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Evaluation of Regional Economic Policy in the New Economic Geography

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Evaluation of Regional Economic Policy in the New Economic Geography

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Abstract

In this paper we analyze the impact of a simple regional economic policy in the context of the core periphery model. More specifically, we look at the welfare effects of a decrease in transport cost that is financed by a lump-sum tax on all inhabitants of the country. Our results are based on simulation. We compare the effects of traditional cost benefit analysis that measure consumer's surplus on the basis of the partial demand curve for transport with the full general equilibrium effects. Since the manufacturing sector is characterized by imperfect competition, there is potentially a substantial difference between the change in consumer's surplus and the true effects. We also consider the possibility that the investment causes a change in the long run development of the economy. In particular, we look at an investments that induces an economy that was converging to the dispersed equilibrium to move towards agglomeration. We compare the welfare effects of the redistribution of manufacturing workers and industries with those referring to a given distribution of economic activities.

1 Introduction

In recent years a 'new economic geography' has emerged from the application of the tools for analysis of monopolistic competition to issues that belonged traditionally to the realm of economic geographers. The monograph of Fujita, Krugman and Venables (1999) is generally regarded as the most important achievement in this new area of economic research (see e.g. the reviews of Neary (2001) and Anas (2001)). The models that are now available rely on imperfect competition and the pecuniary externalities involved in the movement of labour from one region to another. If employment grows in a particular region and workers are attracted to it, the result will be that the 'home market' grows and this may stimulate further growth. This implies that a mechanism of 'cumulative causation' is embodied in the model that may explain why some regions, for no obvious physical geographic reason, flourish, while others stay behind. Economic geographers have produced a long literature that studies the differences in development of apparently similar regions, but one of the main achievements of the new economic geography is that it provides for the first time a coherent model of this phenomenon that is consistent with economic theory.

This development has potentially important consequences for the analysis of regional economic policy. Such policy deals traditionally with the differences in economic performance between core regions and peripheral regions and the possibilities to influence regional economic development in such a way that it diminishes. Policy analysis was hampered by the fact that no coherent model of the formation of core and periphery regions existed. That situation has changed with the emergence of the new economic geography. It is therefore interesting to consider the question what this new literature has to say about such policy measures as improving the connection between core and periphery by means of investments in road infrastructure or subsidising industries in backward regions.

In order to answer the question involved, a welfare economic framework for such a policy analysis needs to be developed. The core periphery model is well suited for such an approach since all behavioural relations involved are based on the standard economic assumptions of utility and profit maximisation among consumers and producers, respectively. One would therefore expect that there would have been some interest in the topic in the existing literature. There is indeed the recent book by Baldwin et al. (2003), but is focused more on international trade than on regional policy. The issues to be discussed in this paper are somewhat related to the contents of chapter 17 of that monograph, although Baldwin et al. there use a 'local spillovers' model that differs from the core-periphery model used here. Moreover, there is the paper by Charlot et al. (2003), which compares the long term equilibria of dispersion and agglomeration. Our focus will be somewhat different: we will consider the cost benefit analysis of improvements in infrastructure in short-run equilibria.

One issue that we are particularly interested in is whether in the context of the core-periphery model the results of conventional cost-benefit analysis, using consumer's surplus, are valid. The industrial sector in the core-periphery model is characterised by imperfect competition this opens the possibility that there exist indirect effects. In a closed Arrow-Debreu economy the direct benefits of an investment (i.e. the benefits that accrue to the entrepreneur that carries out the investment) are equal to the benefits that are experienced by the consumers in the economy. The basic reason for this is that in this economy all prices are equal to variable costs. In the absence of scale effects, improvements in transport infrastructure can only imply decreases in variable costs that are equal to decreases in prices. For investments in road infrastructure this means that the direct benefits for the traffic that uses that infrastructure are equal to the total benefits. In an economy with imperfect competition this is different. With less than perfect competition the

effects of an investment that reach a consumer may be different from those the direct effects. This point has been made in the SACTRA (1999) report on the basis of work by Venables and Gasiorok (1998) and Newbery (1998) who give examples of such differences on the basis of simulation exercises. In these models the improvement in road infrastructure implies a decrease in the price of one or more inputs for firms in markets with monopolistic competition. The discrepancy between prices and marginal costs in such industries opens the possibility that the effect of the transport improvement on consumer welfare differs from the direct effect, that is the change in the surplus measured on the basis of the input demand function, see Rouwendal (2002). In the core periphery model that will be used in this paper transport is used for shipping completed products and labour is the only input. It is nevertheless possible that improvements in transport facilities have welfare effects that differ from those measured in conventional cost-benefit analyses because such improvements stimulate the demand for manufactures that are under-consumed because of the positive markups.

The core periphery model also allows us to compare the results of a partial analysis with those of a general equilibrium analysis. Even if the effects of a transport improvement that reach the consumer ‘in the first round’ are equal to those measured by the partial analysis, the reaction of the consumer to this effect may induce further changes in the economy that make the ultimate general equilibrium effect different from that suggested by the partial analysis. The core periphery model offers the possibility to compare the results of a partial and a general equilibrium analysis of the effects of transport improvements in a relatively simple setting. Lower transport costs will increase the demand for manufactures produced in the other region. Since labour supply is fixed in the short run, this higher demand can only be met at the prevailing prices when less is produced for the domestic market in the other region. Although demand in the other region will also shift as a result of the improvement in transport infrastructure, one must expect that price adjustments are in general necessary in order to bring the economy to a new equilibrium after the improvement in transport infrastructure has taken place. Price adjustments imply wage adjustments, so all endogenous variables should be expected to change. As a result, the general equilibrium effects of improvements in transport infrastructure may be much different from those suggested by a partial equilibrium analysis.

Such a comparison between partial and general equilibrium effects seems particularly interesting since in view of the cumulative causation and related non-linear effects that may occur in the core-periphery model. Such processes are a generic property of models with imperfect competition (see Matsuyama, 1993) and although the mechanism leading to such non-linear effects are analysed in detail, there has been less interest in the welfare consequences of these phenomena. We will consider one case in which a modest improvement in transport infrastructure changes the long-run development of the economy completely.

All the results presented below are based on the core-periphery model as presented in chapter 5 of Fujita, Krugman and Venables (1999). Since this model has no closed-form solutions, we use simulation for parameter values that seem reasonable.

2 A welfare economic framework for policy analysis in the core-periphery model

In this section we develop a welfare economic framework for regional policy analysis and discuss its implementation in the context of the core-periphery model.

Indirect utility in the core periphery model

We first consider individual behaviour. For simplicity of notation we suppress the subscript n . In this model it is assumed that all workers have a utility function of the form:

$$U = \left(\int_0^n q(i)^\rho di \right)^{\mu/\rho} z^{1-\mu} \quad (1)$$

where n is the number of manufactured products, $q(i)$ is the amount consumed of product i , z is the amount consumed of the product of agriculture and ρ and μ are parameters. The parameter ρ reflects the consumer's taste for variety and is related to the elasticity of substitution σ :

$\sigma = 1/(1 - \rho)$. The budget constraint is:

$$\int_0^n p(i)q(i)di + z = w - t \quad (2)$$

where $p(i)$ is the price of product i , w is the wage and t is the (lump-sum) tax to be paid by the worker. This tax is needed to finance transport policy. The price of agricultural products is used as a numéraire. Utility maximisation gives the following demand functions:

$$z = (1 - \mu)(w - t) \quad (3)$$

$$q(i) = \frac{p(i)^{-\sigma}}{G^{-(\sigma-1)}} \mu(w - t) \quad (4)$$

with:

$$G = \left[\int_0^n (p(i))^{1-\sigma} dj \right]^{1/(1-\sigma)}. \quad (5)$$

The prices include transport cost if the product originates from a different region.

Indirect utility is:

$$x = \mu^\mu (1 - \mu)^{1-\mu} \frac{w - t}{G^\mu} \quad (6)$$

It is apparent that indirect utility is equal to the real income of the workers, up to a constant. In what follows we will suppress the term $\mu^\mu (1 - \mu)^{1-\mu}$ and use the terms real income and indirect utility interchangeably.

The social welfare function

In order to evaluate regional economic policy we need a welfare function. The welfare function links welfare of a population to the utility experienced by the individuals in the population. That utility is given by the indirect utility function. In the core-periphery model indirect utility is equal to a measure of real income. More exactly: it is the ratio between the (nominal) wage and a price index. This means that, in the present context, we can interpret the social welfare function as a function W of real income x_n of all actors $n=1, \dots, N$:

$$W = W(x_1, \dots, x_N) \quad (7)$$

One possible specification of the social welfare function is the sum (or average) of all individual indirect utilities. This is the utilitarian social welfare function. Since indirect utility is equal to real income, this means that social welfare can be interpreted as aggregate real income. A drawback of the utilitarian specification is that it disregards equity issues: it is insensitive to the way total income is distributed over the population. Since equity issues usually play a role in regional economic policy, there is some reason to look for more general specifications. An attractive possibility is the use of a CES-function:

$$W = \begin{cases} \left(\sum_n \frac{x_n^{1-\varepsilon}}{1-\varepsilon} \right)^{1/(1-\varepsilon)} & \text{if } \varepsilon \neq 1, \\ \sum_n \ln(x_n) & \text{if } \varepsilon = 1. \end{cases} \quad (8)$$

with $\varepsilon \geq 0$. If ε is strictly positive, this function satisfies the principle of transfers, which requires that a transfer of money from a person to someone who is worse off should increase social welfare. ε is sometimes referred to as the coefficient of inequality aversion. For $\varepsilon=0$ we return to the utilitarian social welfare function, for $\varepsilon \rightarrow \infty$ it approaches the Rawlsian social welfare function that identifies social welfare with that of the worst-off actor.

This welfare function can be rewritten as:

$$W = \bar{x}(1 - A) \quad (9)$$

where A is Atkinson's inequality index:

$$A = \begin{cases} 1 - \left(\sum_n \frac{(x_n / \bar{x})^{1-\varepsilon}}{1-\varepsilon} \right)^{1/1-\varepsilon} & \text{if } \varepsilon \neq 1, \\ 1 - \sum_n \ln(x_n / \bar{x}) & \text{if } \varepsilon = 1. \end{cases} \quad (10)$$

One disadvantage of the welfare function for the purposes of regional policy analysis is that it is in general not decomposable. However, two special cases satisfy this property: $\varepsilon=0$, the utilitarian function and $\varepsilon=1$, the logarithmic social welfare function.

Other welfare measures

Two alternative welfare measures that are often used in cost benefit analysis are the compensating and equivalent variations. They are used to compare two situations, say 0 and 1, where 0 is the original situation and 1 the new situation. The compensating variation is the minus the amount of money that could be taken from the consumer in the new situation so as to leave him with the same utility as experienced in the original situation. Applying this definition to the indirect utility function used in the core-periphery model gives:

$$\frac{w(1) - t(1) - cv}{g(1)^\mu} = \frac{w(0) - t(0)}{g(0)^\mu} \quad (11)$$

where cv denotes the compensating variation. Elaboration gives:

$$cv = (w(1) - t(1)) - (w(0) - t(0)) \left(\frac{g(1)}{g(0)} \right)^\mu \quad (12)$$

The compensating variation is equal to the change in real income (indirect utility) multiplied by $g(1)^\mu$.

The equivalent variation is defined as the amount of money that should be given to the consumer in the original situation in order to make him as well off as he would be in the new situation.

Denoting this welfare measure as ev , we can write:

$$\frac{w(1) - t(1)}{g(1)^\mu} = \frac{w(0) - t(0) + ev}{g(0)^\mu} \quad (13)$$

and further elaboration gives:

$$ev = (w(1) - t(1)) \left(\frac{g(0)}{g(1)} \right)^\mu - (w(0) - t(0)) \quad (14)$$

From the formula's given above it is easy to conclude that:

$$ev = \left(\frac{g(0)}{g(1)} \right)^\mu cv \quad (15)$$

The compensating and equivalent variations are related to the increase in consumer's surplus that is a consequence of the investment. Consumer's surplus is often used in cost-benefit analysis of transport investments.

Four groups of workers

In the core periphery model four types of workers have to be distinguished: agricultural and manufacturing workers in regions 1 and 2. We will refer to the utility of an agricultural worker in region 1 as $x_{1,A}$ and to that of a manufacturing worker in region 1 as $x_{1,M}$. Similar definitions are used to refer to workers in region 2.

The agricultural sector is characterised by perfect competition and wages in this sector are therefore equal to the value of the product per worker. We can choose the unit so that this productivity equals 1, which implies that wages in this sector are also equal to 1.

In equilibrium all products originating from the same region have the same prices. We denote the price of a product manufactured in region 1 and sold in region 2 as $p_{1,2}$ and use similar expressions for the other possible combinations of origin and destination. Furthermore, we let n_1 and n_2 denote the number of manufacturing firms in regions 1 and 2, respectively. The value of the price index G in the two regions is then:

$$G_1 = (n_1 p_{1,1}^{1-\sigma} + n_2 p_{2,1}^{1-\sigma})^{1/(1-\sigma)} \quad (16a)$$

$$G_2 = (n_1 p_{1,2}^{1-\sigma} + n_2 p_{2,2}^{1-\sigma})^{1/(1-\sigma)}. \quad (16b)$$

It follows that the real incomes or indirect utilities of the four groups of workers are:

$$x_{1,A} = \frac{1-t}{G_1^\mu} \quad (17a)$$

$$x_{2,A} = \frac{1-t}{G_2^\mu} \quad (17b)$$

$$x_{1,M} = \frac{w_1 - t}{G_1^\mu} \quad (17c)$$

$$x_{2,M} = \frac{w_2 - t}{G_2^\mu} \quad (17d)$$

These indirect utilities can be used as inputs in the social welfare function. We let $b_{1,A}$ denote the number of agricultural workers in workers in region 1 and use similar notation for the other groups of workers. The social welfare function can then be written as:

$$W = \begin{cases} \left(b_{1,A} \frac{x_{1,A}^{1-\varepsilon}}{1-\varepsilon} + b_{1,M} \frac{x_{1,M}^{1-\varepsilon}}{1-\varepsilon} + b_{2,A} \frac{x_{2,A}^{1-\varepsilon}}{1-\varepsilon} + b_{2,M} \frac{x_{2,M}^{1-\varepsilon}}{1-\varepsilon} \right)^{1/(1-\varepsilon)} & \text{if } \varepsilon \neq 1, \\ \exp(b_{1,A} \ln(x_{1,A}) + b_{1,M} \ln(x_{1,M}) + b_{2,A} \ln(x_{2,A}) + b_{2,M} \ln(x_{2,M})) & \text{if } \varepsilon = 1. \end{cases} \quad (18)$$

One advantage of this welfare function is that it allows for a clear separation between issues of equity and efficiency. The latter appear in the value of average income, the former in the inequality index.

One requirement for a welfare function that is especially relevant in the context of regional policy evaluation is additive (regional) decomposability. If the welfare function satisfies this requirement, one is able to express the welfare of a country as a sum or weighted average of the welfare of its regions. Welfare function (.) does not in general satisfy this requirement, but it does in two special cases: $\varepsilon = 0$ and $\varepsilon = 1$.

Determination of wages and prices in the core periphery model

Until now we have mainly discussed consumer behavior. We will now consider producer behavior. We start by doing this in general terms and suppress the subscripts. There is only one production factor, labor supplied by workers in the manufacturing sector. The demand for labor of a firm producing q units of product is:

$$l = F + c q$$

where l is the amount of labor needed, F are the fixed cost of production and c the variable cost, both expressed in units of labor. The firm can sell its product on two markets: in region 1 and in region 2. Because of the iceberg transport costs, the firm has to produce $T > 1$ units in order to be able to sell one unit in the other region. A profit-maximizing firm will set its price as:

$$p = \frac{c w}{\rho} \quad (19)$$

if the product is sold in the region in which it is produced and to

$$p = T \frac{c w}{\rho} \quad (20)$$

if it is sold in the other region. These formulas show that transport costs are completely passed on to customers. This practice is known as mill pricing. Transport policy will typically change the value of T .

Under free entry profits will be equal to zero, which implies that:

$$q = \frac{F(\sigma - 1)}{c} \quad (21)$$

This equation shows that in equilibrium all firms have equal size, and that the number of firms in each regio is proportional to the number of manufacturing workers. We now reintroduce the subscripts and find that these number are equal to:

$$n_1 = \frac{b_{1,M}}{\sigma F} \quad (22a)$$

$$n_2 = \frac{b_{2,M}}{\sigma F} \quad (22b)$$

and consider the relation between producer behavior and the other part of the economy. It follows from the discussion above that we have:

$$p_{1,1} = \frac{c w_1}{\rho}, p_{1,2} = T \frac{c w_1}{\rho}, p_{2,1} = T \frac{c w_2}{\rho}, p_{2,2} = \frac{c w_2}{\rho} \quad (23)$$

Total production q_1 of a firm located in region 1 is:

$$q_1 = \frac{p_{1,1}^{-\sigma}}{G_1^{-(\sigma-1)}} \mu E_1 + T \frac{p_{1,2}^{-\sigma}}{G_2^{-(\sigma-1)}} \mu E_2 \quad (24)$$

and the production of a firm located in region 2 is determined by a similar expression. Using eqs. (21) and (23) we can derive the following wage equation from this expression:

$$w_1 = \left(\frac{\mu c^{1-\sigma} \rho^\sigma}{F(\sigma-1)} \right)^{1/\sigma} \left(G_1^{\sigma-1} E_1 + (G_2 / T)^{\sigma-1} E_2 \right)^{1/\sigma} \quad (25a)$$

$$w_2 = \left(\frac{\mu c^{1-\sigma} \rho^\sigma}{F(\sigma-1)} \right)^{1/\sigma} \left((G_1 / T)^{\sigma-1} E_1 + G_2^{\sigma-1} E_2 \right)^{1/\sigma} \quad (25b)$$

In these equations E denotes total expenditure, which is given as:

$$E_1 = b_{1,A} (1-t) + b_{1,M} (w_1 - t) \quad (26a)$$

$$E_2 = b_{2,A} (1-t) + b_{2,M} (w_2 - t) \quad (26b)$$

In the long run the distribution of the workers in the manufacturing sector over the two regions may change. This distribution is described by the parameter λ :

$$\lambda = \frac{b_{1,M}}{b_{1,M} + b_{2,M}} \quad (27)$$

The distribution of agricultural workers over the two regions is fixed and is it typically assumed that this population is evenly distributed:

$$b_{1,A} = .5(b_{1,A} + b_{2,A}). \quad (28)$$

We are now ready to study the effects of simple regional policy in a short run equilibrium setting. We assume that the policy implies a reduction in transport costs, which can be realized at a cost. The cost is paid by means of the lump sum tax, the benefits are the lower prices for goods that are shipped to other regions.

3 The benefits of transport improvements

In this section we will be concerned with measuring the benefits of a decrease in the parameter T in the context of the core periphery model. All our results are based on simulation.

Parameter values

In the exercises that we report below, we have used $\sigma=7$ and $\mu=.2$ and all the normalizations introduced by Fujita, Krugman and Venables. Break and sustain points as reported in FKV, Table 5.1, p75 were easily verified. In the base case for our simulations we have set T equal to 1.160 (that is: at a value between the break and sustain points, so that three stable equilibria exist). The value chosen for the share of manufacturing seems empirically reasonable. The value of the elasticity of substitution is on the high side when it refers to all tradeable goods in the economy, but reasonable when it refers to a specific sector (see Head and Mayer (2003) for a review of relevant empirical studies). The chosen values are particularly attractive for the purpose of the present study, since they imply that for transition from dispersion to agglomeration occurs for relatively small values of the transport costs (between 15 and 17% of the price of the product) and that the break and sustain points are close to each other. We therefore have a case in which small changes in transport costs, possibly as a result of policy measures, may have a large influence on the spatial equilibrium configuration of economic activity.

The wage in the agricultural sector is always equal to 1. The wages in the manufacturing sector are dependent on the size of the population of manufacturing workers relative to that of agricultural workers. This can be seen from the equilibrium condition for the agricultural industry:

$$b_{1,A} + b_{2,A} = (1 - \mu + \mu t)(w_1 b_{1,M} + w_2 b_{2,M} + b_{1,A} + b_{2,A}) \quad (29)$$

Walras' law says that one equilibrium condition is automatically fulfilled and in the core periphery model the equilibrium condition for the market for agricultural goods is for this reason usually not discussed explicitly. The condition shows that in a dispersed equilibrium with $t=0$, the wage in the manufacturing sector is equal to that in the agricultural sector if:

$$b_{1,M} + b_{2,M} = \frac{\mu}{1 - \mu}(b_{1,A} + b_{2,A}) \quad (30)$$

At the chosen value of μ this implies that the number of manufacturing workers should be one quarter of that in the agricultural sector. Equality of wages in both sectors appears to be an attractive property of the base case. We have chosen the number of agricultural workers to be 1 and that of the manufacturing workers to be 0.25.

Base case

Short run equilibria in the base case can be described by a number of figures. The first is the 'wobble diagram,' which shows the familiar shape for transport cost lying between the break point and the sustain point. This diagram refers to differences between the real wages of manufacturing workers in both regions.

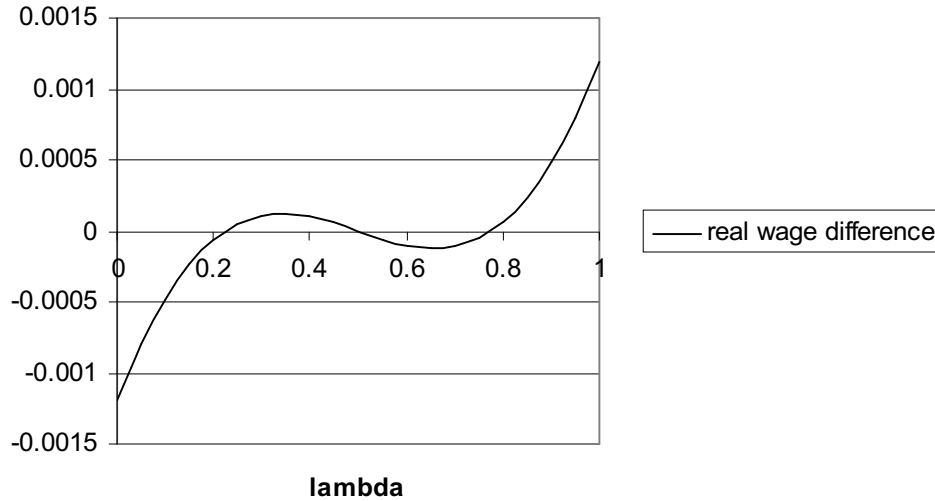


Figure 1 The wobble diagram for the base case

Figure 2 shows the real wages of the four groups of workers as a function of the share of manufacturing workers in region 1. It appears from this figure that workers in the manufacturing sector reach the highest level of welfare in agglomeration and the lowest level of welfare in dispersion. Workers in the agricultural sector are best off when all economic activity is concentrated in their own region and worst off when all is concentrated in the other region. The changes in the real incomes of agricultural sector workers induced by changes in the spatial

distribution of manufacturing activities are much large than those for the manufacturing workers. Note also that the differences between the real wages of manufacturing workers in both regions are small, except for case in which the economy is near one of the two long run equilibria with concentration.

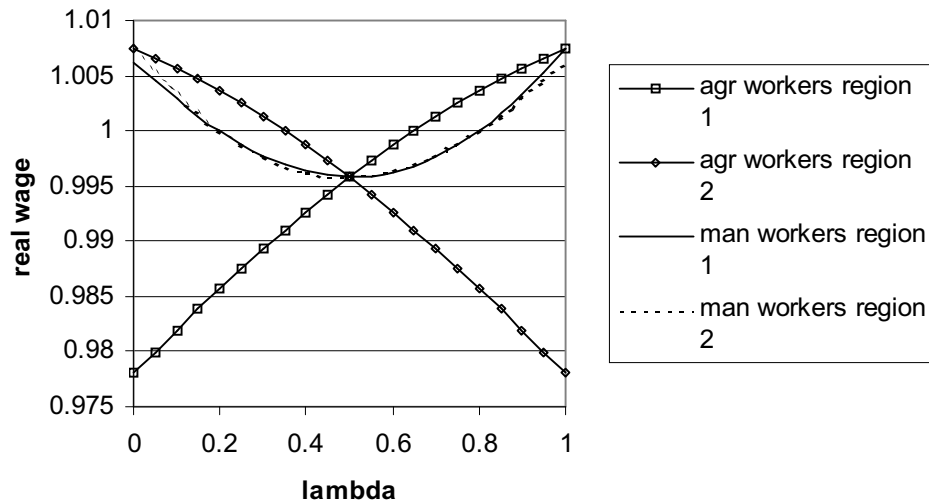


Figure 2 Real wages in the base case

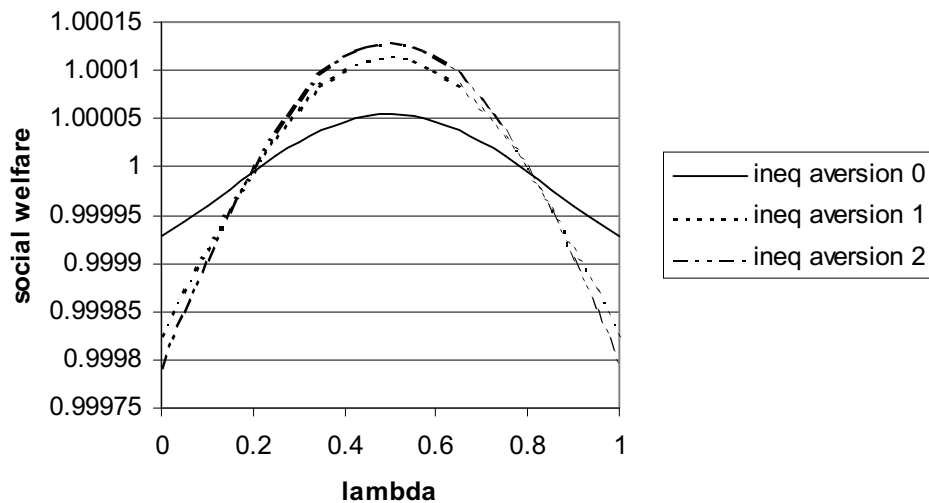


Figure 3 Social welfare in the base case (the curves are scaled by the average value of the welfare function over all distributions of the manufacturing population)

In the base case considered here there are three stable equilibria. From the wiggle diagram it is apparent that the model moves towards the dispersed equilibrium whenever λ is between (approximately) 0.25 and 0.75. Figure 2 suggests that this movement towards the dispersed equilibrium makes three of the four groups considered here worse off. Closer inspection reveals that this is not completely true. The real wages of the workers in the manufacturing sector reach a

minimum to the right (region 1) and to the left (region 2) of the dispersed equilibrium, but (for the chosen parameter values) very close to this equilibrium. This means that during the movement towards the dispersed equilibrium workers in the manufacturing sector in both regions will become worse off, even though the migration that drives this movement is induced by their desire to increase the real wage.

We have computed social welfare when the inequality aversion parameter is equal to 0, 1 and 2. Social welfare is almost insensitive to the distribution of the manufacturing workers over the two regions. This is easiest to explain for the utilitarian social welfare function. For the agricultural workers real income is a close to linear function of λ and since the two functions are symmetric, their sum is close to being constant. In fact, average welfare among the agricultural workers is a bit higher when the economy is close to the dispersed equilibrium. The manufacturing workers, have a higher welfare when the economy is agglomerated. This effect is too small to compensate for the lower welfare of the agricultural workers under these circumstances, and the net effect is a slightly higher social welfare under dispersion. With positive inequality aversion, the beneficial effects of dispersion become larger.

Partial equilibrium analysis of a change in transport cost

We will now see how the benefits of a decrease in the transport cost would be evaluated in a cost benefit analysis in a partial equilibrium framework. This means that the benefits are computed as if the price of transport is the only price that changes. All other prices (and wages) are assumed to be constant. The benefits of a change in transport costs are measured as the change in consumer's surplus as measured on the basis of this partial demand curve. Since the utility function used here is homothetic, the change in consumer's surplus is equivalent to the compensating or equivalent variation of the change in transport cost.

It must of course be recognized that the partial approach to cost benefit analysis is usually justified on the basis of the assumption that the effect whose benefit is measured is small in comparison with the economy as a whole. This is the reason why changes in other prices can be ignored. It is often doubtful whether this assumption is satisfied in practice when, for instance, the construction of a new road improves the connection between two regions substantially. It is therefore of some interest to see how large the difference between the partial and the full equilibrium approach is.

In the context of the core periphery model the partial demand for transport can be determined on the basis of the consumer demand functions for manufactured products. The number of units of manufactured commodities produced in region 1 and consumed in region 2 will be denoted as $Q_{1,2}$. It can be determined easily on the basis of the consumer demand functions as:

$$Q_{1,2} = \frac{n_1 (Tp_1)^{-\sigma}}{G_2^{-(\sigma-1)}} \mu E_2 \quad (31a)$$

and is equal to the demand for transport from 1 to 2.

We can derive a similar equation for the demand for transport from 2 to 1:

$$Q_{2,1} = \frac{n_2 (Tp_2)^{-\sigma}}{G_1^{-(\sigma-1)}} \mu E_1 \quad (31b)$$

Total demand for transport is equal to the sum of the demands in regions 1 and 2. It should, of course, be noted that the price indices G are also dependent on transport costs.

The price of transport is $(T-1)p_r$ where r denotes the region where the commodity is produced. The change in transport cost we consider is a decrease in T of 0.01. Since the mill prices of manufactured differ between the two regions, so will the change in transport cost. Expenditure in region 1 is an increasing function of the share of manufacturing workers living in that region. It is perhaps somewhat surprising to find that the export flow from region 1 to region 2 is also increasing in that share. The reason is that the demand from the agricultural population dominates export flows. The agricultural population in the peripheral region demands more manufacturing products from the other region when the share of manufacturing in its own region is lower.

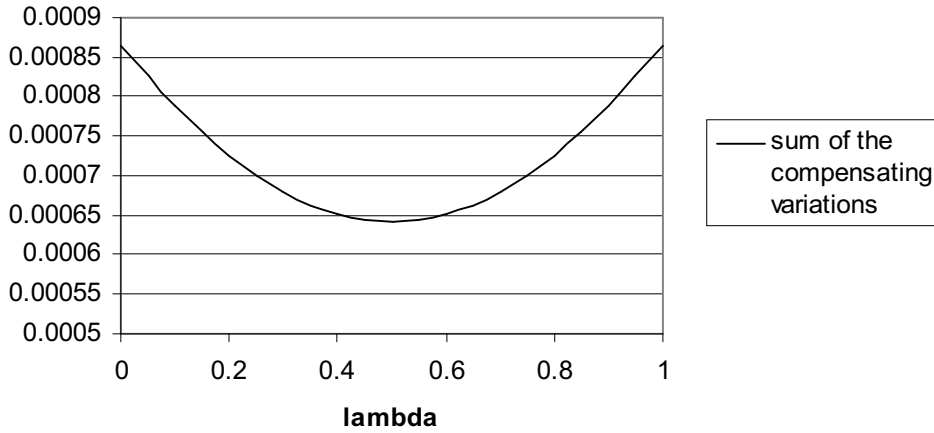


Figure 4 Sum of the compensating variations of a change in transport cost

We have approximated the increase in consumer's surplus by means of the 'rule of half':

$$\Delta CS^h = .5 \Delta T (p_1 (Q_{1,2}(0) + Q_{1,2}(1)) + p_2 (Q_{2,1}(0) + Q_{2,1}(1))) \quad (32)$$

We also used a more accurate approximation on the basis of the formula:

$$\Delta CS^e = \int_{p_1(T+\Delta T)}^{p_1 T} Q_{1,2}(z) dz + \int_{p_2(T+\Delta T)}^{p_2 T} Q_{2,1}(z) dz \quad (33)$$

Finally, we computed the compensating and equivalent variations on the basis of the formulas given above. In Figure 4 we only present the results for the compensating variation (the others are almost identical). They indicate (perhaps unsurprisingly) that improvements in transport infrastructure are most valuable when transport flows are large. With the current parameter values this means: when the economy is at or close to a core-periphery structure.

General equilibrium analysis

Now we consider the effects of an improvement in transport infrastructure when we allow the economy to adjust completely. We compute three welfare measures.

The first is a kind of consumer surplus measured along a demand curve for transport that incorporates the general equilibrium effects of the improvement in transport. The only thing that changes in the economy is the price of transport T and all changes in the other prices can

therefore be considered as a function of the change in transport cost. We used the rule of half to compute this measure.

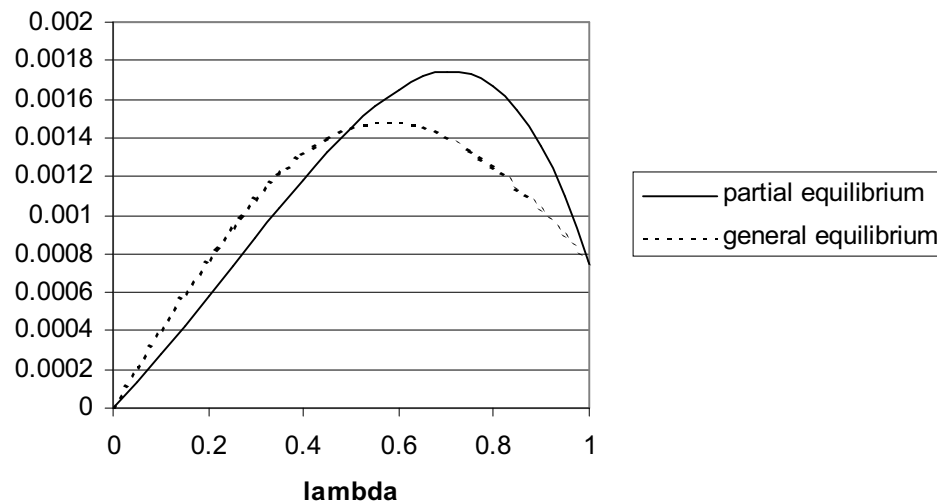


Figure 5 Effects of the decrease in cost on transport from region 1 to region 2

Figure 5 shows that there is a difference between the partial equilibrium effect of the decrease in transport cost on the flow of manufactures from region 1 to region 2. The effect on the other flow is symmetric. There is a small difference also in the consumer's surplus as computed in the partial equilibrium and in the general equilibrium setting, but it is negligible: it never exceeds 1,5% of the partial equilibrium consumer's surplus. We used the rule of half for these computations.

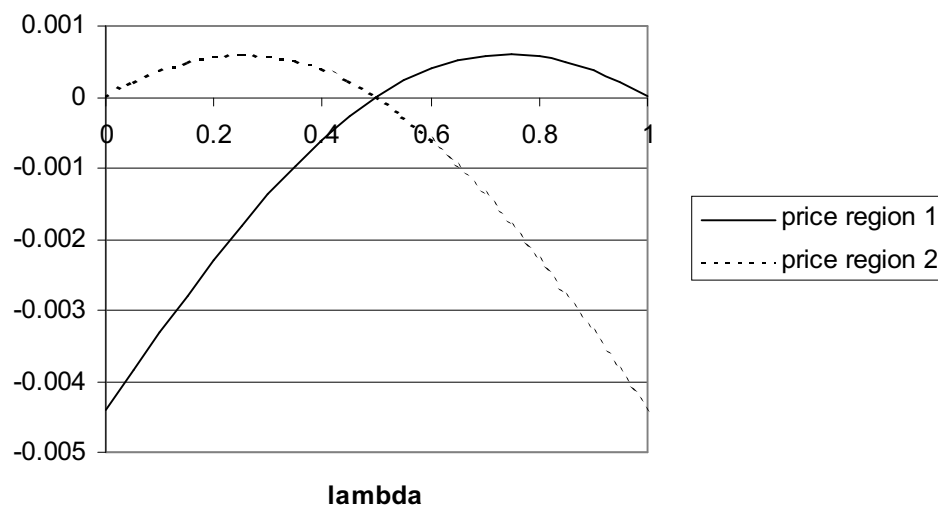


Figure 6 Changes in the prices of manufactured goods caused by the improvement in transport infrastructure.

The second measure is the sum of the compensating variations of all workers that occurs as a consequence of the change in the transport cost. In order to compute this, we have to consider the changes in prices induced by the improvement in the transport infrastructure. Figure 6 shows the difference between the prices of manufactured goods before and after the change in transport infrastructure. Since the price of manufactured goods is equal to the nominal wage, the figure also shows how the nominal wage change.

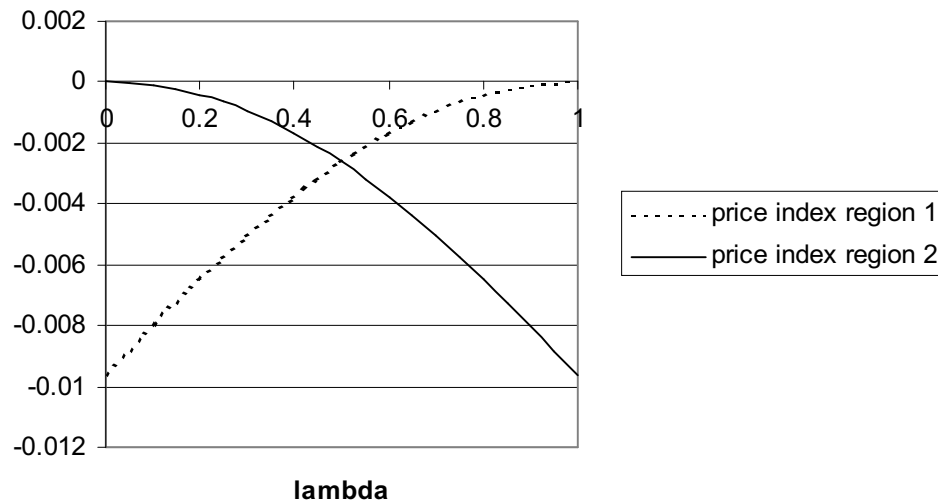


Figure 7 Changes in the price indices caused by the improvement in transport infrastructure.

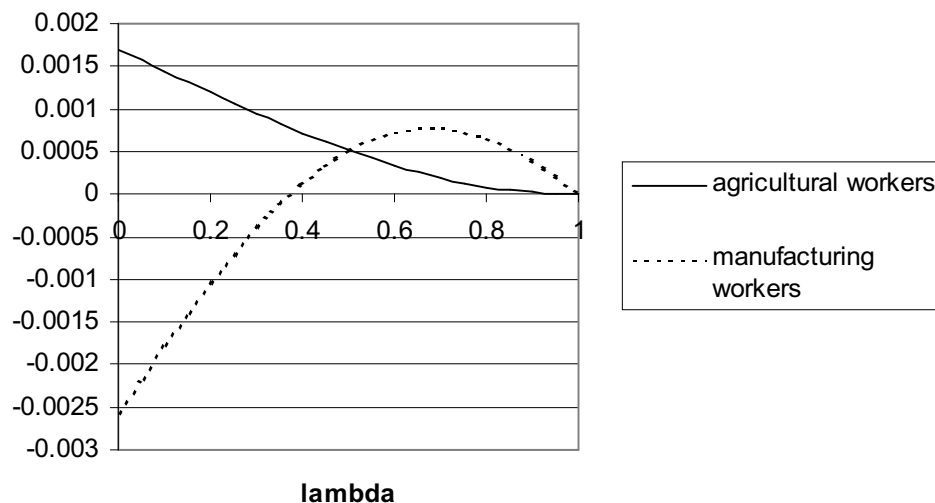


Figure 8 Changes in real wages of workers in region 1

In order to find the difference in the real wages, we need the change in the price indices. The next figure pictures the difference between the values of these indices G before and after the

improvement in transport infrastructure. This difference is never positive, indicating that the effect of the investment on the prices of consumption goods is always to the advantage of the workers.

Figure 8 shows the difference in the real wages (indirect utilities) of workers in region 1. The corresponding curves for workers in region 2 can easily be deduced from the symmetry of the model. The picture shows that welfare of manufacturing workers can *decrease* because of the improvement in transport infrastructure. However, this occurs only in the region when less than 40% of such workers lives.

The compensating variation per worker gives a picture that is similar to that of the change in the real wage. The sum of the compensating variations for workers in region 1 is shown in Figure 9.

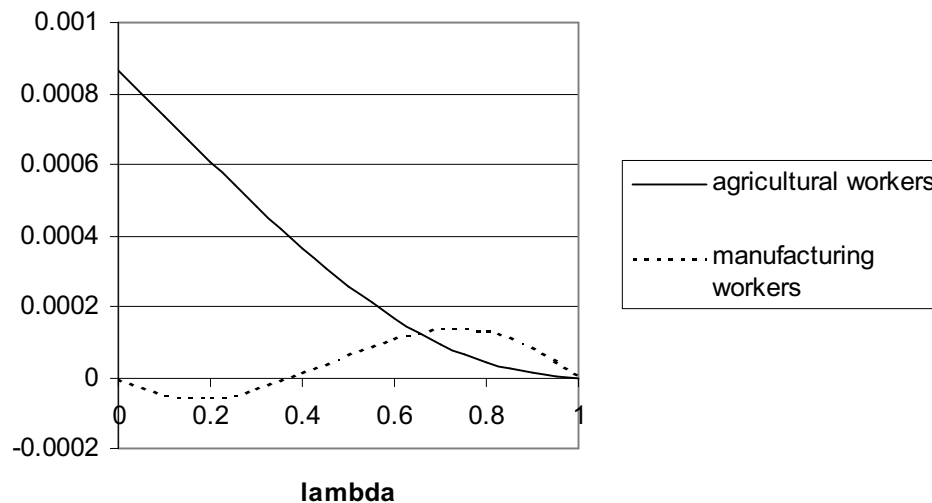


Figure 9 Sum of compensating variations for workers in region 1.

This picture shows clearly that the positive welfare effects for the larger group of agricultural workers dominate the total welfare effect. The picture of this total welfare effect (the sum of the compensating variations for all workers) is indistinguishable from that shown in Figure 4, which gives the result of the partial analysis.

Figure 10 shows the difference between the partial and the general equilibrium effects, expressed as a percentage of the partial equilibrium effect. Both effects are computed as the sum of the compensated variations over all workers. The difference is always small: it never exceeds .15% of the partial effect. Moreover, it is negative: the general equilibrium effect is *smaller* than the partial equilibrium effect.

The partial equilibrium approach is based on the assumption that effects on other markets can be ignored as long as the change in transport cost is small. If this assumption is true, one would presumably expect the ratio between the partial and general equilibrium effects to become smaller when the change in T gets smaller and approach 1 when this change goes to 0. We have checked this by varying the change in the parameter T . The results of this exercise are shown in Figure 11. They provide some support for the basic assumption of the partial equilibrium analysis, but the most important aspect of the picture seems to be that even for large

improvements in infrastructure (recall that $T=1.16$, so a change of 0.04 would imply a decrease in transport cost of 25%) the general equilibrium effects remain small. They never exceed 0.5%.

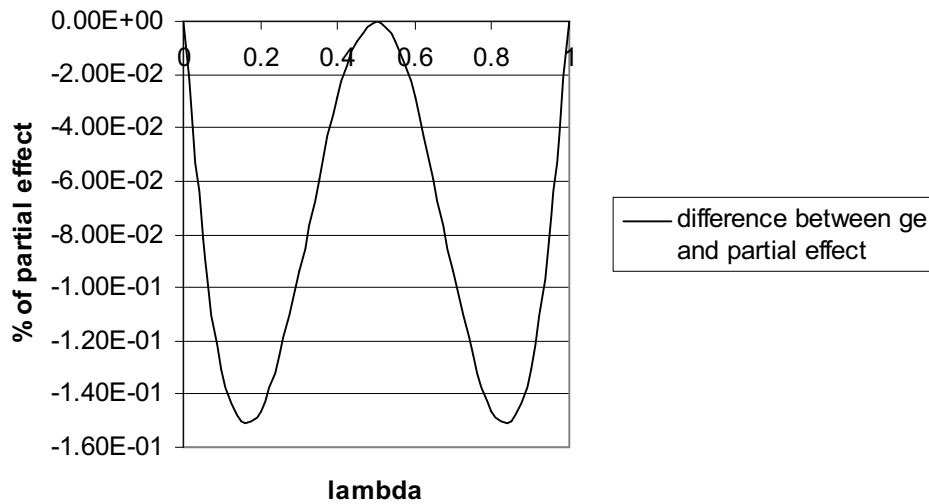


Figure 10 Difference between the partial and general equilibrium effects of an improvement in transport infrastructure.

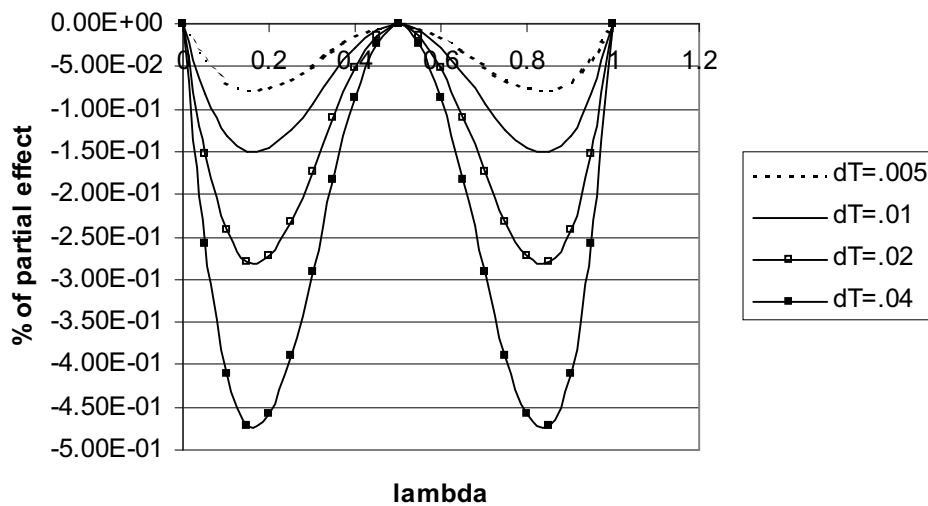


Figure 11 Difference between partial and general equilibrium effects for various changes in transport cost.

The third measure we use is the change in the value of the social welfare function. We computed the increase in social welfare resulting from the improvement in transport infrastructure for inequality aversion equal to 0, 1 and 2. Figure 12 plots the results, together with the sum of the compensating variation. The latter is not exactly equal to the change in the utilitarian welfare function (ineq. aversion = 0) because the compensating variations have to be computed by G_r^u (with r the region of residence) in order to find the corresponding change in direct utility or real

income. However, as shown in the Figure, the results are very close. When inequality aversion rises to 1, the valuation of the improvement in infrastructure still does not change much. However, when inequality aversion equals 2, a much lower evaluation results. Since the welfare function can be written as the product of the utilitarian function and an equality index, and the former is independent of the inequality aversion, it is clear that the reason for this difference is the increased inequality between the real incomes of the various groups of workers.

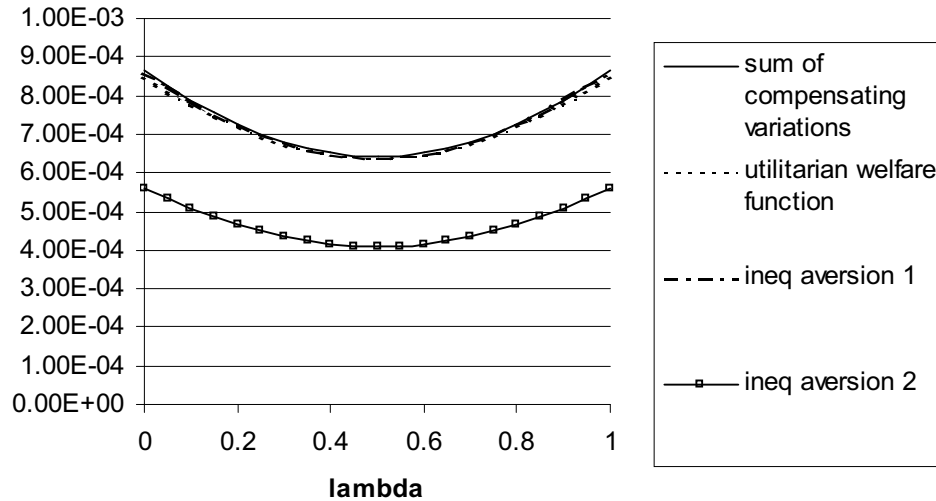


Figure 12 Valuation of an improvement in transport infrastructure for various degrees of inequality aversion.

Financing the investment with a lump-sum tax

Until now, we have not yet considered the possible effect of the way the improvement in the transport infrastructure is financed. In order to introduce this consideration into the model we assume that the improvement is financed by devoting a fixed amount of agricultural labor to the improvement of transport infrastructure. The workers concerned are paid their usual wage, which is equal to 1, from the revenues of a lump-sum tax t , which is equal for all workers. We fixed the cost of the investment at 95% of the minimum value of the sum of the compensating variations. This amount of money was fixed equally over the workers.

The effects of this way of financing the improvement in transport infrastructure are in general small. There is a small change in the effect on trade between the two regions, resulting in a negligible change in consumer's surplus. Other changes are also in general small or negligible. In order to illustrate the effects of the various approaches on the ultimate estimates of the net benefits, we constructed Figure 13. It gives the difference between the net benefits determined by other methods and those determined by the full general equilibrium in which also the effects of the particular way of financing the investment have been taken into account.

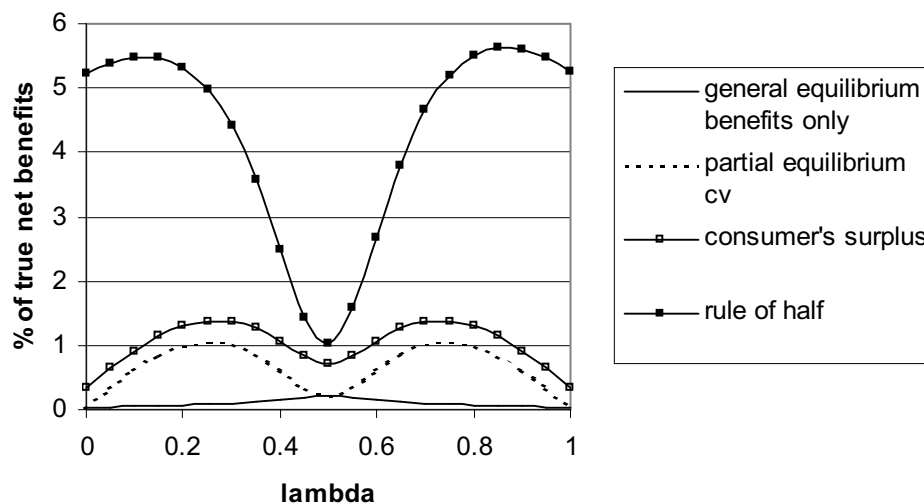


Figure 13 Differences between the true benefits and the net benefits estimated by various methods

The Figure shows that the differences are in general less than 6% of the true benefits and the largest source of error is the approximation implied by using the ‘rule of one half’. If a better approximation to consumer’s surplus is made, the error decreases to less than 1.5%.

Long term effects of an improvement in road infrastructure

Until now we have only considered the effect of the investment on short run equilibria in the model. However, there are also potentially important long run consequences of an investment. The long run development of the model is determined by the real wage difference. Workers migrate to the region with the highest real wage. It was discussed above that this dynamics mechanism will lead to lower real wages for manufacturing workers if the model moves towards the long run dispersed equilibrium. The dispersed equilibrium can only occur for sufficiently low transport costs and in our base case this equilibrium is stable, and so are the two agglomeration equilibria. Lowering transport costs may change the dynamics of the model in such a way that the movement is no longer towards the dispersed equilibrium, but to one of the agglomeration equilibria. For the base case parameters chosen, a decrease in the transport cost parameter T of 0.01 will make the dispersed equilibrium unstable and induce the system to move to one of the agglomeration equilibria. Figure 14 shows the wobble diagram before and after the decrease in transport cost. The effects of financing the improvement by means of a lump sum tax are negligible.

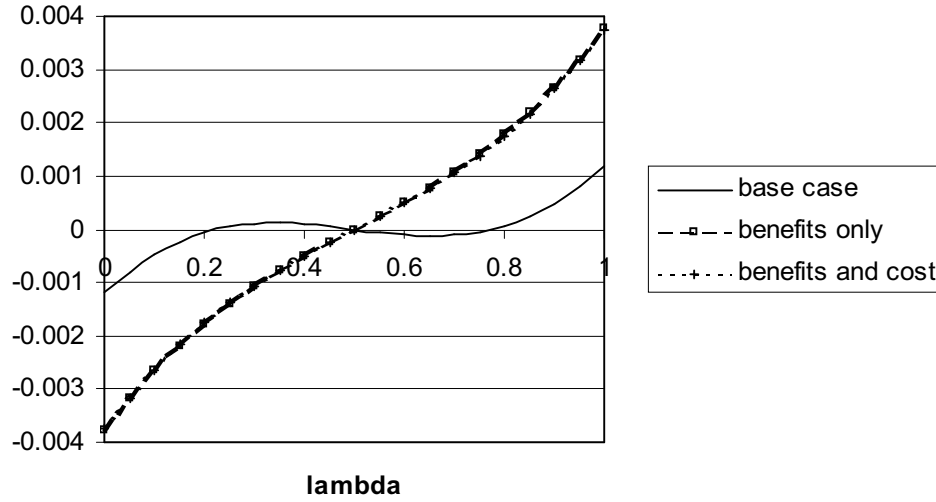


Figure 14 The wigggle diagram before and after the improvement in transport infrastructure

The effects of the improvement in transport infrastructure on the long term development of the spatial distribution of the workers in the manufacturing sector are shown in Figure 15. We assume that initially 40% of these workers reside in region 1. The model is then converging towards the dispersed long run equilibrium.

We use a discrete time approximation to the ad hoc dynamics proposed by Fujita, Krugman and Venables (1999, p.62):

$$\Delta\lambda_r = \gamma(x_r - \bar{x})\lambda_r \text{ with } \bar{x} = .5(x_1 + x_2) \quad (34)$$

with $\gamma=15$. Since real wage differences are small, a relatively large numerical value has been chosen in order to arrive at a case with substantial effects.

Figure 15 shows that the convergence towards the dispersed equilibrium in the case without the investment is much slower than that towards agglomeration in the case with the investment. In the former case 43% of the manufacturing workers would be in region 1 after 100 periods, in the latter only 7%.

What does this imply for the cost-benefit analysis of the improvement in transport? In order to find an answer to this question we computed the values of the utilitarian social welfare function. The results are shown in Figure 16. Without the investment social welfare would increase slowly over time. The reason is that in the base case the highest level of social welfare is reached at the dispersed equilibrium and the economy converges slowly to that equilibrium. Because of the investment, the economy will start to move away from the dispersed equilibrium. The spatial redistribution of manufacturing workers induced by the investment would in itself imply a decrease in social welfare. However, the investment itself is beneficial to the economy especially when it is close to one of the agglomeration equilibria. Indeed, these benefits are large enough to overcome the disadvantages associated with the redistribution of manufacturing workers and Figure 16 shows that ultimately a positive net effect of the investment results.

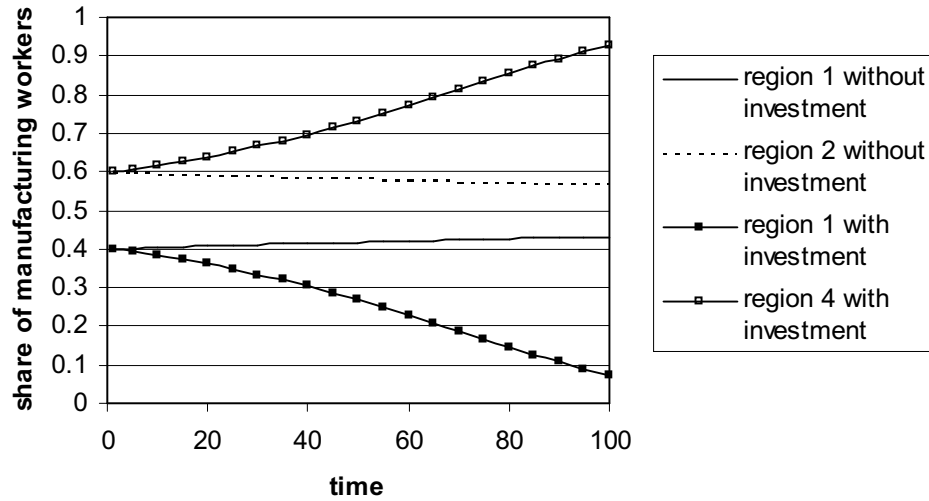


Figure 15 Effects of the investment in transport infrastructure on the spatial distribution of the manufacturing workers

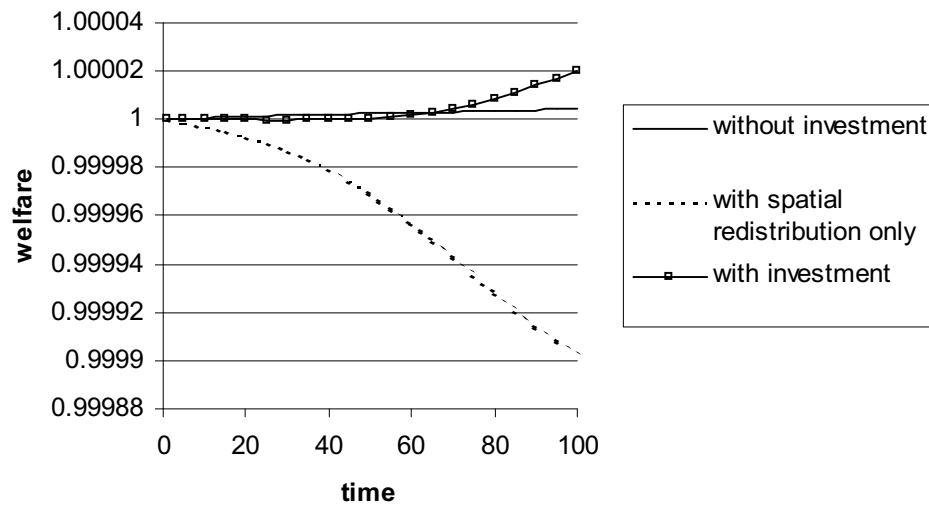


Figure 16 Welfare effects of the investment in transport infrastructure and the redistribution of manufacturing workers.

Utilitarian welfare can be higher after the investment because at the new level of transport cost the (now unstable) dispersed equilibrium is no longer a welfare maximum. In fact, the maximum level of welfare is now reached in the agglomerative equilibria.

If the degree of inequality aversion is positive, the investment in transport infrastructure decreases welfare. The dispersed equilibrium still corresponds with a welfare optimum at the lower level of transport costs when the relevant parameter equals 1 or 2.

Note that even with the utilitarian welfare functions the effects of the transport investment are not unambiguously positive. During the first 60-70 periods the level of social welfare without the investment is somewhat higher than it is with the investment. So it depends on the value of the rate of discount whether the investment is socially desirable.

4 Conclusion

In the previous section we have considered the validity of conventional cost-benefit analyses of an improvement in transport infrastructure in the context of the core periphery model. A main conclusion is that in the short run traditional cost benefit analysis based on consumer surplus measures of the benefits of an improvement in transport infrastructure does a surprisingly good job. Despite the fact that the model contains a manufacturing sector where prices differ from marginal costs, computation of the full general equilibrium effects shows that the change in consumer surplus is an accurate measure for the true welfare effect of the investment.

To be sure, there are general equilibrium effects. Expressed as a percentage of the partial effect they become larger when the investment gets larger. However, the size of these general equilibrium effects is so small that they are in practice negligible, even if transport costs are reduced by 25% as a consequence of the investment. The approximation error made by using the 'rule of half' is much larger than that of ignoring the general equilibrium effects.

In order to study the dynamic effects of a transport investment, we have considered the most spectacular case in which a modest improvement in transport infrastructure reverses the long run pattern of spatial development of the economy. Without the investment it moves towards the dispersed equilibrium, when the investment is made it starts moving towards agglomeration. The ultimate effect of the investment is therefore a completely different spatial configuration of manufacturing activities. However, the welfare effect of this relocation is of the same order of magnitude as the short run effects of the investment when a utilitarian welfare function is used. In fact, the benefits of the investment are larger than the 'cost' associated with the changing spatial configuration and the investment may still be beneficial even though the dispersed equilibrium corresponded with a welfare optimum in the original situation.

This conclusion no longer holds when there is inequality aversion. Agglomeration equilibria are more unequal than the dispersed equilibrium, mainly because of the lower welfare of the agricultural workers in the periphery. This tends to make the dispersed equilibrium preferred over agglomeration.

In the core periphery model a dispersed equilibrium is only possible when transport costs are high enough. Transport policy is usually not thought of as an instrument to keep transport costs at a sufficiently high level and are often used to allow lagging regions to reap the presumed benefits from better connections with the core region. The core periphery model does not support this policy: improvements in transport infrastructure will in general encourage agglomeration and may, as the example studied here shows, reverse a long run tendency towards dispersion into one that results in agglomeration.

The analysis highlights the important role that equity considerations play in the evaluation of regional economic policy. A movement from dispersion towards agglomeration is in the interest of three of the four groups of workers concerned. Those who lose are the agricultural workers in the periphery who are unable to move.

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