The impact of Productive Infrastructure on Economic Geography and Welfare

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Abstract :

This paper considers the links between public expenditures in productive infrastructure and activity location and welfare, using an economic geography model, *à la* Krugman. We assume public spending has an effect on firms' productivity and is financed by a proportional tax on firms. The consequences of these assumptions on firms' location are then analysed. We show that public spending for developed countries can reduce regional inequalities only if taxes are very high. If national welfare is considered, a total agglomeration of activity and public spending is optimal, as well as a positive tax rate which depends on the degree of competition in the economy.

JEL Categorisation : H20, R12,R38.

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Introduction

Since P. Krugman wrote his famous paper (1991), the economic geography has seen huge development. Krugman has renewed the spatial analysis by integrating different well-known spatial mechanisms in a single model. In these kind of models there are two regions and two sectors. The mobile sector (manufacturing sector) is in monopolistic competition *à la* Dixit-Stiglitz (1977): there are fixed and variable costs of production, i.e. increasing returns to scale and each firm is in monopoly competition in its specific differentiated produce market. There is also an agricultural sector in constant returns to scale and the agricultural produce is tradable without cost. Consumers have the same preferences in both regions and have a preference for variety. They consume manufactured goods produced in their region and in the foreign region and pay an "iceberg" transport cost on foreign products. I. e., one assumes a part of the goods "melts" during the transport between one region to the other.

As workers in the manufacturing sector are supposed to be perfectly mobile, the increasing returns to scale mean that manufacturing producers want to be close to consumers to satisfy a large demand, and consumers want to be close to producers to benefit by a greater variety of goods without sustaining transport costs. Therefore, there is a cumulative process of agglomeration where intensity depends on the values of transport costs, on the magnitude of the preference for diversity and on shares of the manufacturing and the agricultural sectors in the economy. In most configurations, especially when these parameters characterise a developed country (high share of manufacturing sector, important preference for variety and low transport cost), the only stable long-run equilibrium location is a core-periphery equilibrium in which industry is concentrated in one region. In Krugman's model, the only dispersion force is the immobile agricultural population consuming manufactured goods and representing a dispersed demand. In some recent models, there are more dispersion forces such as congestion costs (Brakman and al., 1996) or as the presence of a transport cost on the agricultural product (Kilkenny, 1998). In some other models the link between regional integration (i. e. transport costs decreasing) and the economic activities location which is in three stages : there is dispersion when transport cost is very high, agglomeration when transport cost is mean and once again dispersion when transport cost is very low. We can observe these three configurations when labour is not perfectly mobile between both regions (Krugman and Venables, 1995), when there is vertical-linkage between different manufacturing sectors (Venables, 1996) or when labour is perfectly mobile between both

sectors but firms are not perfectly mobile (Puga, 1999).

These results can be interpreted in terms of public policies especially in terms of transport infrastructure expenditure ; a policy developing transport infrastructure may have different consequences depending on regional configurations. But as Fujita, Krugman and Venables (1999) wrote to determinate the difference between a regional and a national analysis "*A national boundary is, of course, a point at which political juridictions change*" (p. 240). In this aim, some of economic geography models explicitly point out the impact of public policies.

For example, Martin and Rogers (1995) analyse how public expenditure in transport infrastructure affects location equilibrium in the case of two kinds of transport cost : an inter-regional one and an intra-regional one. They mainly show that when regional disparities are high, spending in regional infrastructure in the poorer region can increase disparities if infrastructure affect inter-regional transport cost and not intra-regional transport cost.

Trionfetti (1997) also introduces public spending in a model a la Krugman (1991). In this model, government taxes the agricultural income and consumes manufactured or agricultural goods. When public income is only spent on local manufactured goods, this expenditure can counteract agglomeration forces and makes the dispersed equilibrium more often stable, even if the transport cost of manufactured goods is low.

Other models focus on the effect of local taxation in a fiscal competition framework (Kind et al., 1999 ; Andersson et Forslid, 1999). Their main topics are the effect of agglomeration forces on the fiscal competition. Generally, the presence of agglomeration forces decreases fiscal competition that is to say the optimal tax rates are lower than without agglomeration economies.

We also propose an economic geography model with a public sector. In this model, we assume public expenditure affects the productivity of firms. This model is derived from assumptions of endogenous growth models with public spending. We introduce in an economic geography model the idea that public spending can produce externality because it can affect the productivity of firms without firms taking this effect into account. Barro (1990) has first assumed it in a model of endogenous growth and Barro and Sala-I-Martin (1992) have proposed a model with congestion on public services. The endogenous growth models focus on the impact of public spending on growth rate and on competition equilibrium in one hand and on centralised equilibriums on the other. The main topic concerns the optimality of the

government size and of the fiscal system.

In this paper we want to explain how public spending affects location decisions and welfare when we assume there is a public spending externality. This question is very important because a lot of Structural Funds of UM are allowed to increase public infrastructure. Public infrastructure can have an impact on transport cost as Martin and Rogers (1995) assume, it also has an impact on productivity for firms located just near it. Then, we can analyse the impact of this kind of public spending effect on agglomeration forces and then on the firms and workers location. We can also derive this kind of policy impact of the global welfare.

In section 1, the large model assumptions are presented and the short-run equilibrium conditions are derived. In section 2 we introduce explicitly public expenditure externality and examine the impact of this assumption on the long-run equilibrium conditions and the impact of public policies on manufacturing activities location. In section 3, we analyse the impact of transport cost, the competition degree, the spatial distribution of public investments and the tax rate on welfare.

1. Assumptions and short-run equilibrium conditions

Like Krugman (1991) and most models in economic geography (Puga, 1998), we consider a model with two regions and two sectors : a sector which is in constant returns to scale tied to the land and a manufacturing and increasing returns to scale sector. The manufacturing sector is imperfectly competitive and produces differentiated manufactures. There are two production factors and each factor is assumed to be specific to one sector. Consumers have a preference for manufacturing variety and manufactured goods can be exported from one region to the other with an “iceberg” transportation cost : for each unit of goods shipped from one region to the other, only a fraction τ arrives. τ is an inverse index of transportation cost. In this model there is a public sector which produces public infrastructure and public infrastructure is paid by a proportional national tax. Government exogenously allocates public investments among the two regions.

Assumptions

In the sector tied to land (agricultural sector), one unit of labour produces one unit of product and wage is the numeraire. Therefore, the price of product produced by this sector is also

equal to one. The agricultural labour market is in equilibrium. Thus, the quantity of labor (La) used in this sector is the share of income spent on agricultural produce :

$$L_a = (1-\alpha)R \qquad (1)$$

R is the total income of the economy.
α is the expenditure share of manufactured goods.

The labour supply in this sector is equally distributed among the two regions :

$$L_{ak} = L_a / 2 \quad \forall k \text{, k=1,2} \qquad (2)$$

The manufacturing sector is in monopolistic competition (Dixit-Stiglitz, 1977) ; this sector produces differenciated goods under increasing returns to scale. Each firm produces one product and each product is produced solely by one firm, but unlike most economic geography models, production technologies differ from one region to another. Brakman et al. (1996) also propose a model where regional technology depends on the number of firms located in the region thus introducing congestion forces.

The production of a quantity x_i of any variety i requires a fixed and a variable quantity of a specific labour input. The cost function in the manufactured sector is :

$$L_{ik} = \beta_k x_i + \upsilon_k \qquad (3)$$

L_{ik} is the quantity of labour necessary to produce x units of product i in region k. β_k and υ_k are respectively the variable and the fixed cost in region K. Technologies depend here on the characteristics of regions, especially on regional infrastructure endowment.

The manufacturing labour market is in equilibrium, and we assume the total supply of labour is distributed among the two regions like :

$$L_1 + L_2 = L \quad \text{with} \quad L_1 = fL \quad \text{and} \quad L_2 = (1-f)L \quad \text{where} \quad 0 \le f \le 1 \qquad (4)$$

where f is the share of manufacturing labour force located in region 1.

The global income of each region is :

$$R = L_1 w_1 + L_2 w_2 + L_a \qquad R_1 = L_1 w_1 + L_a / 2 \qquad R_2 = L_2 w_2 + L_a / 2 \qquad (5)$$

where w_1 and w_2 are respectively the wage in region 1 and in region 2.
The public sector deduces a tax G on the manufacturing production to finance public capital and to produce public services. The tax rate is g :

$$G = g \int_{i=1}^{N} p_i x_i \qquad (6)$$

p_i is the price of the manufactured product i produced in both regions. N is the range of varieties produced.

The profits for each firm in each region depend on the local technology and is equal to :

$$\begin{aligned} \pi_1 &= (1-g)\,p_1 x_1 - [x_1\beta_1 - \upsilon_1]w_1 \\ \pi_2 &= (1-g)\,p_2 x_2 - [x_2\beta_2 - \upsilon_2]w_2 \end{aligned} \qquad (7)$$

π_1 and π_2 are respectively the profits of each firm in region 1 and in region 2.

Consumers have the same preferences in both regions. They have a Cobb-Douglas preference function over homogenous product and a CES aggregate one of the N manufactured goods :

$$U = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} D^{\alpha} A^{1-\alpha} \text{ with } D = \left[\int_{i=1}^{N} d_i^{\,1-\frac{1}{\sigma}}\right]^{\frac{1}{1-1/\sigma}} \text{ and } \sigma > 1 \qquad (8)$$

A is the quantity of homogenous product consumed. D is the global quantity of manufactured goods consumed. d_i is the quantity of each manufactured good consumed. α is the substitution elasticity between manufactured goods and product tied to the land. σ is the elasticity of substitution between different manufactured goods.

Consumers maximise their utility under income constraints, which are in each region :

$$\int_{i=1}^{n_1} p_i d_i + \int_{n_1+1}^{n_1+n_2} \frac{1}{\tau} p_i d_i + A = r_1 \qquad \int_{i=1}^{n_1} \frac{1}{\tau} p_i d_i + \int_{n_1+1}^{n_1+n_2} p_i d_i + A = r_2 \ . \qquad (9)$$

τ is the “iceberg” transport cost. n_1 is the number of manufactured goods produced in region 1and n_2 is the number of manufactured goods produced in region 2. r_1 and r_2 are the income of agents located in region 1 and 2.

Because of the identical technologies for all goods produced in one region, they have identical prices and are consumed in the same share, σ. We can rewrite the utility function and the expenditure constraints with a representative product for each region. :

$$U = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} D^{\alpha} A^{1-\alpha} \text{ with } D = \left[n_1 d_1^{\,1-1/\sigma} + n_2 d_2^{\,1-1/\sigma}\right]^{\frac{1}{1-1/\sigma}}$$

$$n_1 p_1 d_1 + n_2 \frac{1}{\tau} p_2 d_2 + A = r_1 \qquad n_1 \frac{1}{\tau} p_1 d_1 + n_2 p_2 d_2 + A = r_2 \qquad (9a)$$

Thus short run equilibrium conditions can now be defined.

The short run equilibrium conditions

To derive short-run equilibrium conditions, we must first consider equilibrium conditions with a fixed manufacturing workers location. Profits maximising conditions with supply constraints give the equilibrium firms' prices

$$p_1 = \frac{\sigma\beta_1 w_1}{(\sigma-1)(1-g)} \qquad p_2 = \frac{\sigma\beta_2 w_2}{(\sigma-1)(1-g)} \qquad \frac{p_1}{p_2} = \frac{\beta_1 w_1}{\beta_2 w_2} \tag{10}$$

So the manufactured goods price are increases functions of tax rate, in both regions.

Because of labour market clearing conditions, the numbers of firms in each region, n_1 and n_2, are :

$$n_1 = \frac{fL}{\sigma\upsilon_1} \qquad n_2 = \frac{(1-f)L}{\sigma\upsilon_2} \tag{11}$$

With free entrance to manufacturing market, profits should tend to zero, thus :

$$x_1 = \frac{(\sigma-1)\upsilon_1}{\beta_1} \qquad x_2 = \frac{(\sigma-1)\upsilon_2}{\beta_2} \qquad \frac{x_1}{x_2} = \frac{\upsilon_1\beta_2}{\beta_1\upsilon_2} \tag{12}$$

The offered quantity of each good is a function of technology in each region, by fixed and variable cost production. If the fixed cost decreases the quantity produced by a firm also decreases (because of the number of firms increases) and if the variable cost decreases the quantity increases.

Thus, public capital stock available in the economy is :

$$G = g\sum_{i=1}^{N} p_i x_i = g\left(n_1 p_1 x_1 + n_2 p_2 x_2\right) = \frac{g}{(1-g)}\left[fw_1 + (1-f)w_2\right]L \tag{6a}$$

This public capital stock obviously depends positively on the tax rate and also on the equilibrium wages. We obtain consumer equilibrium in the exchange economy and the quantities consumed in each good in region 1 are :

$$d_{11} = \frac{{p_2}^{\sigma}\alpha r_1}{n_1 p_1 {p_2}^{\sigma} + {p_1}^{\sigma}\tau^{\sigma-1} p_2 n_2} \qquad d_{12} = \frac{\tau^{\sigma}{p_1}^{\sigma}\alpha r_1}{n_1 p_1 {p_2}^{\sigma} + {p_1}^{\sigma}\tau^{\sigma-1} p_2 n_2} \qquad A_1 = (1-\alpha)r_1 \tag{13}$$

In region 2 these quantities are :

$$d_{21} = \frac{\tau^{\sigma} p_2{}^{\sigma} \alpha r_2}{\tau^{\sigma-1} n_1 p_1 p_2{}^{\sigma} + p_1{}^{\sigma} p_2 n_2} \qquad d_{22} = \frac{\tau p_1{}^{\sigma} \alpha r_2}{\tau^{\sigma} n_1 p_1 p_2{}^{\sigma} + \tau p_1{}^{\sigma} p_2 n_2} \qquad A_2 = (1-\alpha) r_2 \tag{14}$$

Because of “iceberg” transport cost, quantities of foreign goods supplied in one region are :

$$q_{12} = \frac{\alpha r_1}{n_2 p_2 + n_1 p_2{}^{\sigma} (p_1 \tau)^{1-\sigma}} \qquad q_{21} = \frac{\alpha r_2}{n_1 p_1 + n_2 p_1{}^{\sigma} (p_2 \tau)^{1-\sigma}}$$

We replace individuals incomes (r_1 and r_2) by total incomes in each region (R_1 and R_2) in equations (13) and (14) to obtain global supplies :

$$D_{11} = \frac{\alpha R_1}{n_1 p_1 + n_2 p_1{}^{\sigma} \left(\frac{p_2}{\tau} \right)^{1-\sigma}} \qquad D_{21} = \frac{\alpha R_2}{n_1 p_1 + n_2 p_1{}^{\sigma} (p_2 \tau)^{1-\sigma}} \tag{15}$$

$$D_{22} = \frac{\alpha R_2}{n_2 p_2 + n_1 p_2{}^{\sigma} \left(\frac{p_1}{\tau} \right)^{1-\sigma}} \qquad D_{12} = \frac{\alpha R_1}{n_2 p_2 + n_1 p_2{}^{\sigma} (p_1 \tau)^{1-\sigma}} \tag{16}$$

In these conditions, the price index in each region is :

$$Pm_1 = \left(\sum_{i=1}^{n} p_1{}^{1-\sigma} + \sum_{i=n+1}^{N} \left(\frac{p_2}{\tau} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad Pm_2 = \left(\sum_{i=1}^{n} \left(\frac{p_1}{\tau} \right)^{1-\sigma} + \sum_{i=n+1}^{N} p_2{}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{17}$$

And then real wages are given by :

$$\omega_1 = \frac{(\alpha w_1)^{1-\alpha} ((1-\alpha) w_1)^{\alpha}}{(Pm_1)^{\alpha}} \qquad \omega_2 = \frac{(\alpha w_2)^{1-\alpha} ((1-\alpha) w_2)^{\alpha}}{(Pm_2)^{\alpha}} \tag{18}$$

If the workers location is fixed, equilibrium prices for each product are given by the solution of the system :

$$\begin{cases} x_1 = D_{11} + DD_{21} \\ x_2 = D_{22} + DD_{12} \end{cases} \tag{19}$$

That is to say :

$$\begin{cases} x_1 = \dfrac{\alpha}{p_1}\left[\dfrac{R_1}{n_1 + n_2\left(\dfrac{p_1\tau}{p_2}\right)^{\sigma-1}} + \dfrac{R_2}{n_1 + n_2\left(\dfrac{p_1}{p_2\tau}\right)^{\sigma-1}}\right] \\ x_2 = \dfrac{\alpha}{p_2}\left[\dfrac{R_1}{n_2 + n_1\left(\dfrac{p_2}{p_1\tau}\right)^{\sigma-1}} + \dfrac{R_2}{n_2 + n_1\left(\dfrac{p_2\tau}{p_1}\right)^{\sigma-1}}\right] \end{cases} \tag{19a}$$

Like in all the other economic geography models, equilibrium conditions are complex. The elasticity between manufactured goods and homogenous product that i. e. the shares of income spent on the agricultural product and on manufactured goods are especially important. The transport cost and the demand elasticity of manufactured goods also play a main role in agglomeration forces. These equilibrium conditions also depend on the production costs of firms located in each region. Technologies differ from one region to another, and then they in turn each affect equilibrium conditions by the quantities of goods produced in each firm (x_1 and x_2) and thereby prices (p_1 and p_2)). Production technology also indirectly affects equilibrium conditions by the number of firms located in each region (n_1 and n_2) which depends on fixed costs. As we have already seen, the tax rate, being identical in both regions, doesn't affect the location equilibrium; as wherever the firm is located, it supports the same tax rate.

2. Public expenditure externality and activities location

We now consider the effect that public infrastructure has on the productivity of firms. If there is no congestion in public infrastructure it has an identical effect on all the productivity of firms located in one region. The assumption of a public infrastructure externality and of public infrastructure effect on the local manufacturing technology can be introduced in the model in two ways. We can assume that public infrastructure affects the fixed or the variable production costs in terms of workers necessary to produce x units of goods. In this paper we assume it affects fixed production costs. The variable cost is assumed to be the same in both regions. The same kind of results are obtained concerning the workers location equilibrium if public infrastructure affects the variable cost. However, here there is no effect on the number of firms located in each region as against the opposing case in which infrastructure affects fixed cost.

We also consider that public infrastructure is a pure public good without access cost for firms located in the region where this infrastructure is also located. Nevertheless public infrastructure effects are limited on the region where public spending is down. Thus, we assume that the production fixed cost is a decreasing function of the global quantity of public capital available in one region. This assumption is more of a concern in transport infrastructure, water supply and telecommunication networks. But all public services that have a positive impact on the economic firm frame could be concerned by this assumption. This assumption means public infrastructure affects increasing returns. It decreases the fixed cost and then contributes to a decrease in the growth of returns. As we have said previously, public infrastructure has direct consequences on the number of firms located in the concerned region. It increases the number of firms located in a region because it decreases the mark-up cost.

In this case, equation (3) is now :

$$L_{Ik} = \beta x_i + \upsilon_k \tag{3b}$$

with $\upsilon_k = \upsilon_k(G_k)$ and $\upsilon_k'(G_k) < 0$.

The relationship between fixed costs and regional public infrastructure is assumed to have an inverse form :

$$\upsilon_k = \frac{1}{G_k} \tag{20}$$

with $G_1 = \lambda G$ et $G_2 = (1-\lambda)G$

λ is then the share of public capital invested in region 1 and (1-λ) is the share invested in region 2.
The relationship assumed is very strong and simple and this assumption will have some implications on the values chosen for simulations. But, if we assume the function is decreasing and linear, we can show that main results remain the same.

We can see that when n_i are affected by public policy, this effect is neutralised when we consider $n_i x_i$. Whatever the fixed cost, the total production of a region is the same and only depends on the elasticity of substitution between manufactured goods (σ), on the variable cost of production (β) and on the number of workers (f).

In our model, we have two policy instruments. The first one is the tax rate and the second is the distribution of public spending. We are interested by the impact of public policies on the spatial distribution of activities and we have seen that the tax rate doesn't affect this

distribution because it has the same effect in both regions. Thus in the following work g, the tax rate, will be fixed and we will focus on the effect of λ, the spatial distribution of public spending.

Because there is no analytical solution for the equilibrium model, we have carried out numerical simulations with different values for key parameters. Short-run equilibrium is a situation where spatial distribution of population is fixed and goods market is in equilibrium. Long-run equilibrium is a situation where regional real wages are equalised. And stable long-run equilibrium is a situation where if a worker moves his real wage is lower than before and then he goes back to his first location. Thus, the relation between the real regional wages ratio and the fraction of workers located in region 1 gives the long run equilibrium situations and their stability. When ω_1/ω_2 is equal to one, nothing attracts workers in an another region. If one worker moves (for example from region 2 to region 1, that is to say f increases) and has a bigger wage (that is to say ω_1/ω_2 increases), he will stay in region 1 and everybody will go to region 1. Thus, when the curve is positive, equilibrium (ω_1/ω_2=1) is not stable. Inversely when the slope is negative, the equilibrium is stable.

We can show that if λ=0,5, i. e. there is an homogenous spatial distribution of public spending, we have exactly the same results as Krugman (1991). In this case, if the share of income spent in manufactured goods is low (α=0,3) and if preference for diversity and transport cost are large (σ=4 and τ=0,5), there is a stable symmetric equilibrium in which manufacturing activities are equally distributed between both regions. But with the same other parameters, if transport cost is low (τ=0,75), the only stable equilibriums are the “core periphery” ones. When transport costs decrease agglomeration forces are stronger and manufacturing activities are concentrated in one region.

Can public investments in productive infrastructure counteract these agglomeration forces? This is a very important question because a lot of policies assume that is it true and governments or EU spend a lot of money on public infrastructure to try to reduce regional disparities. To answer this question we examine equilibrium when spending in public capital is more important in a region (the least developed for example) than in the other. We assume that λ=0,45 (more public capital in region 2). The small deviance from λ=0,5 is due to the function linking the public spending (G) and the fixed cost (υ). This relation is very strong and a small change in λ gives a large change in υ.

In a first stage, we study location equilibrium for both situations with a high and a low transport cost (respectively τ=0,5 and τ=0,75), in an “underdeveloped” economy; with a low level of preference for variety (a high σ) and a low share of industry in the total activity (α=0,3).

Figure 1: Regional public capital inequalities in “underdeveloped” case

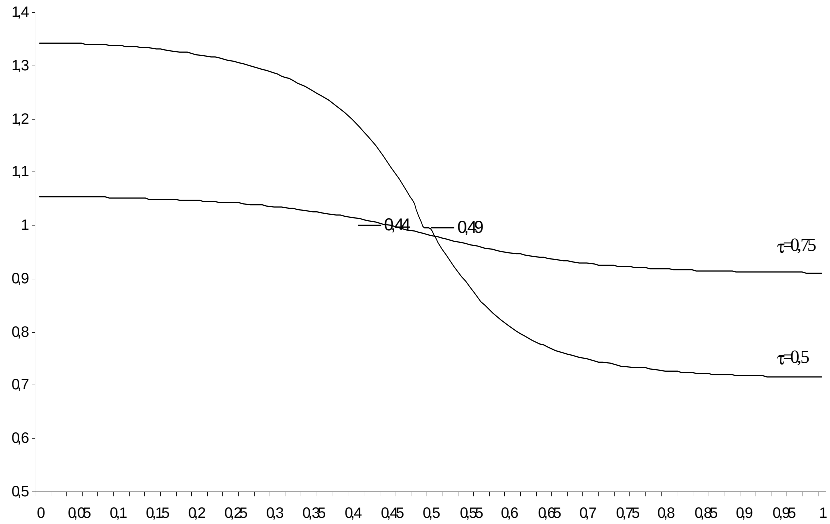
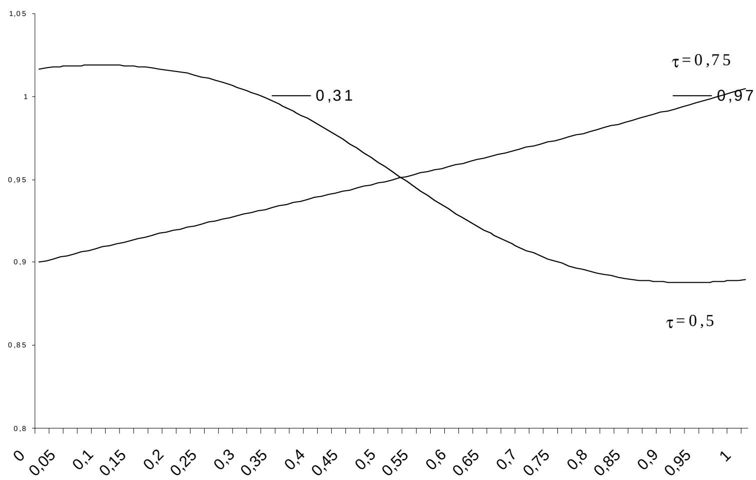


Figure 1 shows that in the case of an underdeveloped country, when transport cost is high, there are three stable equilibrium : the two core periphery ones and one situation with more people in region 2 where there is more public capital. Thus, in the case of high transport cost and preference for diversity, government can invest more in the poorer region to attract firms in that region. A public policy can counteracts agglomeration forces by using regional distribution of public investments. When transport costs decrease, the impact of this kind of policy can be more important since the non-symmetric equilibrium is characterised by more people in region 2 where public spending is higher. Thus, in the first stage, a public policy investing in a specific region (the poorer) is all the more efficient as the transport cost is low.

In the first stage the share of income spent in manufactured goods and preference for diversity were low. We now analyse what results when preference for variety increases. Figure 2 represents the equilibrium situation in exactly the same conditions as Krugman’s model (low share of income spent in manufactured goods and high preference for variety) except that public capital is more important in region 2 than in region 1.

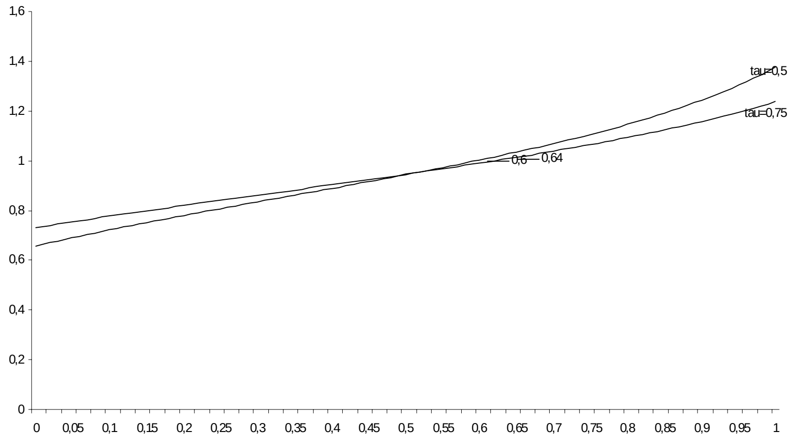
Figure 2: Regional public capital inequalities in Krugman's case



When transport cost is high (τ=0,5), there is one stable equilibrium added to the core-periphery ones. This equilibrium is stable and characterised by a more important share of manufacturing activities in region in which public capital is more important; (1-f), the share of workers located in region 2, is equal to 0, 69. This is different from the situation outside a public sector where the equilibrium is perfectly symmetric (f=0,5). Thus, in case of high transport costs and with a high preference for variety, government can invest more in the poorer region to attract firms to that region. Public policy can counteract agglomeration forces by using regional distribution of public investment. When transport cost is low (τ=0,5), there is an equilibrium with a more important share of manufacturing activities in region 1 but which is unstable. Thus, core-periphery equilibrium are the only stable ones. In the case of high preference for variety, a public policy should try to counteract agglomeration forces by investing in public infrastructure being efficient only when transport cost remains high. But when transport cost decreases, the public investments become inefficient.

Developed countries are characterised by a large preference for diversity but also by a small share of income spent on agricultural product. Figure 3 sets out this situation when public infrastructure is unequally distributed between both regions.

Figure 3: Regional public capital inequalities in a developed country



When the preference for diversity and the share of manufactured goods are high, even when transport cost is high, the agglomeration forces are really strong and only both core-periphery equilibrium are stable.

We can conclude that, in an underdeveloped country, public policy consisting in productive infrastructure investments can counteract agglomeration forces and try to reduce regional inequalities by this way. In this case, there are asymmetric equilibrium without agglomeration in one region. The level of dispersion depends on the share of public investments done in each region. But in case of manufacturing countries as USA or Europe, this kind of policy cannot counteract agglomeration forces which are too strong and the solely equilibrium is a core-periphery one as in Krugman's model context.

If central public institutions can want to reduce regional disparities by dispersing economic activity, one of their main goals is to increase their country's population welfare.

3. Welfare analysis

One way to analyse welfare is by computing the total number of manufactured goods with which the individual utility grows. Using equations (11) (6a) and (20), we can see that N, the total number of manufactured goods in global economy, depends on workers spatial distribution and on public capital spatial distribution :

$$N = \frac{LG\left[f\lambda + (1-f)(1-\lambda)\right]}{\sigma} \qquad (11a)$$

N is also an increasing function of preference for variety (a decreasing function of σ) whatever the other parameters values. It does not depend on transport cost.

As we can see, $\frac{\partial N}{\partial f} = \frac{LG(2\lambda - 1)}{\sigma}$, and therefore when the public capital invested in region 2 is superior than those invested in region 1 ($\lambda < 0{,}5$), N is a decreasing function of f, the number of workers located in region 1, and inversely when the public capital invested in region 1 is more important than those invested in region 2.

We can illustrate this by Figure 4, which represents N in case of an underdeveloped economy (a high preference for diversity, σ=10, and a low share of industry in the total activity, α=0,3).

Figure 4: Total number of firms in the underdeveloped case

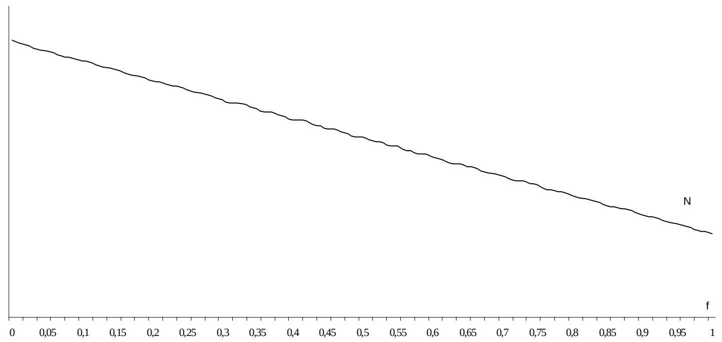


Figure shows that in the case of an underdeveloped country and in all other previous cases, the number of total firms in the economy decreases with the increase in the number of workers located in a region with less public capital, region 1.

Welfare can also be approximated by measuring total indirect utility as in Helpman's (1996) model, i. e. the sum of individual satisfactions whatever the individuals' location, at the equilibrium. Because in economic geography models profits are nil, we only focus on consumers' surplus.

Regional indirect utilities have the following form:

$$U_1 = \left[n_1 \left(\frac{1}{n_1 p_1 + n_2 p_1{}^{\sigma} \left(\frac{p_2}{\tau} \right)^{(1-\sigma)}} \right)^{(1-\frac{1}{\sigma})} + n_2 \left(\frac{1}{n_2 p_2 + n_1 p_2{}^{\sigma} (p_1 \tau)^{(1-\sigma)}} \right)^{(1-\frac{1}{\sigma})} \right]^{\frac{\alpha}{1-1/\sigma}} R_1$$

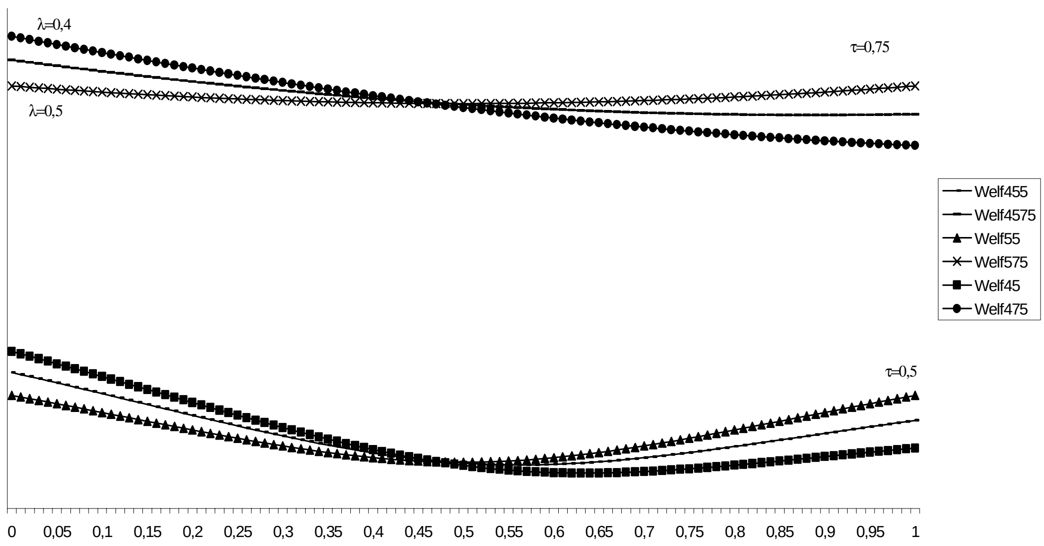
$$U_2 = \left[n_1 \left(\frac{1}{n_1 p_1 + n_2 p_1{}^{\sigma} (p_2 \tau)^{(1-\sigma)}} \right)^{(1-\frac{1}{\sigma})} + n_2 \left(\frac{1}{n_2 p_2 + n_1 p_2{}^{\sigma} \left(\frac{p_1}{\tau} \right)^{(1-\sigma)}} \right)^{(1-\frac{1}{\sigma})} \right]^{\frac{\alpha}{1-1/\sigma}} R_2$$

Welfare is evaluated by the sum of regional welfare in which we introduce equilibrium quantities, prices and wages.

The impact of transport cost and public capital distribution on welfare

Figure 5 shows different levels of welfare for different public capital distributions and transport cost values[2].

Figure 5: Welfare in economy



[2] In all cases g=0.1, β=0.01, σ=4 and α=0.3.

In general, we can see that the lower the transport cost is (τ higher) the higher the welfare is because when transport cost is low, consumers can access a higher quantity of manufactured goods with a fixed income and it increases their satisfaction, whatever their location.

We can also note that when public investments are equally distributed among both regions, the more the population is concentrated in one region (whatever the region), the more important the welfare is to state. In the case of no spatial distribution policy, one of the optimal public policies (the one maximising national welfare) can be to make the increasing returns activities more concentrated.

When central government tries to reduce regional inequalities by investing more in one region where there are less people (region 2, for example), it diminishes the national welfare. And this effect is more important when the transport cost is low because of it increases the size of the home-market effect. For example, when τ=0.5 and f=0.4, λ=0.39 maximises total welfare. And when τ=0.75, total welfare is maximised when λ=0.36. Thus, when workers are concentrated in a region endowed with more public capital, the total utility, which strongly depends on the number of manufactured goods, is maximised.

Regarding these different results, we can see in all cases welfare is maximised when population and mobile economic activities are concentrated in one region and the higher the transport cost is the more efficient the agglomeration is. This is also true when public capital is not equally distributed over the nation. In this last case, the welfare is maximised when public investments are concentrated in the region where mobile economic activities are also concentrated.

The impact of tax rate on welfare

If the spatial distribution of public capital is important for national government in terms of trade-off between the location of activities and the maximisation of the welfare, the effect of taxation on welfare is maybe the more determining concern for government. Finding the tax rate which maximises the welfare is the first objective of a national public instance.

Then, in a first stage, we derive this optimal tax rate from the short-run equilibrium, i. e. the equilibrium without labour mobility. In a second stage, we simulate the way in which tax rate affects national welfare, especially when the elasticity of substitution and the transport cost

vary, at the long-run equilibrium.

If we first consider that workers are not mobile and that local wages are fixed, the national welfare can be written as a function of the elasticity of substitution between manufactured goods, the expenditure share of manufactured goods, and tax rate :

$$U = \left(\frac{g}{(1-g)\sigma} \right)^{\left(\frac{\alpha}{1-\frac{1}{\sigma}} \right)} \left(\frac{(1-g)^2 \sigma(\sigma-1)}{g} \right)^{\alpha} \tag{21}$$

In this case, the tax maximising welfare is a very simple function of solely the elasticity of substitution between manufactured goods:

$$g^* = \frac{1}{\sigma - 1} \tag{22}$$

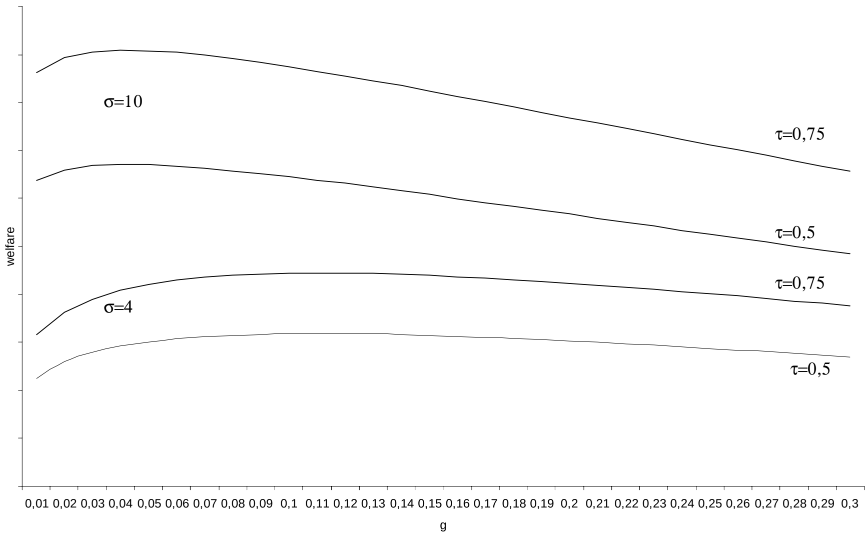
In short run equilibrium conditions, the tax rate should be equal to the marginal utility of public investments introducing their effect on productivity. Actually, if we replace equations (11) and (12) into the welfare equation and after simplifications, we can see that g* is exactly the contribution of public investments to the utility. As in endogenous growth model with public expenditure (Barro, 1990) where the tax rate maximising growth is equal to the marginal productivity of this public expenditure, here the tax rate maximising welfare is equal to the marginal utility depending on the degree of market competition.

In extreme case, when σ tends toward one, i. e. the monopoly situation, a high taxation is optimal. In the opposite extreme case, when σ tends toward infinity, i. e. the market conditions tend to the perfect competition, the optimal tax rate tends toward zero and "*laisser fair*e" is an optimal policy. Thus classically, the more competitive the market is the less the government must interfere to maximise welfare.

Previously, in short-run equilibrium, population distribution and wages were fixed and then the tax rate maximising welfare depended only on the elasticity of substitution between manufactured goods. It did not depend on the spatial distribution of public investments.

We now turn on the long-run equilibrium by simulations and examine how this optimal tax rate varies with the elasticity of substitution between manufactured goods and transport cost, at the symmetric equilibrium. Figure 6 shows national welfare comparing to tax rate, when population and public investments are equally distributed among regions for different values of σ and τ.

Figure 6: Tax rate maximising welfare



We can see that the optimal tax rate is always smaller in long-run equilibrium than in short-run equilibrium, due to the impact of this tax rate on equilibrium wages. However, as in short-run equilibrium conditions, the elasticity of substitution between manufactured goods remains the more important variable to determine the optimal tax rate. Variations of transport cost weakly affect this optimal tax rate. When transport cost decreases, welfare obviously increases but the optimal tax rate weakly increases[3].

Finally in terms of welfare, our model shows that it can be optimal to have a positive tax on firms but this optimal tax decreases with the degree of competition and is relative low. Indeed it is lower than the tax necessary to counteract agglomeration forces when manufacturing is in increasing returns to scale. Even if government does not want to reduce regional disparities, taxation is necessary when market is not in perfect competition.

Conclusion

In the European context, many questions are still suspended about public policies and their

[3] For example, when σ=10, g*=4% when τ=0.5 and g*=5% when τ=0.75.

impact on regional disparities. We particularly tried to answer the question: are the public investments in productive infrastructure efficient to reduce regional disparities measured by population's and firms' spatial distribution ? We, therefore constructed an economic geography model with productive infrastructure and analysed equilibrium location when the government does not equally distribute public investments between both regions.

Different conclusions can be derived from the equilibrium situations studied. First, in our model, whatever the economic characteristics, the total number of firms and thus the social welfare rise when public investments are concentrated where population is also concentrated. Therefore, in order to maximise national welfare, it is optimal to concentrate public capital in a particular region.

Second, when the values of parameters characterise underdeveloped or pre-industrial economies, the policy can counteract agglomeration forces and this is more efficient when transport costs fall. In this case, regional integration coupled to investment in productive infrastructure can help to attain more dispersed equilibrium. But when the economy is more developed, especially a more industrial economy (a large share of income spent in manufactured goods plus a low transport cost or a high preference for diversity), the productive infrastructure is not sufficient to disperse the mobile economic activity and, as in most models of economic geography, the core-periphery equilibrium is only stable.

Third, we can conclude that in underdeveloped countries there is a trade-off between national objectives, i. e. between maximising welfare and attenuating regional disparities. In developed countries there is another trade-off concerning the decision whether or not to invest in public infrastructure, and we showed that the optimal size of government depends on the market conditions: the degree of public intervention should decrease with the degree of competition on the goods' market. But in all cases the optimal location of those investments is totally determinate: they should be in the centre region to maximise welfare.

Finally, our model is a Krugman's type where dispersion forces are very low. When there are more dispersion forces such as imperfect factors mobility or vertical linkages (Krugman and Venables, 1996), the economic activities are more dispersed at the equilibriums. In this last framework, if transport costs are very low, there are dispersed equilibriums even if the economy is industrialised. If our model were constructed with more dispersion forces, public policies trying to reduce regional inequality would certainly be more efficient in most cases.

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