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How Growth And Location Are Sensitive To Transport And Telecommunication Infrastructures: A Simple Theoretical Approach

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How Growth and Location are Sensitive to Transport and Telecommunication Infrastructures:

A Simple Theoretical Approach

Preliminary version

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Abstract: this article comes within the recent developments which aim at reconciling endogenous growth theories and economic geography. We go back to the models with two regions of Martin and Ottaviano (1999) and Martin (1999) adding two simple assumptions. First we postulate the existence of both inter and intra-regional knowledge spillovers in order to convey a situation of technological dependence between regions. Secondly, we consider two types of infrastructures generating non market interactions between regions: transports and telecommunications infrastructures. We show that only a policy based on the development of telecommunications is able to restore a spatial equality between regions while generating growth benefits.

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1 Introduction

The European integration process is bolstered by public policies in various fields. Especially regional policies, by structural interventions come under an accompaniment logic clearly aiming at promoting a regional convergence dynamic. The fact that one third of the community budget for the period from 1994 to 1999 is devoted to the structural policies illustrates this accompaniment will. These policies consist in counteracting the unbalanced regional development which is a well known stylized fact. The productive activities regional distribution is strongly concentrated in some European regions which represent large markets (Puga (1998)). The same statement can be made concerning the distribution of the innovation activities within the European regions. An OST (1998) report shows a spatial concentration of scientist and technological activities both on the level of the European Union and its member countries. This feature seems on one side more obvious in the more developed countries concerning technology and on the other side more pronounced that the productive geography (Paci and Usai (1999)).

The inter-regional inequalities being regarded as a potential slow-down to the convergence, public policies aim first at restoring spatial equity, a necessary and intermediate step, in order to reach the purpose of macroeconomic efficiency. In an analysis which couples together the new theories of endogenous growth and economic geography, Martin (1999) (2000) stresses however the uncertainty about this kind of economic reasoning. Especially, the policies of transport infrastructures aiming at developing external relations of disadvantaged regions can give rise to location dynamics opposed to the one initially wanted. A transport cost decreasing would set up for the firms an incentive to locate in regions with large markets. In returns and because of localized knowledge spillovers, an higher spatial concentration would create benefits for the whole economy. Consequently, traditional regional policies based on the development of transport infrastructures would be confronted with the incapacity to promote simultaneously a more homogeneous spatial distribution of activities and growth benefits. In other word, macroeconomic efficiency would not be a natural corollary to spatial equity.

In this article we tend to test the strength of this conclusion introducing two new assumptions to the Martin and Ottaviano (1999) and Martin (1999) models.

First, Martin (1999) considers that growth is simply due to intra-regional knowledge spillovers. By localized or intra-regional spillovers, we mean that

when two regions develop technological knowledge, the share which is not appropriated to one can not spread to the other one. Despite it has been reinforced by empirical tests (Jaffe (1989), Feldman (1994)), this assumption underestimates the least spatial dependence of the non market interactions induced by the process of integration (Baldwin and Forslid (1999)). In order to take into account these two tendencies which do not exclude each other we consider the existence of both intra and inter-regional knowledge spillovers.

On the other hand we link the possibility of knowledge diffusion between regions with two mediums. Contrary to what is usually stated in the models of economic geography we suppose that the conditions of knowledge and goods exchanges between regions both depend on a variable qualifying the quality level of transport infrastructures. Together with this first medium, the telecommunication infrastructures or those related to the new technologies of information and communication are regarded as if they hold inter-regional knowledge spillovers. These last years, various projects aiming at linking European disadvantaged regions with numerical networks have been approved by the European Social Fund. This tends to prove that the European Union becomes aware of the possibilities offered by this kind of infrastructures both on education policy and knowledge diffusion.

Despite it can produce a centrifugal force via its effects on knowledge spillovers, we show as Martin (1999) that a policy of transport infrastructures tends to generate a growth benefit at the expense of a greater spatial inequality. Furthermore, our results suggest that only an investment policy turned towards telecommunications would help to restore a spatial equality and in the same time to generate a higher growth rate.

The general model of Martin et Ottaviano (1999) is presented in a first section. In the second one we introduce the assumptions concerning knowledge spillovers and their mediums and then their consequences on the growth rate of the economy. The third and last section deals with the obtaining of the steady state equilibrium and with the various effects that the two kinds of infrastructures policies previously described can have.

2 The model of Martin and Ottaviano [1999]

2.1 The general framework

Martin and Ottaviano (1999) develop a model with two regions called a and b . Each region is endowed with a fixed amount of labor, $L = L^a = L^b$, which is assumed to be immobile between regions so as to abstract from that particular agglomeration channel which is not prevalent in Europe. Labor can be used to produce an homogenous good Y and differentiated technological goods which are aggregated into a composite good D .

Let's denote N the total number of varieties available in the economy. The model being symmetric, we concentrate on the specification of region a . Preferences are instantaneously Cobb-Douglas and intertemporally CES with unit elasticity of intertemporal substitution:

$$U = \int_0^{\infty} \ln [D(t)^\alpha Y(t)^{1-\alpha}] e^{-\rho t} dt, \quad (1)$$

where Y is the consumption of the homogenous good and $\rho > 0$ is the rate of time preference. $\alpha \in]0, 1[$ is the share of expenditure devoted to D which, following Dixit and Stiglitz (1977), consists of a number of different varieties:

$$D(t) = \left[\sum_{i=1}^{N(t)} D_i(t)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \sigma > 1 \quad (2)$$

σ is the elasticity of substitution between varieties as well as own-price elasticity of demand for each variety. As Grossman and Helpman (1991), growth will come from an increase in the variety of goods measured by N .

The expenditures E^a of a representative consumer is given by:

$$E^a = \sum_{i=1}^{n^a} p_i D_i + \sum_{j=n^a+1}^{n^b} \tau p_j D_j + p_y Y \quad (3)$$

where p_i is the price of the i -th variety and n^a is the number of varieties produced in region a , such that $N = n^a + n^b$.

As Samuelson (1954), and frequently in economic geography literature, transport cost is modeled in the form of an iceberg cost. τ is more than 1 so that only a fraction of the good purchased is consumed.

In order to tie down the wage rate of the economy w , homogenous good is costlessly traded. This homogenous good is produced using only labor with constant returns to scale in a perfectly competitive sector. Without loss of generality, the input requirement is set to 1. For convenience, the demand of this good in the whole economy is large enough that it cannot be satisfied production in one region only. This hypothesis ensures that in equilibrium the homogenous good will be produced in both regions. Hence, because of free trade and the choice of Y as the numeraire, the wage rate and price of Y are equal to one everywhere.

The differentiated goods are produced in a monopolistically competitive sector. Each variety is produced with increasing returns to scale. With costless differentiation this ensures that each firm produces only its own variety. For the production of a variety to be possible, its blueprint has to be invented first. Consequently, development of a blueprint represents a fixed cost. After registration, a patent gives an infinitely lived property. For convenience, we suppose that research is performed by firms themselves which then use the invention to start production. Furthermore, innovation and production processes can be conducted in different regions. For example, firms are free to locate the production process in either region and then repatriate the profits. The supply of one unit of each variety requires β units of labor. Consequently, optimal pricing for any variety gives producer prices:

$$p^a = p^b = \frac{\beta\sigma}{\sigma - 1}$$

The operating profits of a producer are revenues minus the labor costs:

$$\pi^{a,b} = p^{a,b}x^{a,b} - \beta x^{a,b} = \frac{\beta x^{a,b}}{\sigma - 1}$$

where $x^{a,b}$ is the output or size of a typical firm in equilibrium locating its production process in region a or b .

Demand of a representative consumer in homogenous good and differentiated technological goods and derived from utility maximisation. The maximisation program of a representative consumer living in region a is given by:

$$\begin{aligned} & \text{Max} \left[n^a D_i^{\frac{\sigma-1}{\sigma}} + n^b D_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\alpha\sigma}{\sigma-1}} Y^{1-\alpha} \\ \text{s.t. } & E^a - Y = \frac{\beta\sigma}{\sigma-1} D \text{ with } D = n^a D_i + n^b \tau D_j \end{aligned}$$

Solving this program gives the usual following demands:

$$Y = (1 - \alpha) E^a \quad (4)$$

$$D_i^a = \frac{\sigma - 1}{\beta\sigma} \frac{\alpha E^a}{n^a + n^b \delta} \quad (5)$$

$$D_j^a = \frac{\sigma - 1}{\beta\sigma} \frac{\alpha E^a \tau^{-\sigma}}{n^a + n^b \delta} \quad (6)$$

with $\delta = \tau^{1-\sigma} \in]0, 1[$. Following Martin and Rogers (1995) and Martin (1999), δ qualifies the quality of transport infrastructures. A δ value close to unity indicates a high quality level of transport infrastructures. As usually in economic geography literature, an increase in δ increases demand of differentiated goods produced in region b from a representative consumer in region a :

$$\frac{\partial D_j^a}{\partial \delta} > 0$$

Finally, to close the model we have to specify the institution that governs the intertemporal allocation of resources. There exists a financial market where a safe bond is traded and bears an interest rate r in units of the numeraire. This market is global in the sense that it is accessible by all consumers, no matter where they live. By this market, firms finance their investment in R&D. Consequently, total individual income is composed of the wage rate equal to one and of the returns investment in innovation. Let's denote H^a and H^b , total investment in region a and b . Investment capacities being completely used for all t , we have:

$$H^a + H^b = n^a + n^b = N$$

For innovation to happen at all, some investment capacities $H^a(0)$ and $H^b(0)$ or blueprints $n^a(0), n^b(0)$ are assumed to be owned by consumers from the start with an inequality such that:

$$H^a(0) > H^b(0)$$

which implies that:

$$n^a(0) > n^b(0)$$

This initial asymmetry gives rise to more important pure rents and total income or expenditure in region a .

As usually in endogenous growth models (see Grossman and Helpman (1991 chap.3)), the intertemporal optimization by consumers implies that the growth rate of individual expenditures, E^a and E^b , is equal to the difference between the interest rate and the rate of time preference:

$$\frac{\dot{E}^a}{E^a} = \frac{\dot{E}^b}{E^b} = r - \rho$$

2.2 The equilibrium location of production

Let's denote $\gamma = \frac{n^a}{N} \in]0, 1[$, the share of varieties or firms producing in region a . Consequently, $1 - \gamma$ represents firms locating in region b and the value of γ indicates how production is agglomerated in region a . To a steady state of the model corresponds an equilibrium where the geographical distribution of firms γ is time invariant and their total number grows at a constant rate $g = \frac{\dot{N}}{N}$.

The equilibrium condition for the location of firms production is derived from the market clearing condition for the technological sector. According to this condition, the supply of each variety has to be equal to its demand from consumers in both regions:

$$x^a = \frac{\alpha L (\sigma - 1)}{\beta \sigma} \left(\frac{E^a}{N [\gamma + (1 - \gamma) \delta]} + \frac{E^b \delta}{N [\gamma \delta + (1 - \gamma)]} \right) \quad (7)$$

$$x^b = \frac{\alpha L (\sigma - 1)}{\beta \sigma} \left(\frac{E^a \delta}{N [\gamma + (1 - \gamma) \delta]} + \frac{E^b}{N [\gamma \delta + (1 - \gamma)]} \right), \quad (8)$$

For γ to be constant, firms must have no incentive to relocate their production. For this to be the case, firms must be indifferent between producing in region a or b . This happens if $\pi^a = \pi^b$ or $x^a = x^b$. Let's denote $\theta = \frac{E^a}{E^a + E^b}$ the share of per-capita expenditures from region a , this equilibrium condition implies that we can solve (7) and (8) for γ :

$$\gamma = \frac{\theta - (1 - \theta) \delta}{(1 - \delta)} \quad (9)$$

Two types of equilibria are possible: core-periphery equilibria ($\gamma = 0$ and $\gamma = 1$) and interior equilibria ($0 < \gamma < 1$). We'll concentrate only on the second type which exists if and only if:

$$\frac{\delta}{1+\delta} < \theta < \frac{1}{1+\delta}$$

Consequently, we'll suppose that this condition is verified.

Equation (9) illustrates the forward linkage at work in the model implying that agglomeration increases with θ . Firms in the increasing returns sector tend to locate in the region which has the highest level of per-capita expenditures. This is the traditional home market effect. The location equilibrium will also depend on quality of transport infrastructures. δ is at the origin of a pecuniary externality: the level of inter-regional infrastructures influences, through a direct effect, market interactions and location choices. For example, demands are not very sensitive to a high level of δ . Consequently, if one region represents a more important total demand than the others, firms have more incentives to locate there.

Initial difference in investment capacity between regions ($H^a(0) > H^b(0)$) implies higher level of income and expenditure in region a , such that:

$$\theta > \frac{1}{2}$$

In this case, the home market effect produces a relative spatial concentration in region a for all t :

$$\gamma > \frac{1}{2}$$

Optimal size of firms (x) for a given level of expenditures is obtained by combining (7) and (8):

$$x = \alpha L \frac{\sigma-1}{\beta\sigma} \frac{E^a + E^b}{N} \quad \text{with} \quad x = x^a = x^b$$

3 Innovation, growth and spatial knowledge spillovers

3.1 Intra and inter-regional knowledge spillovers

R&D effect on growth is similar to the model of Grossman and Helpman (1991 chap.3). Innovation is modeled as a constant returns to scale

activity for the individual firms but producing external increasing returns to scale. R&D productivity of a new firm depends negatively on the number of existing production plants. Hence, knowledge spillovers are diffused from production to R&D. We introduce two assumptions concerning spatial characteristics and mediums of knowledge spillovers.

Spatial dimension of technological complementarities

Knowledge spillovers are usually modeled as strictly intra or inter-regional phenomena (Englman and Walz (1995), Walz (1996), Martin (1999)). The hypothesis of intra-regional spillovers is linked to a Marshallian approach of knowledge diffusion. According to this approach, knowledge is highly localized and only benefits to firms located in the same regions or areas where it is initially produced. On the contrary, inter-regional spillovers imply a diffusion from a region to another one. We postulate the existence of both inter and intra-regional spillovers. This first assumption is linked to the idea that the levels of agglomeration and growth in an economy are simultaneously influenced by technological activities proper to each region and intensity of diffusion effects between them. In order to analyze this double causality, it is necessary to reject the simple hypothesis of strictly inter or intra-regional spillovers.

Intra-regional spillovers are illustrated by Feldman (1994) and Jaffe (1989). Geographical proximity between firms intensifies non market interactions and increases both spillovers and R&D productivity in a geographical area (Lucas (1989)). We'll suppose a full absorption of intra-regional spillovers.

But, it's difficult to avoid the importance of inter-regional technological relations within an economy. These kinds of relations are frequently generated by technological proximity compensating the absence of geographical proximity. For example, Coe and Helpman (1995), Eaton and Kortum (1997) or Caballero and Jaffe (1993) tend to show how knowledge spillovers can be intra or inter-national phenomena. These stylized facts can be interpreted as one of the consequences of the integration process creating a largely open technological environment. Integration process modifies conditions of non market interactions and constitutes new incentives to develop inter-regional relations. Furthermore, if geographical proximity can be regarded as the principal source of intra-regional spillovers, flows of knowledge between regions more depend on infrastructures which improve communication or exchange of informations.

Telecommunication and transport infrastructures: two mediums of inter-regional knowledge spillovers

We consider that two kinds of infrastructures can improve non market interactions between firms located in different regions: transport and telecommunication infrastructures.

Telecommunication infrastructures or new technologies of information and communication represent new patterns relations in knowledge exchange for which distance is not real an impediment (Quah (2000)), requiring few direct interactions. Consequently, those infrastructures reduce the implicit or explicit shifting costs. We will suppose that one part of inter-regional knowledge spillovers are diffused by this kind of medium but depends on its quality level. This quality level is measured by $\lambda \in]0, 1[$. A λ value close to 1 indicates an high quality level of telecommunication infrastructures.

In economic geography models, transport infrastructures or iceberg cost only influence market interactions. We have shown the presence of this effect in the model of Martin and Ottaviano (1999). Depending on the quality of transport infrastructures, different equilibria location of production can be obtained. But quality of transport infrastructures have also an impact on incentives to create relations with other firms located in other regions. Hence, we assume a positive relation of causality between quality of transport infrastructures and inter-regional spillovers. By this assumption, we postulate that an investment in transport infrastructures modifies market and non market interactions. For this reason, knowledge flows between regions formally depend on δ . We propose two elements justifying this choice.

First, if a transport infrastructure policy simultaneously affects both trade and knowledge flows, it is necessary to introduce one and only one variable in order to isolate the net effect of this policy on growth and location.

Secondly, definition of δ seems adapted to describe the spatial differentiation effect on knowledge flows between firms. $\delta = \tau^{1-\sigma}$ is a particular formulation of the iceberg cost. The iceberg cost signifies that when an unit of good is traded only a share $\frac{1}{\tau}$ is consumed. But the same definition can be applied for knowledge: if each production plant represents a potential knowledge spillover for R&D activities, only a share $\frac{1}{\tau}$ will be really exploited when the spillover is inter-regional. Therefore, we assume that inter-regional spillovers are influenced by interactions opportunities permitted by δ , with $0 < \delta < 1$, $\tau > 1$ and $\sigma > 1$. So knowledge flows are a decreasing function of τ and σ . The more the elasticity of substitution σ is high the less inter-regional knowledge flows are important. By this assumption, we postulate that the degree of substitution between different knowledges accentuates the spatial distance effect on the production of knowledge spillovers.

3.2 The equilibrium location of innovation and growth rate

The next step is to find the growth in the economy and how innovation activities are located.

Potential knowledge spillovers within each region determine the equilibrium location of innovation. It is less costly to engage in R&D in the region with an higher share of production plants. As $H^a(0) > H^b(0)$, pure rents induced by investment in innovation are higher in region a for all t . Therefore, region a presents an higher level of income and expenditure ($\theta > \frac{1}{2}$) and more firms are located in this region in equilibrium:

$$\gamma > \frac{1}{2} \quad \forall t$$

Moreover as intra-regional spillovers are perfect for all λ and $\delta \in]0, 1[$, location of innovation activities defines a core-periphery equilibrium and all R&D activities take place in region a .

To find the equilibrium growth rate, we must analyze the incentive to develop new varieties and firms and so, the condition of no-arbitrage-opportunity between investing in R&D and borrowing at the safe rate r .

Let's denote v the equilibrium value of a firm equals to the discounted sum of future profits:

$$v(t) = \int_t^\infty e^{-r(s-t)} \frac{\beta x(s)}{\sigma - 1} \quad (10)$$

The condition of no-arbitrage-opportunity, is therefore:

$$\dot{v} + \frac{\beta x}{\sigma - 1} = rv \quad (11)$$

Given free entry and zero profits in the R&D activity, the value of a firm is equal to the marginal cost. Firms use labor with a unit input requirement $\frac{\eta}{\Omega}$, with η a fixed cost and Ω a knowledge spillovers variable defined by:

$$\Omega = n^a + \frac{\delta + \lambda}{2} n^b$$

As $w = 1$, marginal cost is therefore:

$$c = \frac{\eta}{n^a + \frac{\delta + \lambda}{2} n^b}$$

For convenience, we assume that knowledge spillovers produced by region b and benefiting to region a depend on the average quality of inter-regional infrastructures of telecommunication and transport. As there are more firms located in region a and $\lambda, \delta \in]0, 1[$, R&D productivity is more influenced by intra-regional spillovers.

We can define the following equality in equilibrium:

$$c = v = \frac{\eta}{n^a + \frac{\delta+\lambda}{2}n^b} = \frac{\eta}{N \left[\gamma + \frac{\delta+\lambda}{2}(1-\gamma) \right]}$$

At a steady state, γ is constant so that n^a, n^b and N grow at the same constant rate $g = \frac{\dot{N}}{N}$. Therefore, c and v decrease at the same rate:

$$\frac{\dot{v}}{v} = \frac{\dot{c}}{c} = -g \quad (12)$$

Because also consumers expenditures are constant in steady state, the interest rate r is equal to the rate of time preference ρ . By combining equation (11) and (12), the no-arbitrage-opportunity condition is given by:

$$g + \rho = \frac{\beta x}{\sigma - 1} \left(\frac{n^a + \frac{\delta+\lambda}{2}n^b}{\eta} \right) \quad (13)$$

Consider now the market clearing condition for labor. Labor employed in R&D (L_I) depends on growth rate so that we obtain:

$$L_I = \frac{\eta \dot{N}}{N \left[\gamma + \frac{\delta+\lambda}{2}(1-\gamma) \right]} = \frac{\eta g}{\gamma + \frac{\delta+\lambda}{2}(1-\gamma)}$$

With total demand in technological differentiated goods and homogenous good, we define labor market equilibrium:

$$2L = \frac{\eta g}{\gamma + \frac{\delta+\lambda}{2}(1-\gamma)} + \frac{\sigma - \alpha}{\sigma} L (E^a + E^b) \quad (14)$$

Substituting optimal size of firms in (13) and with (14), it is easy to find the following growth rate:

$$g = \frac{2L\alpha}{\eta\sigma} \left[\gamma + \frac{\delta+\lambda}{2}(1-\gamma) \right] - \left(\frac{\sigma - \alpha}{\sigma} \right) \rho \quad (15)$$

Because of the localized spillovers, growth is sensitive to the equilibrium location (γ). But contrary to Martin and Ottaviano (1999) who only take into account intra-regional spillovers, growth largely depends on location in both regions. Nevertheless, firms located in region b less contribute to growth than those located in a and their impact is highly sensitive to the quality of infrastructures measured by λ and δ .

4 Spatial equilibrium, growth and regional policies

4.1 Definition of the steady state equilibrium

We are now ready to determine the steady state equilibrium. Total expenditures of consumers are composed of wage rate equal to 1 and initial investment returns in innovation multiplied by the rate of time preference ρ . Investment returns is the equilibrium value of firms:

$$v = \frac{\pi}{\rho + g}$$

v is lower the higher the growth rate g , since future profits decrease if more firms are created and enter the market (Grossman and Helpman (1991)). Total expenditures are therefore:

$$(E^a + E^b) L = 2L + \frac{\rho N \pi}{(\rho + g)} \quad (16)$$

As $H^a + H^b = N$ for all t and by substituting π by its expression in (16), we obtain:

$$E^a + E^b = 2 + \frac{\rho (H^a + H^b) \alpha (E^a + E^b)}{\sigma N (\rho + g)} \quad (17)$$

Let's denote $h = \frac{H^a}{N}$, the share of investment by region a . This share is constant over time as H^a, H^b, n^a and n^b grow at the same rate in both regions. With equation (17) we obtain the share of expenditures and incomes of consumers in region a :

$$\theta = \frac{1}{2} \frac{\sigma(g + \rho) + \alpha\rho(2h - 1)}{\sigma(g + \rho)} \quad (18)$$

Initial difference in investment between regions creates higher incomes and expenditures in region a :

$$\theta > \frac{1}{2} \quad \forall h > \frac{1}{2}$$

Note that equation (18) defines that incomes and expenditures differences negatively depend on growth rate. An high growth rate then weakens the income gap, because capital invested in innovation constitutes a larger part of income in region a than in region b . Consequently, an increase of the innovation rate, by a kind of competition effect deteriorating capital rents, tends to reduce the gap of income and expenditure because the leader region is more sensitive to a decrease of income capital. For this reason, incomes and expenditures inequalities are closely linked to variables determining the growth rate and, precisely, quality of transport and telecommunication infrastructures. Introducing growth rate equation in (18) we obtain:

$$\theta = \frac{L \left[\gamma + \frac{\delta + \lambda}{2} (1 - \gamma) \right] + \rho\eta h}{2L \left[\gamma + \frac{\delta + \lambda}{2} (1 - \gamma) \right] + \rho\eta} \quad (19)$$

We can now define the relation between the steady state equilibrium location and both infrastructures.

The influence of telecommunication infrastructures is obvious. An higher level of connection generates a relatively high growth of which effect on capital income produces a weak agglomeration in region a .

The effects of transport infrastructures are more ambiguous. Depending on whether quality of infrastructures governs market interactions and non market interactions, results are different. For convenience and clarity we isolate them.

First, one of the main purpose of integration policies consists of intensifying participation of regions to trade. In this purpose, investments in transport infrastructures are frequently privileged. Nevertheless, Martin (1999) shows that this kind of policy can possibly create a de-stabilizing force on geography and emphasize regional inequality through a traditional direct effect consisting of a perturbation of market interactions.

Secondly, and jointly to this first effect, an increase in δ produces a centrifugal force. By an improvement of transport infrastructures a public policy stimulates non market interactions and therefore, knowledge spillovers

from production plants located in region b to R&D located in region a . The growth rate being higher, the decrease in expenditures disparities (c.f equation (18)) weakens agglomeration in region a . This is an indirect effect of a policy improving transport infrastructures, inverse to the direct effect, and which is not modeled in Martin and Ottaviano (1999). We can now define the equilibrium location of production at the steady state. By substituting the equilibrium expenditures in (9), we define:

$$\gamma = \frac{(1 - \delta) (L (\gamma + \frac{\delta + \lambda}{2} (1 - \gamma))) + \rho \eta ((1 + \delta) h - \delta)}{(2L (\gamma + \frac{\delta + \lambda}{2} (1 - \gamma)) + \rho \eta) (1 - \delta)}$$

where γ is solution of the following quadratic function:

$$\gamma^2 (L (1 - \delta) (2 - (\lambda + \delta))) + \gamma ((1 - \delta) (L ((\delta + \lambda) + \frac{\delta + \lambda}{2} - 1) + \rho \eta)) + (- (1 - \delta) L (\frac{\lambda + \delta}{2}) - \rho \eta ((1 + \delta) h - \delta)) = 0,$$

which admits two roots: one is positive, the other is negative. A steady state equilibrium corresponds to the positive one:

$$\gamma = \frac{-(1 - \delta) (A + \rho \eta) + \sqrt{(1 - \delta)^2 (A + \rho \eta)^2 - 4LBC}}{2LB}$$

with $A = L ((\delta + \lambda) + \frac{\delta + \lambda}{2} - 1)$, $B = (1 - \delta) (2 - (\lambda + \delta))$ and $C = (- (1 - \delta) L (\frac{\lambda + \delta}{2}) - \rho \eta ((1 + \delta) h - \delta))$. γ is an interior solution ($\frac{1}{2} < \gamma < 1$) if income and expenditure inequality is not too high and δ doesn't take extreme values. The equilibrium value of g at the steady state follows from equation (15).

4.2 Regional policies and choice between spatial equality and growth

Regional policies can be defined as exogenous action on economic environment. If the economic environment is initially at an equilibrium, and depending on its stability, a policy may shift the economy towards a new equilibrium both more efficient and equitable. But as shown by Martin (1999)(2000), transition towards this new equilibrium and its superiority are not automatically obtained. In other word, Martin (1999) suggests that regional policies would obtain some growth benefits and a decrease in geographical disparities with difficulties. With strictly intra-regional spillovers,

a decrease in the transport cost generates a dynamic of agglomeration towards the leader region which, by a lower cost of innovation, increases the rate of introduction of new varieties. Consequently, Martin (1999) demonstrates that only a technological policy consisting of reducing the cost of innovation ($\searrow \eta$) would lead to an higher growth rate and a more even spatial distribution of economic activities. By introducing new hypothesis concerning knowledge spillovers and theirs mediums, we establish the following proposition:

Proposition 1 *A policy consisting of developping transport infrastructures between regions leads the economy toward a new steady state equilibrium with an higher growth rate and less equal spatial distribution of economic activities.*

Proof:

(i) first, we demonstrate that the centrifugal and indirect effect generated by an increase in δ doesn't compensate the centripetal direct effect. Therefore we suggest that market interactions are more sensitive to transport policies than the non market interactions are. For this we demonstrate that $\frac{\partial \gamma}{\partial \delta} > 0$.
 γ is defined by:

$$\gamma = \frac{\theta - (1 - \theta) \delta}{(1 - \delta)}$$

with $\theta = \frac{[\gamma + \frac{\delta + \lambda}{2} (1 - \gamma)] L + \rho \eta h}{2 [\gamma + \frac{\delta + \lambda}{2} (1 - \gamma)] L + \rho \eta}$. The partial derivatives of these two preceding equations with respect to δ are:

$$\frac{\partial \gamma}{\partial \delta} = \frac{(1 - \delta^2) \frac{\partial \theta}{\partial \delta} - 1 + 2\theta}{(1 - \delta)^2}$$

and

$$\frac{\partial \theta}{\partial \delta} = \frac{\rho \eta (1 - 2h) \left(L \left(\left(1 - \frac{\delta + \lambda}{2} \right) \frac{\partial \gamma}{\partial \delta} + \frac{1}{2} (1 - \gamma) \right) \right)}{(2L (\gamma + \frac{\delta + \lambda}{2} (1 - \gamma)) + \rho \eta)^2}$$

After substitutions and simplifications, we obtain:

$$\frac{\partial \gamma}{\partial \delta} = \frac{L \frac{1}{2} (1 - \gamma) (1 - \delta^2) \rho \eta (1 - 2h) + \rho \eta (2h - 1) (2L (\gamma + \frac{\delta + \lambda}{2} (1 - \gamma)) + \rho \eta)}{(2L (\gamma + \frac{\delta + \lambda}{2} (1 - \gamma)) + \rho \eta)^2 (1 - \delta)^2 - (1 - \delta^2) L (1 - \frac{\delta + \lambda}{2}) \rho \eta (1 - 2h)}$$

Denominator of $\frac{\partial \gamma}{\partial \delta}$ is positive for all $h > \frac{1}{2}$. As $\rho \eta (2h - 1) > 0$ and $\rho \eta (1 - 2h) < 0$, a sufficient condition for $\frac{\partial \gamma}{\partial \delta} > 0$ is:

$$1 - \gamma < 4\gamma$$

which is always verified for all $\gamma > \frac{1}{2}$.

(ii) Secondly, we prove that $\frac{\partial g}{\partial \delta} > 0$.

As $\text{sign} \frac{\partial g}{\partial \delta} \iff \text{sign} \frac{\partial (\gamma + \frac{\delta + \lambda}{2} (1 - \gamma))}{\partial \delta}$, we obtain:

$$\text{sign} \frac{\partial g}{\partial \delta} \iff \text{sign} \left[\left(1 - \frac{\delta + \lambda}{2}\right) \frac{\partial \gamma}{\partial \delta} + \frac{1}{2} (1 - \gamma) \right]$$

and with $\frac{\partial \gamma}{\partial \delta} > 0$ and $\frac{\lambda + \delta}{2} < 1$ for all $\delta, \lambda \in]0, 1[$ we verify that:

$$\frac{\partial g}{\partial \delta} > 0$$

Proposition 1 gives the simultaneous effects of a transport policy on growth and location. Here, it's clear that the higher spatial concentration generated by pecuniary externalities (market interactions) is more important than the centrifugal effect produced by non market interactions. This result corroborates Martin (1999). A regional policy developping telecommunication infrastructures would partially reduce spatial inequalities and generate an higher growth rate.

Proposition 2 *A regional policy developping telecommunication infrastructures would partially reduce spatial inequalities and generate an higher growth rate.*

In Martin (1999) only a policy subsidizing innovation can lead to higher growth and more even spatial distribution of economic activities. Nevertheless, this kind of policy is essentially an unilateral policy consisting of a

subsidy to the leader region. On the contrary an investment in telecommunication infrastructures implies both regions, aiming at converting potential complementarities between regions into efficiency gains. Moreover, proposition 2 suggests that there are no incompatibilities between growth and homogenous spatial distribution of economic activities.

Proof:

(i) First, we demonstrate that a policy of telecommunication infrastructures create a dominant centrifugal force. By the same method previously used, we obtain:

$$\frac{\partial \gamma}{\partial \lambda} = \frac{\rho \eta (1 - 2h) (1 + \delta) (1 - \gamma) \frac{L}{2}}{(1 - \delta) \left(2L \left(\gamma + \frac{\delta + \lambda}{2} (1 - \gamma) \right) + \rho \eta \right)^2 - (1 + \delta) \rho \eta (1 - 2h) \left(1 - \frac{\delta + \lambda}{2} \right) L}$$

with $\frac{\partial \gamma}{\partial \lambda} < 0$.

(ii) Secondly, we demonstrate that $\frac{\partial g}{\partial \lambda} > 0$. As previously proposed:

$$\text{sign } \frac{\partial g}{\partial \lambda} \Leftrightarrow \text{sign } \frac{\partial \left(\gamma + \frac{\delta + \lambda}{2} (1 - \gamma) \right)}{\partial \lambda}$$

and:

$$\text{sign } \frac{\partial g}{\partial \lambda} \Leftrightarrow \text{sign } \left[\left(1 - \frac{\delta + \lambda}{2} \right) \frac{\partial \gamma}{\partial \lambda} + \frac{1}{2} (1 - \gamma) \right]$$

After substitutions, we obtain:

$$\frac{\partial g}{\partial \lambda} = \frac{1}{2} \frac{\left(2L \left(\gamma + \frac{\delta + \lambda}{2} (1 - \gamma) \right) + \rho \eta \right)^2 (1 - \delta)^2 (1 - \gamma)}{(1 - \delta) \left(2L \left(\gamma + \frac{\delta + \lambda}{2} (1 - \gamma) \right) + \rho \eta \right)^2 - (1 + \delta) \rho \eta (1 - 2h) \left(1 - \frac{\delta + \lambda}{2} \right) L}$$

with $\frac{\partial g}{\partial \lambda} > 0$.

Consequently, even if the influence on growth of the leader region is lower, the more even spatial distribution of economic activities can produce macroeconomic efficiency gains.

5 Conclusion

Regional policies in Europe aim at counteracting spatial and income disparities. But Martin (1999) demonstrates that the efficacy of these policies is not automatically obtained. If our version of his model confirms this important analytical result, we suggest that interdependencies between regions are better analyzed by modelling both market and technological relations. By taking into account this second relation, we have defined a new variable on which regional policies are able to influence. In particular, policies developing telecommunication infrastructures may generate higher growth and reduce spatial disparities.

But as Martin (1999) suggests it, the main point of this kind of model is to clarify some economic mechanisms, explaining why regional policies potentially can have complex and undesirable consequences.

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