Working Paper Version – Cite as Chiambaretto P., De Palma A., Proost S. (2013), "A normative analysis of transport policies in a footloose capital model with interregional and intraregional transportation costs", The Annals of Regional Science, vol. 51, n°3, pp. 811-831

A normative analysis of transport policies in a footloose capital model with interregional and intraregional transportation costs

Abstract: We introduce a distinction between interregional and intraregional transportation costs, in a footloose capital model. This allows assessing more precisely the effects of different types of transport policies on the spatial distribution of activities. From a normative point of view we find that, in the absence of regulation, the concentration of firms is too high in the center. We show what set of transport policies improves the equilibrium.

***Key-words** : Economic geography ; Industrial location ; Welfare economic analysis of regional policies ; Transportation costs; Intraregional ; Interregional ; Concentration ; Transport Policies*

JEL Classification : R11; R12; R13 ; R42; R48; R58

1. Introduction

In economic geography, the normative aspect is too often neglected. If the agglomeration phenomenon has been well documented, the question of its fairness is generally not addressed. As explained in Martin (2000), in economic geography one should devote more attention to this trade-off between efficiency and equity. In this paper, using a framework that distinguishes between interregional and intraregional transportation costs, we study the agglomeration effects from a normative point of view, so that we can study the effects of transport policies on efficiency and on regional inequalities.

From an historical perspective, we should recall that Marshall (1890) explained that "a lowering of tariffs, or of freights for the transport of goods, tends to make each locality buy more largely from a distance what it requires; and thus tends to concentrate particular industries in special localities." Indeed, during the industrial revolution, Marshall witnessed a key moment in the history of geography. As Bairoch (1997) explains, throughout the nineteenth century, transportation costs have decreased by a factor of ten, and at the very same time, inequalities between countries have emerged: the standard deviation of GDP per capita in Europe has been multiplied by 7.5. A very detailed analysis of this phenomenon is given by Lafourcade and Thisse (2011). The reduction of trade costs is one of the causes of these inequalities.

Even if Marshall (1890) had a good intuition of the relation between the reduction of transportation costs and the concentration of activities, the main contributions only began to emerge in the 1980's. Three main models have been developed to study the effect of interregional trade on industrial location. The first one has been developed by Krugman (1980) (although it is usually called the Dixit-Stiglitz-Krugman model). He sets the basis of interregional trade in an imperfect competition framework with increasing returns to scale. The second model is called the "footloose capital model", and it has been further developed by Helpman and Krugman (1985). Labor is immobile, whereas capital is mobile between the two regions. Each worker has a unit of capital he can invest in either region A or B. Defining equilibrium as the equality of returns in the two regions, they managed to highlight what they referred to as the "Home-Market Effect". This means that the share of industry in the employment of the central region is bigger than its share in the population. The last main contribution is by Krugman (1991). He analyzes which workers move between regions, and how wages are set endogenously. Workers and firms move between regions comparing their expected utilities and profits. Krugman observes that, below a certain threshold, the reduction of transportation costs will automatically lead to the concentration of all the industrial activity in one of the two regions. These three models have two points in common: first, they all find that the reduction of interregional transportation costs will increase inequalities between regions. Second, they all use the same assumption: they consider regions as dots, without spatial dimension, and in which there are no intraregional transportation costs (see Behrens and Thisse, 2007).

This last point is important, and an entire field of economics has been developed to address the spatial dimension in cities: urban economics. Many contributions have been made, but most of them were neglected by interregional trade economists. The first attempt to unify this field was the paper of Tabuchi (1998), in which the author proposes a synthesis of Alonso (1964) and Krugman (1991). Other papers have contributed to the linkage of these two growing fields. We can think of the paper by Puga (1999), where he observes that, with congestion costs, the "tomahawk curve" of Krugman (1991) becomes a bell-shaped curve.

Nonetheless, these contributions have not yet addressed an important scale: "the region". As observed by Behrens and Thisse (2007), these contributions have gone from the interregional scale to the urban scale, skipping the region. We help to fill this gap, making a difference between interregional and intraregional infrastructures. Such a distinction has already been made by several authors. Martin and Rogers (1995) use this distinction to analyze FDIs (Foreign Direct Investments) in developing countries. Using the Helpman & Krugman's (1985) frame, they observe that an improvement of the international infrastructure will motivate firms to move to developed countries, whereas an improvement of the regional infrastructure in the periphery will lead to a transfer of firms from the developed country to the developing one. These results are extended to transport infrastructures by Martin (1999) and Baldwin & al. (2003) in an endogenous growth model, and even to a three region model. In all these cases, they focus on comparative statics to understand the effects of an improvement of different kinds of infrastructures on the distribution of activities and on growth. This distinction between interregional and intraregional transportation costs can be found in other articles that use Krugman's (1991) model. Without being exhaustive, we signal the existence of papers such as Crozet & Koenig-Soubeyran (2002), Brülhart & al. (2004) or Behrens & al. (2006).

There are several empirical and historical examples of the effects of infrastructure on regional inequalities. To put things on perspective, we begin with an historical example provided by Cohen (2004). He explains that during the French colonization of Algeria, many roads were built to connect distant villages to central cities. These roads allowed firms from the center to sell their products to the villages. Far from improving the situation, these roads emptied the remote villages and increased the spatial polarization of activities. Aside from historical examples, there have been many empirical contributions to test the conclusions of economic geography models. An excellent synthesis of these contributions is provided by Redding (2010). He highlights four trends in empirical papers : (1) showing that market potential attracts firms (Head & Mayer, 2004), (2) trying to prove the existence of the home-market effect (Davis & Weinstein, 1996, 1999, 2003 ; Head & Ries, 2001, Claver & al., 2011), (3) highlighting the impact of the market potential on factor prices (Hanson, 2005 ; Mayer, 2008, Redding & Venables, 2004), and finally (4) studying the impact of trade on agglomeration (Ellison & Glaeser, 1997).

Some empirical papers have raised methodological concerns about what should be taken into account in transportation costs (Combes & Lafourcade, 2005), or about how to disentangle infrastructures' effects when more than two regions are concerned (Thisse, 2009). More precisely, several contributions have tried to measure the impact of new infrastructures on regional inequality, especially in the case of European projects (Vickerman, 1994, 1995, 2007 and Vickerman & al., 1999). However, a new trend has been to use simulations and SCGE - Spatial Computable General Equilibrium - to measure future effects of infrastructures on the localization of activity (Bröcker, 1998 ; Bröcker & Mercenier, 2011 ; Bröcker & al., 2010 ; Texeira, 2006). These contributions generally confirm the previous theoretical results, that is, interregional infrastructure will increase regional inequality, whereas intraregional infrastructure in the poorest regions reduces it.

In this article, we use the Helpman & Krugman's (1985) framework, that is, a footloose capital model. This choice can be justified in two ways. The first one concerns the hypotheses of the model. Contrary to Krugman (1991), in the Helpman & Krugman model it is supposed that workers are immobile, and capital is mobile. This assumption is, in our opinion, more credible when we investigate the case of regions/countries that do not share a common language. The second reason is a practical one. One of the main advantages of the Helpman & Krugman model is that it can be solved analytically, whereas it is not the case for Krugman (1991). These analytical results are highly useful for comparative statics, welfare analysis or recommendations for regional policies.

It is crucial to understand the various mechanisms at stake, in order to implement a transport policy taking into account the cohesion objective. Another interesting objective is the normative study of such a situation.

Indeed, is the geographical equilibrium an optimum from a Pareto point of view? Few contributions have focused on the normative point of view of the economic geography. Among these contributions, Martin (1998, 1999, 2000) analyzes the equity issues that are associated to regional policies. He observes that the improvement of regional infrastructures raises the welfare of individuals in both regions, but the level reached remains below the optimal one. Martin uses an endogenous growth model where the higher number of firms in the Core generates relatively more growth that cannot be fully corrected by regional policies. Martin is not the only one to address normative issues. Charlot & al. (2006) devote a full paper on the comparison of welfare measures to analyze the effects of agglomeration on welfare. However they use the Krugman (1991) model and they exclude the distinction between interregional and intraregional transportation costs. Fratesi (2008) also analyzes the way regional structural differences affect the trade-off between equity and efficiency in a two-country four-region model, but his contribution primarily studies the effects on growth.

In this article, we make a normative analysis of agglomeration, making a distinction between inter and intraregional transportation costs. We use a footloose capital model because of its convenient mathematical characteristics. However, the primary contribution of this paper is to address normative issues with the footloose capital model with intraregional transportation costs. The normative analysis allows us to characterize a set of regional transport policies that decentralize the welfare optimum.

This paper has two sections. In the first section, we start from an existing model of intraregional trade (Helpman and Krugman 1985), and introduce intraregional transportation costs. The intraregional costs allow to assess the effects of different transport policies on industrial location. In this section, we find the comparative statics results obtained by Martin & Rogers (1995), Martin (1999) and Baldwin & al. (2003). Our main contributions are in the second section, where we adopt a normative point of view. Using the model studied earlier, we compare the spatial equilibrium to the Pareto optimal one. We show that the geographical equilibrium is not optimal. We next examine policies like road pricing that improve the efficiency of the equilibrium. A numerical example with transport policies for African countries illustrates the model. In a final part of the paper, we draw some conclusions. Detailed mathematical proofs of the propositions are relegated to the appendixes.

2. A theoretical model to study the impact of interregional and intraregional transportation costs on industrial location

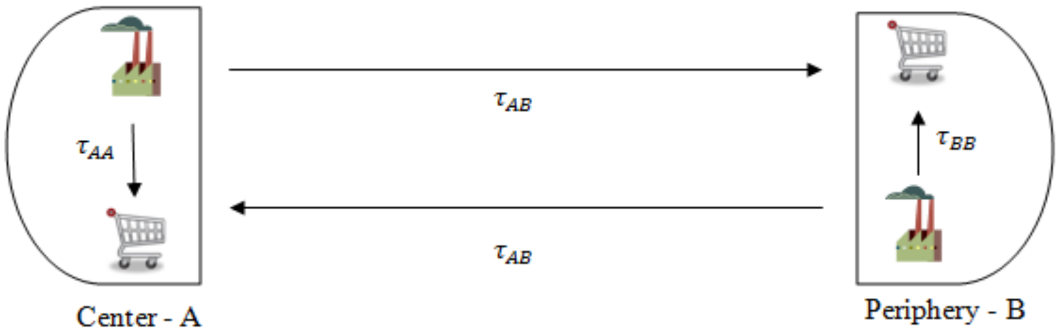
2.1. Description of the model

Most previous models in Economic Geography have not addressed intraregional transportation costs. One exception is the model developed by Martin and Rogers (1995), in which they make a distinction between international and domestic trade costs. However, they do not use a normative framework to understand the impact of intraregional trade costs, i.e., they do not look for efficiency improving policies.

In this paper, we add to Helpman and Krugman's model (1985) of intraregional transportation costs. The advantage of this model is that it has an analytical solution, which is not the case in the Krugman (1991) model. Our reasoning is similarto that proposed by Martin and Rogers (1995), and extended by Martin (1999) and Baldwin & al. (2003) in an endogenous growth model, although we adjust the mathematical notations.

We consider 2 regions: A (the center) and B (the periphery), where A has a bigger share of the population. In each region, there are two sub-regions: factories on one side and houses (with shops) on the other side.

Figure 1. Structure of the regions and transportation costs



The structure of these regions allows us to have intraregional as well as interregional transportation costs.

2.2. Main Assumptions

Before solving the equilibrium, we need some assumptions. We consider a model of two regions: the center and the periphery. In the economy, there are L workers. A share θ of the workers are in the central region, with $\theta \geq 1/2$. In this model there are two kinds of factors: labor which is immobile and capital which is mobile, all members of the population own one unit of capital. As in Helpman and Krugman (1985), wages in the two regions are set to 1: $w_A = w_B = 1$.

More precisely, we define the different unit transportation costs within regions (AA, BB) and between regions (AB, BA). The intraregional transportation costs are given by τ_{AA} and τ_{BB}, whereas interregional ones are given by $\tau_{AB} = \tau_{BA}$.

We suppose that the intraregional transportation costs are more important in the poor region (given the low quality of transport infrastructure) than in the rich region. Moreover, we assume that interregional transportation costs are much higher than intraregional ones. We then have the following inequality:

$$(1)\ \tau_{BA} = \tau_{AB} > \tau_{BB} > \tau_{AA}..$$

2.3. Equilibrium

The objective of this model is to determine the value of λ, which is the share of the industry located in the central region. As labor is immobile, intraregional commuting costs do not affect the location of production. We focus then on transportation costs. To obtain the value λ we must first specify some elements concerning production and demand.

2.3.1. Production

The cost function of a firm is defined as $C(q) = f\ r(\lambda) + cq$, so that there are increasing returns. Each firm needs f units of capital and each of the L workers have a unit of capital. All firms have the same cost function and produce each a different variety. Denote by λ the share of the capital invested in A, Since capital is perfectly mobile between the two regions, the number of firms in regions A and B are:

$$(2)\ n_A = \frac{\lambda L}{f} \text{ and } n_B = \frac{(1-\lambda)L}{f}.$$

Given that we have assumed that capital is mobile, the spatial equilibrium is defined by the equalization of returns :

$$r_A(\lambda^*) = r_B(\lambda^*) = r(\lambda^*).$$

The returns are spent in the region of the owner. We obtain the value of the income of each region:

$$(3)\ Y_A = [1 + r(\lambda)]\theta L \quad and \quad Y_B = [1 + r(\lambda)](1-\theta)L.$$

Without iceberg transportation cost, the profit equation for a representative firm i is given by $\pi_i = p_i q(p_i) - fr(\lambda) - cq(p_i)$. Profit maximization leads to the equilibrium price $p_i\left(1-\frac{1}{\varepsilon_i}\right)=c$, where $\varepsilon_i=-\frac{\partial q_i}{\partial p_i}\frac{p_i}{q_i}$. With the utility function defined in the Section 2.3.2, we have: $\varepsilon_i=\sigma$, where σ is the elasticity of substitution between varieties.

We now introduce iceberg transportation costs as the percentage of the good that is lost because of transportation costs. If we want to receive a quantity q of a product, it will be necessary to ship τq of the product, with $\tau>1$. We then infer the price p_{lm}, paid by a consumer living in the region *m*, and purchasing a product made in region *l* :

$$(4)\quad p_{lm}=\tau_{lm}p_i=\frac{\tau_{lm}c\sigma}{\sigma-1} \text{ where } l=A,B \text{ and } m=A,B,$$

where τ_{lm} represents the iceberg cost.

2.3.2. Demand

As in the Dixit-Stiglitz-Krugman model, we have the following utility function: $U=M^{\mu}A^{1-\mu}$ where μ, the part of the income spent on the composite good, is such that $\mu<1$. M is the composite good produced by the industry and A is the numeraire good. This numeraire good can be transported without cost between regions and every unit of labor that is not used to produce the industrial goods can generate one unit of the numeraire good. This allows us to set the price of the numeraire good and the wage equal to 1 in both regions, as in Krugman's model. The share of revenue dedicated to the composite good is μY_m, where Y_m is the total income in region m. Maximizing $\mathcal{L}=M+\lambda(\mu Y_m-q_{lm}(i)\tau_{lm}p_i)$, we obtain the demand for a variety i, made in l and consumed in m :

$$(5)\quad q_{lm}(i)=\frac{(\tau_{lm}p_i)^{-\sigma}}{\sum_j(\tau_{lm}p_j)^{-(\sigma-1)}}\mu Y_m, \text{where } l=A,B \text{ and } m=A,B.$$

Throughout the remainder of this paper, we use the notation: $\boldsymbol{\phi_{lm}=\tau_{lm}}^{-(\sigma-1)}$. We observe that ϕ_{lm} takes a value between 0 and 1, if $\sigma>1$. When ϕ_{lm} is near 1, there are low barriers for trade.

We add some assumptions on the values of ϕ :

(6) $\phi_{AA} > \phi_{BB} > \phi_{AB} = \phi_{BA}$ which is another way to write (1) and

(7) $1-\theta > \dfrac{\phi_{AB}}{\phi_{BB}}$.

The first hypothesis is the transportation cost inequality written in terms of ϕ. The second assumption is needed to ensure that the share of industry in the region belongs to [0,1]. In other words, this assumption implies that interregional transportation costs must be much higher than the intraregional ones. This assumption seems reasonable.

The total demand for the variety i produced in A is given by the sum of the demand for this variety by the region A and by the region B. The revenues in (5) refer to (3). Since the prices are given by the (4) and the number of firms by (2), we find:

(8) $$q_A^i(\lambda) = \frac{\mu(\sigma-1)}{c\sigma}\left(\frac{\phi_{AA}(1+r_A(\lambda))\theta L}{\phi_{AA}\lambda L + \phi_{AB}(1-\lambda)L} + \frac{\phi_{AB}(1+r_B(\lambda))(1-\theta)L}{\phi_{AB}\lambda L + \phi_{BB}(1-\lambda)L}\right).$$

The first part of this equation is the demand for the variety from the consumers of the region A, whereas the second part is the demand from the consumers of region B

2.3.3. Determining the equilibrium

In the long term, the profits are just high enough to cover the cost of the capital. So the profit of the firm, producing variety i in region A is:

(9) $$\Pi_A(i) = p_{AA}^*(i)q_{AA}(i) + p_{AB}^*(i)q_{AB}(i) - c\left[\tau_{AA}q_{AA}(i) + \tau_{AB}q_{AB}(i)\right] - fr(\lambda) = 0$$

Let us define the aggregate production as $q_A(i) = \tau_{AA}q_{AA}(i) + \tau_{AB}q_{AB}(i)$. Then we have:

(10) $$r_A(\lambda) = \frac{cq_A(i)}{f(\sigma-1)},$$

which can, using the demand functions defined by (7), also be written as:

$$(11)\quad r_A(\lambda) = \frac{\mu}{\sigma f}\left(\frac{\phi_{AA}\left(1+r_A(\lambda)\right)\theta}{\phi_{AA}\lambda + \phi_{AB}(1-\lambda)} + \frac{\phi_{AB}\left(1+r_B(\lambda)\right)(1-\theta)}{\phi_{AB}\lambda + \phi_{BB}(1-\lambda)} \right).$$

Symmetrically, we find $r_B(\lambda)$:

$$(12)\quad r_B(\lambda) = \frac{\mu}{\sigma f}\left(\frac{\phi_{AB}\left(1+r_A(\lambda)\right)\theta}{\phi_{AA}\lambda + \phi_{AB}(1-\lambda)} + \frac{\phi_{BB}\left(1+r_B(\lambda)\right)(1-\theta)}{\phi_{AB}\lambda + \phi_{BB}(1-\lambda)} \right).$$

The spatial equilibrium is obtained when the returns in the two zones are identical. Therefore we are looking for the λ value such that r_A and r_B are equal:

$$\frac{\phi_{AA}\theta}{\phi_{AA}\lambda + \phi_{AB}(1-\lambda)} + \frac{\phi_{AB}(1-\theta)}{\phi_{AB}\lambda + \phi_{BB}(1-\lambda)} = \frac{\phi_{AB}\theta}{\phi_{AA}\lambda + \phi_{AB}(1-\lambda)} + \frac{\phi_{BB}(1-\theta)}{\phi_{AB}\lambda + \phi_{BB}(1-\lambda)} .$$

After simplifications, we find λ (the share of industry in the central region):

$$(13)\quad \lambda = \frac{\Psi}{\left(\boldsymbol{\phi_{AA}} - \boldsymbol{\phi_{AB}}\right)\left(\boldsymbol{\phi_{AB}} - \boldsymbol{\phi_{BB}}\right)},$$

where $\Psi = (1-\theta)\left(\phi_{BB} - \phi_{AB}\right)\phi_{AB} + \theta\left(\phi_{AB} - \phi_{AA}\right)\phi_{BB}$.

Proposition 1: If the interregional transportation cost is sufficiently large, compared to the intraregional cost ($\boldsymbol{\phi_{BB}}(1-\theta) \geq \boldsymbol{\phi_{AB}}$), then there exists a unique interior equilibrium where the industrial activity is shared between the two regions ($\lambda \in [0,1]$). If the interregional cost is too low ($\boldsymbol{\phi_{BB}}(1-\theta) < \boldsymbol{\phi_{AB}}$), then there is a corner solution and all industrial activity is in the center ($\lambda = 1$).

The proof of this proposition is relegated to Appendix 1.

2.4. Comparative statics

One of the advantages of building our model on Helpman and Krugman (1985) is that we have an analytical solution for the equilibrium, which allows for comparative statics. Indeed, we wish to know the effects of improving the different types of infrastructure on the industrial location patterns.

In this part, we modify the quality of a specific type of road and we evaluate its impact on the distribution of industrial activity. We assume that the funds (and resources) for the realization of this infrastructure are external. For instance, the funds could come from an international development agency (World Bank) or be part of a federal effort to help peripheral regions (Regional investment Fund in the EU). In Appendix 2 we prove the following proposition.

Proposition 2: Both the improvement of the quality of interregional infrastructure and the reduction of intraregional transportation costs in the center lead to a higher concentration of industries in the center. However, lowering the peripheral intraregional transportation costs increases the attractiveness of the periphery for firms.

Proposition 2 can be explained using the notion of market potential. As it was defined by Harris (1954), and then extended by Head and Mayer (2004), the market potential is like a weighted sum of the different potential sales on the national market and the surrounding markets where a firm would like to export its product. The weights are inversely proportional to the trade costs.

Since the center is bigger than the periphery, it naturally has a higher market potential, which attracts firms. Reducing the interregional transportation costs will increase the market potential of the center, because central firms will have better access to the periphery. Due to increasing returns, firms seek to move to the center. The reasoning is the same with intraregional transportation cost in the center. However, a decrease of the intraregional transportation cost in the periphery will increase the weight of the periphery in its market potential. The market potential of the periphery will then increase, and will consequently attract firms that will relocate from the center to the periphery. We reach the same conclusion as Martin & Rogers (1995), Martin (1999) and Baldwin & al. (2003).

3. Is this equilibrium efficient and can we improve it?

In this section, we first look for the efficiency benchmark: what geographical distribution of industrial activity maximizes the sum of utilities in the two regions. The equilibrium we described in the previous section is then compared to the benchmark. Next we look for policies that could bring the equilibrium closer to the efficiency benchmark.

3.1. Computation of the indirect utility functions in the two regions

In order to maximize overall efficiency, we need an analytical expression for the utility in both regions. Recall that: $U = M^{\mu} A^{1-\mu}$, where $\mu < 1$. Moreover, since A is the numéraire, the budget constraint reduces to: $P.M + A = 1$. Substituting into the utility function, we obtain: $U = M^{\mu}(1 - PM)^{1-\mu}$.

Maximizing the utility with respect to M, and injecting the optimal value of M in the utility function, we obtain the indirect utility function:

$$(14) \quad \tilde{V} = \frac{\mu^{\mu}\left(1-\mu\right)^{(1-\mu)}}{P^{\mu}}.$$

Moreover, we know that maximizing $\tilde{V}$ is equivalent to maximizing any increasing transformation of $\tilde{V}$. We rely on the following indirect utilities in this section:

$$(15) \quad V_A = P_A^{-\mu} \text{ and } V_B = P_B^{-\mu}.$$

In the new economic geography literature, the price index in the region A is given by:

$$(16)\quad P_A = \frac{c\sigma}{\sigma-1}(\phi_{AA}n_A + \phi_{AB}n_B)^{\frac{-1}{\sigma-1}}.$$

Using (2) for the number of firms, we obtain (17), which can be rewritten as (18):

$$(17)\quad P_A = \frac{c\sigma}{\sigma-1}\left(\phi_{AA}\frac{\lambda L}{f} + \phi_{AB}\frac{(1-\lambda)L}{f}\right)^{\frac{-1}{\sigma-1}},$$

or

$$(18)\quad P_A = K\left(\phi_{AA}\lambda + \phi_{AB}\left(1-\lambda\right)\right)^{\alpha},$$

where $K = \frac{c\sigma}{\sigma-1}\left(\frac{L}{f}\right)^{\frac{-1}{\sigma-1}}$ and $\alpha = \frac{-1}{\sigma-1}$.

We then have the indirect utility functions for an agent living in A (V_A) and in B (V_B) :

$$(19)\quad V_A = K^{-\mu}(\phi_{AA}\lambda + \phi_{AB}(1-\lambda))^{-\alpha\mu},$$

and

$$(20)\quad V_B = K^{-\mu}(\phi_{AB}\lambda + \phi_{BB}(1-\lambda))^{-\alpha\mu}.$$

3.2. Maximization of the total welfare in the economy

We start by looking for the maximum of the unweighted sum of utilities in the two regions. Since utility in our formulation is expressed as real income (see (15)), in our formulation social welfare is equivalent to real national income. Using the sum of utilities as a societal objective can then be justified in two ways. First, one can allow for lump sum redistributive transfers (of real income) by a federal government. Second, one can see the maximization of utilities as the basis for an efficient bargaining between the two regions where the two regions share the gains of a better equilibrium via transfers amoong themselves.

Charlot et al (2006) examine the normative ranking of the stable concentration and dispersion equilibriums in the Krugman model and show that these, in general, cannot be ranked unambiguously. The main problem they identify is that there are three different types of individuals that are important for the equity dimension: the immobile unskilled in the two regions, and also the mobile skilled individual. For one equilibrium to be better than another, one requires that all three types gain. Our setting is simpler: the returns of our mobile factor (capital) are shared equally among all unskilled individuals in the two regions. In our case we only have to compare the real income of the unskilled in both regions. Of course, one can object to a policy prescription that maximizes a simple sum of real incomes. This is a valid objection when no redistribution is possible between regions or when one objects against the interpersonal utility comparison as such. We show later (cf. Section 3.3) how a higher weight for the poorer region affects the results.

Since a share θ of the population is in the center (and $1-\theta$ in the periphery), the welfare function in the economy is then given by:

$$\tilde{W} = \theta V_A + \left(1-\theta\right) V_B,$$

$$\tilde{W} = \theta \left[K^{-\mu} \left(\phi_{AA}\lambda + \phi_{AB}\left(1-\lambda\right)\right)^{-\alpha\mu} \right] + \left(1-\theta\right)\left[K^{-\mu}\left(\phi_{AB}\lambda + \phi_{BB}\left(1-\lambda\right)\right)^{-\alpha\mu}\right].$$

We look for the value λ^o that maximizes the welfare function:

$$\max_{\lambda} \tilde{W} \Leftrightarrow \max_{\lambda}\left\{ W = \theta\left[\left(\phi_{AA}\lambda + \phi_{AB}\left(1-\lambda\right)\right)^{-\alpha\mu}\right] + \left(1-\theta\right)\left[\left(\phi_{AB}\lambda + \phi_{BB}\left(1-\lambda\right)\right)^{-\alpha\mu}\right]\right\}.$$

The first order condition gives us the following value:

$$(21)\quad \lambda^o = \frac{\zeta\phi_{BB} - \phi_{AB}}{\zeta\phi_{BB} - \phi_{AB} + \phi_{AA} - \zeta\phi_{AB}},$$

where $\zeta = \left[\dfrac{\left(1-\theta\right)\left(\phi_{BB}-\phi_{AB}\right)}{\theta\left(\phi_{AA}-\phi_{AB}\right)}\right]^{\frac{-1}{\alpha\mu+1}}$.

We note that $1-\theta<\zeta<1$, and as a consequence, $\lambda^o\in[0,1]$. The proof of these properties is relegated to Appendix 3.

3.3. Comparison of the optimal and equilibrium values of the shares in industrial activity

The question here is whether the concentration in the center is too high when the regulator does not intervene. To answer this question, we must compare the equilibrium value λ^{Eq} and the optimal value λ^o. Recall that:

$$\lambda^{Eq}=\frac{\theta\phi_{BB}}{\phi_{BB}-\phi_{AB}}+\frac{\theta\phi_{AB}-\phi_{AB}}{\phi_{AA}-\phi_{AB}},$$

and that :

$$\lambda^o=\frac{\zeta\phi_{BB}}{\phi_{AA}-\phi_{AB}+\zeta\left(\phi_{BB}-\phi_{AB}\right)}+\frac{-\phi_{AB}}{\phi_{AA}-\phi_{AB}+\zeta\left(\phi_{BB}-\phi_{AB}\right)}.$$

After some calculations (see Appendix 5), it can be shown that $\lambda^{Eq}>\lambda^o$. The results are summarized in:

Proposition 3: At equilibrium, when intraregional transport costs are higher in the periphery than in the core, and interregional costs are higher than intraregional costs, the spatial concentration of industrial activity in the center is too high compared to the first best optimum.

That the spatial equilibrium leads to a higher concentration than the first best optimum can be easily understood. In fact, without any intervention, there is a kind of "magnet effect", which highlights the "Home-Market Effect" explained by Krugman (1980) and Helpman & Krugman (1985). Since the core is bigger than the periphery, its market potential is higher. Due to increasing returns and transportation costs, firms have interest in settling in the core because they will reach more clients while minimizing their shipping costs. By maximizing their individual profit, firms do not take into account their impact on consumers, such that the concentration of the industrial activity in the center is too high compared to the first best optimum.

We have supposed earlier that all citizens should be weighted equally. What would be the effect on Proposition 3 if one gave a higher weight to peripheral citizens, resulting in no lump sum redistribution possible or no efficient bargaining between the two regions?

Proposition 4 : When a higher weight is given to peripheral citizens, the value of the optimal share of industry in the core decreases.

Proof of this proposition is given in Appendix 4 where it is shown that a higher weight to peripheral citizens decreases the value of the optimal share of industry in the center. This is obvious since, giving a higher importance to peripheral citizens, a lower concentration of firms in the center reduces the price index in the periphery and increases the welfare of peripheral citizens.

In order to improve the total welfare, the concentration of firms in the center must be reduced. This means that the government must intervene so as to favor the transfer of firms from the center to the periphery.

3.4. Policies to reach the optimal location : the role of road pricing

In order to decentralize the social optimum λ^o, we will use a set of incentives. In principle one could use different instruments; the regulator could tax the firms in the center and/or subsidize the firms in the periphery. Here, we focus on instruments that tax or subsidize the use of transport infrastructures. This can be understood as a form of road pricing or as a shadow cost used to compute the optimal size of different transport infrastructures. These incentives will allow us to match λ^o and λ^{Eq}. We note that we do not focus on the use of the taxes collected. We fully understand that such taxes may create distortions on other markets, such that we may obtain a second-best optimum. However, we remind the reader that the public policy objective here is only to implement a sound spatial distribution of activities, and determine the set of public policies to do so.

We must tax the use of the interregional road, tax the use of the intraregional road in the center and/or subsidize the use of the intraregional road in the periphery. What remains to be determined is the precise value of these taxes or subsidies.

3.4.1. Taxation of the use of the interregional road

We seek to tax the interregional infrastructure. This is equivalent to reducing the value of ϕ_{AB}, which is the "freeness of trade". To do this, we will look for the value t such that $\tilde{\phi}_{AB} = \phi_{AB} - t_{AB}$. We seek to reach the value λ^o, so we look for t that solves :

$$\frac{(1-\theta)\left(\phi_{BB} - \tilde{\phi}_{AB}\right)\tilde{\phi}_{AB} + \theta\left(\tilde{\phi}_{AB} - \phi_{AA}\right)\phi_{BB}}{\left(\phi_{AA} - \tilde{\phi}_{AB}\right)(\tilde{\phi}_{AB} - \phi_{BB})} = \lambda^o .$$

After some calculations, and after solving for the polynomial function in $\tilde{\phi}_{AB}$, we find :

$$\text{(22)} \quad \tilde{\phi}_{AB} = \frac{1}{2(\theta + \lambda^o - 1)}\left[\lambda^o\phi_{AA} + (\lambda^o - 1)\phi_{BB} - \sqrt{\begin{matrix}\left((1-\lambda^o)^2\phi_{BB} - \lambda^o\phi_{AA}\right)^2 \\ -4\phi_{AA}\phi_{AB}(\lambda^o - \theta)(\lambda^o + \theta - 1)\end{matrix}}\right]$$

Two remarks are in order:

Remark 1: From $\tilde{\phi}_{AB}$, we can determine the value of t_{AB}.

Remark 2: Reducing the value of ϕ_{AB} to $\phi_{AB} - t$ is equivalent to increasing the iceberg cost from τ_{AB} to $\tau_{AB} + k$. The value of k is then given by the following expression:

$$k = \left(\phi_{AB} - t_{AB}\right)^{\frac{1}{1-\sigma}} - \tau_{AB}.$$

3.4.2. Taxation of the use of intraregional infrastructure in the center

We wish to tax the use of intraregional infrastructure in the center. This is equivalent to reducing the value of ϕ_{AA}, which is the "freeness of trade". To do this, we look for the value t such that $\phi'_{AA} = \phi_{AA} - t_{AA}$. We wish to reach the value λ^o, so we look for t that solves:

$$\frac{(1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB} + \theta\left(\phi_{AB} - \phi'_{AA}\right)\phi_{BB}}{\left(\phi'_{AA} - \phi_{AB}\right)(\phi_{AB} - \phi_{BB})} = \lambda^o.$$

After some calculations, and after solving for the polynomial function in ϕ'_{AA}, we find:

$$\text{(23)}\quad \phi'_{AA} = \phi_{AB} + \frac{(1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB}}{\lambda^o(\phi_{AB} - \phi_{BB}) + \theta\phi_{BB}}.$$

The above remarks become:

Remark 1: From ϕ'_{AA}, we can deduce the value of t_{AA}.

Remark 2: Reducing the value of ϕ_{AA} to $\phi_{AA} - t$ is equivalent to increasing the iceberg cost from τ_{AA} to $\tau_{AA} + k$. The value of k is then given by the following expression:

$$k = \left(\phi_{AA} - t\right)^{\frac{1}{1-\sigma}} - \tau_{AA}.$$

3.4.3. Subsiding of the use of the intraregional road in the periphery

We want to subsidize the use of the intraregional infrastructure in the periphery. This is equivalent to increasing the value of ϕ_{BB}, which is the "freeness of trade". To do this, we will look for the value of the subsidy s such that $\phi'_{BB} = \phi_{BB} + s_{BB}$.

We wish to reach the value λ^o, so we look for ϕ'_{BB}, that solves:

$$\frac{(1-\theta)\left(\hat{\phi}_{BB}-\phi_{AB}\right)\phi_{AB}+\theta\left(\phi_{AB}-\phi_{AA}\right)\hat{\phi}_{BB}}{\left(\phi_{AA}-\phi_{AB}\right)(\phi_{AB}-\hat{\phi}_{BB})}=\lambda^{o}.$$

After some calculations, we obtain:

$$(24)\quad \hat{\phi}_{BB}=\frac{\lambda^{o}\phi_{AA}\phi_{AB}+\phi_{AB}^{2}(1-\theta-\lambda^{o})}{(1-\lambda^{o})\phi_{AB}+(\lambda^{o}-\theta)\phi_{AA}}.$$

Two remarks are in order. First, from $\hat{\phi}_{BB}$, we can deduce the value of s_{BB}. Second, it is the case that increasing the value of ϕ_{BB} to $\phi_{BB}+s$ is equivalent to reducing the iceberg cost from τ_{BB} to $\tau_{BB}-k$. The value of k is then given by the following expression:

$$k=\tau_{BB}-\left(\phi_{BB}+s_{BB}\right)^{\frac{1}{1-\sigma}}.$$

We have developed a set of incentives such that the equilibrium will be the optimal one. To do this, we focused on road pricing. One can reach the optimum in three different ways: taxing the use of the interregional infrastructure; taxing the use of the intraregional infrastructure in the center or subsidizing the use of the intraregional infrastructure in the periphery. Note that subsidizing the intraregional infrastructure in the periphery does not mean building a road. Indeed, the creation of the infrastructure is costly, while a subsidy is in principle a mere transfer of resources that corrects incentives and is not consuming real resources (except for the transaction costs). We illustrate our model below with a numerical example.

3.4.4. A numerical example: Mozambique and Malawi

In order to illustrate the mechanisms of the model, we use a numerical example. We use data on interregional and intraregional transportation costs for road transport from UNCTAD (2004). In their report, they calculate very accurate values for transportation costs in Africa. We take the example of two countries, instead of two regions. This choice is mainly due to the availability of data, and does not affect the assumptions and results. The two selected countries are Mozambique (the center) and Malawi (the periphery).

First, we calibrate our model. To do so, we match real data with the various parameters used in the model. Table 1a displays values for the central country, whereas Table 1b does for the periphery.

Table 1a. Numerical values for the parameters of Mozambique

Region A – The core	**Mozambique**
Population	**19M**
Share of the population θ	**0.6**
Infrastructure quality index	**23.1**
ϕ_{AA}	**0.9**

Table 1b. Numerical value for the parameters of Malawi

Region B – The Periphery	**Malawi**
Population	**13M**
Share of the population $1-\theta$	**0.4**
Infrastructure quality index	**20.4**
ϕ_{BB}	**0.79**

Once these parameters have been calibrated, we must set the values of other parameters, that are not always known (for instance σ). Others, like the interregional transportation cost, can be found in UNCTAD (2004) .

Table 2. Other parameters to run the simulation

Other parameters	
w (wage)	**1**
σ (elasticity of substitution)	**6**
Share of transport cost in the price of goods sold in the other region	**22%**
Iceberg cost τ_{AB}	**1.28**
ϕ_{AB}	**0.29**
μ	**0.6**

Note that several values have been tested for the elasticity of substitution, and they do not change dramatically the results. We can now compute the spatial equilibrium and the spatial optimum. It is interesting to note that the simulated spatial equilibrium ($\lambda = 0.75$) is very close to the real value ($\lambda = 0.74$).

Table 3. Spatial equilibrium and spatial optimum

Spatial equilibrium and optimum	
Spatial equilibrium λ^{Eq}	**0.75**
Intermediate parameter ζ	**1.59**
Optimal concentration λ^{o}	**0.69**

As predicted by Proposition 3, there is a significant difference between the spatial equilibrium and the optimal concentration. The next step is to calculate the values of the different taxes or subsidies to reach the optimal concentration.

Table 4. Optimal taxes and subsidies on use of infrastructure to reach the optimum and their impact on the transportation costs.

Road pricing to reach the equilibrium

Optimal ϕ_{AA}	**0.74**
Optimal tax t_{AA}	**0.16**
Optimal ϕ_{AB}	**0.20**
Optimal tax t_{AB}	**0.09**
Optimal ϕ_{BB}	**0.91**
Optimal subsidy s_{BB}	**0.12**

From these new values of transportation costs, we can deduce the impact on the product prices:

Table 5. Impact of taxes on transportation costs

Share of the transport cost in the price of a shipped product	**Before tax**	**After tax**
Interregional	**22%**	**27%**
Intraregional in the center	**2%**	**6%**
Intraregional in the periphery	**4%**	**2%**

This numerical example illustrates the different values predicted by our model. The values of the various taxes or subsidies are realistic, and these numerical simulations confirm that the predictions of our model are in agreement with theoretical results. At equilibrium, the concentration of activities in the center is too large and the use of interregional road taxes can restore the optimum.

CONCLUSION

The regional science literature has studied the impact of transportation costs on the geographical distribution of activities,. In contrast, this paper is among the first to analyze the specific roles of interregional and intraregional transport costs from a normative point of view.

Several conclusions can be drawn from this paper. First, the improvements of the different categories (interregional/intraregional) of infrastructures have different effects on industrial location. We confirm the analysis of Martin and Rogers (1995), Martin (1999) and Baldwin & al. (2003): if the decision maker wishes to use transport policy to reduce regional inequalities, then s/he must improve the quality of the peripheral intraregional infrastructure. The second conclusion follows from the normative analysis. Indeed, we show that the spatial equilibrium is far from being Pareto optimal. Without any intervention, the spatial equilibrium will lead to a concentration of firms in the center that is too high. The third result is that it is possible to use tax and subsidy instruments such as road pricing to reach the optimal share of firms in the center.

This model may be improved in several ways. First, it was designed in such a way that interregional and intraregional transportation costs were independent. In reality, intraregional infrastructures may affect directly the interregional transportation costs. These network effects must be taken into account to obtain a more realistic view of the effects of infrastructures on industrial location. Second, the introduction of congestion costs within regions may yield interesting results. As explained by Lafourcade and Thisse (2011), congestion costs moderate the spatial polarization of activities. In our model, they would affect strongly the optimal taxes and subsidies. With these improvements, future research will allow a better understanding of the dynamics of spatial activities.

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Appendix 1. Proof of Proposition 1

We want to prove that if $\phi_{AB} < (1-\theta)\phi_{BB}$, then $\lambda \in [0,1]$

Proof of $\lambda > 0$

We know that: $(\phi_{AA} - \phi_{AB})(\phi_{AB} - \phi_{BB}) < 0$. If $\lambda > 0$, then we must have $\Psi \leq 0$. We use proof by contradiction. If $\Psi > 0$, then we have

$$\Psi = (1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB} + \theta(\phi_{AB} - \phi_{AA})\phi_{BB} > 0$$
$$\Leftrightarrow (1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB} > \theta(\phi_{AA} - \phi_{AB})\phi_{BB}.$$

Since $1-\theta < \theta$ and $\phi_{BB} - \phi_{AB} < \phi_{AA} - \phi_{AB}$ and since $\phi_{AB} < \phi_{BB}$, the previous line cannot be true. Thus, $\Psi \leq 0$, so that $\lambda \geq 0$.

Proof of $\lambda < 1$

We know that $(\phi_{AA} - \phi_{AB})(\phi_{AB} - \phi_{BB}) < 0$. If $\lambda \leq 1$, then we must have :

$$(1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB} + \theta(\phi_{AB} - \phi_{AA})\phi_{BB} > (\phi_{AA} - \phi_{AB})(\phi_{AB} - \phi_{BB})$$
$$\Leftrightarrow (1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB} + (\phi_{AB} - \phi_{AA})[\theta\phi_{BB} + \phi_{AB} - \phi_{BB}] > 0.$$

Since $(1-\theta)(\phi_{BB} - \phi_{AB}) > 0$ and $(\phi_{AB} - \phi_{AA}) < 0$, we must have $\theta\phi_{BB} + \phi_{AB} - \phi_{BB} < 0$, which is true if $\phi_{AB} < (1-\theta)\phi_{BB}$.

Proof that if $\phi_{AB} > (1-\theta)\phi_{BB}$, then $\lambda > 1$

We know that: $(\phi_{AA} - \phi_{AB})(\phi_{AB} - \phi_{BB}) < 0$. If $\lambda > 1$, then we must have:

$$(1-\theta)(\phi_{BB} - \phi_{AB})\phi_{AB} + \theta(\phi_{AB} - \phi_{AA})\phi_{BB} < (\phi_{AA} - \phi_{AB})(\phi_{AB} - \phi_{BB})$$
$$\Leftrightarrow (\phi_{BB} - \phi_{AB})(\phi_{AA} - \theta\phi_{AB}) < \theta(\phi_{AA} - \phi_{AB})\phi_{BB}.$$

Since $\phi_{AB} > (1-\theta)\phi_{BB}$, then $-\phi_{AB} < (\theta - 1)\phi_{BB}$, so that we have

$$(\phi_{BB} - \phi_{AB})(\phi_{AA} - \theta\phi_{AB}) < \theta\phi_{BB}(\phi_{AA} - \theta\phi_{AB}).$$

Moreover, we note that: $\phi_{AA} - \theta\phi_{AB} < \theta\left(\phi_{AA} - \phi_{AB}\right)$. Thus,we conclude that: $\left(\phi_{BB} - \phi_{AB}\right)\left(\phi_{AA} - \theta\phi_{AB}\right) < \theta\left(\phi_{AA} - \phi_{AB}\right)\phi_{BB}$, which implies that if $\phi_{AB} > \left(1-\theta\right)\phi_{BB}$, then $\lambda > 1$.

Appendix 2. Proof of Proposition 2

Impact of $\boldsymbol{\phi_{AB}}$: Improving the quality of the interregional infrastructure is equivalent to an increase in ϕ_{AB}.

$$\frac{\partial\lambda}{\partial\phi_{AB}} = \frac{\left[\left(1-\theta\right)\left(\phi_{BB} - 2\phi_{AB}\right) + \theta\phi_{BB}\right]\left(\phi_{AA} - \phi_{AB}\right)\left(\phi_{AB} - \phi_{BB}\right) - \Psi[\phi_{AA} + \phi_{BB} - 2\phi_{AB}]}{\left[\left(\phi_{AA} - \phi_{AB}\right)\left(\phi_{AB} - \phi_{BB}\right)\right]^2}$$

We have $\frac{\partial\lambda}{\partial\phi_{AB}} > 0$,if the condition $\frac{\phi_{AA}}{\phi_{AB}} > 2\theta$ is respected (which always holds underour assumptions). Using this hypothesis, we observe that the improvement of the infrastructure between regions will strengthen the concentration in the center.

Impact of $\boldsymbol{\phi_{AA}}$ **:** We measure the effects of an improvement of infrastructures in the center. We anticipate that it will lead to a higher concentration in the center.

$$\frac{\partial\lambda}{\partial\phi_{AA}} = \frac{-\theta\phi_{BB}\left[\phi_{AA} - \phi_{AB}\right]\left[\phi_{AB} - \phi_{BB}\right] - [\phi_{AB} - \phi_{BB}]\Psi}{\left[\left(\phi_{AA} - \phi_{AB}\right)\left(\phi_{AB} - \phi_{BB}\right)\right]^2}$$

We obtain $\frac{\partial\lambda}{\partial\phi_{AA}} > 0$. As anticipated, we conclude that the higher quality of infrastructure in the center will increase the concentration.

Impact of ϕ_{BB} : Since the other actions on infrastructures have led to a higher concentration, we anticipate that the reduction of transport costs in the periphery will lead to a reduction of the concentration in the center.

$$\frac{\partial\lambda}{\partial\phi_{BB}} = \frac{\left[(1-\theta)\phi_{AB}+\theta\left(\phi_{AB}-\phi_{AA}\right)\right]\left[\phi_{AA}-\phi_{AB}\right]\left[\phi_{AB}-\phi_{BB}\right]+[\phi_{AA}-\phi_{AB}]\Psi}{\left[\left(\phi_{AA}-\phi_{AB}\right)\left(\phi_{AB}-\phi_{BB}\right)\right]^{2}}$$

We find that $\frac{\partial\lambda}{\partial\phi_{BB}}<0$ if we have $\phi_{AB}>\theta\phi_{AA}$ (which holds under our hypotheses) .The better quality of infrastructure in the periphery will lead to a relocation of firms from the center to the periphery.

Appendix 3. Remarks concerning the value of ζ

First, we want to show that $0<\zeta<1$.

We can rewrite ζ as:

$$\zeta=\left[\frac{(1-\theta)\left(\phi_{BB}-\phi_{AB}\right)}{\theta\left(\phi_{AA}-\phi_{AB}\right)}\right]^{\frac{-1}{\alpha\mu+1}}=\left[\Omega\frac{\phi_{BB}}{\phi_{AA}}\right]^{\frac{-1}{\alpha\mu+1}}.$$

Since $0<\Omega<1$ and $\phi_{BB}<\phi_{AA}$, we conclude that $0<\zeta<1$.

Second, we want to show that $\zeta>1-\theta$.

We use proof by contradiction. Assume that $1-\theta>\zeta$,so that we must have:

$$1-\theta>\left[\frac{(1-\theta)\left(\phi_{BB}-\phi_{AB}\right)}{\theta\left(\phi_{AA}-\phi_{AB}\right)}\right]^{\frac{-1}{\alpha\mu+1}}\Leftrightarrow 1-\theta>(1-\theta)^{\frac{-1}{\alpha\mu+1}}\left[\frac{\left(\phi_{BB}-\phi_{AB}\right)}{\theta\left(\phi_{AA}-\phi_{AB}\right)}\right]^{\frac{-1}{\alpha\mu+1}}$$

$$\Leftrightarrow (1-\theta)^{\frac{1}{\alpha\mu+1}+1}>\left[\frac{\theta\left(\phi_{AA}-\phi_{AB}\right)}{\left(\phi_{BB}-\phi_{AB}\right)}\right]^{\frac{1}{\alpha\mu+1}}.$$

Since $\frac{1}{\alpha\mu+1}=\frac{\sigma-1}{\sigma-1-\mu}$ and since $0<1-\theta<1$ we then have :

$$(1-\theta)^{\frac{1}{\alpha\mu+1}}>(1-\theta)^{\frac{1}{\alpha\mu+1}+1}.$$

We can then rewrite the inequality:

$$(1-\theta)^{\frac{1}{\alpha\mu+1}}>\left[\frac{\theta\left(\phi_{AA}-\phi_{AB}\right)}{\left(\phi_{BB}-\phi_{AB}\right)}\right]^{\frac{1}{\alpha\mu+1}}\Leftrightarrow 1-\theta>\frac{\theta\left(\phi_{AA}-\phi_{AB}\right)}{\left(\phi_{BB}-\phi_{AB}\right)}\Leftrightarrow 1>\frac{\theta\left(\phi_{AA}-\phi_{AB}\right)}{\left(1-\theta\right)\left(\phi_{BB}-\phi_{AB}\right)},$$

which is false. Thus, must have $1-\boldsymbol{\theta}<\zeta$.

Third, with $1-\boldsymbol{\theta}<\boldsymbol{\zeta}<1$, we then have $\boldsymbol{\lambda}^{o}\in[0,1]$

We know that $1-\theta<\zeta$. Since we have shown that $\left(1-\theta\right)\phi_{BB}>\phi_{AB}$, we now have: $\zeta\phi_{BB}>\phi_{AB}$.

This allows us to deduce:

$$\boldsymbol{\lambda}^{o}=\frac{\boldsymbol{\zeta\phi_{BB}-\phi_{AB}}}{\boldsymbol{\zeta\phi_{BB}-\phi_{AB}+\phi_{AA}-\zeta\phi_{AB}}}\in[0,1].$$

Appendix 4. Impact of the weights on the optimal value of industry share

We wish to assess the impact of the weights in the total utility function on the optimal value of the industry share. To do this, we normalize the weight for region A to 1 and give a weight η to region B. The indirect utility function to be maximized is then:

$$\tilde{W}=\theta V_A+\left(1-\theta\right)\eta V_B$$

$$\max_{\lambda}\tilde{W}\Leftrightarrow\max_{\lambda}\left\{W=\theta\left[\left(\phi_{AA}\lambda+\phi_{AB}\left(1-\lambda\right)\right)^{-\alpha\mu}\right]+\left(1-\theta\right)\eta\left[\left(\phi_{AB}\lambda+\phi_{BB}\left(1-\lambda\right)\right)^{-\alpha\mu}\right]\right\}$$

The first order condition gives us the following value:

$$\boldsymbol{\lambda}^{o}=\frac{\boldsymbol{\tilde{\zeta}\phi_{BB}-\phi_{AB}}}{\boldsymbol{\tilde{\zeta}\phi_{BB}-\phi_{AB}+\phi_{AA}-\tilde{\zeta}\phi_{AB}}},$$

where $\zeta^{o} = \left[\dfrac{\eta\left(1-\theta\right)\left(\phi_{BB}-\phi_{AB}\right)}{\theta\left(\phi_{AA}-\phi_{AB}\right)}\right]^{\frac{-1}{\alpha\mu+1}}$.

It is easy to show that $\dfrac{\partial\zeta^{o}}{\partial\eta}<0$. Moreover, one can prove that $\dfrac{\partial\lambda^{o}}{\partial\zeta^{o}}>0$. Knowing the signs of these two derivatives, we conclude that an increase in η will lead to a reduction of λ^{o}.

Appendix 5. Proof of Proposition 3

The spatial equilibrium is given by the value λ^{Eq}:

$$\lambda^{Eq} = \frac{\left(1-\theta\right)\left(\phi_{BB}-\phi_{AB}\right)\phi_{AB}+\theta\left(\phi_{AB}-\phi_{AA}\right)\phi_{BB}}{\left(\phi_{AA}-\phi_{AB}\right)\left(\phi_{AB}-\phi_{BB}\right)}$$

$$\lambda^{Eq} = \frac{\theta\phi_{BB}}{\phi_{BB}-\phi_{AB}}+\frac{\theta\phi_{AB}-\phi_{AB}}{\phi_{AA}-\phi_{AB}}.$$

We wish to compare λ^{Eq} with the optimal share of firms λ^{o} that can be rewritten as:

$$\lambda^{o} = \frac{\zeta\phi_{BB}}{\phi_{AA}-\phi_{AB}+\zeta(\phi_{BB}-\phi_{AB})}+\frac{-\phi_{AB}}{\phi_{AA}-\phi_{AB}+\zeta(\phi_{BB}-\phi_{AB})}$$

First, we compare the second parts of the two equations. Since $\zeta\left(\phi_{BB}-\phi_{AB}\right)>0$ and $\theta\phi_{AB}>0$, then we observe that:

$$\frac{\theta\phi_{AB}-\phi_{AB}}{\phi_{AA}-\phi_{AB}} > \frac{-\phi_{AB}}{\phi_{AA}-\phi_{AB}+\zeta(\phi_{BB}-\phi_{AB})}.$$

Second, we wishto compare the first parts of the equations. Let's prove by contradiction that

$$\frac{\theta\phi_{BB}}{\phi_{BB}-\phi_{AB}} > \frac{\zeta\phi_{BB}}{\phi_{AA}-\phi_{AB}+\zeta(\phi_{BB}-\phi_{AB})}$$

To do so, we make the hypothesis that:

$$\frac{\theta\phi_{BB}}{\phi_{BB}-\phi_{AB}} < \frac{\zeta\phi_{BB}}{\phi_{AA}-\phi_{AB}+\zeta(\phi_{BB}-\phi_{AB})},$$

which implies that :

$$\theta\left[\phi_{AA}-\phi_{AB}+\zeta\left(\phi_{BB}-\phi_{AB}\right)\right] < \zeta\left(\phi_{BB}-\phi_{AB}\right)$$

$$\Leftrightarrow \theta\left(\phi_{AA}-\phi_{AB}\right)+\zeta\left(\theta-1\right)\left(\phi_{BB}-\phi_{AB}\right) < 0$$

$$\Leftrightarrow \frac{\theta\left(\phi_{AA}-\phi_{AB}\right)}{\left(1-\theta\right)\left(\phi_{BB}-\phi_{AB}\right)} < \zeta$$

$$\Leftrightarrow 1 < \zeta.$$

This is a contradiction, since we know that $0 < \zeta < 1$. Thus,we must have:

$$\frac{\theta\phi_{BB}}{\phi_{BB}-\phi_{AB}} > \frac{\zeta\phi_{BB}}{\phi_{AA}-\phi_{AB}+\zeta(\phi_{BB}-\phi_{AB})}.$$

These two inequalities lead us to the conclusion that: $\lambda^{Eq} > \lambda^{o}$.