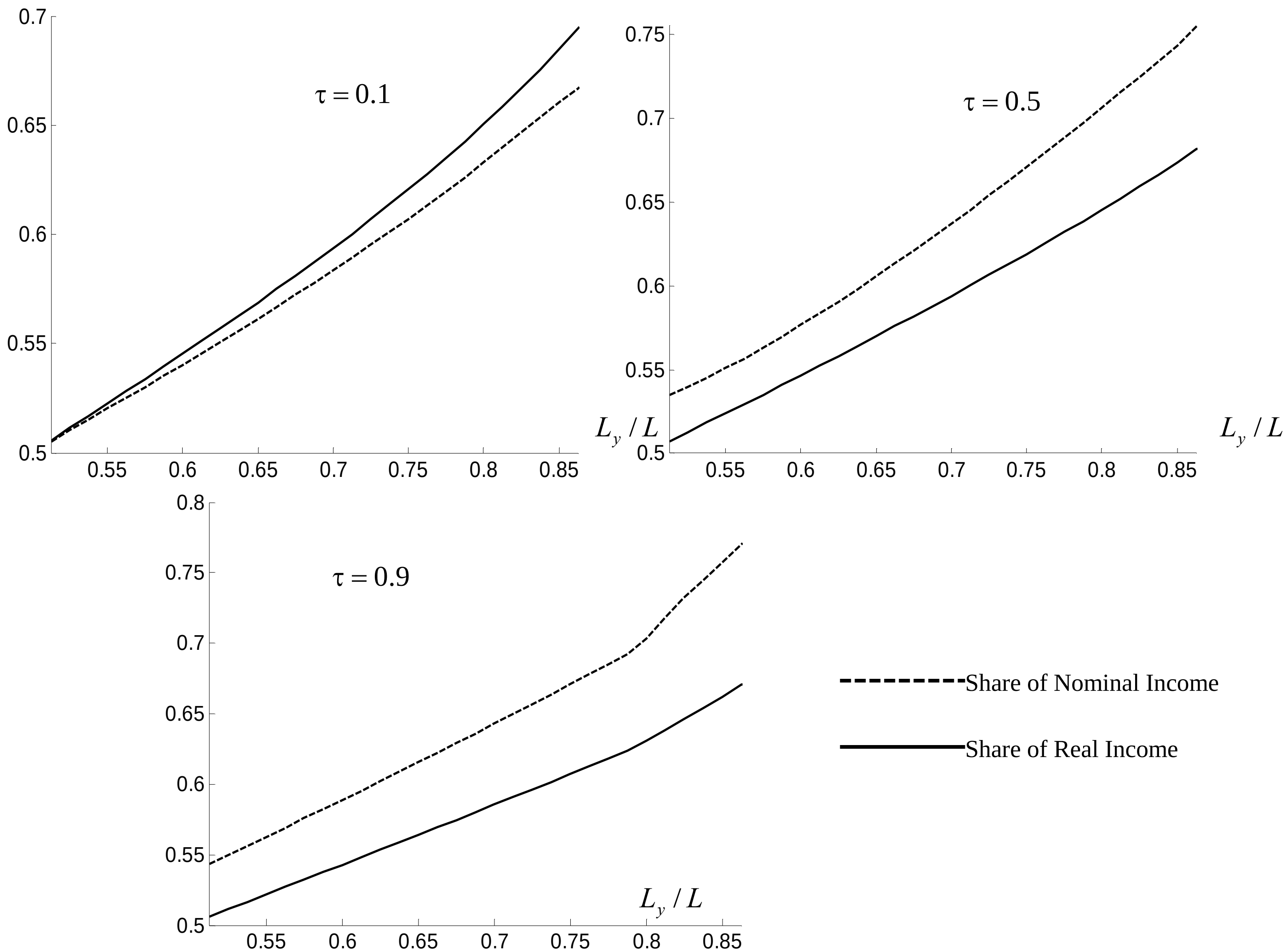

Figure 2. Income Ratios of Two Countries with Immobile Factors

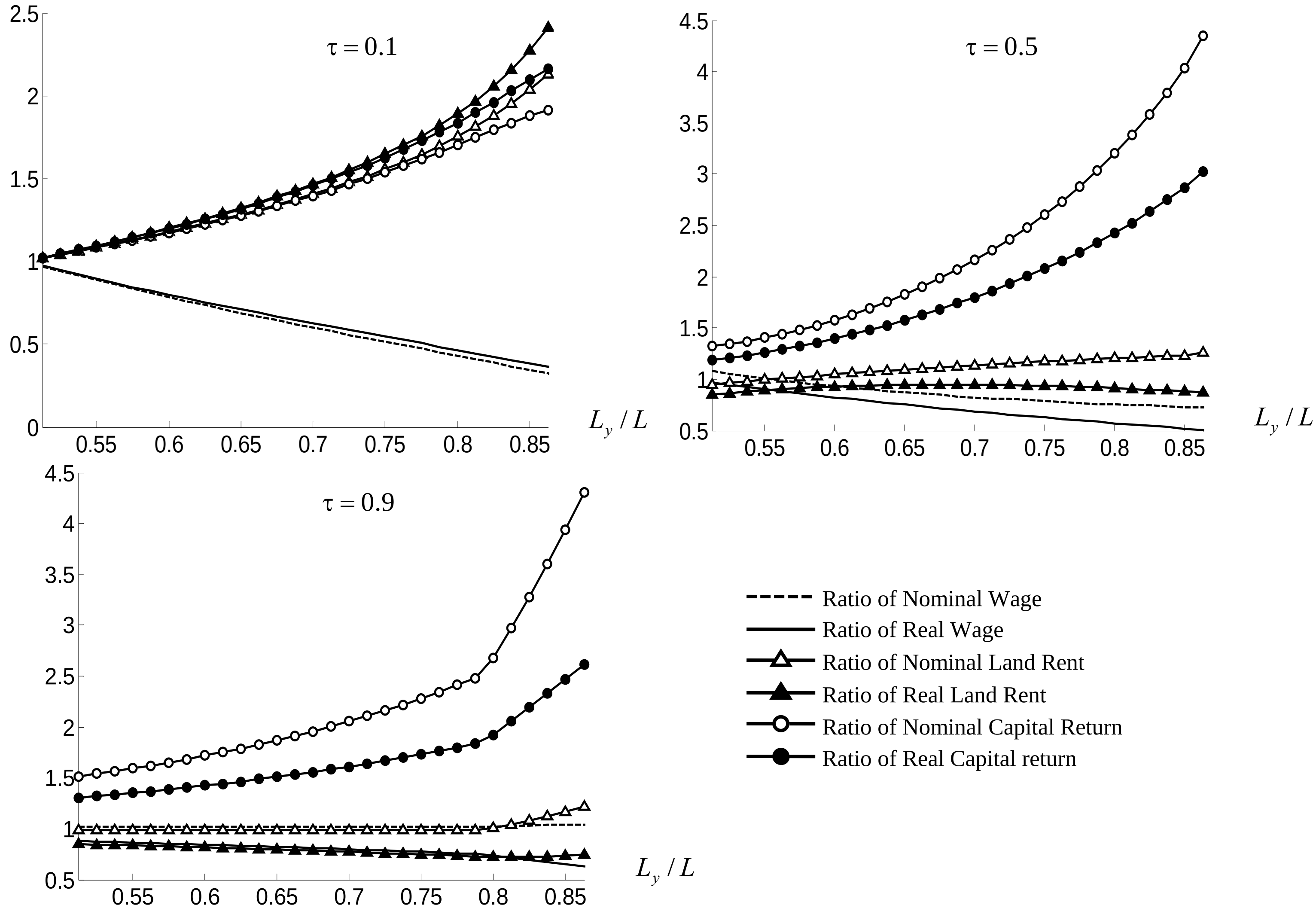

Figure 3. Factor Returns of Two Countries with Immobile Factors

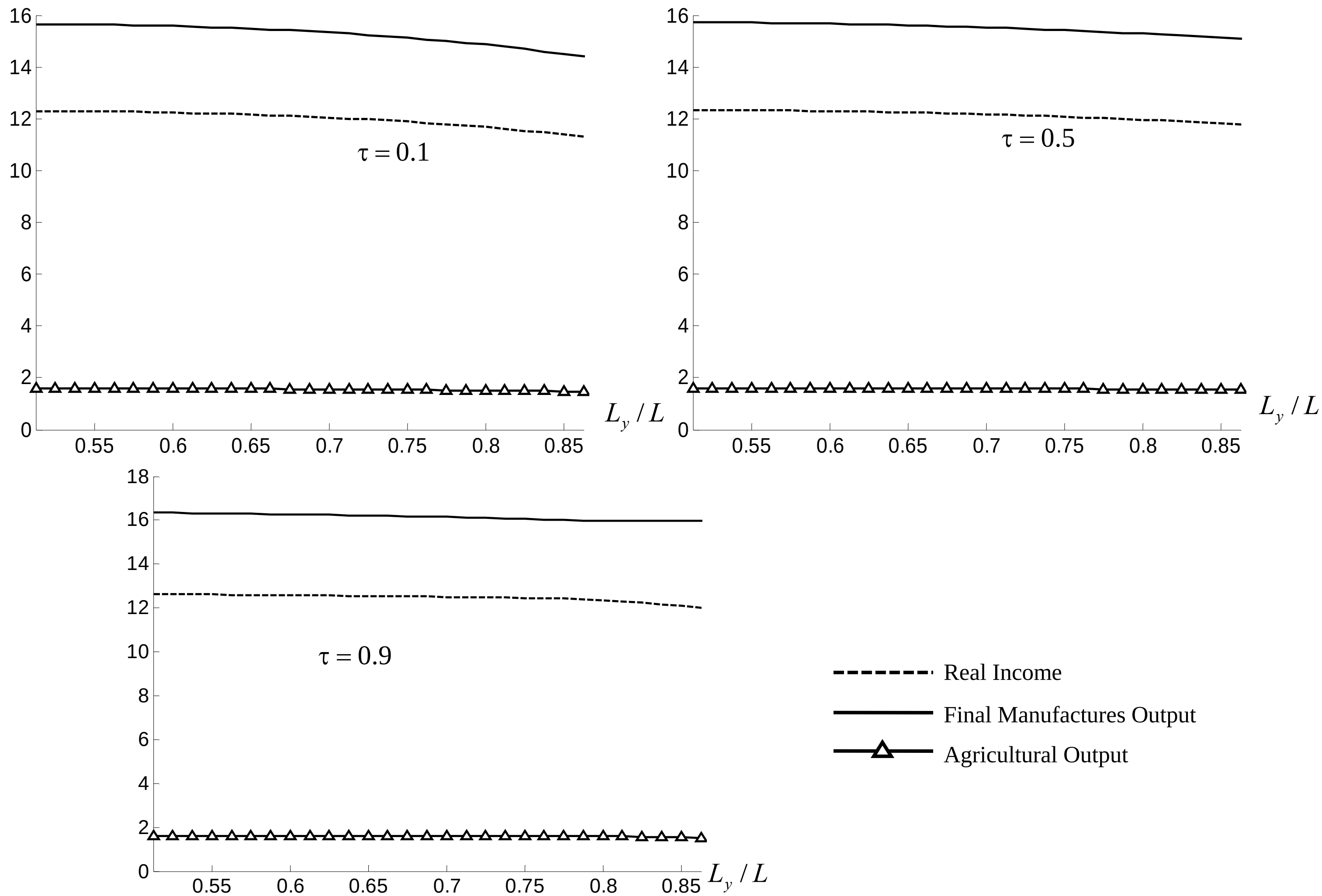

Figure 4. Output of Two Countries with Immobile Factors

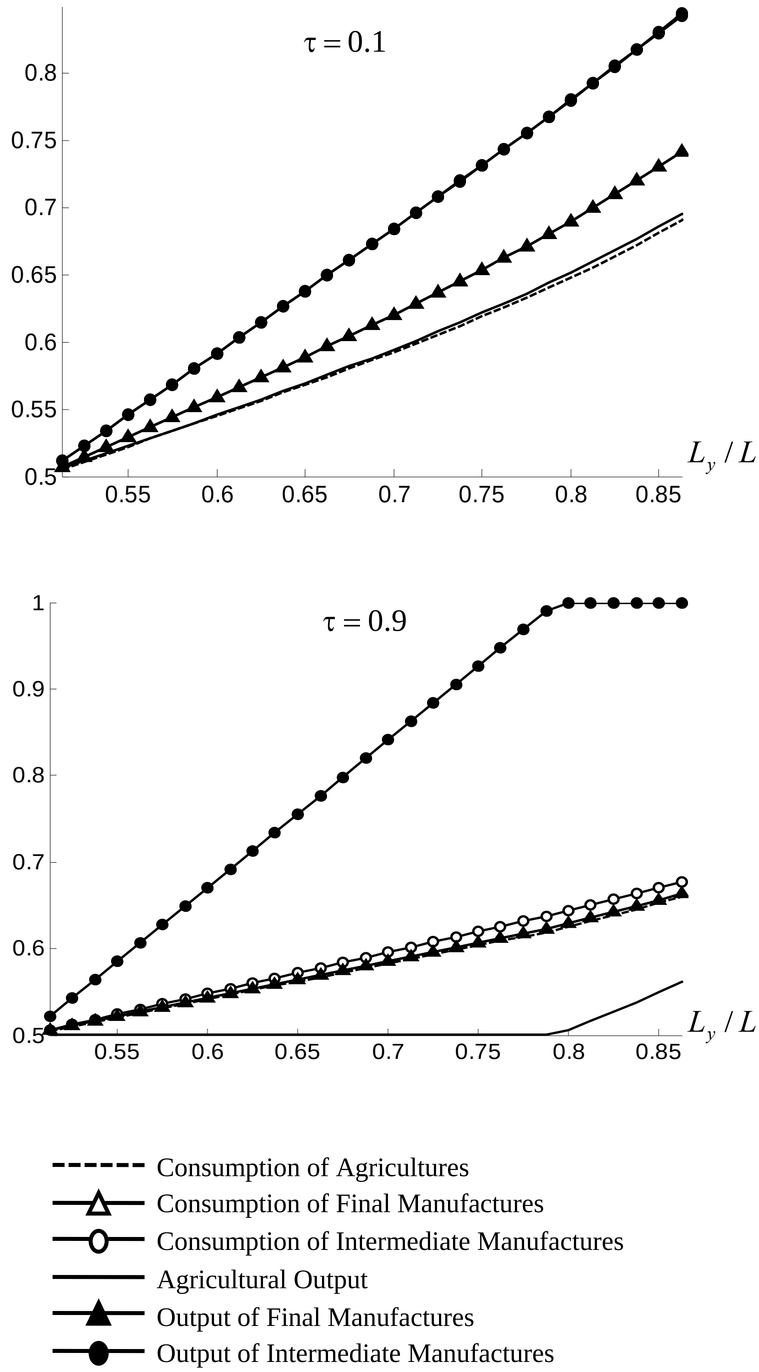

Figure 5. Trade Patterns of Two Countries with Mobile Capital and Immobile Labor

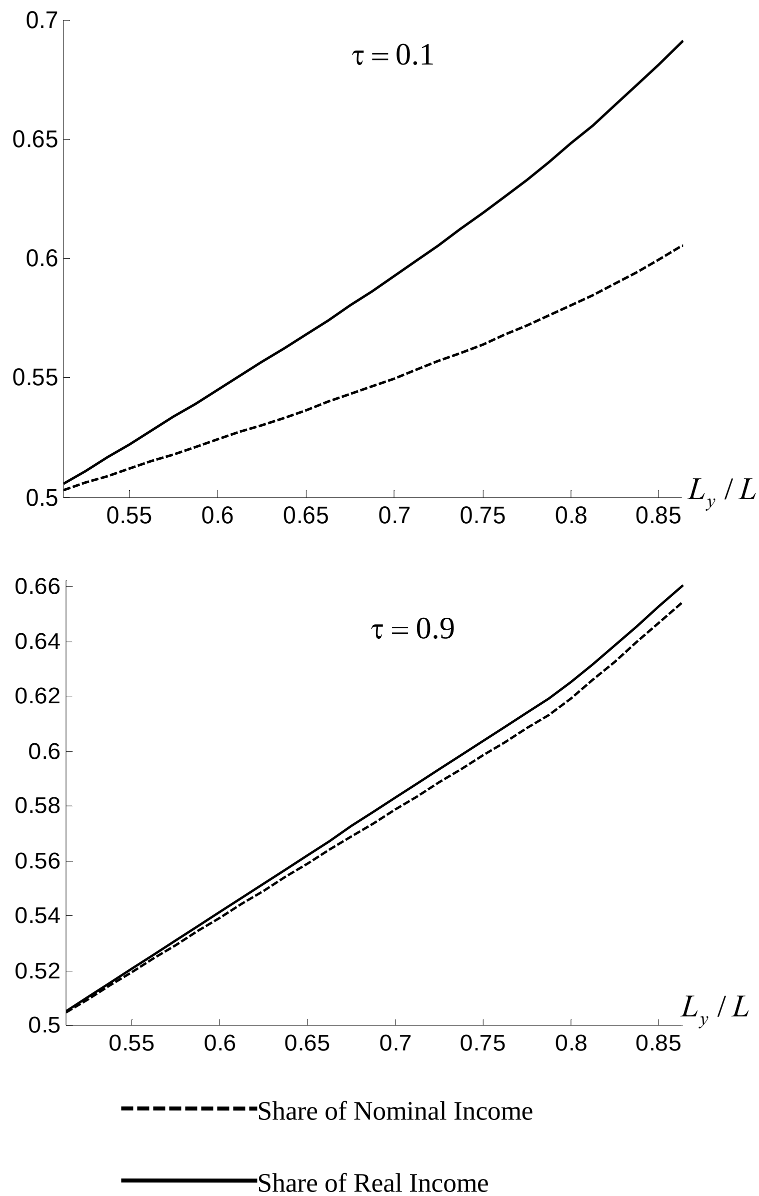

Figure 6. Income of Two Countries with Mobile Capital and Immobile Labor

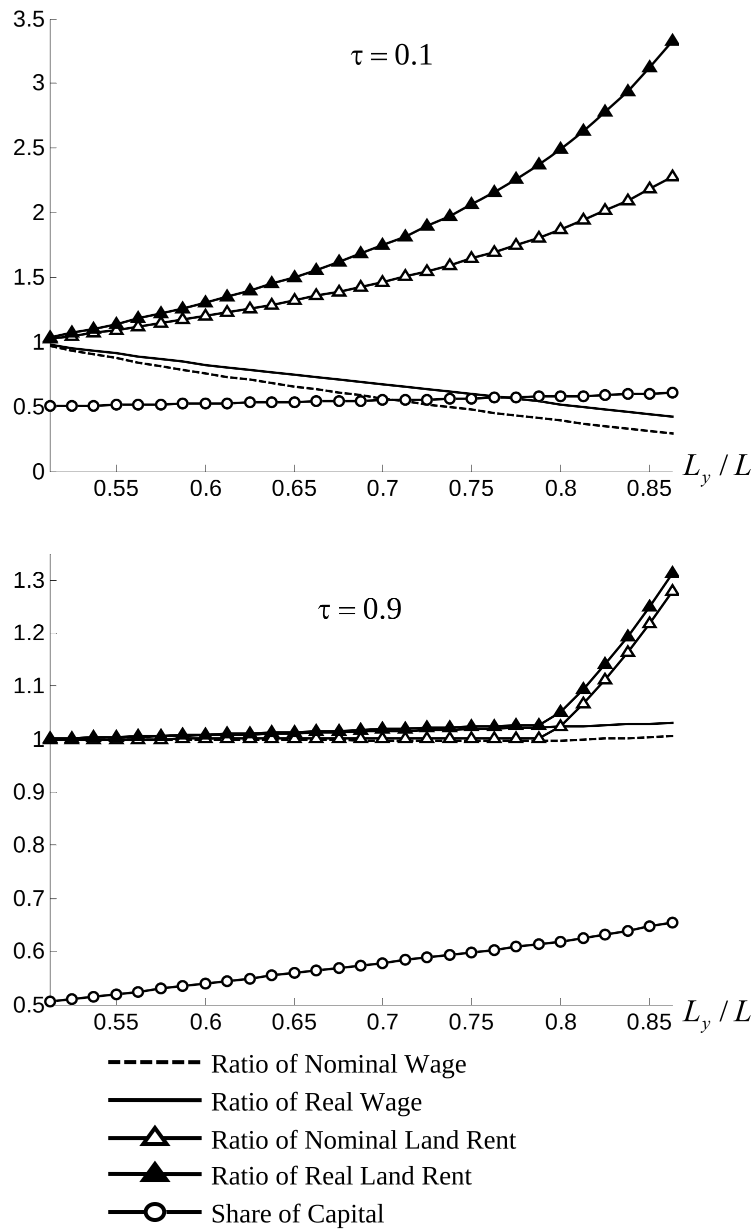

Figure 7. Factor Returns of Two Countries with Mobile Capital and Immobile Labor

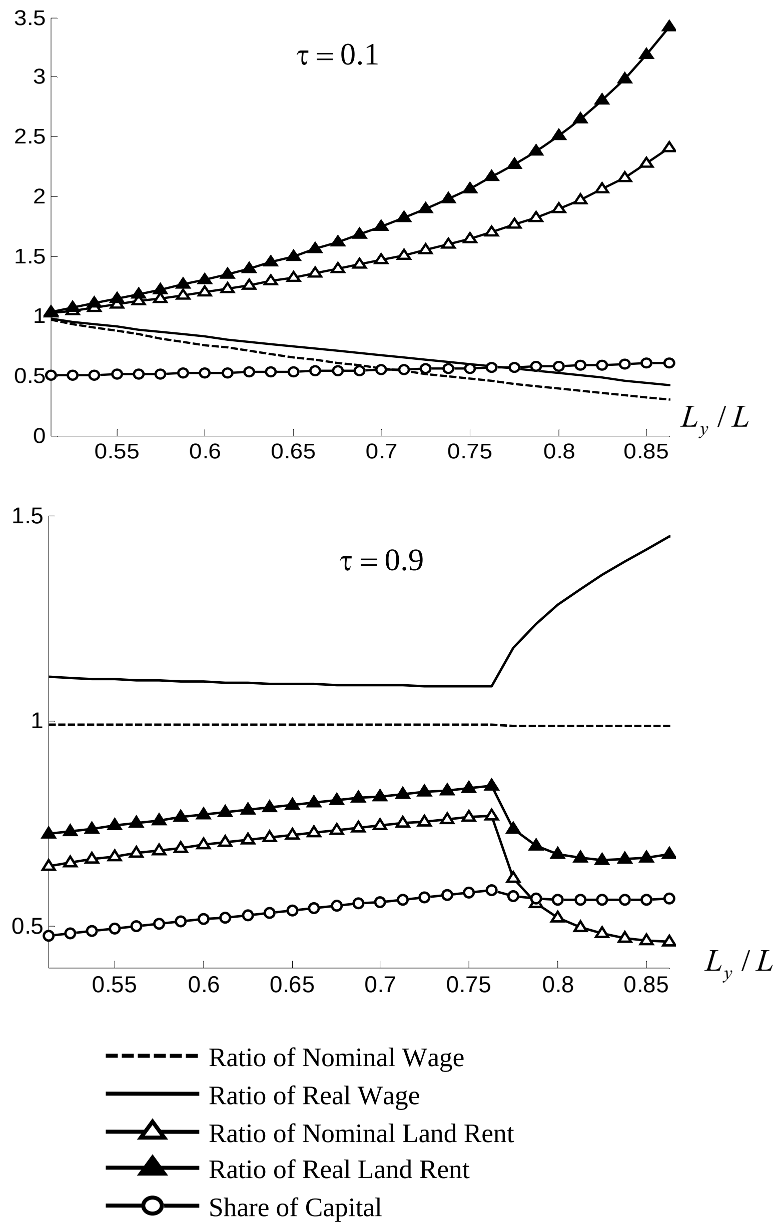

Figure 8. Factor Returns of Two Countries with Transportation Cost for All Sectors

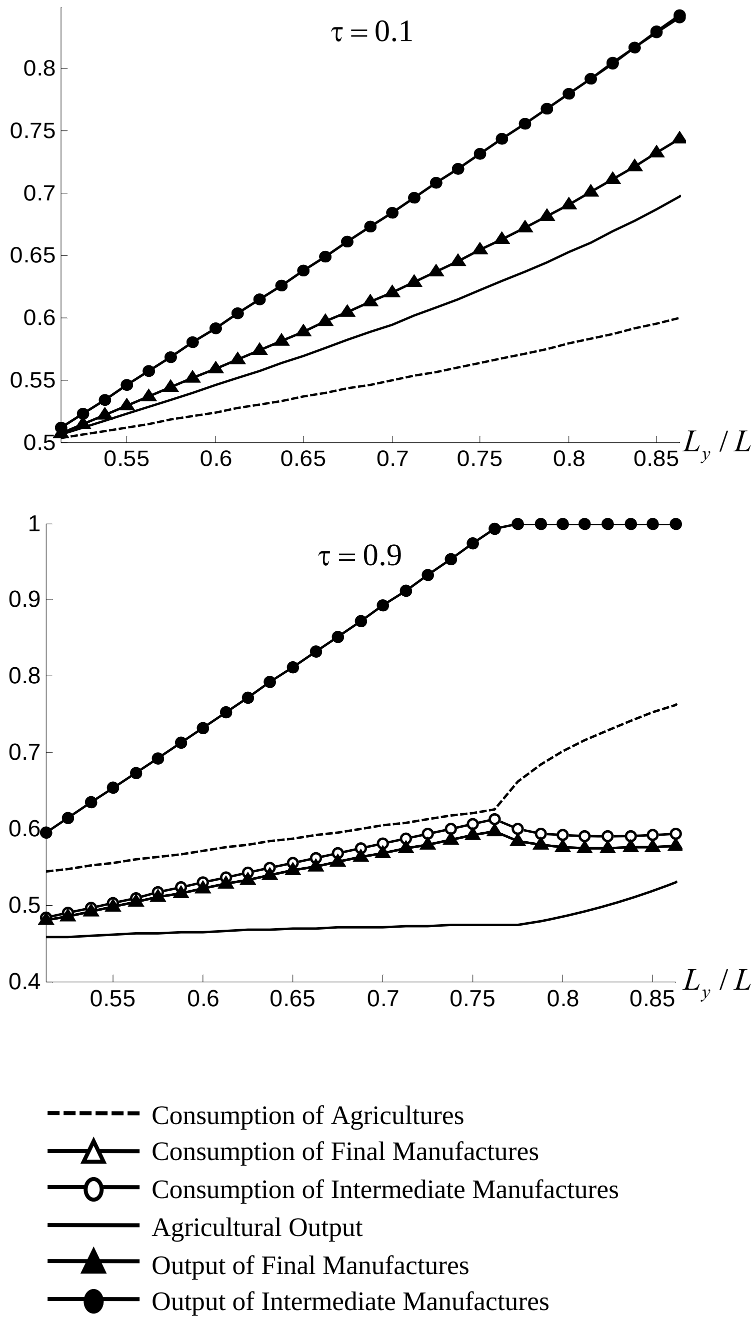

Figure 9. Trade Patterns of Two Countries with Transportation Cost for All Sectors