First Nature vs. Second Nature Causes: Industry Location

and Growth in the Presence of an Open-Access Renewable Resource

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Abstract: In this paper we present a model integrating characteristics of the New Economic Geography, the theory of endogenous growth and the economy of natural resources. This theoretical framework enables us to study explicitly the effect of "first nature causes" in the concentration of economic activity, more specifically, the consequences of an asymmetrical distribution of natural resources. The natural resource we consider appears as a localized input in one of the two countries, giving firms located in that country a cost advantage. In this context, after a decrease in transport costs, firms decide to move to the country with the greatest domestic demand and market size, where they can take more advantage of increasing returns, despite the cost advantage of locating in the South, due to the presence of the natural resource.

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1. Introduction

There are many factors influencing the distribution of economic activity. It is traditional to distinguish between characteristics linked to the physical landscape, such as temperature, rainfall, access to the sea, the presence of natural resources or the availability of arable land, and factors relating to human actions and economic incentives (for example, scale economies or knowledge spillovers). The first group of factors, related to natural geographical circumstances, are called "first nature causes", and the second group are called "second nature causes".

A great deal of effort has been dedicated to researching the influence of second nature causes, especially after the pioneering work of Krugman (1991), who demonstrated how economic forces (increasing returns and transport costs) determine the distribution of activity. However, the models of New Economic Geography are usually based on the assumption that the space is homogenous, thus controlling the first nature causes. This means that less work has been invested in the theoretical study of the effect of first nature causes, even though many empirical studies demonstrate their important influence on economic growth and the concentration of economic activity.

For the case of the United States, Ellison and Glaeser (1999) state that natural advantages, such as the presence of a natural harbour or a particular climate, can explain at least half of the observed geographic concentration. Glaeser and Shapiro (2003) find that in the 1990s people moved to warmer, dryer places. Black and Henderson (1998) conclude that the extent of city growth and mobility are related to natural advantages, or geography. Beeson et al. (2001) show that access to transport networks, either natural (oceans) or produced (railroads) was an important source of growth during the period 1840-1990, and that climate is one of the factors promoting population growth. And Mitchener et al. (2003) find that some geographical characteristics account for a high proportion of the differences in productivity levels between American states.

The aim of this paper is to provide a theoretical model which enables us to analyse the influence of one of the first nature causes, the presence of natural resources, on the concentration of economic activity and growth. To do this we will build a model in which firms can choose to locate in one of two countries which trade with each other, which we will call North and South. This model integrates characteristics of the New Economic Geography, the theory of endogenous growth and the economy of natural resources.

We will follow the model developed by Martin and Ottaviano (1999), which combines a model of endogenous growth similar to that of Romer (1990), and Grossman and Helpman (1991), with a geographical framework like that of Helpman and Krugman (1985), and Krugman (1991). Economic growth is supported by an endogenous framework with national spillovers in innovation, causing research activities to take place in a single country, and thus, the greater the industrial concentration in that country, the higher the economic growth rate.

To this model, we add an open access renewable natural resource, used by firms as a productive input. This introduces an additional element that conditions firms' decisions about whether to locate in the North or in the South, besides the traditional home market effect and the existence of trade costs. The relative importance of these three forces determines a non-symmetrical location of firms. The industrial geography here relates to the natural resource in two ways. First, the natural resource is located in only one of the two countries, namely, the South. And, second, the international trade of the natural resource is subject to a transport cost.

There are other theoretical models which study how the presence of natural resources affects international trade, focusing on factors such as comparative advantages and relative prices (Brander and Taylor, 1997a, 1997b, 1998a, 1998b), or differences in property rights of the resources (Chichilnisky, 1994). This paper proposes a different approach, as the natural resource has an influence not only on international trade, but also on the distribution of firms among countries, which is endogenously determined. In turn, the distribution of economic activity also affects the equilibrium stock of the natural resource.

The following results are obtained. After a decrease in any of the transport costs, firms decide to move to the country with the greatest domestic demand and market size. Despite the cost advantage of locating in the South due to the presence of the resource, firms prefer to move to the North, the rich country, where they can take more advantage of increasing returns. In turn, concentration improves the economic growth rate, given the national nature of the spillovers. The concentration of firms in the North also has a positive effect on the stock of the natural resource, which increases. This means that in the framework of our model, second nature causes (the home market effect), acting centripetally, have greater weight in firm decisions than the advantages of natural geographic circumstances (first nature causes) which act centrifugally.

However, the South can increase the importance of the first nature cause by introducing public policies to reinforce the cost advantage of the resource's presence for firms located in the South. We will consider two public policies: imposing restrictions on the international trade of the resource and promoting a technological change to a technology which uses the resource more intensively. In both cases, after such policies the South attracts firms from the North, producing decreases in the growth rate and in the stock of the natural resource in equilibrium. The effect on welfare remains undetermined.

The next section presents the basic characteristics of the theoretical model. Section 3 describes the market equilibrium of differentiated goods, with special attention given to the distribution of firms in the equilibrium. Section 4 describes the natural resource market and solves the corresponding equilibrium. Section 5 determines the steady state growth rate, which depends on geography, and also shows how economic growth in turn influences geography through income inequality. Once the general equilibrium is described, section 6 analyses the effect of changes in differentiated goods' and resource's transport costs. These transport costs can also be interpreted in terms of public policies, as seen in section 7. Finally, the paper ends with the main conclusions.

2. The model

The diagram in Figure 1 describes schematically how the model works. We will consider two countries, North and South, which trade with each other. Both are identical except for their initial level of capital, K_0 in the North and K_0^* in the South, and the presence of a natural resource only in the South. Let us suppose that the North has a higher initial income level, such that $K_0 > K_0^*$. Both countries are inhabited by representative households playing the part of consumers, workers and researchers. There are L households, both in the North and in the South. Labour is mobile between sectors but immobile between countries.

Given that the model is nearly symmetrical, we will focus on describing the economy of the North (an asterisk denotes the variables corresponding to the South).

The preferences are instantaneously nested CES, and intertemporally CES, with an elasticity of intertemporal substitution equal to the unit:

$$U = \int_0^\infty \log\left[D(t)^\alpha Y(t)^{1-\alpha}\right] e^{-\rho \cdot t} dt, \qquad 0 < \alpha < 1, \qquad (1)$$

where ρ is the intertemporal discount rate, Y is the numerary good and D is a composite good which, in the style of Dixit and Stiglitz, consists of a number of different varieties:

$$D(t) = \left[\int_{i=0}^{N(t)} D_i(t)^{1-\frac{1}{\sigma}} di\right]^{\frac{1}{\left(1-\frac{1}{\sigma}\right)}}, \qquad \sigma > 1. \qquad (2)$$

N is the total number of varieties available, both in the North and the South. σ is the elasticity of substitution between varieties, and is also the demand price elasticity of the demand for each variety (assuming that N is high enough). Growth comes from an increase in the number of varieties. Note that the natural resource does not appear explicitly in the structure of individual preferences, meaning that it lacks value for them (but it might have social value, as a planner might exist who decides to maintain a minimum level). This assumption is restrictive, but has a double justification. First, the indirect utility function is very difficult to analyse even without including the natural resource (see section 7). Including it would give rise to more indeterminacy (although, as we will see below, the resource does appear in the indirect utility function indirectly through its price). And second, individuals cannot move between countries. This means that they cannot react in any way to changes in the stock of the resource, and so introducing it into its utility function makes no sense.

The value of per capita expenditure E in terms of the numerary Y is:

$$\int_{i \in n} p_i D_i di + \int_{j \in n^*} \tau p_j^* D_j dj + Y = E. \qquad (3)$$

The number of manufactured goods produced in each country, n and n^*, is endogenous, with $N = n + n^*$. There is a transport cost $(\tau > 1)$ that affects international trade between the two countries. Also, international trading of the natural resource from South to North is also subject to a transport cost τ_R. τ and τ_R represent iceberg-type costs, as in Samuelson (1954), and reflect the part of the good which is lost in transit. The transport costs operate according to the following schema:
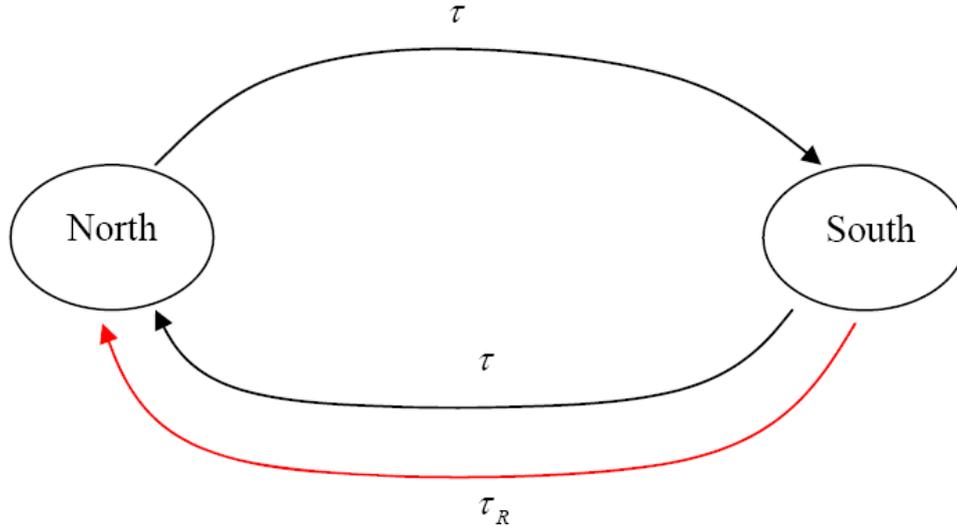
Thus, only $\tau^{-1} < 1$ of each unit of differentiated variety sent from the other country is available for consumption. Similarly, the North incurs an additional transport cost deriving from the natural resource (only $\tau_R^{-1} < 1$ of each unit of the natural resource sent from the South can be used) which the South does not bear. Decreases in τ or τ_R facilitate trade. From here we will assume that $\tau_R \leq \tau$; in other words, it is less costly or, at best, the same in terms of transaction costs to send units of the natural resource than the differentiated good[1]. Meanwhile, the numerary good is not subject to any transaction cost.

The numerary good is produced using only labour, subject to constant returns in a perfectly competitive sector. As labour is mobile between sectors, the constant returns in this sector tie down the wage rate w in each country at each moment. We assume throughout the paper that the parameters of the model are such that the numerary is produced in both countries, that is, that the total demand for the numerary is big enough so as not to be satisfied with its production in a single country. In this way, wages are maintained constant and identical in both countries. A unit of labour is needed to produce a unit of Y, so free competition in the labour market implies that $w = 1$ in both countries.

The differentiated goods are produced with identical technologies, in an industry with monopolistic competition with increasing scale returns in the production of each variety. To begin to produce a variety of a good, a unit of capital is needed; this fixed cost (FC) is the source of the scale economies. Labour (L) and natural resource (R) combine through a Cobb-Douglas type technology, $x_i = L_i^{1-\mu} R_i^{\mu}$, with a proportion $\mu \in (0,1)$ for the natural resource that represents how intensive the technology is in the use of the resource. This makes firm costs different if they are located in the North or South. If β represents the variable cost, the costs function of a representative firm in the North is as follows: $c_i = FC + \beta x_i q$, while that of a firm in the South, which does not have to bear transport costs for the natural resource (τ_R), is: $c_i = FC + \beta x_i q^*$,

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[1] The results are maintained even when transport cost for the resource is higher than that of the differentiated good, as long as the difference is not too great (it is a sufficient condition).

where q and q^* are the price indexes of the producers: $q = w^{1-\mu}(\tau_R p_R)^\mu$, and $q^* = w^{1-\mu} p_R^\mu$, and p_R is the market price of the natural resource. Therefore, firms in the South enjoy a competitive advantage in costs derived from the presence of the natural resource in its territory.

The standard rule of monopolistic competition determines the price of any variety produced either in the North or the South. The difference in costs implies that these prices are different: $p = \beta\left(\dfrac{\sigma}{\sigma-1}\right)(\tau_R p_R)^\mu$ in the North and $p^* = \beta\left(\dfrac{\sigma}{\sigma-1}\right)p_R^\mu$ in the South, where we have taken into account that $w = 1$ in both countries. Specifically, the price for any variety fixed by firms in the North is higher than the price fixed by firms in the South due to the additional transport costs for the natural resource that they bear ($p > p^*$ as $\tau_R > 1$).

The operating profits of the firms are also different depending on the country where they are located:

$$\pi = p_i x_i(p_i) - \beta x_i(p_i)q = \left(\frac{\beta x}{\sigma-1}\right)(\tau_R p_R)^\mu \qquad (4)$$

in the North, and

$$\pi^* = p_i^* x_i^*(p_i^*) - \beta x_i^*(p_i^*)q^* = \left(\frac{\beta x^*}{\sigma-1}\right)p_R^\mu \qquad (5)$$

in the South, where x and x^* are the production scale of a representative firm in the North and in the South, respectively.

In order to produce a new variety a previous investment is required, either in a physical asset (machinery) or an intangible one (patent). The concept of capital used in this paper corresponds to a mixture of both types of investment. We assume that each new variety requires one unit of capital. Thus, the value of any firm is the value of its unit of capital. The total number of varieties and firms is determined by the aggregate stock of capital at any given time: $N = n + n^* = K + K^*$. Once the investment is made, each firm produces the new variety in a situation of monopoly and chooses where to locate its production, as there are no costs of relocating the capital from one country to the other. Unlike firms, households (workers/researchers/consumers) are immobile, so their income is geographically fixed, although the firms can move. In other words, if a firm owner decides to locate production in the country where he does not reside, he repatriates the profits.

Finally, we assume there is a safe asset which pays an interest rate r on units of the numerary, whose market is characterized by freedom of international movements $(r = r^*)$.

Solving the first order conditions of the problem of the consumer in the North we obtain the demands for each variety produced in the North (D_i), in the South (D_j), and for the numerary good:

$$D_i = \frac{\sigma-1}{\beta\sigma} \cdot \frac{\left((\tau_R p_R)^\mu\right)^{-\sigma} \alpha E}{\left(n\left((\tau_R p_R)^\mu\right)^{1-\sigma} + n^*\delta\left(p_R^\mu\right)^{1-\sigma}\right)} \qquad (6)$$

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$$D_j = \frac{\sigma-1}{\beta\sigma} \cdot \frac{\tau^{-\sigma}\left(p_R^{\mu}\right)^{-\sigma}\alpha E}{\left(n\left((\tau_R p_R)^{\mu}\right)^{1-\sigma} + n^*\delta\left(p_R^{\mu}\right)^{1-\sigma}\right)} \qquad (7)$$

$$Y = (1-\alpha)E \qquad (8)$$

where $\delta = \tau^{1-\sigma}$ is a parameter between 0 and 1 that measures the openness of trade: $\delta = 1$ represents a situation in which transport costs do not exist, while if $\delta = 0$ trade would be impossible due to the high transaction costs.

The intertemporal optimization of consumers implies that the growth rate of expenditure is given by the difference between the interest rate and the intertemporal discount rate: $\dfrac{\dot{E}}{E} = \dfrac{\dot{E^*}}{E^*} = r - \rho$. As we will show below, in the steady state, E and E^* will be constant, so $r = \rho$.

3. Equilibrium in the market of differentiated goods

The equilibrium in the differentiated goods market involves two issues. First, we have to determine x and x^*, the production scales in the equilibrium of a representative firm located in the North or in the South, respectively. Second, the distribution of firms between both countries is determined endogenously, depending directly on geography and transport costs. The geographical part of the model refers to the location of firms, as the population does not move between countries[2].

The location of firms in equilibrium is determined by four conditions. The first two refer to the fact that when differentiated goods are produced in both countries, total demand, from both North and South, for each variety (including transport costs) must equal supply. Thus, from (6) and (7):

$$x = \frac{\alpha L(\sigma-1)}{\beta\sigma} \cdot \left((\tau_R p_R)^{\mu}\right)^{-\sigma} \cdot$$
$$\cdot \left(\frac{E}{N\left(S_n\left((\tau_R p_R)^{\mu}\right)^{1-\sigma} + (1-S_n)\delta\left(p_R^{\mu}\right)^{1-\sigma}\right)} + \frac{\delta E^*}{N\left(S_n\delta\left((\tau_R p_R)^{\mu}\right)^{1-\sigma} + (1-S_n)\left(p_R^{\mu}\right)^{1-\sigma}\right)} \right) \qquad (9)$$

$$x^* = \frac{\alpha L(\sigma-1)}{\beta\sigma} \cdot \left(p_R^{\mu}\right)^{-\sigma} \cdot$$
$$\cdot \left(\frac{E^*}{N\left(S_n\delta\left((\tau_R p_R)^{\mu}\right)^{1-\sigma} + (1-S_n)\left(p_R^{\mu}\right)^{1-\sigma}\right)} + \frac{\delta E}{N\left(S_n\left((\tau_R p_R)^{\mu}\right)^{1-\sigma} + (1-S_n)\delta\left(p_R^{\mu}\right)^{1-\sigma}\right)} \right) \qquad (10)$$

where $S_n = \dfrac{n}{N}$ is the share of varieties of the manufactured good produced in the North.

The third condition is the consequence of the free movements of capital between countries ($r = r^*$), which implies an equal retribution via profits:

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[2] Population is tied to their native country, but individuals are affected by the location of firms, because the more firms in the country, the lower the price index they have to bear. The price indexes are: $P = \left(\dfrac{\beta\sigma}{\sigma-1}\right)p_R^{\mu}\left[n\tau_R^{\mu(1-\sigma)} + n^*\delta\right]^{\frac{1}{1-\sigma}}$ in the North, and $P^* = \left(\dfrac{\beta\sigma}{\sigma-1}\right)p_R^{\mu}\left[n\delta\tau_R^{\mu(1-\sigma)} + n^*\right]^{\frac{1}{1-\sigma}}$ in the South.

$$\pi = \pi^*, \tag{11}$$

and, therefore, according to (4) and (5), $x = \dfrac{x^*}{\tau_R^{\mu}}$. Finally, the fourth condition, already mentioned, indicates that the total number of varieties is fixed by the worldwide supply of capital at each moment:

$$n + n^* = K + K^* = N. \tag{12}$$

Solving the system formed by these four equations, we obtain the optimum size of each firm in equilibrium in the North and in the South:

$$x = \frac{\alpha L (\sigma - 1)}{\beta \sigma} \cdot \frac{\left(E + E^*\right)}{N} \cdot \left(\tau_R p_R\right)^{-\mu}, \tag{13}$$

$$x^* = \frac{\alpha L (\sigma - 1)}{\beta \sigma} \cdot \frac{\left(E + E^*\right)}{N} \cdot p_R^{-\mu}. \tag{14}$$

The equilibrium production scales are different in each country. Locating in the North implies an additional cost due to the transport of the natural resource, and the firms react by producing fewer units of the differentiated good that they sell at a higher price. In turn, this different behaviour is what enables profits obtained in equilibrium to be the same in both countries.

The proportion of firms (or varieties) in the North ($S_n = \dfrac{n}{N}$) is given by:

$$S_n = \frac{S_E}{\left(1 - \delta \cdot \phi_R\right)} - \frac{\delta \left(1 - S_E\right)}{\left(\phi_R - \delta\right)}, \tag{15}$$

where, in turn, $S_E = \dfrac{E}{E + E^*}$ is the participation of the North in total expenditure and $\phi_R = \tau_R^{\mu(1-\sigma)}$ is a parameter between 0 and 1 of similar interpretation to δ, measuring the freedom of trade of the natural resource. It is also possible to demonstrate that, as long as the North has a larger domestic market[3] $\left(S_E > \dfrac{1}{2}\right)$, most firms are located in the North $\left(S_n > \dfrac{1}{2}\right)$.

The location of equilibrium of the firms depends on national expenditure – higher local expenditure or income means a larger domestic market, which attracts more firms wanting to take advantage of increasing returns (home market effect) – and the relationship between the level of openness of trade of differentiated goods (δ) and of the natural resource (ϕ_R). The natural resource influences the distribution of firms in equilibrium via ϕ_R: the lower the transport cost of the natural resource, the smaller the advantage for firms located in the South. It is easy to see that $(\phi_R - \delta) > 0$ as long as $\tau_R \leq \tau$. Given that most firms are concentrated in the North, the home market effect, which we may identify as a second nature cause, acts centripetally, favouring the

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[3] Below it is shown that this condition is always borne out as long as $K_0 > K_0^*$, as we have supposed.

agglomeration of economic activity, while the cost advantage offered by the natural resource to firms located in the South, the first nature cause, acts centrifugally.

4. Natural resource growth

The South is endowed with a stock of natural resource (S), characterized as in Eliasson and Turnovsky (2004) or in Brander and Taylor (1997a, 1997b, 1998a, 1998b). This natural resource has some specific characteristics. It is (i) renewable, (ii) open access, (iii) used only as an input in the production of manufactured goods, and (iv) its exploitation requires only labour. These four conditions can be considered as restrictive, but are necessary to keep the model tractable. A natural resource with such characteristics is, for example, the wood from the forests of the South.

At any point of time, the net change in the stock of the resource is given by $\dot{S} = G(S) - R$, where $G(S)$ describes the natural growth of the resource and R is the harvested amount. We assume that the reproduction function G is a concave function depending on the current stock of the resource, and positive in the interval between $\underline{S}$ and $\overline{S}$, where $\underline{S}$ is the minimum viable stock size and $\overline{S}$ is the maximum amount which the stock can reach, given physical and natural limitations (for example, available space). $G(S)$ is analogous to a production function, with the difference that the rate of accumulation of the stock is limited. See Brown (2000) for a wider discussion of $G(S)$ and its properties.

For simplicity, we fix $\underline{S} = 0$ and assume that the growth of the resource, $G(S)$, corresponds to a logistic function:

$$G(S) = \gamma S \left(1 - \frac{S}{\overline{S}}\right), \qquad \gamma > 0 \qquad (16)$$

where γ is the intrinsic growth rate of the resource (the natural growth rate). In the absence of harvesting $(R = 0)$, S converges to its maximum sustainable stock level, $\overline{S}$. This function has been widely used in the analysis of renewable resources, and may be the simplest and most empirically plausible functional form of describing biological growth in a restricted environment.

The harvest of the natural resource requires economic resources; for the sake of simplicity, we will assume it requires only labour. We assume that harvesting is carried out according to the Schaefer harvesting production function:

$$R^S = BSL_R, \qquad (17)$$

where L_R is the amount of labour used in the renewable resource sector (workers in the South, where the resource is located), R^S is the harvested quantity offered by the producers and B is a positive constant. If $a_{L_R}(S)$ represents the unit labour requirement in the resource sector, (17) implies that $a_{L_R}(S) = \frac{L_R}{R^S} = \frac{1}{BS}$. It verifies $a'_{L_R}(S) < 0$: labour requirement increases as the stock of the resource decreases.

Production is carried out by profit-maximizing firms operating under conditions of free entry (perfect competition). Therefore, the price of the resource good must equal its unit production cost:

$$p_R = wa_{L_R} = \frac{w}{BS} = \frac{1}{BS}. \qquad (18)$$

Both B and w are in terms of the numerary good, so p_R is too. This price incorporates the assumption of open access to the resource, because the only explicit production cost is labour. There are no other explicit costs of using the resource[4].

The firms in the sector of the differentiated goods demand the natural resource as an input in the production of their varieties. Applying Shephard's lemma to the cost functions we obtain the demand for the natural resource: $\beta x \cdot \mu (\tau_R p_R)^{\mu-1}$ for a representative firm of the North and $\beta x^* \cdot \mu p_R^{\mu-1}$ for a representative firm of the South. Substituting the equilibrium production levels given by (13) and (14), and aggregating for the firms in the North (taking into account the transport cost they bear) and in the South, we obtain the worldwide demand for the resource (R^D):

$$R^D = \mu p_R^{-1} \cdot \frac{\alpha(\sigma-1)}{\sigma} \cdot L(E + E^*). \qquad (19)$$

This demand depends on some structural parameters, the price of the resource and world aggregate income, $L(E + E^*)$.

Replacing in (19) the price set by the producers, given by (18), we obtain the *resource market equilibrium condition*, which gives us the equilibrium harvest level R:

$$R(S) = \mu BS \cdot \frac{\alpha(\sigma-1)}{\sigma} \cdot L(E + E^*). \qquad (20)$$

Note that this harvest level R is a function $R(S)$ that grows with the size of the stock S. Steady state is reached when the stock evolves to a level in which the harvest of the natural resource, $R(S)$, is equal to its capacity for reproduction, $G(S)$, given by equation 16, meaning that $\dot{S} = G(S) - R(S) = 0$. A trivial solution is reached when $S = R = 0$. The other solution is given by:

$$\tilde{S} = \overline{S}\left[1 - \mu B \cdot \frac{\alpha(\sigma-1)}{\gamma\sigma} \cdot L(E + E^*)\right]. \qquad (21)$$

Figure 2 shows how convergence is produced to the steady state level. The figure illustrates a situation in which at the initial stock S_0 the amount harvested, $R(S_0)$, exceeds natural growth, $G(S_0)$. The stock then decreases until it reaches the steady state level $\tilde{S}$. This indicates that, in steady state, the quantity of the resource used by firms is constant.

The steady state harvest level is obtained by replacing $\tilde{S}$ in $R(S)$:

$$R(\tilde{S}) = \mu B \cdot \frac{\alpha(\sigma-1)}{\sigma} \cdot L(E + E^*) \cdot \overline{S}\left[1 - \mu B \cdot \frac{\alpha(\sigma-1)}{\gamma\sigma} \cdot L(E + E^*)\right]. \quad (22)$$

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[4] If there were no free access to the resource, another cost would exist deriving from the reduction of the capacity for reproduction of the resource, which relates to Hotelling's rule. The resource would be exploited only by firms with property rights in a situation which would then not be perfect competition, making the final price greater than the unit cost, and generating additional income.

As shown by Brander and Taylor (1997a), a positive steady state solution exists if and only if the term between brackets is positive, that is to say, if the condition $\mu B \cdot \frac{\alpha(\sigma-1)}{\sigma} \cdot (E+E^*) < \frac{\gamma}{L}$ holds. In this case the solution is globally stable (for any $S_0 > 0$). If such condition is not satisfied the resource would disappear and the unique possible steady state is $S = R = 0$. Graphically, this condition means that, in the origin, the slope of the function $R(S)$ is less than the slope of $G(S)$, thus ensuring that they cut off at some point for positive values of S.

5. Economic growth and income inequality

5.1 Economic growth

We will first examine the growth rate of the economy. Starting from the solution of the problem of the intertemporal optimization of the consumer, we know that, in equilibrium, $\frac{\dot{E}}{E} = \frac{\dot{E^*}}{E^*} = r - \rho$. As the capital flows are free, $r = r^*$, and the expenditure growth rate will be the same in both countries. From (15), this implies that the ratio of firms producing in the North, S_n, is also constant in time, and, therefore, n, n^* and N grow at the same constant rate $g = \frac{\dot{N}}{N} = \frac{\dot{n}}{n} = \frac{\dot{n^*}}{n^*}$.

National spillovers exist in the innovation sector, so that the more firms producing different manufactured goods are located in the same country, the less costly is R&D[5]. This sector follows Grossman and Helpman (1991), with $\frac{\eta}{n}$ being the cost in terms of labour of an innovation in the North and $\frac{\eta}{n^*}$ in the South. The immediate conclusion of this formulation of the sector is that, for reasons of efficiency, research activity will take place in only one of the two countries: the one with the most firms producing manufactured goods (which will be the rich country, the North, given that $S_n > \frac{1}{2}$). No researcher will have any incentive to begin R&D in the other country. This formulation makes the analytical treatment of the model easier, although the results are maintained even if a certain degree of diffusion of the knowledge exists at the international level (Hirose and Yamamoto, 2007).

The value of the firm is given by the value of its unit of capital. As the capital market is competitive, this value (v) will be given by the marginal cost of innovation, $v = \frac{\eta}{n} = \frac{\eta}{NS_n}$, which is therefore decreasing at the rate g, the rate of innovation ($\frac{\dot{v}}{v} = -g$). As the number of varieties increases, the profits of each firm decrease, and also does its value, which can also be interpreted as the future flow of discounted profits

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[5] This type of knowledge spillovers is closer to the concept of Jacobs (1969) than to that of Marshall-Arrow-Romer (MAR). The empirical evidence for these external effects between different industries in the same geographical unit is documented; see, for example, Glaeser et al. (1992) and Henderson et al. (1995).

$$\left(v(t) = \int_t^\infty e^{-[\bar{r}(s)-\bar{r}(t)]} \frac{\beta x(s)}{\sigma-1} ds \right),$$ where $\bar{r}$ represents the cumulative discount factor.

Taking into account the *arbitrage condition between the capital market and the safe asset market*, the relation between the interest rate and the value of the capital is given by [6]:

$$r = \frac{\dot{v}}{v} + \frac{\pi}{v} \ . \tag{23}$$

On the other hand, the constraint of world resources, $E + E^* = 2 + (r\eta)/(LS_n)$, where the right-hand includes the sum of labour income ($w = 1$ in the two countries) and capital returns, implies that worldwide expenditure is constant over time, so that in steady state $r = \rho$, as pointed above. Note that this restriction includes only labour and capital returns; the harvest of the natural resource does not generate additional income for either of the two countries, as it is an open access resource exploited in a competitive industry.

Finally, we must take into account the labour market. The world's labour is devoted to R&D activities (using only workers from the North), and to the production of goods. From the latter, a proportion $(1 - \alpha)$ is dedicated to the production of the numerary good, and a proportion α to the production of differentiated goods. In turn, given the Cobb-Douglas technology properties, from the labor used, either directly or indirectly, in the production of manufactured goods, a proportion μ is used in the exploitation of the resource (using only workers in the South), and a proportion $1 - \mu$ is used directly as an input in the production of varieties. Thus, the *world labour market equilibrium condition* is given by:

$$\eta \frac{g}{S_n} + \left(\frac{\sigma - \alpha}{\sigma} \right) L(E + E^*) = 2L . \tag{24}$$

In steady state (see details in Appendix A), all the variables will grow at a constant rate. Replacing in (23) the profits obtained in (4), the optimum size of firms in the equilibrium (13), and considering (24) and that in steady state $r = \rho$, we obtain the *labour and capital markets equilibrium condition*:

$$g = \frac{2L}{\eta} \cdot \frac{\alpha}{\sigma} S_n - \left(\frac{\sigma - \alpha}{\sigma} \right)\rho = g(S_n). \tag{25}$$

where g is the growth rate of K and K^* (the same for the two countries) in steady state[7]. This rate depends on structural parameters of the model ($L, \eta, \alpha, \sigma, \rho$), but also on S_n (the geography), lineally.

5.2 World income distribution

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[6] This condition is formulated in terms of the profits of the firms in the North (π), but applies in the same way to the South because, although the expressions of π and π^* differ (equations 4 and 5), one of the conditions of equilibrium (equation 11) requires that $\pi = \pi^*$.

[7] Again the results are presented in terms of the variables of the North (π and x). Using π^* and x^* the same result is obtained (the steady state economic growth rate is the same for the two countries), taking into account that in equilibrium $\pi = \pi^*$, meaning that $x = \dfrac{x^*}{\tau_R^\mu}$.

Secondly, we are interested in how this economic growth rate affects income inequality between the countries. Remember that we assumed the North to be richer initially ($K_0 > K_0^*$). The per capita income of each country is the sum of labour income (which, as we have already seen, is the unit), plus the capital income, which is r times the value of per capita wealth. Thus, it will be $E = 1 + r\dfrac{Kv}{L} = 1 + \rho\dfrac{Kv}{L}$ for any individual in the North. If we replace v from the *arbitrage condition between the capital market and the safe asset market* (23), the equilibrium profits (4), and the optimum production scale (13), it is possible to express Northern expenditure as a function of g:

$$E = 1 + \frac{2\alpha\rho S_K}{(\sigma - \alpha)\rho + \sigma g}, \tag{26}$$

where $S_K = \dfrac{K}{K + K^*}$ is the share of capital owned by the individuals in the North, that remains constant because K and K^* grow at the same rate g in the steady state.

Similarly, for the South:

$$E^* = 1 + \frac{2\alpha\rho(1 - S_K)}{(\sigma - \alpha)\rho + \sigma g}. \tag{27}$$

We have previously defined the ratio $S_E = \dfrac{E}{E + E^*}$, which represents the participation of the North in total income or expenditure. Replacing the expressions (26) and (27) we obtain:

$$S_E = \frac{1}{2} \cdot \frac{\sigma(\rho + g) + \alpha\rho(2S_K - 1)}{\sigma(\rho + g)}. \tag{28}$$

If, as we have supposed, the North is richer and $S_K > \dfrac{1}{2}$, then $S_E > \dfrac{1}{2}$. However, the relationship of S_E with the economic growth rate is negative: as the number of varieties increases, the value of the capital is reduced, and, as the North individuals own more capital, the income difference is reduced in relative terms.

Finally, to carry out the analysis of the next section, we need to relate the geography (S_n) with the growth rate g. To do this, we replace (28) in (15), obtaining the *differentiated goods market equilibrium condition*, indicating the distribution of firms for each value of g:

$$S_n(g) = \frac{1/2}{(1 - \delta\cdot\phi_R)(\phi_R - \delta)}\left[(1 + \delta^2)\phi_R - 2\delta + (1 - \delta^2)\phi_R \cdot \frac{\alpha\rho(2S_k - 1)}{\sigma(\rho + g)}\right] = S_n[S_E(g)]. \tag{29}$$

5.3. Equilibrium

We have obtained two equations, (25) and (29), representing, respectively, the *labour and capital markets equilibrium condition* and the *differentiated goods market equilibrium condition*. These functions relate the growth rate with the spatial distribution of firms, and define the equilibrium values of these variables. Since the algebraic solution is not easy, we follow a graphical approach.

The function $g = g(S_n)$ is linear and increasing: given the nature of the technological spillovers (national), the greater the concentration of firms, the lower the costs of innovation and the higher the growth rate. The function $S_n = S_n(g)$ is convex and decreasing[8]. Remember that this equation incorporates the inequality of income, $S_n = S_n[S_E(g)]$, and that this decreases as g increases via the reduction of monopolistic profits of firms. At the same time, as the differences in income vanish, industrial concentration and the market size of the rich country decrease due to the home market effect.

These functions are represented in Figure 3. The intersection point determines the steady state location of firms as well as the growth rate of the economy.

6. Effects of reducing trade costs

As we explained in the introduction, the purpose of this paper is explicitly to study the effect of first nature causes on the concentration of economic activity, analyzing one of the possible natural geographical characteristics, the role which may be played by a natural resource.

Starting from the equilibrium situation, a change in differentiated goods' or natural resource's transport cost will lead to changes in the distribution of firms. Firms move according to two types of incentives: the North attracts firms thanks to its larger domestic market, $S_E > \dfrac{1}{2}$, which we can identify as one of the second nature causes of concentration of firms, while the first nature causes in our model refer to the advantage in costs enjoyed by firms in the South thanks to the geographical presence of the natural resource in its territory.

Variations in any type of transaction cost do not affect the function $g = g(S_n)$, which depends only on the structural parameters of the model. It is the curve $S_n = S_n(g)$ which will reflect the changes in transport costs, moving and changing its slope. We carry out our analysis, first, from the perspective of the effects that decreasing transport costs have on the industrial localization and the growth rate. Then, the effect on the equilibrium stock of the resource is analyzed.

6.1 Effects on industrial concentration and economic growth

Decrease in the transport cost of differentiated goods

Let us consider first a decrease in the differentiated goods trading cost: $d\tau < 0$. After differentiating the equations (25) and (29), we obtain that $\dfrac{dS_n}{d\tau} < 0$, $\dfrac{dg}{d\tau} < 0$ and, thus, both the proportion of firms located in the North and the economic growth rate increase. This situation is represented in Figure 4.

The decrease in transaction costs enables an easier access to the market of the other country, so some firms prefer to move to the North (remember that there are no relocation costs). Despite the cost advantage of locating in the South due to the presence of the natural resource, firms prefer to move to the North, the rich country and thus the

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[8] $S_n = S_n(g)$ is convex and decreasing as long as $(\phi_R - \delta) > 0$. This condition is verified if $\tau_R \leq \tau$, as we have been assuming from the begining. Additionally, $(\phi_R - \delta)$ is greater than zero even when transport cost for the resource is higher than that of the differentiated good, as long as the difference is not too great.

bigger market, where they can take more advantage of increasing returns. This means that, in the framework of our model, the home market effect (second nature causes), acting centripetally, have a greater weight in firm decisions than the advantages of natural geographic circumstances (first nature causes), which act centrifugally.

In turn, concentration speeds up the economic growth rate, because the more manufacturing firms are located in the North, the lower the cost of innovation given the national nature of the spillovers.

Decrease in the transport cost of the resource

If the transport cost of the natural resource decreases, $d\tau_R < 0$, we obtain that $\dfrac{dS_n}{d\tau_R} < 0$, $\dfrac{dg}{d\tau_R} < 0$. Thus, both the proportion of firms located in the North and the economic growth rate rise: Figure 5 shows this situation. The difference from Figure 4 is that, in this case, the slope of the curve $S_n = S_n(g)$ moves upwards rather than downwards.

The lower transport cost of the natural resource means a loss in the cost advantage of the firms located in the South, close to the natural resource, over those located in the North. At the limit, if this transport cost did not exist ($\tau_R = 1$) the firms could not extract any advantage from its location close to the resource and there would be no relationship between the distribution of natural resource and the economic geography. In other words, as the transport cost of natural resources decreases, the importance of the first nature cause (in our model, the natural resource) vanishes.

As a consequence of this decrease in relative costs in the North, firms move from the South to the North, which has a bigger domestic market and greater demand. Moreover, as the number of firms in the North increases, the cost of research decreases due to national spillovers, and the economic growth rate increases.

6.2 Effects on the stock of the natural resource

Any variation in the distribution of firms or in the economic growth rate, whether due to a change in the transport cost of differentiated goods or of the resource, will have an effect on the stock level of the resource in steady state. That is, changes in the geographical distribution of firms affect the market of the natural resource.

Let us remember that both the harvest level, given by the *resource market equilibrium condition* (equation 20), and the stock of the resource in equilibrium (equation 21), depend on aggregate world income $L(E + E^*)$. In turn, world income can be related to S_n and g, replacing in (23) the profits obtained in (4) and the optimum size of firms in the equilibrium (13):

$$L(E + E^*) = \frac{\eta\sigma(\rho + g)}{\alpha S_n}. \qquad (30)$$

If we replace this expression of world income in (20) and (21) we obtain:

$$S = \overline{S}\left[1 - \mu B \cdot \frac{(\sigma - 1)}{\gamma} \cdot \frac{\eta(\rho + g)}{S_n}\right], \qquad (31)$$

$$R(S) = \mu BS \cdot (\sigma - 1) \cdot \frac{\eta(\rho + g)}{S_n}. \tag{32}$$

From these expressions we can analyse the effects on the natural resource of the changes in the distribution of firms. Let us consider changes in the transport costs that lead to a higher proportion of firms located in the North ($dS_n > 0$), that is, reductions in the transport cost of either the intermediate goods or the natural resource. In turn, given the national nature of the R&D spillovers, the higher concentration of firms in the North reduces the cost of innovation and raises economic growth: $dg > 0$. So, by differentiating (31), we obtain the effect of the reduction in transport costs on the stock of the natural resource in steady state:

$$dS = -\bar{S}\mu B \cdot \frac{(\sigma - 1)}{\gamma} \cdot \eta \frac{1}{S_n}\left[dg - \frac{1}{S_n}(\rho + g)dS_n\right].$$

This expression enables us to identify two opposite effects:

a) Industry localization effect: As the number of firms located in the North increases, the amount of the resource which is harvested decreases, because the firms in the North produce less units of differentiated good $(x < x^*)$ and thus require less natural resource.

b) Growth effect: As the number of firms in the North increases, the growth rate of the number of varieties also increases, so that the number of firms grows faster. More firms require a higher aggregate amount of the natural resource.

However, applying that, from (25), $dg = \frac{2L}{\eta} \cdot \frac{\alpha}{\sigma}dS_n$, it is possible to obtain a clear sign:

$$dS = -\bar{S}\mu B \cdot \frac{(\sigma - 1)}{\gamma} \cdot \eta \frac{1}{S_n^2}\left[\frac{-\alpha}{\sigma}\rho\right]dS_n > 0,$$

indicating that the firms localization effect dominates: more firms in the North means that less resource is consumed on average, enabling the level of stock to increase in steady state.

On the other hand, the effect on the harvested amount is not clearly determined. If we differentiate (32), and replace dg and dS with the expressions obtained earlier, we have:

$$dR = \mu B(\sigma - 1)\eta \frac{2}{S_n^2}\left(\frac{-\alpha}{\sigma}\rho\right)\left[S - \frac{\bar{S}}{2}\right]dS_n \gtrless 0.$$

The sign of the above expression depends on $S - \frac{\bar{S}}{2}$, that is, on whether the initial steady state stock exceeds or not $\frac{\bar{S}}{2}$. The same conclusion can be obtained if we differentiate the function $G(S)$ (equation 16). Graphically, it depends on whether $\tilde{S}$ is on the increasing or decreasing part of $G(S)$. Figures 6 and 7 illustrate the two possibilities.

In Figure 6 we consider the case $\tilde{S} > \dfrac{\overline{S}}{2}$, meaning that $dR < 0$ after the reduction in transport costs. In this situation, the increasing number of firms in the North is accompanied by a decrease in the amount harvested. This will be the most common solution, as it corresponds to situations where the slope of the function $R(S)$ is low. From (32), this is the more probable case when the industry is highly concentrated in the North and/or the technology of the intermediate good firms is not very intensive in the use of the natural resource.

In contrast, if the function $R(S)$ is very steep and $\tilde{S} < \dfrac{\overline{S}}{2}$, the amount harvested increases ($dR > 0$). This case is represented in Figure 7, and corresponds to situations where, despite consuming more resource, the equilibrium stock increases due to the high capacity of regeneration of the natural resource on this side of the curve $G(S)$.

7. Public policies: How to protect the South's natural advantage?

In the previous section we analyzed the effects of decreases in transport costs, obtaining as a result an increase in industrial concentration in the North, the rich country, and an increase in the growth rate and the stock level of the resource in steady state. Such lower transport cost of the natural resource meant that the firms of the South lost some of the cost advantage due to the closer location of the natural resource. That is, as the transport cost of the resource decreases, the less important this first nature cause becomes, configured as a centrifugal force, and the more firms concentrate in the North.

From this point of view, there is not much the South can do faced with a rich North with the home market effect in its favour, in a context of international transport costs trending downwards over time, so that sooner or later the cost advantage will disappear. However, the South can consider some public policies in order to protect the cost advantage.

Restrictions on international trading of the resource

A first route, the most direct, would be to influence τ_R, since higher transport costs for the resource increase the cost advantage for firms in the South. By modifying slightly the interpretation of the parameter τ_R, we can consider some ways the South could protect and even increase the cost advantage given by nature.

Martin and Rogers (1995) posited that the transport costs used in the models of Economic Geography can alternatively be interpreted as a measure of the quantity and quality of transport infrastructures, and, thus, can be modified by public policies. From this point of view, they defined public transport infrastructures as any good or service provided by the state which can facilitate the connection between production and consumption. It is evident that transport and communication media can be included among these trade infrastructures, but there are other non-physical elements, such as the legal system or the levels of public safety, which have an equally great influence on trade. Good infrastructures mean low transaction costs; poor infrastructures represent a situation where trade is difficult because of the high costs incurred. From this wide sense of the term, the parameter ϕ_R becomes an index between 0 and 1 which measures the level of infrastructures and/or legal restrictions related to the natural resource trade.

The best (worst) quality in trade infrastructures is found when $\phi_R = 1 (0)$. Such is also the case when there are no legal restrictions for trade of the natural resource.

In this way, the South could act through public policies and reinforce the cost advantage of Southern firms by restricting the international trade of the natural resource. The easiest way can be the introduction of exportation tariffs. The more difficult it is to access the natural resource from outside, the more firms will decide to locate in the South. This will enable to attract firms from the North, which would in turn cause a reduction in the growth rate and in the stock of the natural resource in equilibrium (because the firms in the South use more quantity of the natural resource than those in the North).

Technological change

There is another parameter that can influence the importance of the cost advantage which the natural resource gives to firms in the South. This is μ, which measures the degree in which the technology of the differentiated goods sector is intensive in the use of the natural resource.

Specifically, the more dependent the technology is on the natural resource, the greater the cost advantage of locating production in the South. If the South could use some kind of public policy, such as subsidising firms, to promote a change to a technology that used the resource more intensively, this would reinforce the cost advantage of its firms.

This policy can be represented as an increase in the parameter μ $(d\mu > 0)$. After differentiating the equations (25) and (29), we find that this leads to a decrease in the proportion of firms located in the North, S_n, as well as in the economic growth rate g, due to the national nature of the spillovers: $\dfrac{dS_n}{d\mu} < 0, \dfrac{dg}{d\mu} < 0$.

The equilibrium stock of the resource also decreases. Differentiating (31), and taking into account that, from (25), $dg = \dfrac{2L}{\eta} \cdot \dfrac{\alpha}{\sigma} dS_n$, we have:

$$dS = -\bar{S}B \cdot \frac{(\sigma - 1)}{\gamma} \cdot \eta \frac{1}{S_n}\left[(\rho + g)d\mu - \frac{\mu}{S_n} \cdot \frac{\alpha}{\sigma} \rho dS_n\right] < 0.$$

The effect on the harvested amount in equilibrium is again not clearly determined, depending on whether $\tilde{S}$ is in the increasing or decreasing side of the function $G(S)$.

Meanwhile, the effect on the variables would be the opposite if the North were to try to reduce firms' technological dependence $(d\mu < 0)$ on the natural resource not present in its territory. In this case the concentration of firms in the North and the economic growth rate would increase.

It is not difficult to find examples of this kind of policies, carried out by countries either to protect their advantages associated to the presence of natural resources, either to reduce the dependence in the case of importers. The case of oil, although it is not a renewable open access natural resource, is possibly the more representative. On one hand, the producers try to protect the profits derived from its exploitation by controlling (even reducing) the international availability of the input. On

the other hand, the countries which have to import the resource promote changes in the technology and research in substitute inputs in order to reduce its dependence.

What about utility?

The two types of policies proposed above strengthen the influence of the first nature cause, leading firms to move from the North to the South. A question that arises at this point is whether such change would be desirable.

In order to try to answer this question, we analyse the indirect utility functions. Although it is difficult to carry out a rigorous analysis of welfare, given that any variation in the distribution of firms (the ratio S_n) has several different effects on the indirect utility function, with the global sign remaining undetermined, we can identify the different effects that consumers would experience in utility. The indirect utility function of a household in the North is given by:

$$V = \frac{1}{\rho}\ln\left\{\alpha^{\alpha}(1-\alpha)^{1-\alpha}\left(\frac{\sigma-1}{\beta\sigma}\right)^{\alpha}\left(\frac{1}{p_R^{\mu}}\right)^{\alpha}\left(1+\frac{\rho\eta S_k}{S_n L}\right)N_0^{\frac{\alpha}{\sigma-1}}\left(S_n(\phi_R-\delta)+\delta\right)^{\frac{\alpha}{\sigma-1}}e^{\frac{\alpha g}{\rho(\sigma-1)}}\right\}. \quad (33)$$

As we remarked above, although the natural resource does not appear explicitly in consumer preferences (equation 1), it influences the indirect utility function indirectly through its price p_R. If we replace p_R from (18), the utility function becomes:

$$V = \frac{1}{\rho}\ln\left\{\alpha^{\alpha}(1-\alpha)^{1-\alpha}\left(\frac{\sigma-1}{\beta\sigma}\right)^{\alpha}(BS)^{\alpha\mu}\left(1+\frac{\rho\eta S_k}{S_n L}\right)N_0^{\frac{\alpha}{\sigma-1}}\left(S_n(\phi_R-\delta)+\delta\right)^{\frac{\alpha}{\sigma-1}}e^{\frac{\alpha g}{\rho(\sigma-1)}}\right\}. \quad (34)$$

The impact of a change in the concentration of firms[9] can be obtained by differentiating the above function with respect to S_n, taking into account that, from (25), $dg = \frac{2L}{\eta}\cdot\frac{\alpha}{\sigma}dS_n$, and considering the expression obtained earlier for the change in the natural resource stock $dS = \overline{S}\mu B\cdot\frac{(\sigma-1)}{\gamma}\cdot\eta\frac{1}{S_n^2}\left[\frac{\alpha}{\sigma}\rho\right]dS_n$:

$$\partial V = \left[-\frac{\eta S_k}{S_n^2 L + \rho\eta S_n S_k} + \frac{2L\alpha^2}{\rho^2\eta\sigma(\sigma-1)} + \frac{\alpha}{\rho(\sigma-1)}\cdot\frac{(\phi_R-\delta)}{(S_n(\phi_R-\delta)+\delta)} + \frac{\alpha^2\mu^2(\sigma-1)\overline{S}B\eta}{S_n^2\sigma\gamma S}\right]\partial S_n \overset{>}{\underset{<}{}}0$$

The effect on a Northern household welfare is undetermined. Besides the three effects obtained by Martin and Ottaviano (1999), in our model a fourth effect deriving from the price of the natural resource arises. Thus, if the South manages, using public policies, to attract firms from the North $(dS_n < 0)$, not only the economic growth rate and the level of equilibrium stock of the resource will decrease. Consumers in the North also experience four effects on utility:

a) The first element of the above derivative captures the positive impact of a decrease in the growth rate on the wealth of Northern households. Since the

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[9] This analysis of utility is partial, as we consider that the change in S_n is exogenous. In the concrete case that the cause of the variation in the concentration of firms were a change in τ_R or in μ, additional effects would exist that would increase indeterminacy. See Appendix B.

concentration of firms in the North is reduced, the cost of R&D rises and the economic growth rate decreases. This leads to a rise in intermediate firms' monopolistic profits and, thus, per capita income increases in the North.

b) The second element represents the negative impact on the reduction of the growth rate, which implies a slower rate of introduction of new varieties of the intermediate good, on the utility of individuals due to their structure of preferences and the love-of-variety effect.

c) The third term captures the decrease in welfare due to rising trade costs for consumers in the North when S_n decreases, since a higher range of varieties have to be imported. This effect depends on the differential $(\phi_R - \delta)$. It is easy to see that $(\phi_R - \delta) > 0$ as long as $\tau_R \leq \tau$, as we supposed. Thus, a lower proportion of firms located in the North, imply that Northern consumers will bear higher transport costs.

d) The last element represents the negative effect of a lower concentration of firms in the North on the price of the natural resource. As the proportion of firms in the North decreases, so does the stock of the natural resource in equilibrium, $\dfrac{dS}{dS_n} > 0$, and this leads to an increase in its price (equation 18). In turn, this increase in the price of the input translates to the price of the differentiated goods, with consumers losing utility.

Similarly, the indirect utility function of a household in the South is:

$$V^* = \frac{1}{\rho} \ln \left\{ \alpha^\alpha (1-\alpha)^{1-\alpha} \left(\frac{\sigma-1}{\beta\sigma} \right)^\alpha (BS)^{\alpha\mu} \left(1 + \frac{\rho\eta(1-S_K)}{S_n L} \right) N_0^{\frac{\alpha}{\sigma-1}} \left(1 - S_n(1-\phi_R\delta) \right)^{\frac{\alpha}{\sigma-1}} e^{\frac{\alpha g}{\rho(\sigma-1)}} \right\}.$$

(35)

And, by differentiating this function with respect to S_n, we obtain an analogous expression to that above:

$$\partial V^* = \left[-\frac{\eta(1-S_K)}{S_n^2 L + \rho\eta S_n(1-S_K)} + \frac{2L\alpha^2}{\rho^2 \eta\sigma(\sigma-1)} - \frac{\alpha}{\rho(\sigma-1)} \cdot \frac{(1-\phi_R\delta)}{(1-S_n(1-\phi_R\delta))} + \frac{\alpha^2\mu^2(\sigma-1)\overline{S}B\eta}{S_n^2 \sigma\gamma S} \right] \partial S_n \gtrless 0$$

with the difference that the sign of the third effect is the opposite, since a lower concentration of firms in the North causes a decrease in the transport costs borne by consumers in the South, so that their welfare increases via prices.

In this situation, in which both the concentration of firms in the North and the economic growth rate decrease, two negative effects on welfare are shared by the individuals of both countries: the love-of-variety effect (negative as the consequence of a slower growth rate of the number of varieties), and the negative effect of the increased price of the natural resource on the price of the differentiated goods. In the opposite, the reduction in the growth rate causes monopolistic profits of intermediate good producers to rise, and thus increase per capita income in both countries.

Only the trading cost effect has an opposite impact on each country. While Northern consumers lose utility because they have to import more varieties and bear

higher transport costs, the opposite holds for Southern individuals, which gain utility. This enables us to affirm that, when the South succeeds in attracting firms from the North, either consumers in the South lose utility, although less than the consumers in the North (in which case the public policy would be pointless), or they would gain utility, depending on the concrete values of the parameters. Therefore, in some situations (for a certain range of parameters), the South will be interested in applying such public policies that enable it to increase the cost advantage of the presence of the natural resource in its territory, the first nature cause, thus attracting firms from the other country.

8. Conclusions and future lines of research

In this paper, we present a model integrating characteristics of the New Economic Geography, the theory of endogenous growth, and the economy of natural resources. This theoretical framework enables us to study explicitly the effect of first nature causes in the concentration of economic activity, analyzing one of the possible natural geographical characteristics, the presence of a natural resource in the territory.

Geography enters the model via transport costs, which condition the distribution of firms which attempt to take advantage of increasing returns in a market of monopolistic competition. Economic growth is supported by an endogenous framework with national spillovers in innovation, causing research activities to take place in a single country (the North), and thus, the greater the industrial concentration in that country, the higher the economic growth rate. And the natural resource appears as a localized input in one of the two countries (the South), giving firms located in that country a cost advantage.

After a decrease in any of the transport costs, firms decide to move to the country with the greatest domestic demand and market size. Despite the cost advantage of locating in the South, due to the presence of the natural resource, firms prefer to move to the North, where they can take more advantage of increasing returns. In turn, concentration improves the economic growth rate, given the national nature of the spillovers.

Finally, the concentration of firms in the North would also have a positive effect on the stock of the natural resource in steady state, which would increase. Despite identifying two opposite effects, an industry localization effect and a growth effect, the industry localization effect dominates. Firms located in the North use a lower amount of natural resource, enabling the stock in steady state to increase. This is so because the firms in the North react to the cost advantage of firms in the South by producing a lower quantity of the differentiated good (and thus using less natural resource) and selling them at a higher price.

This means that, in the framework of our model, the home market effect (second nature causes), acting centripetally, have greater weight in firm decisions than the advantages of natural geographic circumstances (first nature causes), which act centrifugally.

However, the South can increase the importance of the first nature cause by introducing public policies to reinforce the cost advantage due to the natural resource presence in its territory. We have considered two different public policies: imposing restrictions on the international trade of the natural resource and promoting a technological change towards a technology which uses the resource more intensively. In both cases, the South attracts firms from the North, causing both the economic growth

rate and the stock level of the natural resource in equilibrium to decrease. The effect of such policies on welfare, both for Northern and Southern households, is undetermined. However, our results depend on the particular characteristics of the natural resource considered in our model: (i) it is renewable, (ii) with open access, (iii) used as an input only in the production of manufactured goods, and (iv) it is exploited using only labour. These assumptions have enabled us to build the simplest possible model in analytical terms, which we can call the basic model. Variations in any of these characteristics can produce extensions of the model.

In particular, there are two possible extensions which could add to our knowledge of the relationship between natural resources and the distribution of economic activity. Firstly, since at present most natural resources used in the production of manufactured goods are derived from oil or mining, it would be interesting to analyse how our model changes when the natural resource is not renewable. Secondly, another very interesting aspect would be to consider alternative mechanisms for the property rights of the natural resource. If the resource were not open access, the sector would generate additional income which, if most property rights were owned by Southern households, could have a positive impact on the size of the South market. This income effect, added to the advantage in costs which already appears in our model, would increase the weight of the first nature causes in the decisions made by firms.

Appendix A: Steady state equilibrium

The value of S_n in the steady state equilibrium is the solution of the second degree equation:

$$(1-\delta\cdot\varphi_R)(\varphi_R-\delta)2L\cdot S_n^2 +$$
$$+S_n\left[(1-\delta\cdot\varphi_R)(\varphi_R-\delta)\rho\eta-\left[(\varphi_R-\delta)+\delta(1-\delta\cdot\varphi_R)\right]L+2\delta(1-\delta\cdot\varphi_R)L\right]-$$
$$-\rho\eta\left(\left[(\varphi_R-\delta)+\delta(1-\delta\cdot\varphi_R)\right]S_k-\delta(1-\delta\cdot\varphi_R)\right)=0.$$

The valid solution is given by:

$$S_n=\frac{\left[\left[(\phi_R-\delta)+\delta(1-\delta\cdot\phi_R)\right]L-(1-\delta\cdot\phi_R)(\phi_R-\delta)\rho\eta-2\delta(1-\delta\cdot\phi_R)L\right]+\sqrt{\Delta}}{4L(1-\delta\cdot\phi_R)(\phi_R-\delta)},$$

where

$$\Delta=\left[(1-\delta\cdot\varphi_R)(\varphi_R-\delta)\rho\eta-\left[(\varphi_R-\delta)+\delta(1-\delta\cdot\varphi_R)\right]L+2\delta(1-\delta\cdot\varphi_R)L\right]^2+$$
$$+8L(1-\delta\cdot\varphi_R)(\varphi_R-\delta)\cdot\rho\eta\left(\left[(\varphi_R-\delta)+\delta(1-\delta\cdot\varphi_R)\right]S_k-\delta(1-\delta\cdot\varphi_R)\right).$$

The other root is greater than the unit and thus has no economic meaning. From this equilibrium value of S_n, which indicates the location of firms, we can obtain the steady state growth rate g in (25), and the North share in aggregate expenditure S_E in (28).

Appendix B: Public policies and changes in utility

Section 7 gives an overall analysis of utility, in which we considered directly a change in S_n without paying attention to its causes. But if such variation in the concentration of firms is the consequence of any of the public policies suggested (a change in τ_R or in μ), additional effects on welfare appear which increase the aggregate indeterminacy, as both parameters appear in the indirect utility function.

In the case of $d\tau_R>0$, after differentiating the indirect utility for the North in (34) we obtain:

$$dV=\left[-\frac{\eta S_k}{S_n^2 L+\rho\eta S_n S_k}+\frac{2L\alpha^2}{\rho^2\eta\sigma(\sigma-1)}+\frac{\alpha}{\rho(\sigma-1)}\cdot\frac{(\phi_R-\delta)}{(S_n(\phi_R-\delta)+\delta)}+\frac{\alpha^2\mu^2(\sigma-1)\bar{S}B\eta}{S_n^2\sigma\gamma S}\right]dS_n-$$
$$-\frac{\alpha\mu S_n}{\rho\phi_R(S_n(\phi_R-\delta)+\delta)}\cdot d\tau_R \underset{<}{\overset{>}{}} 0$$

And, similarly for the South, after differentiating (35):

$$dV^*=\left[-\frac{\eta(1-S_K)}{S_n^2 L+\rho\eta S_n(1-S_K)}+\frac{2L\alpha^2}{\rho^2\eta\sigma(\sigma-1)}-\frac{\alpha}{\rho(\sigma-1)}\cdot\frac{(1-\phi_R\delta)}{(1-S_n(1-\phi_R\delta))}+\frac{\alpha^2\mu^2(\sigma-1)\bar{S}B\eta}{S_n^2\sigma\gamma S}\right]dS_n-$$
$$-\frac{\alpha\mu\delta S_n}{\rho\phi_R(1-S_n(1-\phi_R\delta))}\cdot d\tau_R \underset{<}{\overset{>}{}} 0$$

A new term appears which affects the utility of consumers in the North and in the South. This last term, with a negative sign, represents the loss of utility experienced

by consumers in both countries when the transport cost of the natural resource is increased.

In the case of $d\mu > 0$, after differentiating the indirect utility for the North in (34), we obtain:

$$dV = \left[-\frac{\eta S_k}{S_n^2 L + \rho \eta S_n S_k} + \frac{2L\alpha^2}{\rho^2 \eta \sigma (\sigma - 1)} + \frac{\alpha}{\rho(\sigma - 1)} \cdot \frac{(\phi_R - \delta)}{(S_n(\phi_R - \delta) + \delta)} + \frac{\alpha^2 \mu^2 (\sigma - 1)\overline{S}B\eta}{S_n^2 \sigma \gamma S} \right] dS_n +$$

$$+ \left[\frac{\alpha}{\rho(\sigma - 1)} \cdot \frac{S_n(1 - \sigma)\phi_R \ln(\tau_R)}{(S_n(\phi_R - \delta) + \delta)} + \frac{\alpha}{\rho} \cdot \ln(BS) \right] d\mu \gtrless 0$$

And, similarly for the South, after differentiating (35):

$$dV^* = \left[-\frac{\eta(1 - S_K)}{S_n^2 L + \rho \eta S_n (1 - S_K)} + \frac{2L\alpha^2}{\rho^2 \eta \sigma (\sigma - 1)} - \frac{\alpha}{\rho(\sigma - 1)} \cdot \frac{(1 - \phi_R \delta)}{(1 - S_n(1 - \phi_R \delta))} + \frac{\alpha^2 \mu^2 (\sigma - 1)\overline{S}B\eta}{S_n^2 \sigma \gamma S} \right] dS_n +$$

$$+ \left[\frac{\alpha}{\rho(\sigma - 1)} \cdot \frac{\delta S_n(1 - \sigma)\phi_R \ln(\tau_R)}{(1 - S_n(1 - \phi_R \delta))} + \frac{\alpha}{\rho} \cdot \ln(BS) \right] d\mu \gtrless 0$$

To the effects noted above a new term affecting the utility of consumers in the North and the South appears. It represents the direct impact on utility that would be caused by changing to a technology which uses the resource more intensively, and has an indeterminate sign.
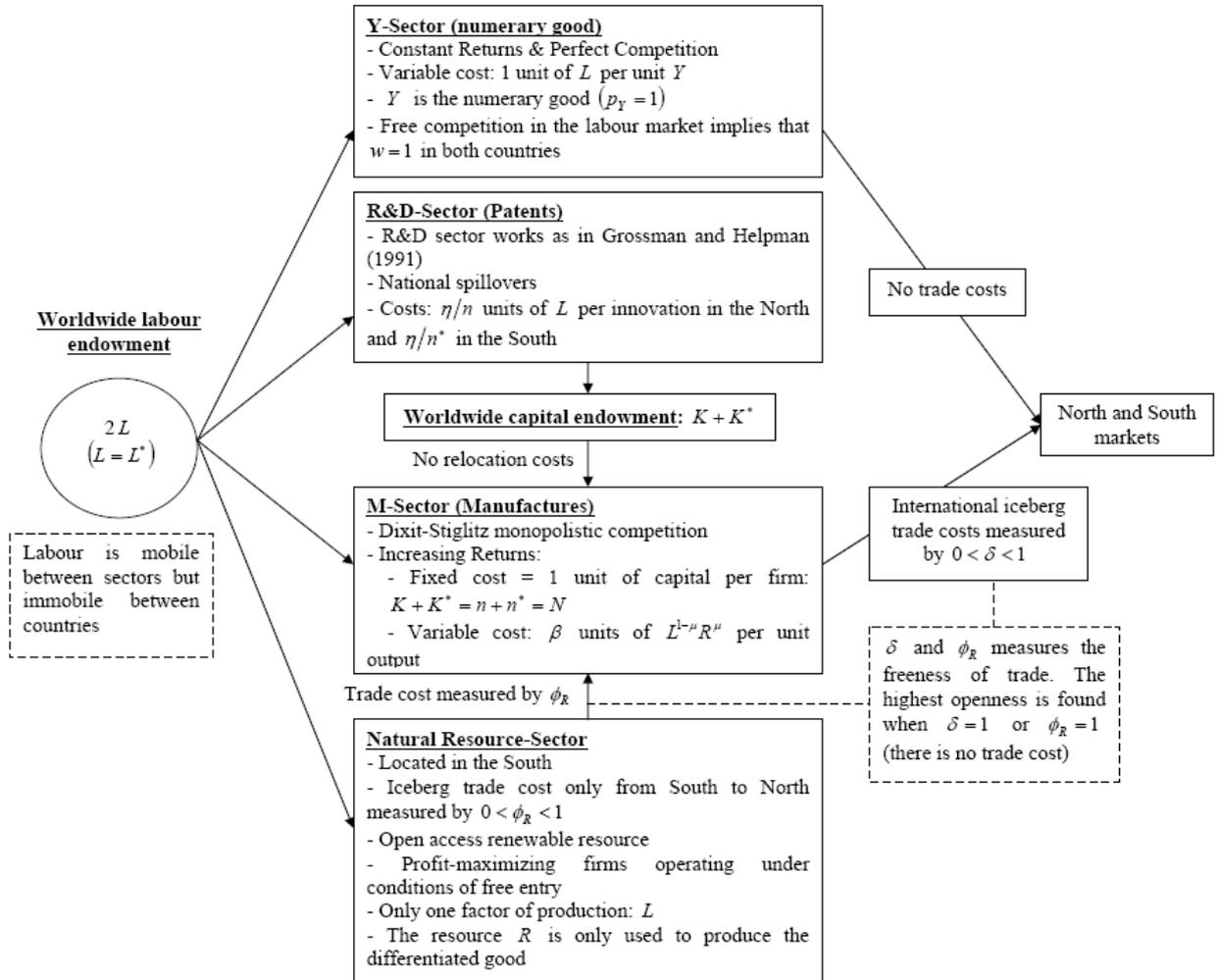
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Figures

Figure 1. Schematic diagram of the model

Y-Sector (numerary good)
- Constant Returns & Perfect Competition
- Variable cost: 1 unit of L per unit Y
- Y is the numerary good $(p_Y = 1)$
- Free competition in the labour market implies that $w = 1$ in both countries

R&D-Sector (Patents)
- R&D sector works as in Grossman and Helpman (1991)
- National spillovers
- Costs: η/n units of L per innovation in the North and η/n^* in the South

Worldwide capital endowment: $K + K^*$

No relocation costs

M-Sector (Manufactures)
- Dixit-Stiglitz monopolistic competition
- Increasing Returns:
  - Fixed cost = 1 unit of capital per firm: $K + K^* = n + n^* = N$
  - Variable cost: β units of $L^{1-\mu}R^\mu$ per unit output

Trade cost measured by ϕ_R

Natural Resource-Sector
- Located in the South
- Iceberg trade cost only from South to North measured by $0 < \phi_R < 1$
- Open access renewable resource
- Profit-maximizing firms operating under conditions of free entry
- Only one factor of production: L
- The resource R is only used to produce the differentiated good

Worldwide labour endowment

$2L$
$(L = L^*)$

Labour is mobile between sectors but immobile between countries

No trade costs

North and South markets

International iceberg trade costs measured by $0 < \delta < 1$

δ and ϕ_R measures the freeness of trade. The highest openness is found when $\delta = 1$ or $\phi_R = 1$ (there is no trade cost)

Note: $\delta = \tau^{1-\sigma}$ and $\phi_R = \tau_R^{\mu(1-\sigma)}$.

Figure 2. Dynamics of the resource

$$R(S) = \mu BS \frac{\alpha L(\sigma - 1)}{\sigma} \cdot (E + E^*)$$

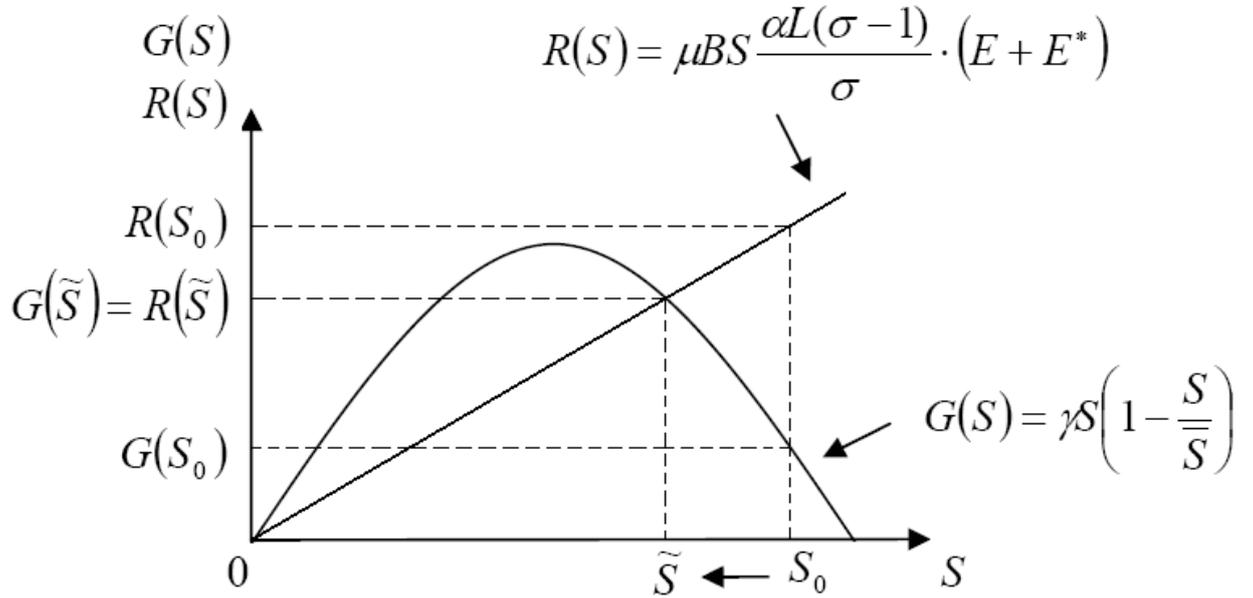$$G(S) = \gamma S \left(1 - \frac{S}{\overline{\overline{S}}} \right)$$

Figure 3. The *labour and capital markets equilibrium condition* ($g = g(S_n)$) and the *differentiated goods market equilibrium condition* ($S_n = S_n(g)$)
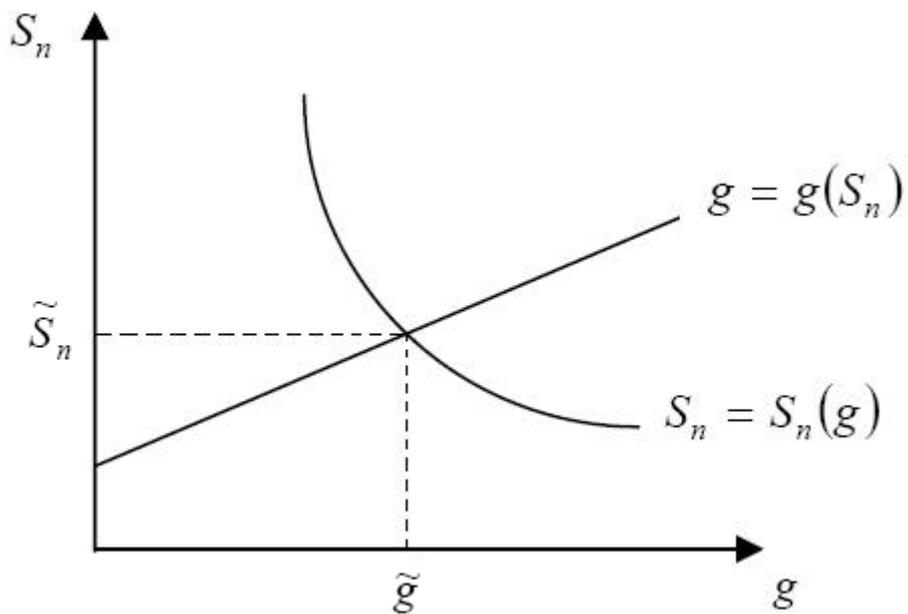
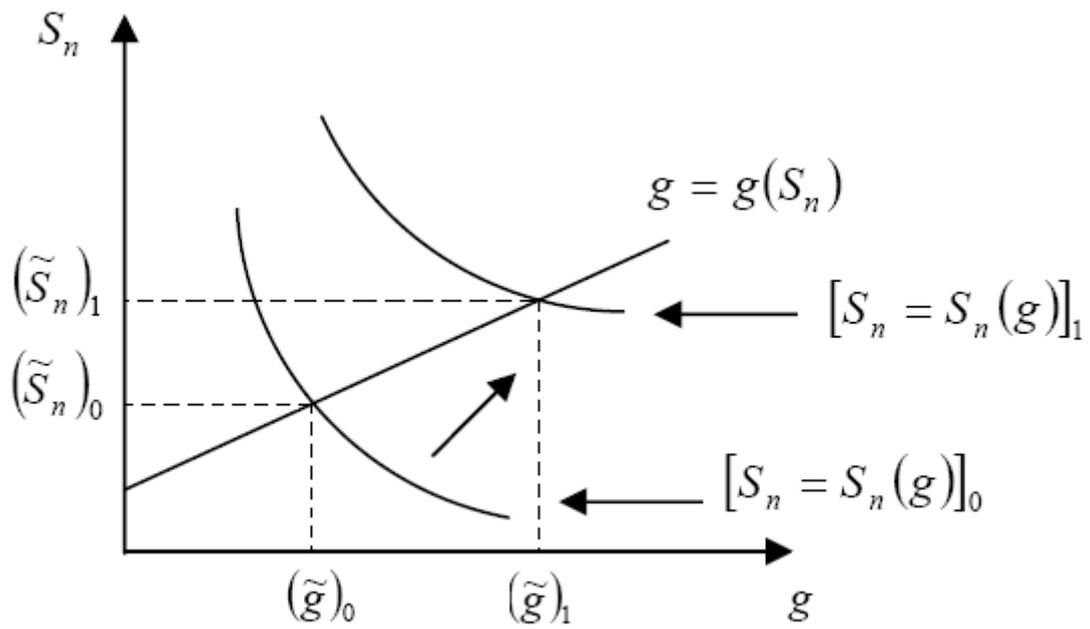**Figure 4. Effects of a reduction in the transport cost of differentiated goods**

Figure 5. Effects of a reduction in the transport cost of the natural resource
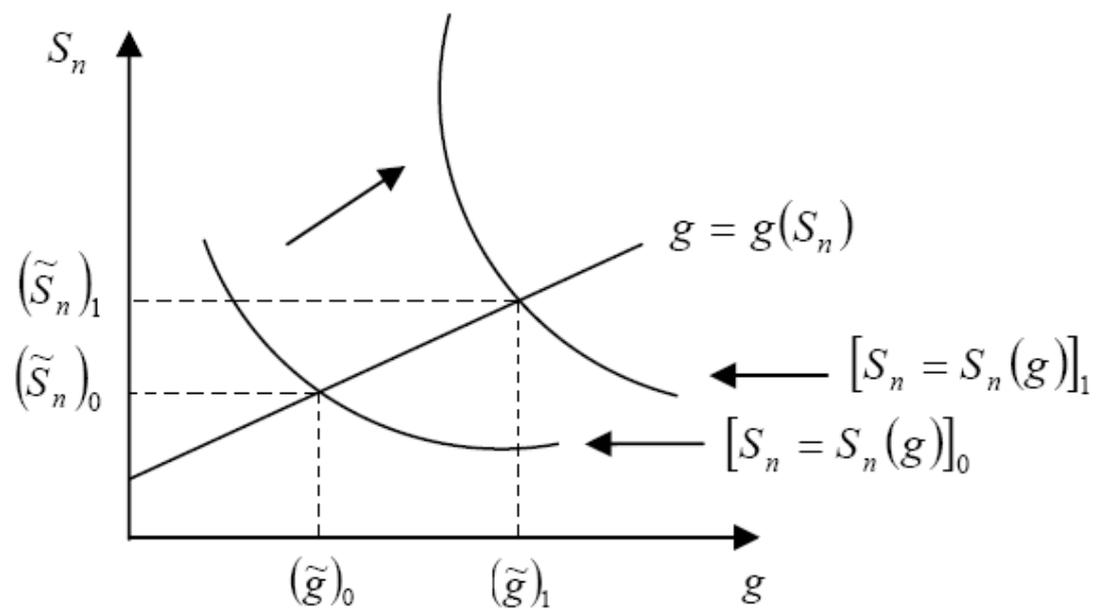
Figure 6. Evolution of the stock of the natural resource when the concentration of firms in the North increases ($dS_n > 0$): Case in which $S > \dfrac{\overline{S}}{2}$

$$G(S)$$
$$R(S)$$

$$\left[G(\tilde{S})\right]_0 = \left[R(\tilde{S})\right]_0$$
$$\left[G(\tilde{S})\right]_1 = \left[R(\tilde{S})\right]_1$$

$$\left[R = R(S)\right]_0$$
$$\left[R = R(S)\right]_1$$
$$G = G(S)$$

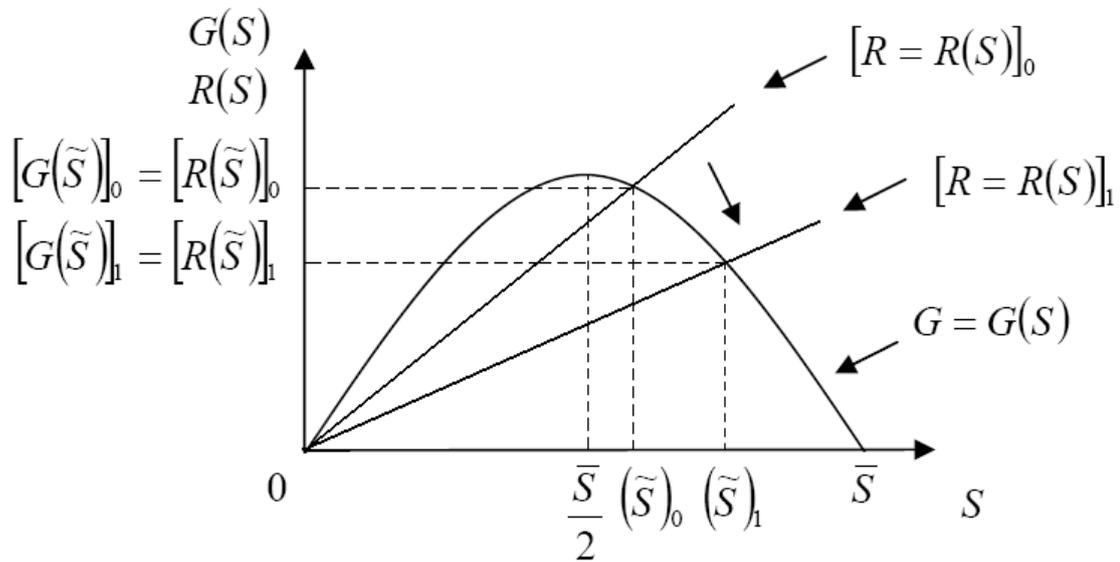$$0 \qquad \dfrac{\overline{S}}{2} \quad (\tilde{S})_0 \ (\tilde{S})_1 \qquad \overline{S} \qquad S$$

Figure 7. Evolution of the stock of the natural resource when the concentration of firms in the North increases ($dS_n > 0$): Case in which $S < \dfrac{\overline{S}}{2}$

$$\left[R = R(S)\right]_0 \quad \left[R = R(S)\right]_1$$

$$G(S)$$
$$R(S)$$

$$\left[G(\tilde{S})\right]_1 = \left[R(\tilde{S})\right]_1$$
$$\left[G(\tilde{S})\right]_0 = \left[R(\tilde{S})\right]_0$$

$$G = G(S)$$

$$0 \qquad (\tilde{S})_0 \qquad (\tilde{S})_1 \ \dfrac{\overline{S}}{2} \qquad \overline{S} \qquad S$$