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Toshihiro Okubo
Graduate Institute of International Studies

Abstract

This paper analyzes the geographical concentration and diversification of industries in the Continuum-of-Goods Trade Model in the presence of labor migration, comparative advantage, and external increasing returns to scale. In the model, higher transportation costs lead to concentration in one region, and lower transportation costs lead to diversification between the regions. For intermediate transportation costs, asymmetric diversification becomes a stable equilibrium through a reduction in the range of nontraded goods due to external increasing returns to scale and transportation costs. However, asymmetric equilibrium is an inefficient outcome: Pareto dominated by the other equilibria. To prevent this inefficient equilibrium, subsidies may be useful to sustain symmetric diversification.

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Toshihiro Okubo[*†]

Graduate Institute of International Studies, Geneva

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This paper analyzes the geographical concentration and diversification of industries in the Continuum-of-Goods Trade Model in the presence of labor migration, comparative advantage, and external increasing returns to scale. In the model, higher transportation costs lead to concentration in one region, and lower transportation costs lead to diversification between the regions. For intermediate transportation costs, asymmetric diversification becomes a stable equilibrium through a reduction in the range of nontraded goods due to external increasing returns to scale and transportation costs. However, asymmetric equilibrium is an inefficient outcome: Pareto dominated by the other equilibria. To prevent this inefficient equilibrium, subsidies may be useful to sustain symmetric diversification.

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[†]E-mail: okubo3@hei.unige.ch

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1 Introduction

1.1 Previous Studies: A Benchmark

In recent years, geographical issues have been considered in international trade models. Krugman (1991a) (1991b) and Fujita, Krugman, and Venables (1999, Ch.5) provide us with the basic structure of the Monopolistic Competition framework: the Core-Periphery (C-P) model, where (internal) increasing returns to scale (IRS) drives concentration in one region and higher transportation costs lead to diversification between two regions.[1] In the model, manufacturing workers migrate gradually in response to real wages, while farmers are immobile. As a result, as transportation costs fall, manufacturing concentrates in one region, while agriculture remains in both regions. The authors term this "Core-periphery Structure" and warn that it may cause inequality of welfare between the regions. The C-P model is simple and intuitive, but its assumptions are crucial: farmers are bound to their land, while manufacturing workers move to the region that offers higher real wages, and transportation costs are only imposed on manufactured goods.[2] The model disregards technological differences between regions and

[1] These models have been extended by many other subsequent studies. Krugman and Venables (1995) proposed the Vertical Linkage Model, which showed that the presence of intermediate goods creates agglomeration even under a single immobile production factor. Martin and Rogers (1995) proposed the Footloose Capital Model. Puga and Venables (1996) and Puga (1999) have considered forward and backward linkages in a multi-industry framework.

[2] Fujita, Krugman and Venables (1999, Ch.7) were aware of the narrow assumptions, citing the plausible example that higher trade costs are often imposed on perishable agricultural goods rather than manufactured goods. They considered agricultural transportation costs and found that diversification occurs not only with higher transportation costs but also with lower costs.

external IRS or knowledge spillovers, which are the most important characteristics in agglomeration in the classical economic geography literature (Marshall, 1920; Hoover, 1948; Mills, 1967).

1.2 Relation to Current Literature

Many recent studies have attempted to overcome the limitations of the C-P model, and some are relevant to this paper. Forslid and Wooton (2003) introduced comparative advantage into the C-P Model in the framework of Dixit-Stiglitz type monopolistic competition. Each region has a comparative advantage for some industries, assuming different fixed costs across regions. The authors thus provided a counterexample to Krugman's model, in which higher transportation costs lead to agglomeration while lower costs lead to diversification. Ricci (1999) also considered comparative advantage in the framework of two IRS sectors together with one constant returns to scale (CRS) sector: each country has a comparative advantage in the production of one of the two IRS sectors in marginal cost. He found that lower trade costs may reduce agglomeration forces.

Aside from the C-P model, a few studies examine comparative advantage and geographical concentration using the Ricardian Model. Matsuyama and Takahashi (1998) found self-defeating and inefficient concentration, and Takahashi (2003) suggested that a reduction in trade costs increases the possibility of choosing an inefficient location of production.

However, we should note that these theoretical studies above on agglomeration and comparative advantage are very rare, in contrast to a great deal of empirical evidence showing the relevance of agglomeration and comparative advantage (Davis and Weinstein, 2003; Midelfart-Knarvik, et al., 2000; 2001; Midelfart-Knarvik and Overman, 2002).

The purpose of this paper is threefold. First, in order to address the issue raised above, we consider comparative advantage in a much simpler and more general manner than Forslid and Wooton (2003) and Ricci (1999), using the Continuum-of-Goods Trade Model by Dornbusch, Fischer, and Samuelson (1977) (the DFS model). Although we work with different mechanisms, our results are consistent with theirs. Like their models, our model assumes a technological difference between regions. This comparative advantage may stem from different stages of economic development. The advantage of the DFS model is that it depends less on the restrictive assumptions of the Krugman-type models by assuming that all people can migrate and that transportation costs are imposed on all tradable goods. Furthermore, this framework provides an easier way to deal with multiple industries and to discuss policy on the basis of welfare.

Second, external IRS is considered, because most models in economic geography are based on internal IRS subject to agglomeration forces while many empirical studies pay considerable attention to external IRS.[3] External IRS has

[3]For instance, Ellison and Glaeser (1999) estimated the effect of location of industries on population density and the percentage of the labor force with high skills. See also Henderson (1999).

long been recognized as a very important factor in geographical concentration. Marshall (1920) pointed out knowledge spillovers as one of the three outstanding features known as Marshallian Externality. Through this effect, the dissemination of innovative ideas tends to be limited to the region, as can be seen in many empirical examples where intra-regional knowledge spillovers are much greater than international ones (Branstetter, 2001; Eaton and Kortum, 1999). Further, Baldwin et al. (2001) suggested that local spillovers crucially contribute to geographical concentration and economic growth. Besides knowledge spillovers, another feature is associated with face-to-face communication. When all the workers are concentrated in one region, a great deal of communication and interaction arises in the region, which drives innovation and the development of efficient production technologies (local communication effect). Yet another aspect is identified in the endogenous growth literature: population growth in a specific region leads to innovation. Goodfriend and McDeremott (1999) showed that industrialization can be driven by increased population and market size. Kremar (1993) also demonstrated this phenomenon empirically over the long term.

The third purpose of this paper is to examine welfare analysis and regional policy implications. In the C-P model, it was difficult to measure regional welfare. Farmers and manufacturing workers face different real wages, even in the same region. However, some recent studies emphasize the importance of welfare analysis and rationality of government intervention (Baldwin et al. 2003; Ottaviano et al. 2002). Along with this current stream of research, it is possible to analyze regional policy more easily by assuming that all people can migrate in response to the same utility in each region. Furthermore, welfare analysis is indispensable to the model presented here: the C-P model cannot account for loss of resources because it assumes manufacturing workers are footloose and that farmers are bound to the land. Our model, however, allows for loss of welfare (a) because the economy can devastate the land and location-specific technology by all people migrating to the other region, (b) because of the presence of transport costs nontraded goods at different prices emerge across the regions, and (c) because migration shifts the range of traded goods and results in a changeable total payment of transport costs for imports even under fixed transport cost rates.

In this paper, "concentration" is defined as a situation where all people concentrate in one region and the other region is devastated. "(Symmetric) diversification" is a situation where a population is equally distributed between two regions, which is assumed to be the initial equilibrium. Finally, "asymmetric diversification" represents a population distributed unequally between two regions.

By considering these aspects, several interesting results arise. First, concentration occurs with higher transportation costs, while diversification results from lower transportation costs. This outcome is contrary to the C-P model. Then, at intermediate levels of transportation costs, multiple equilibria emerge, and the stable equilibrium is associated with asymmetric diversification. External IRS through migration leads to one-sided expansion of the varieties of exports in the more populated region due to transport costs. This increases the payment of transport costs, and thus results in the worst welfare of all the equilibria. In this case, policies to sustain the initial symmetric diversification equilibrium are necessary: to subsidize nontraded goods industries and comparatively less advantageous industries in each region.

The rest of the paper is organized as follows. The next section describes the basic model and examines the equilibria and their stability. In Section 3, welfare is examined in each equilibrium. The fourth section discusses policies based on the welfare analysis, and Section 5 presents the conclusions.

2 Basic Model

2.1 Supply, Demand, and Equilibrium

There are two regions. The total population in the world is normalized to unity: $L(Region\ 1) + L^{*}(Region\ 2) = 1$, and in the initial equilibrium the two regions have the same populations: $L = L^{*} = 0.5$. We assume that people can move from one region to the other and that they can only use the location-specific technology of the destination region. Each region has a location-specific unit labor requirement, denoted as $a(z, L)$ in Region 1 and $a^{*}(z, L^{*})$ in Region2, where $z \in [0, 1]$ indexes the variety and L reflects external economies. We rank goods such as $\frac{a^{*}(z^{'},L^{*})}{a(z^{'},L)} > \frac{a^{*}(z^{''},L^{*})}{a(z^{''},L)}$ for any $z^{''} > z^{'} \in [0, 1]$ under fixed L and L*. For simplicity, the regions' technologies are contrasting, i.e., they are symmetric around z=0.5 with $a(z, L)$ increasing in terms of z in the same way as $a^{*}(z, L^{*})$ is decreasing (taking $L = L^*$). Thus defining $A(z,L) = \frac{a^*(z,L^*)}{a(z,L)}$ as in the DFS model, we assume $A(z,L)$ to be continuous and differentiable in terms of z and L, so:

$$\frac{\partial A(z,L)}{\partial z} < 0 \tag{1}$$

As far as external IRS is concerned, we assume that the unit labor requirement decreases in proportion to the number of workers in the region:

$$\frac{\partial a(z,L)}{\partial L} < 0, \ \frac{\partial a^*(z,L^*)}{\partial L^*} < 0 \tag{2}$$

These imply that an industry is more efficient if there are more workers in the region. If the external economies are very large, concentration occurs at all transportation costs. To keep things interesting, a "no black hole" assumption is made as in Fujita, Krugman, and Venables (1999), which in this model is:

$$-1 < \frac{\partial a(z,L)}{\partial L} < 0, \quad -1 < \frac{\partial a^*(z,L^*)}{\partial L^*} < 0 \tag{3}$$

As in DFS, there is perfect competition, so price equals marginal cost:

$$P = a(z,L)w \tag{4}$$

Trade between regions is costly. Transportation costs are of the iceberg type (Samuelson, 1954), where a unit of the good transported from the other region melts away and g units of the good shipped actually arrives (0<g<1). These apply to all traded goods. As in DFS, transportation costs imply a range of goods is nontraded, with this range described by $\overline{z}$ and $\underline{z}$, the index of the upper and lower marginal goods respectively. Specifically, the marginal goods are defined as DFS by equalization of CIF prices:

$$\begin{aligned} P^*_{\underline{z}} &= a^*(\underline{z}, L^*)w^* = \frac{a(\underline{z}, L)w}{g} = \frac{P_{\underline{z}}}{g} \\ P_{\overline{z}} &= a(\overline{z}, L)w = \frac{a^*(\overline{z}, L^*)w^*}{g} = \frac{P^*_{\overline{z}}}{g} \end{aligned} \quad (5)$$

Using this, the wage ratios will be:

$$\frac{w}{w^*} = \frac{a^*(\underline{z}, L^*)}{a(\underline{z}, L)} g \quad (6)$$

$$\frac{w}{w^*} = \frac{a^*(\overline{z}, L^*)}{a(\overline{z}, L)g} \quad (7)$$

Equations (6) and (7) define the supply wage schedules in both regions (see Figure 1).[4]

On the demand side, the utility function is of the Cobb-Douglas type, so the expenditure share on each good, b(z), is constant and uniform over varieties, z, with $b(z)dz = b = 1$. Hence b(z) is equal to unity for $z \in$[0,1]. The balance of payments condition requires Region 1 and Region 2 spending on imports to be equal. This requires:

$$(1 - \overline{z})wL = \underline{z}w^*L^* \quad (8)$$

[4] As is shown in Figure 1, the shape of the supply wage schedule needs to be convex. This comes from the assumption of the mirror image technological structure on z=0.5 between the regions. Ikema (1978) and Trionfetti (2004) employed a linear schedule, but it is a globally asymmetric technological structure: each region has a non-zero and finite unit labor requirement at z=0, whereas one region must have a zero unit labor requirement at z=1, in spite of a constant finite value in the other, or the other region must have an infinite unit labor requirement at z=1, in spite of a constant finite value in its counterpart.

Solving this, the relative wage is (here the dependent of $\overline{z}$ and $\underline{z}$ on L is implicit in (5)):

$$\frac{w}{w^*} = \frac{\underline{z}}{1-\overline{z}} \frac{L^*}{L} \tag{9}$$

As usual in DFS, but in contrast to the Krugman model, the larger region has the relatively lower wage. This feature is the source of an important diversification force that is absent from new economic geography models.[5] Equation (9) defines the demand wage schedule (See Figure 1).

Equations (6), (7), and (9) are solved for $\overline{z}$ and $\underline{z}$ and $\frac{w}{w^*}$ to determine the equilibrium as illustrated in Figure 1. Note that by symmetric structure $\frac{w}{w^*} = 1$. Consequently, the range from $\underline{z}$ to $\overline{z}$ is nontraded goods, and 0 to $\underline{z}$ is Region 1's exports, and from $\overline{z}$ to 1 is Region 2's exports.[6]

2.2 The Stable Equilibrium

Next the local stability of the initial symmetric equilibrium is examined, following standard practice in the new economic geography model.[7] People can move freely

[5]In the monopolistic competition model, the more populated region has more than proportionally higher wages (the home market effect). See Krugman (1980) and Helpman and Krugman (1985).

[6]Note that the nontraded goods come from the equilibrium feature, not the assumption. On the other hand, Matsuyama and Takahashi (1998) assumed nontradable good industries a priori.

[7]Baldwin (2001) classified dynamic analysis as three ways of migration processes: 1) informal local stability analysis in myopia, 2) formal local stability analysis using the ordinary differential equation method, and 3) global stability analysis by Liaponov's direct method in forward-looking expectation. This paper employs the first method, as most economic geography models, because it is the most simple and consequently equivalent to the global stability analysis in the solution.This comes from Proposition 4 in Baldwin (2001): "The informal stability test of the

between regions, in search of the higher utility (as indicated by the real wage). Utility is equalized at the initial symmetric equilibrium, but stability depends on how marginal migration affects the relative indirect utility ratio between the two regions: namely $\frac{V}{V^*}$. If marginal migration from Region 1 to 2 goes above one, the marginal migrants would move back to Region 1. This indicates a stable initial equilibrium (symmetric diversification). If the migration pushes $\frac{V}{V^*}$ below one, more will move to Region 2. Thus symmetrical diversification is not stable. Hence, the local stability condition can be represented as:

$$\frac{d(\ln V - \ln V^*)}{dL^*}|_{sym} > 0 \tag{10}$$

To study this condition, we take logs of $\frac{V}{V^*}$ to get[8]:

$$\ln V - \ln V^*|_{sym} = \ln \frac{w}{w^*} - \int_{\underline{z}}^{\overline{z}} \ln \frac{P(z, 0.5)}{P^*(z, 0.5)} dz - (\underline{z} - 1 + \overline{z}) \ln g \tag{11}$$

The difference of the utility comes from three gaps: nominal wages, the prices of nontraded goods, and the payment of transport costs for imports. A positive value of (11) spurs the migration from Region 2 to 1, while a negative value creates migration from Region 1 to 2. Differentiating (11) by the marginal migration from Region 1 to 2 yields[9]

$$\frac{d(\ln V - \ln V^*)}{dL^*}|_{sym} = \frac{\partial \ln \frac{w}{w^*}}{\partial L^*} + \left(\frac{\partial \ln \frac{w}{w^*}}{\partial \overline{z}} \frac{\partial \overline{z}}{\partial L^*} + \frac{\partial \ln \frac{w}{w^*}}{\partial \underline{z}} \frac{\partial \underline{z}}{\partial L^*} \right) - \int_{\underline{z}}^{\overline{z}} \frac{\partial \ln \frac{P(z,0.5)}{P^*(z,0.5)}}{\partial L^*} dz \tag{12}$$

standard CP model with myopia is mathematically equivalent to formal, local stability analysis of CP model with forward-looking expectations. In particular, the break and sustain points in the model with forward-looking migrants are identical to those in the model with myopic migrants."

[8] See Appendix 1.

[9] See Appendix 2.

The first term, what can be called the "direct wage effect", is always positive: from (9), the increase in population in Region 2 and the decrease in Region 1 boosts the relative wage, under fixing the marginal goods – that is, the migration raises the relative wage in Region 1. The second term, "indirect wage effect", is always negative.[10] The shifts of marginal goods are affected by external IRS (downward rotation of the supply schedule) and migration (shift-up of the demand schedule) (see Figure 2). In the case of no external IRS (CRS), the indirect effect comes only from migration, and the direct wage effects always exceed the indirect effects, which removes the incentive to migrate.[11] On the other hand, if external IRS were assumed to be so large that the indirect wage effect could exceed the direct wage effect, the increase of L^* could reduce the relative wage $\frac{w}{w^*}$, and it would always drive migration. Obviously, the symmetric outcome would always be unstable for any transportation costs under large IRS. Therefore, the most interesting case to focus on in this paper is when external IRS is small, i.e., no black hole condition (3) holds. The increase of population in Region 2 decreases $\overline{z}$ and $\underline{z}$, which mitigates the increase of $\frac{w}{w^*}$ from (9).[12] Since the indirect wage effect cannot exceed the direct one, the magnitude of the third negative term determines whether it is stable or not. The third term, "local communication effect in nontraded goods," is negative from (2). The increase of

[10] See Appendix 4.

[11] Since the direct effect always exceeds the indirect one and the communication effect disappears under CRS, the total value of (11) becomes positive: symmetric equilibrium is stable at all times, independent of transportation costs. See Appendix 5.

[12] See Appendix 4 on the decrease of marginal goods.

the population in Region 2 leads to the decreases in unit labor requirements in nontraded sectors.

To build intuition, it is useful to consider the model without external IRS. In this case, the migration to Region 2 has only two effects. One is the negative effect on the relative wage in Region 2 through the change in population (direct wage effect). The other is the increase of production variety in Region 2, which has a positive effect on the wage in Region 2 (indirect wage effect). Reintroducing external IRS yields two further effects: one is the decrease of the unit labor requirement in nontraded goods sectors in Region 2, which offers relatively lower prices in nontraded goods exclusively in Region 2 (communication effect). The other strengthens the indirect wage effect: the increase in the variety of production goods, which diminishes the decrease in nominal wage in Region 2, although the indirect effect is weaker than the direct effect. These effects are expressed as the downward rotation of the supply wage schedules (from the solid line curves to the dashed line curves), as in Figure 2. In sum, the direct wage effect acts as a diversification force, while the indirect wage effect and the local communication effect in nontraded goods act as agglomeration forces.

2.3 Global Stability and Simulation Results

In this section, we solve for equilibrium and examine its global stability, supported by Baldwin (2001). We start with symmetric equilibrium, L=0.5, more individuals migrate from one region to the other, and check what the impact is on the difference of utility:

$$\ln V - \ln V^* = \ln \frac{w}{w^*} - \int_{\underline{z}}^{\overline{z}} \ln \frac{P(z,L)}{P^*(z,L^*)} dz - (\underline{z} - 1 + \overline{z}) \ln g \tag{13}$$

Figure 3 plots the resulting utility gaps for all possible distributions of L.[13] For low transportation costs (g=0.8), the diversified equilibrium is globally stable and the agglomerated equilibrium unstable since the $\ln \frac{V}{V^*}$ curve is positively sloped everywhere (Figure 3a). Conversely, for high transportation costs (g=0.4), concentration is globally stable and diversification is globally unstable (Figure 3c). These are parallel to the local stability discussion. However, for intermediate transportation costs (g=0.5) there are multiple stable equilibria: both the concentration and diversification equilibria are unstable, while the asymmetrically diversified equilibria are stable, since $\ln \frac{V}{V^*}$ is negatively sloped at L=0.5, L=0, and L=1 (Figure 3b). Figure 4 summarizes all the outcomes by showing the relationship between transportation costs and population ratio. The solid line represents the stable equilibrium, while the dotted line indicates the unstable equilibrium. The diversification is sustained at lower transportation costs, but when transportation costs exceed a critical value the symmetric equilibrium cannot be sustained – the asymmetric equilibrium appears. The increase of transportation costs makes the two regions much more asymmetric, which results in

[13] See Appendix 7 on the production functions for the simulation.

the concentration becoming stable for high transportation costs.[14]

For extremely low transportation costs, only a few nontraded goods and almost all tradable goods have emerged. Since the local communication effect in nontraded goods is almost negligible, the direct wage effect definitely overcomes the local communication effect and the indirect wage effect. The symmetric diversification can be sustained. However, with increased transportation costs, the communication effect in nontraded goods grows through the increase in the range of nontraded goods. The increase of the population in Region 2 leads to relatively lower prices in its supply. However, only Region 2 can enjoy the lower price of nontraded goods in favor of external IRS, which becomes an unstable symmetric diversification and leads to concentration due to high transportation costs.

For intermediate transportation costs, as migration proceeds, the size of the communication effect drastically diminishes. When the diversification force exceeds agglomeration forces, migration stops and asymmetric equilibrium emerges. The crucial factor slowing down migration is the reduction in the variety of nontraded goods due to external IRS and transportation costs in the process of migration.[15] Figure 5 represents the reduction in nontraded goods ($\overline{z}-\underline{z}$) in the numerical simulations of Figure 2 and can confirm the results: migration reduces the variety of nontraded goods, and the reduction is greater for higher transportation costs. Therefore, the reduction due to external IRS and transportation

[14] I tried to simulate the CRS case. Diversification has occurred at all levels of transportation costs.

[15] See Appendix 6.

costs definitely reduces the communication effect in nontraded goods acting as an agglomeration force, slowing down the migration process with asymmetric equilibrium emerging.

3 Welfare Analysis

3.1 Welfare in Each Equilibrium

Bhagwati (1958) proposed that immiserizing growth may occur when the factor endowment biasedly increases.[16] In this paper, immigration worsens the terms of trade, which is caused by the decrease of the relative nominal wage, as well as by the decrease in the unit labor requirement through external IRS. On the other hand, welfare is relatively enhanced by the decrease in the prices of nontraded goods' prices. This trade-off in welfare is examined by means of Pareto efficiency. If the stable equilibrium Pareto dominates over the unstable equilibria, it produces an efficient outcome. On the other hand, if the stable outcome is Pareto dominated by another unstable one, it is inefficient.

To start, we show Region 1 utility for symmetric and concentrated equilibria. Each region faces the same level of the utility in asymmetric or symmetric equilibrium. In a diversified equilibrium, the utility in Region 1 is given by:[17]

[16]In the 2x2 Ricardian Model with a Cobb-Douglas utility function, a population increase always decreases relative wages and terms of trade (Immiserizing Growth), and the decrease of the unit labor requirement owing to technological improvement also deteriorates terms of trade (Millian Paradox).

[17]See Appendix 3 for the induction.

$$\begin{aligned}\ln V^1_{div} &= (1-\overline{z})\ln\frac{w}{w^*} + (1-\overline{z})\ln g \\ &\quad - \left(\int_0^{\underline{z}} \ln a(z,L)dz + \int_{\underline{z}}^{\overline{z}} \ln a(z,L)dz + \int_{\overline{z}}^{1} \ln a^*(z,L^*)dz\right)\end{aligned} \tag{14}$$

The values of L, $\underline{z}$, and $\overline{z}$ in equilibrium are used.[18] The first term is related to the relative nominal wage, but this term becomes zero in the symmetrically diversified equilibrium under the assumption of symmetrical regions. The second term indicates the payment of transportation costs imposed on imports (from $\overline{z}$ to 1). The higher transportation costs strengthen the negative effect on the utility by the consumption of higher priced import goods. The third term reflects technology embodied in each good.

All the people concentrate in one region (for instance, Region 1), as in autarchy

$$\ln V^1_{con} = -\int_0^1 \ln a(z,1)dz \tag{15}$$

and can largely benefit from external IRS, although they cannot help devastating the location-specific technology of the other region.[19]

3.2 Welfare and Stable Equilibrium

Now we can discuss whether or not globally stable equilibria are efficient by comparing the indirect utility per capita in the stable outcome with unstable ones.

[18] For instance, L=0.5 is used in symmetric equilibrium.
[19] See Appendix 3 for the induction.

If the indirect utility in the stable equilibrium cannot exceed that of unstable ones, this stable equilibrium is dominated by the unstable one and so is inefficient, and vice versa. To facilitate the reasoning, Figure 6 plots how welfare in Region 1 varies with transportation costs, using (14) and (15). The values are the same as in Region 2: $V^1_{div} = V^2_{div}$ from free migration and $V^1_{con} = V^2_{con}$ from two symmetrical regions. Three ranges of transportation costs must be distinguished: range C (see Figure 6) where full concentration is stable and symmetry is unstable, range B where the asymmetric interior equilibrium is stable, and range A where only symmetry is stable. $V^1_{con}$is constant and unaffected by transport costs as there is no interregional trade. By contrast, V^1_{div} is higher as transport costs diminish because of less welfare loss from payments of transport costs for imports.

As seen in Figure 6, range A has higher welfare in the symmetrically diversified equilibrium, which is globally stable (see Figure 3a), compared with the concentrated equilibrium, which is unstable (see Figure 3a). Thus, for lower transportation costs, the symmetric equilibrium has the highest welfare and dominates the concentrated equilibrium, which is consistent with the stable equilibrium. In particular, the case of very low transportation costs brings about almost all traded goods. Thus, the communication effect in nontraded goods is almost nothing, and people can enjoy gains from specialized production and trade. Furthermore, welfare loss in diversification is small due to low transportation costs. These factors result in higher welfare in diversification. On the other hand, terms of trade would worsen welfare if concentration occurred: in the process of migration and full concentration, the population increase brings about the aggravation in terms of trade through immiserizing growth, and technological improvement through increased population simply deteriorates the terms of trade, which is similar to the 2x2 Ricardian Model with the Cobb-Douglas utility function.

Then, range C in Figure 6 shows that full concentration has higher welfare than diversification. As seen in Figure 3c, full concentration is stable whereas diversification is unstable. This implies that concentration is dominant in the presence of higher transportation costs, which corresponds to the stable equilibrium. The case of very high transportation costs brings about almost all nontraded goods. Thus, the local communication effect in nontraded goods is far superior to the wage effects. Terms of trade do not affect welfare greatly, and the local communication effect gives only the benefit of increasing outputs and reducing prices, which can lead to greater wealth through concentration.

However, surprisingly, the case of intermediate transportation costs is problematic: range B shows that diversification provides the best welfare and concentration gives the second best welfare, but Figure 3b demonstrates that both are unstable. The stable equilibrium is asymmetric diversification, and is dominated by the other equilibria, in spite of having the worst welfare. This is related to welfare loss from the payment of transportation costs. At full concentration, there is no welfare loss from transportation costs: they are not paid. In asymmetric diversification, as shown in Figure 5, the range of nontraded goods is much smaller than in symmetric equilibrium (L=0.5) for a given transport cost. Instead, the range of traded goods becomes larger, which leads to more payments for transport costs and to greater loss of welfare than in symmetric equilibrium. This interesting result shows the evidence that people myopically decide on migration without considering external IRS, which allows government intervention to achieve Pareto optimal equilibrium.

4 Policies against Asymmetric Equilibrium

Government intervention is rational to prevent the above inefficient outcome. Ottaviano et al. (2002) suggested the possibility of inefficient agglomeration. Trionfetti (2001) proposed government procurement to defuse inefficient agglomeration. In this paper, the best policy is to reduce transportation costs sufficiently, so as to reach stable symmetric equilibrium and enjoy the highest welfare. However, the implementation of this policy might be difficult for some reasons, such as topographical issues. Also we may face the imbalance of infrastructure allocation between interregional and intraregional transport systems (Martin and Rogers, 1995). Considering these aspects, the second best policy is available: the production subsidy policy can be used in the initial symmetric equilibrium in order to block the migration and sustain the symmetric diversification.

The main cause of the inefficiency is the reduction in nontraded goods, and thus an optimal policy is to exclude nontraded goods through the production subsidy policy. However, the policy is crucial in the way of allocating among industries between regions.[20] The subsidy is distributed to industries in reverse proportion to comparative advantage, as in Figure 7. The greater comparative advantage the industries have, the lower the subsidy granted. The two regions provide this subsidy symmetrically, so that the range of nontraded goods disappears and the only marginal good becomes $\overline{z}=\underline{z}=0.5$.[21] The shape of the supply schedule, considering the subsidy, changes completely: two horizontal lines and a vertical line at the single marginal good ($\overline{z}=\underline{z}=0.5$). This is parallel to the two-good two-country Ricardian Model. The vertical part of the supply schedule wipes out nontraded goods, which leads to no agglomeration forces (indirect wage effect and communication effect in nontraded goods), and strengthens the diversification force (direct wage effect). This allocation of subsidy always maintains a diversification outcome. Thus, the solution to prevent the above inefficient case is to subsidize the comparatively less advantageous industries so as to remove the nontraded goods industries.

This kind of subsidy is completely different from the one proposed in Itoh and Kiyono (1987).[22] The export subsidy in their study drives the country to gain the production of the marginal good industry and to increase the range of

[20] The subsidy is assumed to be the same allocation to firms in the same industry, whereas lump sum tax is levied equally on people in both regions by the central government.

[21] The two regions are assumed to be symmetrical, and subsidy rates are assumed to be symmetrical on the center of z=0.5. Thus the total subsidy in each region is equal, which allows equal tax rates. Further, the relative disposable income (utility ratio in the two regions) does not also change after carrying out this subsidy policy because of the same tax rates per capita.

[22] Itoh and Kiyono analyzed the role of export subsidy in the two-country DFS model, although not related to economic geography literature (no migration and transport costs).

the production, which results in enhancing welfare at the sacrifice or detriment of the welfare of the other region. However, the production subsidy in this paper eliminates the agglomeration force and strengthens the diversification force, and thus it plays a role in creating the stability of the higher-welfare diversification and preventing a move to worse-welfare equilibrium at intermediate transport costs.

5 Conclusions

This paper analyzes geographical concentration and diversification in the DFS framework. Higher transportation costs promote concentration, whereas lower transportation costs drive diversification. Concentration has the advantage of making the best use of external IRS, but results in devastating the other region including location-specific technology. On the other hand, symmetric diversification has the advantage of making the best use of both regions' location-specific technologies, but results in transportation costs being imposed on import goods and no external IRS. More interesting is the case of intermediate transportation costs: asymmetrical diversification is globally stable, while symmetric concentration and diversification are unstable. This is because external IRS and transportation costs reduce the variety of nontraded goods and reduce the agglomeration force as migration proceeds. However, this equilibrium causes the worst welfare due to increased transportation costs. For this reason, government intervention can be required. A production subsidy, weighted to the comparatively less advantageous sectors and nontraded goods sectors, can sustain symmetric diversification and prevent asymmetric diversification.

With regards to recent international circumstances, the acceleration to economic integration will result in a balanced development in each area, rather than a core-periphery structure, on the basis of the movement toward freer trade and the reduction of transportation costs and tariff rates. Krugman's epigram on the future core-periphery world might be unnecessarily pessimistic. The geographical concentration through free trade and labor migration in the future may bring relative prosperity without a disparity in wealth.

A possible extension of the model is when regions are not symmetric. When migration is possible, workers move from the poorer to the richer region, making it more likely that concentration occurs. Thus, it is important to verify by adopting the DFS model (with asymmetric regions) a core-periphery outcome appears.

Appendix 1 Induction of Equation

$$\begin{aligned}
\ln V - \ln V^* &= \ln \frac{w}{w^*} - \left(\int_0^{\underline{z}} \ln P(z,L)dz + \int_{\underline{z}}^{\overline{z}} \ln P(z,L)dz + \int_{\overline{z}}^{1} \ln \frac{P^*(z,L^*)}{g} dz \right) \\
&\quad + \left(\int_0^{\underline{z}} \ln \frac{P(z,L)}{g} dz + \int_{\underline{z}}^{\overline{z}} \ln P^*(z,L^*)dz + \int_{\overline{z}}^{1} \ln P^*(z,L^*)dz \right) \\
&= \ln \frac{w}{w^*} - \left(\int_0^{\underline{z}} \ln g dz + \int_{\underline{z}}^{\overline{z}} \ln \frac{P(z,L)}{P^*(z,L^*)} dz + \int_{\overline{z}}^{1} \ln \frac{1}{g} dz \right) \\
&= \ln \frac{w}{w^*} - \left((\underline{z} - 1 + \overline{z}) \ln g + \int_{\underline{z}}^{\overline{z}} \ln \frac{P(z,L)}{P^*(z,L^*)} dz \right)
\end{aligned}$$

$$= \ln \frac{w}{w^*} - \int_{\underline{z}}^{\overline{z}} \ln \frac{P(z,L)}{P^*(z,L^*)} dz - (\underline{z} - 1 + \overline{z}) \ln g$$

Appendix 2 Induction of Equation The differentiation of the difference of the utility function is induced, using Leibnitz's rule:

$$\begin{aligned}
\frac{d(\ln V - \ln V^*)}{dL^*} &= \left(\frac{\partial \ln \frac{w}{w^*}}{\partial L^*} + \frac{\partial \ln \frac{w}{w^*}}{\partial \overline{z}} \frac{\partial \overline{z}}{\partial L^*} + \frac{\partial \ln \frac{w}{w^*}}{\partial \underline{z}} \frac{\partial \underline{z}}{\partial L^*} \right) \\
&\quad - \left(\int_{\underline{z}}^{\overline{z}} \frac{\partial \ln \frac{P(z,L)}{P^*(z,L^*)}}{\partial L^*} dz + \ln \frac{P(\overline{z},L)}{P^*(\overline{z},L^*)} \frac{\partial \overline{z}}{\partial L^*} - \ln \frac{P(\underline{z},L)}{P^*(\underline{z},L^*)} \frac{\partial \underline{z}}{\partial L^*} \right) \\
&\quad - \left(\frac{\partial \underline{z}}{\partial L^*} + \frac{\partial \overline{z}}{\partial L^*} \right) \ln g \\
&= \frac{\partial \ln \frac{w}{w^*}}{\partial L^*} + \left(\frac{\partial \ln \frac{w}{w^*}}{\partial \overline{z}} \frac{\partial \overline{z}}{\partial L^*} + \frac{\partial \ln \frac{w}{w^*}}{\partial \underline{z}} \frac{\partial \underline{z}}{\partial L^*} \right) \\
&\quad - \int_{\underline{z}}^{\overline{z}} \frac{\partial \ln \frac{P(z,L)}{P^*(z,L^*)}}{\partial L^*} dz - \ln \frac{1}{g} \frac{\partial \overline{z}}{\partial L^*} + \ln g \frac{\partial \underline{z}}{\partial L^*} - \left(\frac{\partial \underline{z}}{\partial L^*} + \frac{\partial \overline{z}}{\partial L^*} \right) \ln g \\
&= \frac{\partial \ln \frac{w}{w^*}}{\partial L^*} + \left(\frac{\partial \ln \frac{w}{w^*}}{\partial \overline{z}} \frac{\partial \overline{z}}{\partial L^*} + \frac{\partial \ln \frac{w}{w^*}}{\partial \underline{z}} \frac{\partial \underline{z}}{\partial L^*} \right) - \int_{\underline{z}}^{\overline{z}} \frac{\partial \ln \frac{P(z,L)}{P^*(z,L^*)}}{\partial L^*} dz
\end{aligned}$$

Appendix 3 Welfare Analysis The utility per capita in a diversified equilibrium in Region 1 is induced in the following way:

$$\begin{aligned}
\ln V_{div}^1 &= \ln w - \int_0^{\overline{z}} \ln a(z,L) w dz - \int_{\overline{z}}^1 \ln \frac{a^*(z,L^*) w^*}{g} dz \\
&= (1-\overline{z}) \ln w - (1-\overline{z}) \ln w^* - \int_0^{\overline{z}} \ln a(z,L) dz - \int_{\overline{z}}^1 \ln \frac{a^*(z,L^*)}{g} dz \\
&= (1-\overline{z}) \ln \frac{w}{w^*} + (1-\overline{z}) \ln g - \int_0^{\overline{z}} \ln a(z,L) dz - \int_{\overline{z}}^1 \ln a^*(z,L^*) dz
\end{aligned}$$

The utility per capita in concentration in Region 1 is induced in the following way:

$$\ln V^1_{con} = \ln w - \int_0^1 \ln a(z,1) w dz = - \int_0^1 \ln a(z,1) dz$$

Appendix 4 The shift of the boundary of traded goods We show a negative relation between $l = \frac{L^*}{L}$ and $\overline{z}$ ($\underline{z}$) at the initial equilibrium. We totally differentiate (5):

$$g A_{\underline{z}}(\underline{z}, l) d\underline{z} - A_{\overline{z}}(\overline{z}, l) d\overline{z} + g^2 A_l(\underline{z}, l) dl - A_l(\overline{z}, l) dl = 0$$

where $A_{\underline{z}}(\underline{z}, l) \equiv \frac{\partial A(\underline{z},l)}{\partial \underline{z}}, A_{\overline{z}}(\overline{z}, l) \equiv \frac{\partial A(\overline{z},l)}{\partial \overline{z}}, A_l(\underline{z}, l) \equiv \frac{\partial A(\underline{z},l)}{\partial l}, A_l(\overline{z}, l) \equiv \frac{\partial A(\overline{z},l)}{\partial l}$. Combining the total differentiation of (9) with the above equation, we get:

$$d\underline{z} = \Omega dl$$

where

$$\Omega \equiv \frac{-\frac{\underline{z}}{1-\overline{z}} + g A_l(\underline{z}, l) + \frac{1}{A_{\overline{z}}(\overline{z},l)} \left(g^2 A_l(\underline{z}, l) - A_l(\overline{z}, l) \right) \left(\frac{\underline{z}}{(1-\overline{z})^2} \right)}{\frac{1}{1-\overline{z}} \left(l - \frac{\underline{z}}{1-\overline{z}} g^2 \frac{A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)} \right) - g A_{\underline{z}}(\underline{z}, l)}.$$

Because of $A_{\underline{z}}(\underline{z}, l) < 0$, $A_{\overline{z}}(\overline{z}, l) < 0$, $\frac{A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)} > 0$, $A_l(\underline{z}, l) < 0$, and $g A_l(\underline{z}, l) - \frac{A_l(\overline{z},l)}{g} > 0$, the nominator is always negative. The denominator is always positive, because $l > 1$, $\frac{\underline{z}}{1-\overline{z}} < 1$ and $0 < g^2 \frac{A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)} < 1$ hold in the marginal increase of l, and thus Ω is negative. From $\Omega < 0$, $\frac{d\underline{z}}{dl} < 0$ holds:

$$d\overline{z} = \left(\left(g^2 \frac{A_{\underline{z}}(\underline{z}, l)}{A_{\overline{z}}(\overline{z}, l)} \right) \Omega + \frac{g^2 A_l(\underline{z}, l) - A_l(\overline{z}, l)}{A_{\overline{z}}(\overline{z}, l)} \right) dl.$$

The first term is negative ($g^2 \frac{A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)} < 1$ and $\Omega < 0$). From $gA_l(\underline{z}, l) - \frac{A_l(\overline{z},l)}{g} < 0$, the second term is negative. Hence, $\frac{d\overline{z}}{dl} < 0$ holds. By these relations, plus $\frac{\partial \ln \frac{w}{w^*}}{\partial \overline{z}} > 0$ and $\frac{\partial \ln \frac{w}{w^*}}{\partial \underline{z}} > 0$ from (9), the indirect effect is always negative.

Appendix 5 Wage Effects under CRS The fact that the direct wage effect always exceeds the indirect effect under no external IRS in absolute value is proved. The migration to Region 2 is assumed. Totally differentiating (9) and divided by dl,

$$\frac{d\omega}{dl} = \frac{\underline{z}}{1-\overline{z}} + \frac{l}{1-\overline{z}} \frac{\partial \underline{z}}{\partial l} + \frac{\underline{z}}{(1-\overline{z})^2} \frac{\partial \overline{z}}{\partial l}.$$

where $\omega = \frac{w}{w^*}$. The second and third term denote the indirect wage effect. Then, totally differentiating (6), we get

$$gA_{\underline{z}}(\underline{z}, l) d\underline{z} = \frac{l}{1-\overline{z}} d\underline{z} + \frac{\underline{z}}{1-\overline{z}} dl + \frac{\underline{z}}{(1-\overline{z})^2} d\overline{z}.$$

Inserting the above equation into the second and third terms (indirect effect) in the equation of $\frac{d\omega}{dl}$:

$$-\left(\frac{\underline{z}}{1-\overline{z}}\right) \left(\frac{\frac{l}{1-\overline{z}} + \frac{\underline{z}}{(1-\overline{z})^2} \frac{g^2 A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)}}{\left(\frac{l}{1-\overline{z}} - gA_{\underline{z}}(\underline{z}, l) + \frac{\underline{z}}{(1-\overline{z})^2} \frac{g^2 A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)}\right)} \right) dl$$

$-gA_{\underline{z}}(\underline{z}, l)$ is positive, and thus $\left(\frac{\frac{l}{1-\overline{z}} + \frac{\underline{z}}{(1-\overline{z})^2} \frac{g^2 A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)}}{\left(\frac{l}{1-\overline{z}} - gA_{\underline{z}}(\underline{z},l) + \frac{\underline{z}}{(1-\overline{z})^2} \frac{g^2 A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)}\right)} \right)$ is always less than one. Hence, the direct effect $\frac{\underline{z}}{1-\overline{z}}$ is always larger than the indirect effect under CRS in absolute values.

Appendix 6 The reduction in nontraded goods The reduction results from $\frac{d\overline{z}}{dl} < \frac{d\underline{z}}{dl} < 0$ (that is, $\frac{d\underline{z}}{dl} - \frac{d\overline{z}}{dl} > 0$). We show (sufficient) condition for the reduction:

$$\frac{d\underline{z}}{dl} - \frac{d\overline{z}}{dl} = \Psi\Omega - \Phi$$

$$= -\Phi \left(\frac{1}{\Phi} \left(\frac{\underline{z}}{1-\overline{z}} \right) \left(1 - \frac{1}{1-\overline{z}} \right) \Psi - gA_l(\underline{z}, l) \left(\frac{1}{\Phi} + \Psi \right) + \frac{l}{1-\overline{z}} - \frac{\underline{z}}{(1-\overline{z})} g^2 \frac{A_{\underline{z}}(\underline{z}, l)}{A_{\overline{z}}(\overline{z}, l)} \right)$$

where $\Psi \equiv 1 - \frac{g^2 A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)}$, $\Phi \equiv \frac{g^2 A_l(\underline{z},l) - A_l(\overline{z},l)}{A_{\overline{z}}(\overline{z},l)}$. Then $\frac{1}{\Phi}\left(\frac{\underline{z}}{1-\overline{z}}\right)\left(1 - \frac{1}{1-\overline{z}}\right)\Psi > 0$ and $\frac{l}{1-\overline{z}} - \frac{\underline{z}}{(1-\overline{z})} g^2 \frac{A_{\underline{z}}(\underline{z},l)}{A_{\overline{z}}(\overline{z},l)} > 0$ hold. Thus sufficient condition is $-gA_l(\underline{z}, l)\left(\frac{1}{\Phi} + \Psi\right) > 0$. Simplifying the sufficient condition, we can get:

$$-\frac{A_{\overline{z}}(\overline{z}, l)}{g} + gA_{\underline{z}}(\underline{z}, l) \leq gA_l(\underline{z}, l) - \frac{A_l(\overline{z}, l)}{g}.$$

High transport costs more easily satisfy this condition. The increased transport costs decrease $\underline{z}$ and increase $\overline{z}$, other things being equal. Then, $A_{\overline{z}}(\overline{z}, l)$ increases and $A_{\underline{z}}(\underline{z}, l)$ decreases more in negative magnitude, while the external IRS is assumed to be kept small as in the no black hole condition: (3).

Appendix 7 Simulation The specific functions for simulation used in this paper, which satisfy all conditions, are:

$$a(z, L) = \frac{z}{\sqrt{L}}, \text{and} a^*(z, L^*) = \frac{1-z}{\sqrt{L^*}}$$

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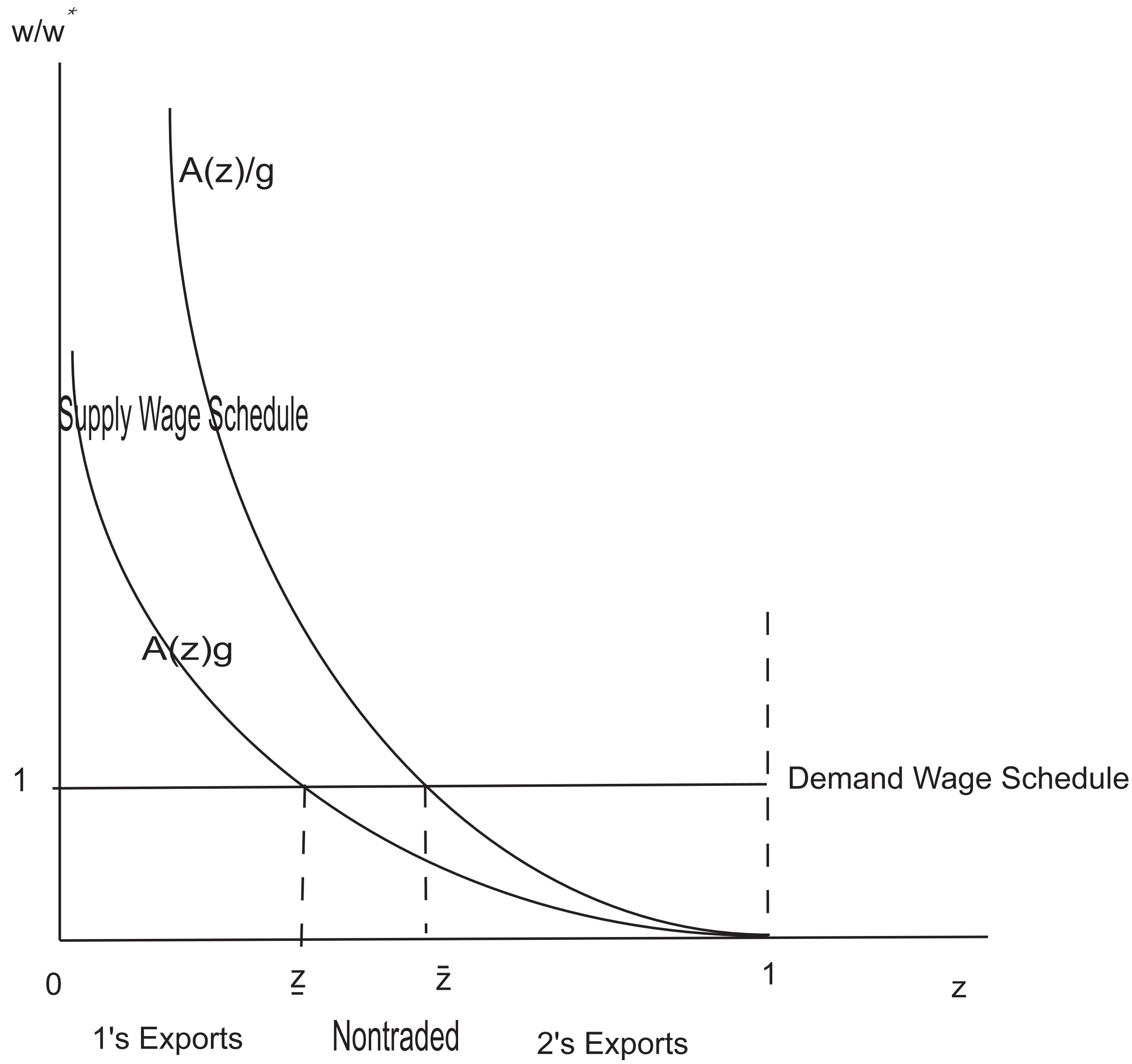


Figure 1 Demand Wage Schedule and Supply Wage Schedule

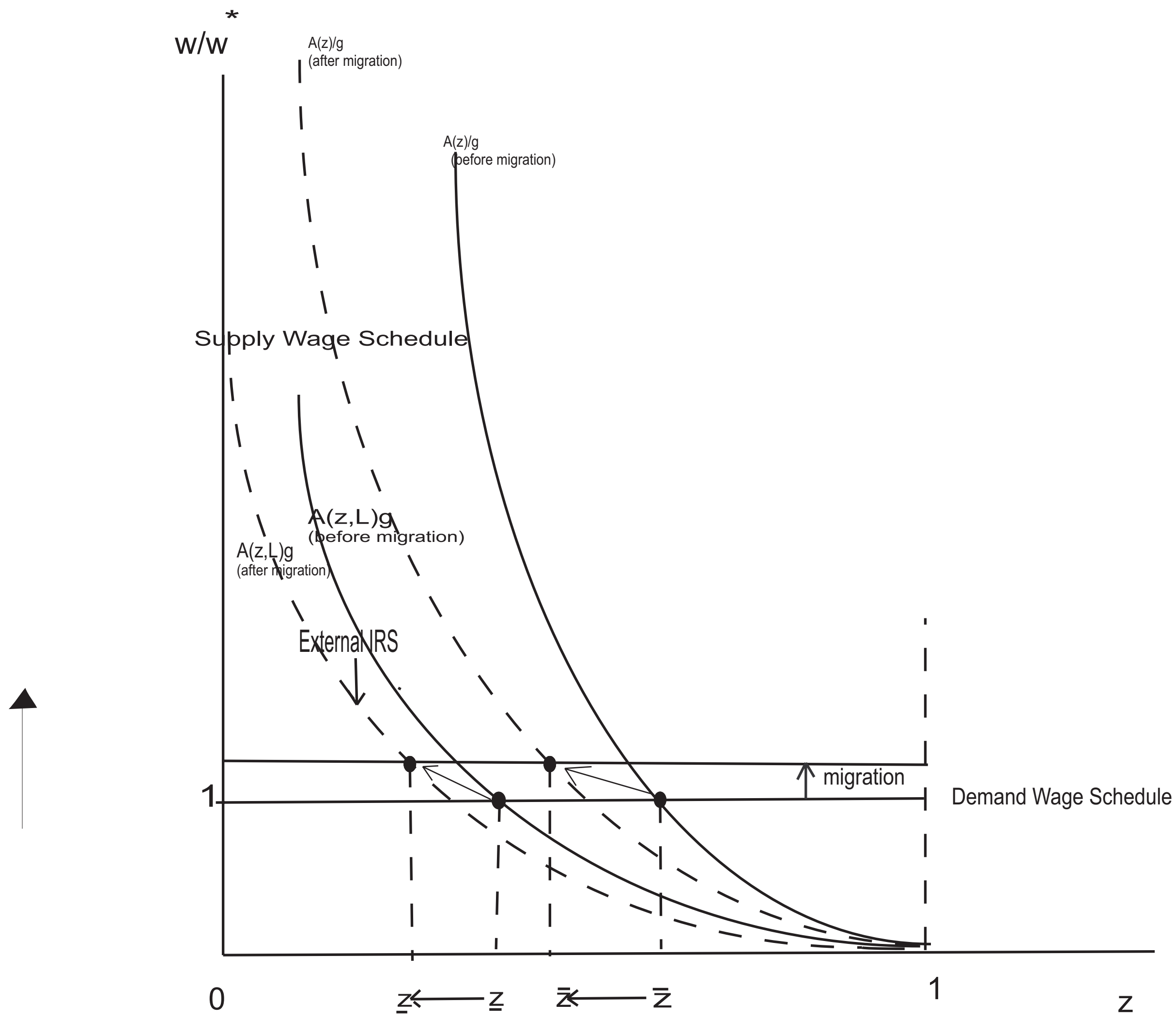


Figure 2 Migration and External IRS

-Demand wage Schedules (before and after migration)in Region 1 are omitted.

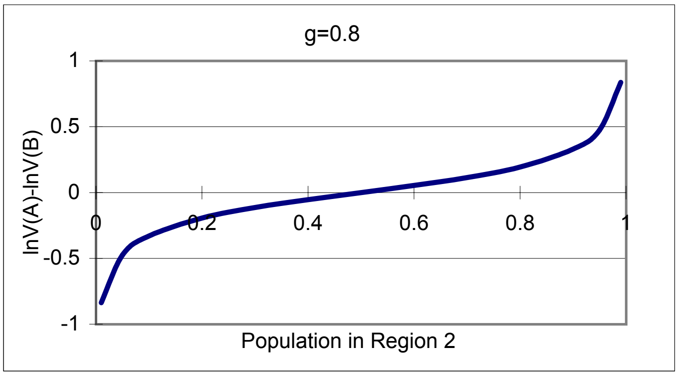


Figure 3a: Low Transportation Costs

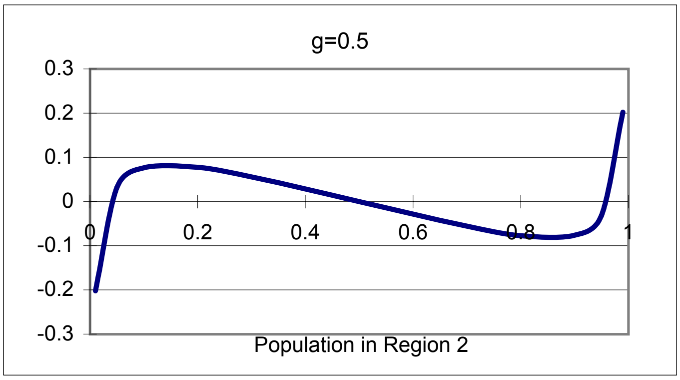


Figure 3b: Intermediate Transportation Costs

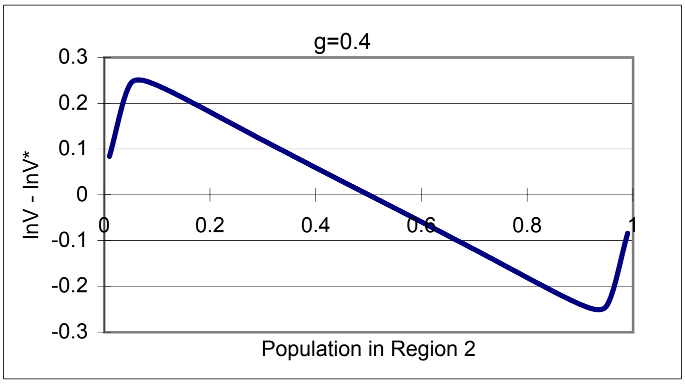


Figure 3c: High Transportation Costs

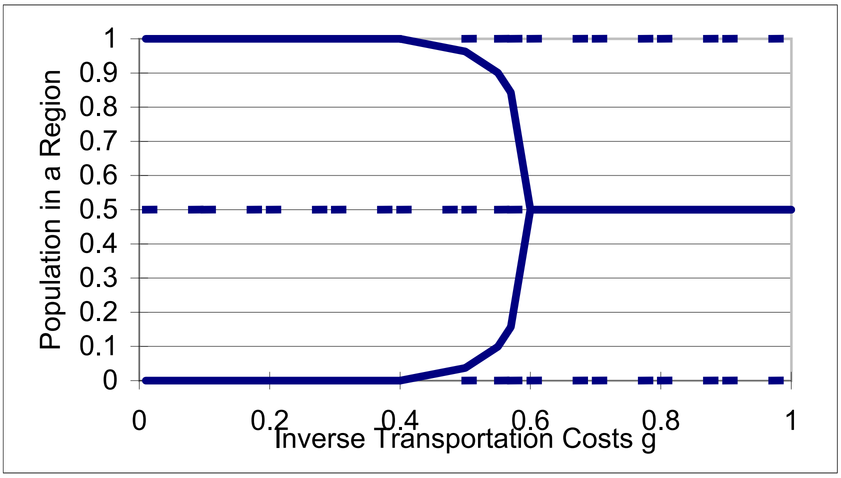
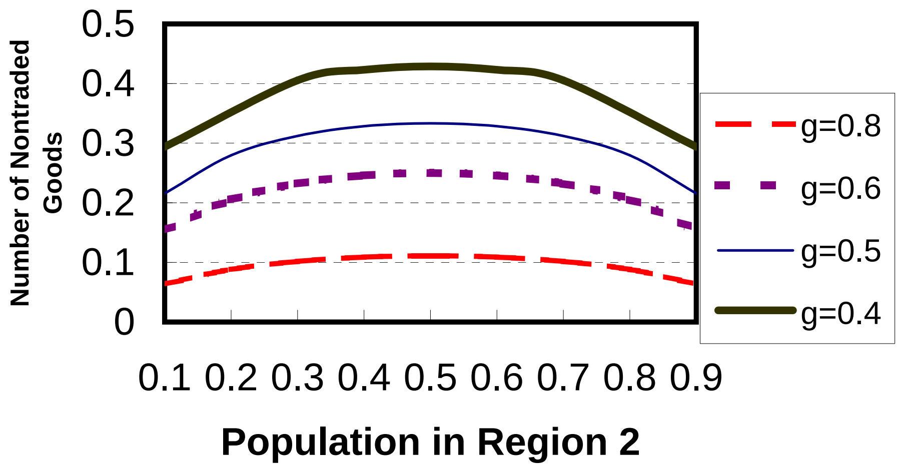


Figure 4: Transportation Costs and Equilibria

Figure 5: Reduction in Nontraded Goods



Note:"Number of Nontraded Goods" is the difference of two marginal goods.

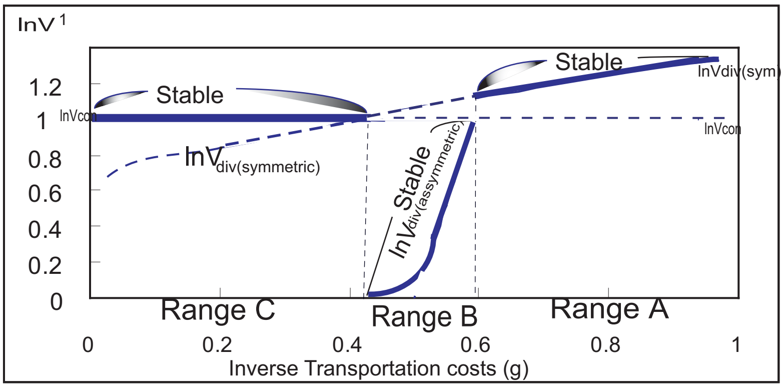


Figure 6 Welfare in Each Equilibrium

The dashed line represents the unstable equilibrium; the solid line represents the stable equilibrium.

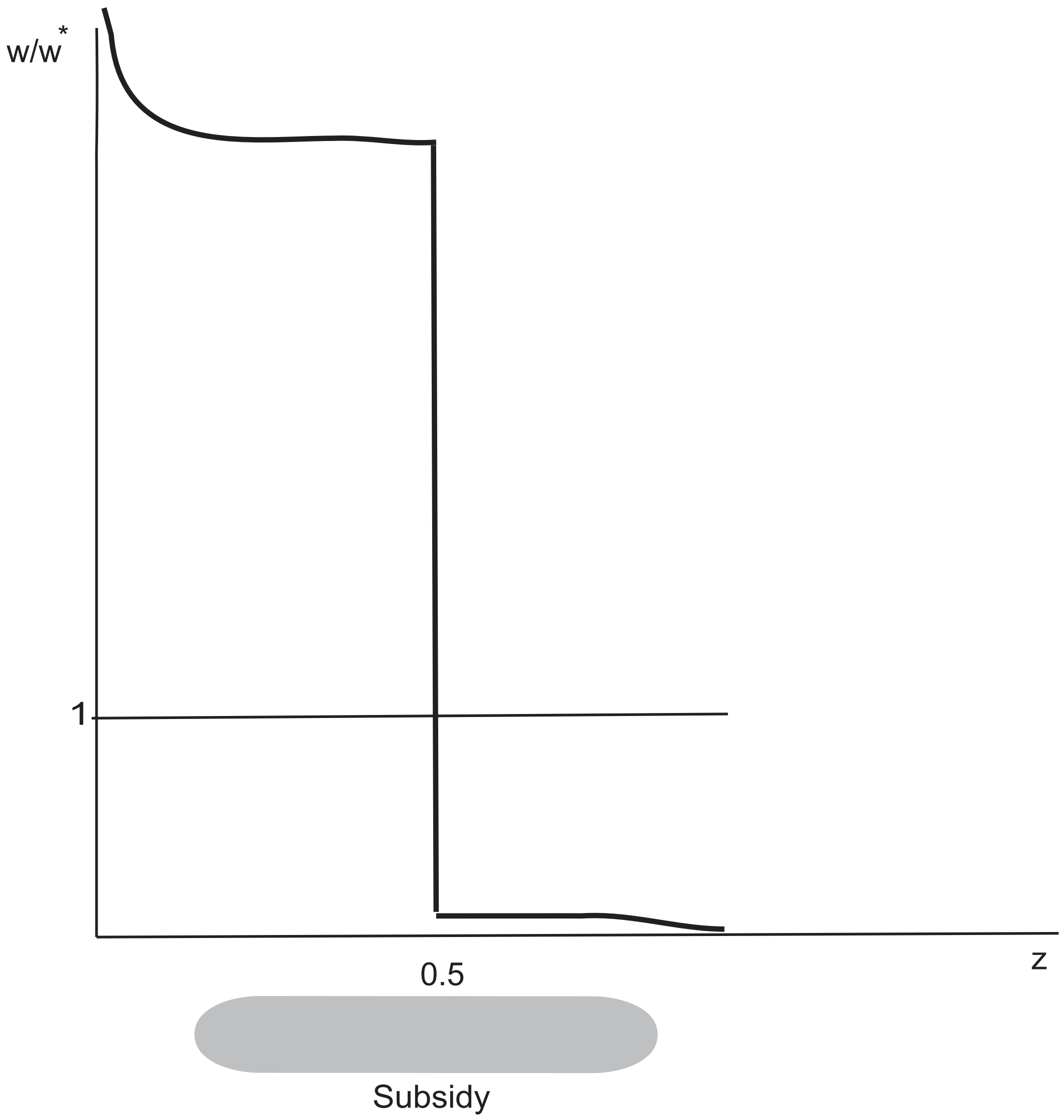


Figure 7: Optimal allocation