The Gravity Model with Endogenous Transport Cost

Gabriel Figueiredo de Oliveira *
University of Nantes, Faculty of Economy, LEN

September 1, 2008

Abstract:
The goal of this paper was to demonstrate that it is possible, from a theoretical gravity model, to show the interaction between the transport cost and bilateral trade. The first direction of causality, i.e. the negative influence of the transport cost on the volume of trade was demonstrated explicitly. The originality consisted in demonstrating the second direction of causality that results from the presence of economies of scale in the transport sector. This was made possible by incorporating this sector in the model, taking account of the characteristics of the cost function and the specificities of the market structure.

Keywords: Equation gravitationnelle, coût de transport, économie d’échelle, niveau d’infrastructure, structure de marché.

JEL Classification: F10

* Any remaining errors are mine.

PhD Candidate, LEN, Faculté des Sciences Économiques, Université de Nantes, BP 52231 Chemin de la Censive du Tertre, 44322 Nantes Cedex 3, France;
E-mail: gabriel.figueiredo@laposte.net.
**Introduction:**

The trade cost represents the total costs, other than the cost of production, involved in supplying the goods to the final consumer. It has a negative impact on trade and is influenced by the interaction of multiple factors such as trade policies, the transportation system, the level of infrastructures, the geographical and historical factors, and so on. As some of these factors are difficult to observe directly, the measurement of the trade cost is relatively complex.

According to the estimations of Anderson and Wincoop (2004), the tariff equivalent of the trade cost is 170% and can be broken down into the local distribution cost and the international cost. The first covers the distribution and sale in the domestic market, representing about 55% in tariff equivalent. The international cost accounts for 74%, of which 21% corresponds to transport and 44% to trade cost linked to border crossing\(^1\). The international costs turns out to be predominantly attributable to the transportation of goods, explaining the increased interest of economists in transport determinants and their influence on bilateral trade.

In particular Limao and Venables (2001) highlight the importance of an efficient transport network, allowing a reduction in transport costs in order to facilitate trade. Their estimations show that, on the one hand, if the country’s infrastructures deteriorate to the point that it moves down from the median group into that of the 25% less well equipped countries, the transport price increases by 12%. On the other hand, however, a 10% increase in transport cost represents a reduction in trade of more than 20%.

In the field of maritime transport, Clark, Dollar and Micco (2004) studied port efficiency and its impact in the determination of transport costs. According to the authors, an improvement in port efficiency that would raise the country from the 25th to the 75th percentile, would result in a 12% reduction in transport charges. On a similar theme, Sánchez, Hoffman et al. (2003), observed a negative relationship between this variable and the freight rate for the Latin American countries. According to Hoffmann et al. (2006) doubling port efficiency in the importing and exporting countries would have the same effect on the freight rate as reducing the distance between them by half. These empirical studies underline the link between the level of infrastructures, the transport costs and the volume of trade.

The aim of this work is to develop a gravity model with an endogenous transport cost, illustrating the relationship between volume of trade and its cost. To demonstrate this interdependence, the gravity equation, based on the Dixit-Stiglitz-Krugman model\(^2\), is used with transport being considered as the only barrier to trade. As a result the first direction of causality becomes explicit, since the gravity equation is a negative function of trade cost.

The focus of this paper is to further show the second causal direction i.e. the trade volume effect on transport price. To analyze this relationship, there is a need to introduce a transport cost function, so as to endogenize its cost. In this context bilateral trade is deemed to happen in two stages. In the first stage, consumers must have access to information on transport costs, which results from weighing the desire to import (expressed by the gravity equation, in which the term representing the transport cost is unknown) against the transport supply function. This adjustment between these two stages, determines the equilibrium price. Incorporating this price into the gravity equation, determines the bilateral value of trade, which can then be considered as the second stage.

---

\(^1\) Border crossing: including 8% for tariff and non-tariff barriers, 7% for linguistic barriers, 14% for transaction costs relating to the difference in currency, 6% for the costs of information and 3% for security costs.

\(^2\) Anderson and Van Wincoop (2003), Hummels (1999), Bergstrand and Baier (2002), Deardorff (2004), were primary developers of the gravity equation based on this kind of model.
However, there must be an *a priori* definition of the supply function. For that, we need to start with the second stage of trade, where the equilibrium price is known, and express it in relation to quantities. In other words, we analyze the supply reaction in the face of changes in demand. The decreasing shape of this function translates into the presence of economies of scales, thus showing the second causal direction between volume of trade and transport costs.

In addition, the level of infrastructures was incorporated into the transport cost function, such that an increase in this factor results in a decrease in costs, thus stimulating trade between the countries. In this model, this level corresponds to stock (or capital), the changing nature of which introduces dynamism into the model.

The model has been tested with reference to two different market structures. In relation to competition and the marginal cost pricing rules, it was found that this structure could not be applied, since such rules generate negative profit. In a monopolistic structure (where the strategy of the company consists in limiting production in order to engender upward pressure on the price) the model can be applied, even though the best structure is a situation where average cost pricing rules apply. In the latter scenario, the quantity transported is maximized, subject to budgetary equilibrium.

This article is divided into three sections, the first of which is devoted to the analysis of the interaction between the trade volume and transport charges, as well as the development of the transport cost function. The second section, comprises a simulation exercise for the three different scenarios, with the goal of studying the influence of the market structure on the model. The last section focus, primarily, on analysing the sensitivity of the two main models and secondly, on the presentation of an alternative model with decreasing multilateral resistance.

1. **Gravitation equation with the endogenous transport cost**

1.1. *Interaction between bilateral trade and the transport sector*

Theoretical gravity models which incorporate trade costs, seem to be a good starting point to introduce a transport sector, in order to endogenize its cost. I would like to point out the two main models. The first model was developed by Anderson and Wincoop (2003), based on the concept of "trade separability", and the second corresponds to the "Comparative local advantage" developed by Deardorff (2004). The latter seems to be better adapted to analysing the relation between the transport cost and bilateral trade, given that in the Anderson and Wincoop model, the import price corresponds to the export market price multiplied by the factor \( t_{ij} \), therefore, the interpretation of this term as the transport cost, assumes that whatever the transported amounts, the price of this service remains identical, which will make it impossible to take into consideration one of the most important characteristics of this sector: economy of scale. In the case of the Deardoff model, the import price \( P_{ij} \) corresponds to the sum of the production cost \( c_i \) of the goods produced by the partner and the cost of the bilateral trade \( t_{ij} \), multiplied by a markup \( \mu \). Furthermore, this last model proposes an equation for bilateral trade volume, which will be used to show the transport demand, as we can see in the following equation:

\[
P_{ij} = P_i t_{ij},
\]

where \( P_i \) and \( t_{ij} \) represent the price of importing, exporting and bilateral trade respectively. This trade cost is such that: \( t_{ij} = 1 + \tau_{ij} \), where \( \tau_{ij} \) is between *zero* and *one*.

3 The positive impact of the level of infrastructures on bilateral trade has been highlighted by several empirical studies such as those carried out by Bougheas, Demetriades and Morgenroth (1999), and by Limao and Venables (2001).

4 \( P_i = P_i t_{ij} \), \( P_i \) and \( t_{ij} \) represent the price of importing, exporting and bilateral trade respectively. This trade cost is such that: \( t_{ij} = 1 + \tau_{ij} \), where \( \tau_{ij} \) is between *zero* and *one*.

5 This markup is equal to one in the Armington model and in the case of monopolistic competition.

\[
\mu = \sigma / \sigma - 1 > 1
\]
\[ x_{ij} = \frac{1}{\mu(c_i + t_{ij})} Y_j s_i \left[ \frac{c_i + t_{ij}}{I_j} \right]^{1-\sigma} \]  

(1)

Where the term \( x_{ij} \) represents the quantities imported by j from the region i, \( Y_j \) and \( s_i \) (where \( s_i = Y_i/Y_w \)) correspond to importing country income and the share of production of country i in relation to world production respectively. As for \( I_j \), it represents the cost index\(^6\) of all the other countries to provide the goods to the importing country j. Finally, \( \sigma \) is the substitution elasticity between varieties. To obtain the equation in terms of value, Deardorff multiplies the two sides by the price of the imported goods; and the new import demand equation is hence:

\[ v_{ij} = \frac{Y_j Y_i}{Y_w} \left[ \frac{c_i + t_{ij}}{I_j} \right]^{1-\sigma} \]  

(2)

According to this equation, the value of the goods produced by i and imported by j depends on the share of the product of their income \((Y_i, Y_j)\) in relation to world income \((Y_w)\) and the ratio of bilateral resistance to multilateral resistance. These two equations are obtained from the maximization of the utility subject to budget constraints. This presupposes that consumers have the necessary information about the imported goods. However, this price is broken down into production and transportation cost, which are exogenous to the model.

The goal is to endogenize the transport cost and for this, a transport sector will be introduced in the model. The demand of this sector is characterized by the fact that this service does not provide a direct utility for consumers, since the transport demand results from the desire of the importer to consume a foreign product. Consequently, the transport demand is a demand derived from trade flows between countries\(^7\) and in order for trade to take place, consumers must have the information about the service price in advance. In this way, bilateral trade will take place in two stages, the first corresponding to adjustment between the desire to import (in which transport cost is unknown) and the supply function of transport. The adjustment between these two factors determines the equilibrium price. Once the price is known, trade can take place, which corresponds to the second stage. Before introducing a transport sector into the model, the form of the supply function should be defined. To do so, it is necessary to start from this second stage, when the equilibrium price is known, and express it in relation to quantities (equation 3).

\[ t_{ij} = I_j \left[ \frac{x_{ij} \mu I_j}{Y_j s_i} \right]^{\frac{1}{\sigma}} - c_i \]  

(3)

The relation between the transport price and trade flows can be analysed by the first and second derivatives analysis. According to equations (4) and (5), this function is decreasing and convex in relation to the transport volume.

\(^6\) Production cost and transfer cost
\(^7\) McConville, p. 93; Evans & Marlow, pp. 61-64.
This curve represents the different intersection points between the offer and demand and if it is decreasing, it supposes that the transport company is able to reduce its price when its output level increases. In order for it to happen, it is necessary that this industry is identified by the presence of economies of scale.

The maritime transport is the first example used to illustrate the existence of economies of scale and according to Marshall (1890), its origin stems from the fact that "a ship’s carrying power varies as the cube of her dimensions, while the resistance offered by the water increases only a little faster than the square of its dimensions". Recent studies focus on the evaluation of economies of scale, as a function of different ships sizes. According to Culline and Khanna (1999, 2000), the function of the total average cost is decreasing and convex in relation to the ship size. The decreasing form of this function can be explained by the fact that the total costs can be divided into fixed and variable costs, consequently, the potential for economy of scale derives from the fact that fixed costs can be distributed across a large number of units.

On the one hand the trade volume equation can be used to represent transport demand, due to the fact that it is a demand derived from import demand. On the other hand the determination of the service price takes place prior to trade and will result from the balance between supply and demand in this sector. In addition, the maritime transport literature underlines the importance of economies of scale, which allow average cost to be reduced as the transported volume increases. The following phase consists in introducing this sector with its specificities, to endogenize the transport cost.

1.2. The function of the transportation cost

Maritime economics literature supports the use of transport cost function taking account of fixed and variable costs. However, it is necessary to make three hypotheses relating to this function to represent a negative relation between average cost and quantity.

First of all, the sector supply should have sufficient stock capacity to avoid being on the short side. The second hypothesis postulates that an equilibrium exists in the balance of trade between the two countries, in order to exclude the additional costs induced by empty return trips. Finally, the sector output is taken to correspond with the transport of goods between the starting point and the final destination, which leads to the interpretation of the fuel cost as a fixed cost, since it does not depend on the trade volume, but on the distance.

---

8 The presence of fixed costs is due to the fact that the company must bear certain costs, in particular operational costs and capital costs, ever when the ship does not move.

9 When supply corresponds to the short side, the price of transport increases. This mechanism is the consequence of inadequate investment in new ships, which leads to an imbalance between supply and demand.
Therefore the transport costs related to the sea segment can be regarded as fixed, contrary to those incurred in the port segment, since it depends on loading/unloading quantities. In addition, the port cost includes not only the costs of labour and capital depreciation, but also those due to ship immobilization in the port. This immobilization can be due either to ship berthing time or to the time the ship spends at berth for handling operation, which in the first case depends on the number of berths and the quality of the pilot assistance and in the second case, on the volume as well as on the equipment performance. On one hand the port charges can be considered as a variable cost, and on the other hand its unit cost depends on the level of infrastructures. To consider these two factors, this function will be shown in the following way:

\[ CV = \frac{Z}{Infra} x_{ij} \]

Where the Z/Infra ratio represents the loading unit costs, which is a decreasing function of the infrastructure level. As the variable cost depends on the infrastructures, it is possible to differentiate two cases. The first case corresponds to a situation where this level is constant over time, whereas in the second case it increases. This increase results from the investment made at the beginning of the period, allowing not only to replace this stock as it deteriorates, but also to increase its capacity. However, these investments result from the public policy decisions, which determine the share of tax revenues which will be used to finance the accumulation of infrastructures. Consequently, this level of investment will be a positive function of the country's revenue, which is an exogenous variable in this model.

In order to make these investments, and thus, the level of the infrastructures, endogenous, it is necessary to introduce three simplifications which allow to link these investments to bilateral trade. The first is to assume that for each pair of countries, there is only one “route” that could link them, in a way the level of the infrastructure \( i \) and \( j \) are independent from \( i \) and \( k \) (with \( k \neq j \)). The second simplification is to take it that the investment for this route is financed by a direct tax levied by the public authorities on import value, which is included in the transport price. The third simplification consists in assuming that the most efficient investments are made during the first periods, which provides an incentive for the public authorities to gradually reduce the tax on the import value. Consequently, the relation between the bilateral trade and investments in infrastructures can be represented by a positive and concave function.

The goal of the two first simplifications is to link the investment made in the infrastructures of each "route" with the volume of trade of each pair of countries. While the last one brings the conditions in the investment function form, that can be shown as a logarithmic function. In order to realise these investments at the beginning of each period, the public authorities finance these investments and after, they deduct from transport firm, a tax equivalent to these expenses.

To summarise, the infrastructure level can be considered as a stock where the accumulation results from the net investment made at the beginning of the period \( t \). These two aspects can be expressed as follows:

---

10 This investment is not only used to invest in new equipment, it is also designed to improve port organization, so as to facilitate trade.
\[ G_t = G_{t-1} (1 - \delta) + I_t \]  
(6)

\[ I_t = \ln(v_{ijt-1}) \]  
(7)

Where \( G_t (G_{t-1}) \) represents the infrastructure stock in the period \( t \) (\( t - 1 \)), \( Inv_t \) is the investment made during the period \( t \), \( \delta \) corresponds to the infrastructure depreciation rate and \( v_{ijt-1} \) represents the value of the goods produced by \( i \) and imported by \( j \) in the period \( t - 1 \).

Replacing these investments as well as the variable cost by their expression, we obtain a transport cost equation that:

\[ CT_t = A + \ln(v_{ijt-1}) + \frac{Z}{G_t} x_{ijt} \]  
(8)

\[ \frac{CT_i}{x_{ijt}} = \frac{A + \ln(v_{ijt-1}) + Z}{x_{ijt}} \]  
(9)

From this average cost function, it is possible to identify two effects through which the trade volume will influence the unit transport cost. The first is a direct effect, resulting from the proportion of the fixed costs in the total cost, which leads to the reduction of the unit cost as the trade quantities increase. This effect can be envisaged as the exploitation of economies of scale within transport companies. The second is an indirect effect, by which trade growth stimulates investment, to increase the level of infrastructures in the following period, in order to reduce the variable costs.

To illustrate this transport cost determination process, we will develop three scenarios. The first corresponds to a situation of perfect competition, the second is characterized by a monopoly market structure and the last corresponds to a situation where the transport company applies the a unit cost pricing procedure.

2. The impact of the market structure of the transport sector on bilateral trade

The purpose of the previous section was to demonstrate that, from a theoretical gravity model it is possible to show the interaction between the transport cost and the volume of trade. The negative impact of transport charges on bilateral trade appears in an explicit way in the model. The originality consisted in showing the second direction of causality, i.e. the reduction of the transport cost induced by the increase in the amount of trade. This relation underlines the importance of economies of scale in the transport sector.

In this section, the transport cost will be determined by the adjustment that is made between import demand and transport supply. This analysis is drawn from the partial equilibrium model elaborated by Hummels and Skiba (2004), which considers the interaction between the trade volume and the transport cost. They imagine two countries, an exporter and an importer, as well as a transport company in a monopoly position. In this model the imported quantities depend on freight rate, and this rate will be established based on the relative strengths of sector supply and import demand.

However the difference is that, the model that will be presented in this article will use the gravity equation (in terms of volume) to express import demand. Moreover the supply function, will take account of the level of infrastructures as well as the accumulation of infrastructure, in order to render the model dynamic. The other original point is to study the
effect of the various market structures, on the determination of transport cost and the amount of trade. To do so, three variants of the model will be explored in this section. Finally, the last section will focus on the analysis of the sensitivity of different parameters of the model, and on the presentation of an alternative model which will consider the decrease in multilateral resistance.

1.2. Pure and perfect competition model

According to economic theory, marginal cost pricing corresponds to the "first-best optimum", since it allows social welfare to be maximized. The price is applied in the competitive market structure, which assumes that the producers and consumers consider the price as given, since individually they cannot influence it. In addition, companies can freely enter or exit the market, and hence the long-term profit of this sector is zero.

This market structure can be analysed by a representative firm, whose goal is to maximize profit. To do so, market price should be equal to marginal cost (equation 10), which gives the optimum output level (equation 11).

\[
t_{ij} = I_j [\frac{x_{ij} \mu I_j}{Y_j s_i}]^\frac{1}{\sigma} - c_i = \frac{Z}{G_i} \\
x_{ij} = \left(\frac{Z/G_i + c_i}{I_j}\right)^{-\sigma} \frac{Y_j s_i}{\mu I_j}
\]

However, this company decides to enter this market if and only if, the expected profit is positive or zero. However, in the presence of economies of scale, the competition pricing rules leads ineluctably to a deficit, since the marginal cost is always lower than the average cost. Consequently, the best strategy for this representative company is not to produce this service, leading, to an absence of trade between countries.

The dynamics of the model stem from the fact that a share of the imported value of the previous period \(v_{ijt-1}\), will be allocated to investment \((\text{Inv}_t)\) in infrastructures \((G_t)\) in the following period. For this level of infrastructures, the company knows the marginal cost \((Cm_t)\) and then the optimal quantity \((x_{ijt})\) to produce that leads to align this cost with the market price \((t_{ij})\). At this stage, the total revenue \((RT_t)\) and the total costs \((CT_t)\) can be calculated and the difference between them determines the profit \((\text{Profit}_t)\). As this profit is negative, the company decides not to produce, which leads to the absence of trade.

The table below contains all the parameters used to carry out the simulations for the three scenarios, as well as the main results obtained for this market structure. All these parameters were selected in an arbitrary way, with the exception of the elasticity of substitution, which according to the literature is between five and ten. In addition, in the three models, the investment equation was multiplied by \(\alpha\) (\(\alpha = 0.5\)), to prevent over-accumulation of infrastructures.

<table>
<thead>
<tr>
<th>Exogenous value</th>
<th>Endogenous value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y_i) : 500 000</td>
<td>(\mu = 1.5)</td>
</tr>
<tr>
<td>(Y_j) : 500 000</td>
<td>(A = 1000)</td>
</tr>
<tr>
<td>(Y_w) : 10 000 000</td>
<td>(Z = 500)</td>
</tr>
<tr>
<td>(c_i = 15)</td>
<td>(G_0 = 30)</td>
</tr>
<tr>
<td>(I_i = 40)</td>
<td>(\delta = 0.1)</td>
</tr>
<tr>
<td>(\sigma = 5)</td>
<td>(\text{Périod} = 30)</td>
</tr>
<tr>
<td>(t_{ij0} = 16.66)</td>
<td>(x_{ij0} = 1339.91)</td>
</tr>
<tr>
<td>(\text{RT}_0 = 22331.90)</td>
<td>(\text{CT}_0 = 23331.90)</td>
</tr>
<tr>
<td>(\text{Profit}_0 = -1000)</td>
<td>(\nu_{ij0} = 63645.92)</td>
</tr>
<tr>
<td>(I_1 = 5.53)</td>
<td>(G_1 = 32.53)</td>
</tr>
</tbody>
</table>
The first group of parameters represents the exogenous variables of this model. The level of infrastructures (G$_0$) is given for the first period, which allows us to calculate the marginal cost and thus the transport price.

The output level is obtained from equation (11). For this price, the total transport supply is 1339.91 units between countries i and j. To obtain the desired import value of country j, either the C.I.F price should be multiplied by these quantities, or this price should be introduced into gravity equation (2). The import value of the first period amounts to 63645.92, which allows us to determine the amount of investment (5.53) and so, the infrastructure stock (32.53) of the following period. However, bilateral trade will not take place, since the revenue generated by the production of this service, does not cover the total cost.

The graphics (Appendix 1: competition model) show the dynamic element in the marginal cost pricing model. Nevertheless, the last graphic shows that the production of this service generates loss that increase over time. If this activity is not subsidized, the countries will not be able to trade.

\[ \text{Graphics} \]

### 1.3. Model with a monopoly market structure

The second case corresponds to a monopolistic market structure, which can be justified by the presence of economies of scale. In this context the marginal cost pricing rule does not cover the total cost, thus the production of transport service leads to a negative profit.

The monopoly market structure supposes that there is only one company is producing the transport service. The demand addressed to this company is equal to total market demand. This demand may be determined by the import volume equation, from which it is possible to obtain the inverse demand function (equation 3).

In a monopoly situation, the company’s profit maximisation objective leads it to choose the output level that allows the adjustment of marginal revenue to marginal cost. However, the revenue should be determined at the outset, as well as the total cost. The total revenue corresponds to quantities produced multiplied by price (equation 3).

\[
RT_{ij} = x_{ij} \left[ I \left( \frac{x_{ij} \mu I_{ij}}{Y_{ij}} \right)^{-\frac{1}{\sigma}} - c_i \right] \tag{12}
\]

The marginal revenue (MR) represents the additional income generated by the monopolist when he sells by selling a new unit, and it results from the derivation of total revenue in relation to quantities:

\[
\frac{\partial RT_i}{\partial x_{ij}} = MR_i = I \left( \frac{x_{ij} \mu I_{ij}}{Y_{ij}} \right)^{-\frac{1}{\sigma}} - c_i - \frac{I_j \left( \frac{x_{ij} \mu I_{ij}}{Y_{ij}} \right)^{-\frac{1}{\sigma}}}{\sigma} \tag{13}
\]

\[
MR_i = I \left( \frac{x_{ij} \mu I_{ij}}{Y_{ij}} \right)^{-\frac{1}{\sigma}} \left( \sigma - 1 \right) \frac{1}{\sigma} - c_i \tag{14}
\]
The company’s cost function includes fixed and variable costs (equation 8). The fixed part can be divided in two groups, of which the first one is consumed by the production process and must be renewed at each period (in this part we also find infrastructure depreciation\(^{11}\)), while the second involves the infrastructure investments, whose objective is to reduce the variable cost.

The marginal cost corresponds to the additional costs borne by the monopolist, when it produces an additional output unit. This cost can be obtained by the deriving the total cost in relation to quantities.

\[
\frac{\partial CT_i}{\partial x_{ijt}} = MC_i = \frac{Z}{G_i} \tag{15}
\]

By balancing the marginal cost and the marginal revenue, the company calculates the output level (equation\(^{16}\)) that maximizes its profit.

\[
x_{ijt} = \left(\frac{\sigma(c_j + Z_i/G_i)}{I_j(\sigma - 1)}\right)^{-\sigma} \frac{Y_j s_j}{\mu I_j} \tag{16}
\]

The optimum quantities are introduced into the inverse demand function (equation\(^{3}3\)), thus allowing to determine the price which maximizes profit. In order to check that this price maximizes profit, it should be such that the profit made (the service price minus the marginal cost) in relation to price, is inversely proportional to demand elasticity. This relation can be written in the following way:

\[
\frac{t_{ij}(x_{ijt}) - Z_i/G_i}{t_{ij}(x_{ijt})} = \frac{1}{|\epsilon|} \tag{18}
\]

Where the term \(\epsilon\) represents demand elasticity, and where the first term of this equation corresponds to the Lerner\(^{12}\) index, i.e. power market indicator. This index will be calculated for the different market structures, in order to analyse the relative importance of this market power.

For this company to accept to produce this service, the expected profit must be positive (or zero). If this is the case, then trade can take place and the volume is determined by the company’s maximization program. If this is not the case, the monopolist refuses to produce and so countries cannot trade.

\(^{11}\) This company must pay an equivalent amount of tax to the investment made at the beginning of the periods, which amounts to internalizing the investment in the transport cost equation

\(^{12}\) This index is between 0 and 1, where zero corresponds to a pure and perfect competition structure and one corresponds to extreme market power.
The mechanism of this model is such that the investment at the beginning of a period determines the level of infrastructures. For this level, the company knows the marginal cost and thus can solve the problem of maximization, which determines transport volume. For these quantities, the market determines the corresponding equilibrium price. At this stage, the company knows its costs and the expected revenue. If the profit is positive, then trade can take place.

These transmission systems between the trade quantities and the transport unit costs can be tested by a simulation exercise. The initial values of parameters are identical to those used in the preceding model.

<table>
<thead>
<tr>
<th>Exogenous value</th>
<th>Endogenous value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_i$ : 500 000</td>
<td>$\mu = 1.5$</td>
</tr>
<tr>
<td>$Y_j$ : 500 000</td>
<td>$X_{ij0} = 439.06$</td>
</tr>
<tr>
<td>$Y_w$ : 10 000 000</td>
<td>$Z = 500$</td>
</tr>
<tr>
<td>$c_i = 15$</td>
<td>$G_0 = 30$</td>
</tr>
<tr>
<td>$I_j = 40$</td>
<td>$\delta = 0.1$</td>
</tr>
<tr>
<td>$\sigma = 5$</td>
<td>Period : = 30</td>
</tr>
</tbody>
</table>

To maximize its profit, the firm decides to transport 439.06 units with a price of 24.58, which leads to a profit of 2475.91. As this profit is positive, the countries will be able to trade. The introduction of this price into the gravity equation, leads to the determination of import value (26069.37). By reducing its production (439.06 as compared with 1339.91), the monopoly market price becomes significantly higher than the marginal cost. This price maximizes the company's profit, since for these quantities the equation (17) has been verified. Moreover, the Lerner index is higher than zero and increases over time, which results in an increase in market power.

The dynamic between the transport cost and the trade quantities is driven by the infrastructures accumulation, which leads to the marginal cost reduction and thus decreasing the transport price. Therefore, the trade quantities will be intensified, which in its turn stimulate the infrastructure investment. Finally, the company's profit is not only positive, but also growing during the time. The perspectives of positive profit, gives the incentives to provide this service.

2.3. Monopoly Model: average cost pricing

In the third model, the economies of scale result from the existence of significant fixed costs, therefore the marginal cost pricing rule could not be applied (first scenario). Consequently the monopoly corresponds to the most efficient market structure. The problem is induced by the power of the monopolist (the Lerner index is 0.322), who is encouraged to establish a high price, in order to reach a superprofit (scenario 2). The result is that leaving production to only one company is socially efficient, if the monopolist allowed to set pricing policies which maximize its profit.

To counter this phenomenon, each country-pair should attribute the operation of this service to only one company, but in return it should transport as many goods as possible, under balanced budget constraint. To achieve this goal, the governments of these two countries impose an average costs pricing rule. Consequently the company will chose the output level that leads to a balance between price market and average unit cost.
\[ I \left( \frac{x_{ij} \mu I_i}{Y_j S_j} \right)^{-1/\sigma} - c_j = \frac{Z}{G_j} + \frac{A + Inv_i}{x_{ij}} \]  

(19)

Then this quantity can be introduced into the equation (3) to find the price that corresponds to the average cost. This equilibrium price determines the trade value, and thus, the investment in the following period. In order to verify that this price allows as many goods as possible to be transported without generating a loss, the profit of each period must be greater than zero and the transported volume should be higher than those in the previous scenario. This simulation uses the same parameter values as those in the previous model; however the results obtained differ.

<table>
<thead>
<tr>
<th>Exogenous value</th>
<th>Endogenous value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y_i) : 500 000</td>
<td>(\mu = 1.5)</td>
</tr>
<tr>
<td>(Y_j) : 500 000</td>
<td>(t_{ij0} = 17.52)</td>
</tr>
<tr>
<td>(Y_w) : 10 000 000</td>
<td>(A = 1000)</td>
</tr>
<tr>
<td>(X_{ij0} = 1173.28)</td>
<td>(R_{ij0} = 20554.80)</td>
</tr>
<tr>
<td>(Z = 500)</td>
<td>(I_1 = 5.48)</td>
</tr>
<tr>
<td>(G_0 = 30)</td>
<td>(G_j = 32.47)</td>
</tr>
<tr>
<td>(\delta = 0.1)</td>
<td>(Lerner_{ij0} = 0.049)</td>
</tr>
<tr>
<td>(\sigma = 5)</td>
<td>(\epsilon_{ij0} = 7.19)</td>
</tr>
<tr>
<td>Period : = 30</td>
<td>(\epsilon_{30} = 5.37)</td>
</tr>
<tr>
<td>Profit_{ij0} = 0</td>
<td>Lerner_{30} = 0.02</td>
</tr>
</tbody>
</table>

For this equilibrium price, the transport volume is almost twice that of the private monopoly case. This price is between the competition and monopoly price. Moreover the zero profit constraint is complied with, which indicates that the trade can take place. For this transport cost, the import value of country \(j\), is higher than that in scenario (2). In addition, the modification of the company's objective has made it possible to reduce its market power, since the Lerner index (0.049) is relatively closer to that obtained in a competitive situation (where this index is equal to zero), than in the monopoly case (0.322). So this pricing rule reduces the distortion induced by the market power, thus approaching the “first best optimum”.

The graphics of these three situations show the dynamic nature of the model, in which the accumulation of infrastructures is faster during the initial periods, due to the positive and concave relation between the investment and the value of trade. As the unit costs depends negatively on the level of the infrastructures, its reduction over time will become gradually smaller, thus leading to a deceleration in trade growth.

3. Sensitivity Analysis

3.1. Sensitivity analysis of two monopolistic structure models

In a competitive market structure, there is no trade since the best strategy for transport companies is not to produce. In the other two models, trade is possible, but not obligatory, since it will occur only if the company's expected profit is positive or above zero. In these three endogenous transport cost models, identical values have been used for each parameter, which leads us to carry out a sensitivity analysis in order to understand their influence on the model. Each table is composed of three scenarios: in the first the values of the parameters are used as a reference; these values decrease in the second scenario and increase in the last. In each scenario we find the values of four main variables: trade quantities, service price, company profit and bilateral trade value.
In addition, each column corresponds to the parameter that we wish to modify, while all the others are taken to be constant. The first and second tables correspond respectively to the monopoly model and the average cost pricing model. These tables indicate the values of the first period, whereas the dynamic nature of the model is represented in the graphics which are found in the appendix II.

Private Monopoly: Sensibility analysis

<table>
<thead>
<tr>
<th></th>
<th>$Y_i/Y_w$</th>
<th>$\sigma$</th>
<th>$I_j$</th>
<th>$c_i$</th>
<th>$G_0$</th>
<th>$A$</th>
<th>$Z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>439.06</td>
<td>439.06</td>
<td>439.06</td>
<td>439.06</td>
<td>439.06</td>
<td>439.06</td>
<td>439.06</td>
</tr>
<tr>
<td>$x_0$</td>
<td>24.58</td>
<td>24.58</td>
<td>24.58</td>
<td>24.58</td>
<td>24.58</td>
<td>24.58</td>
<td>24.58</td>
</tr>
<tr>
<td>$t_0$</td>
<td>2475.91</td>
<td>2475.91</td>
<td>2475.91</td>
<td>2475.91</td>
<td>2475.91</td>
<td>2475.91</td>
<td>2475.91</td>
</tr>
<tr>
<td>$v_0$</td>
<td>26069.37</td>
<td>26069.37</td>
<td>26069.37</td>
<td>26069.37</td>
<td>26069.37</td>
<td>26069.37</td>
<td>26069.37</td>
</tr>
<tr>
<td>2</td>
<td>$Y_i/Y_w = 0.025$</td>
<td>$\sigma = 2$</td>
<td>$I_j = 35$</td>
<td>$c_i = 10$</td>
<td>$G_0 = 15$</td>
<td>$A = 500$</td>
<td>$Z = 200$</td>
</tr>
<tr>
<td></td>
<td>219.53</td>
<td>166.20</td>
<td>257.37</td>
<td>1036.79</td>
<td>53</td>
<td>439.06</td>
<td>2928.05</td>
</tr>
<tr>
<td>$x_0$</td>
<td>24.58</td>
<td>48.33</td>
<td>24.58</td>
<td>23.33</td>
<td>45.42</td>
<td>24.58</td>
<td>12.083</td>
</tr>
<tr>
<td>$t_0$</td>
<td>737.96</td>
<td>4263.15</td>
<td>1037.52</td>
<td>5912</td>
<td>359.54</td>
<td>2975.92</td>
<td>14860.25</td>
</tr>
<tr>
<td>$v_0$</td>
<td>13034.68</td>
<td>15789.47</td>
<td>15281.38</td>
<td>51840</td>
<td>4803.45</td>
<td>26069.37</td>
<td>118951.9</td>
</tr>
</tbody>
</table>

Average cost pricing: Sensibility analysis

<table>
<thead>
<tr>
<th></th>
<th>$Y_i/Y_w$</th>
<th>$\sigma$</th>
<th>$I_j$</th>
<th>$c_i$</th>
<th>$G_0$</th>
<th>$A$</th>
<th>$Z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>1173.28</td>
<td>1173.28</td>
<td>1173.28</td>
<td>1173.28</td>
<td>1173.28</td>
<td>1173.28</td>
<td>1173.28</td>
</tr>
<tr>
<td>$x_0$</td>
<td>17.52</td>
<td>17.52</td>
<td>17.52</td>
<td>17.52</td>
<td>17.52</td>
<td>17.52</td>
<td>17.52</td>
</tr>
<tr>
<td>$t_0$</td>
<td>5951.83</td>
<td>3197.77</td>
<td>4567.74</td>
<td>933.71</td>
<td>6519.30</td>
<td>439.06</td>
<td>111.33</td>
</tr>
<tr>
<td>$v_0$</td>
<td>52138.73</td>
<td>50373.24</td>
<td>41758.08</td>
<td>57231.2</td>
<td>57231.2</td>
<td>57231.2</td>
<td>57231.2</td>
</tr>
<tr>
<td>2</td>
<td>$Y_i/Y_w = 0.025$</td>
<td>$\sigma = 2$</td>
<td>$I_j = 35$</td>
<td>$c_i = 10$</td>
<td>$G_0 = 45$</td>
<td>$A = 1500$</td>
<td>$Z = 800$</td>
</tr>
<tr>
<td></td>
<td>490.37</td>
<td>600</td>
<td>610.3</td>
<td>2971.7</td>
<td>0</td>
<td>1258.96</td>
<td>8702.4</td>
</tr>
<tr>
<td>$x_0$</td>
<td>24.58</td>
<td>18.3</td>
<td>18.3</td>
<td>17.0</td>
<td>0</td>
<td>17.06</td>
<td>6.78</td>
</tr>
<tr>
<td>$t_0$</td>
<td>57231.2</td>
<td>30000</td>
<td>30490.7</td>
<td>120370.8</td>
<td>60550.6</td>
<td>284330.0</td>
<td></td>
</tr>
<tr>
<td>$v_0$</td>
<td>24792.76</td>
<td>30000</td>
<td>30490.7</td>
<td>120370.8</td>
<td>60550.6</td>
<td>284330.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$Y_i/Y_w = 0.1$</td>
<td>$\sigma = 8$</td>
<td>$I_j = 45$</td>
<td>$c_i = 20$</td>
<td>$G_0 = 45$</td>
<td>$A = 1500$</td>
<td>$Z = 800$</td>
</tr>
<tr>
<td></td>
<td>2517.9</td>
<td>2436.14</td>
<td>1983.2</td>
<td>491.40</td>
<td>3319.3</td>
<td>1081.3</td>
<td>184.09</td>
</tr>
<tr>
<td>$x_0$</td>
<td>17.06</td>
<td>17.07</td>
<td>17.17</td>
<td>18.7</td>
<td>11.41</td>
<td>18.05</td>
<td>32.09</td>
</tr>
<tr>
<td>$t_0$</td>
<td>121101.3</td>
<td>117216.6</td>
<td>93705.7</td>
<td>28527.4</td>
<td>131507.3</td>
<td>53616.2</td>
<td>13006.2</td>
</tr>
</tbody>
</table>

In these two tables there are two types of variables: those which belong to the transport demand function ($s_i$, $\sigma$, $I_j$ and $C_i$) and those which belong to the supply function ($G_0$, $A$ and $Z$). The first column corresponds to the variable $s_i$, which represents the exporter's share of income in relation to world income. This variable as well as the importer's income, have the effect of stimulating bilateral trade.

According to graphs 1.1.a and 1.1.b Appendix 2, the difference between the rich (scenario 3) and poor countries (scenario 2) grows over time, so that rich countries will be more efficient in serving the importing country market. The consolidation of this privileged position is the resultant of a faster accumulation of infrastructures, leading to a reduced transport cost and thus a reduced trade resistance ratio.
In the monopoly model, the income variable has a positive influence on the trade volume, profit and on trade value, but not on transport price which remains constant for the first period in the three scenarios. A doubling of \( s_i \) leads to a doubling of quantities and trade value, whereas its impact on profit is amplified.

Indeed, the company’s profit is multiplied by 3.35 and 2.4 when \( s_i \) passes from 2.5% to 5% and from 5% to 10% respectively. A higher than proportional increase in profit is due to the fact that \( t_{ij} \) remains constant whereas the quantities have been increased. The dynamics of the model shows that trade growth is faster in scenario 3 than in the two others (graphic 1.1a), which leads to a greater accumulation of infrastructures. In this context the marginal cost of the transport company, and thus the transport price, will be lower than those in the two other scenarios (graphic 1.1.c).

In the case of average costs pricing (graphics 1.1.b and 1.1.d), the \( s_i \) parameter has an effect on price determination, since an increase in this term leads to a fall of \( t_{ij} \), which in turn stimulates trade. The first increase in \( s_i \) multiplies the quantities as well as the trade value by 2.39 and by 2.30 respectively. When \( s_i \) passes from 5% to 10%, \( x_{ij} \) is multiplied by 2.14 and \( v_{ij} \) by 2.11. These increases are greater than those obtained in the monopoly model. The rate of growth in trade, for the three scenarios in the average unit price model, are higher that those of the first model.

Moreover, the monopoly transport price is increasingly higher, and its reduction over time is less significant. Between the first and the last period, the reference scenario price is divided by two in the unit costs pricing model, as compared with 1.6 in the other model. This difference may be explained by greater accumulation of infrastructures, when the average unit cost rule is applied.

The second column takes into account the substitution elasticity (\( \sigma \)) variation, its influence in the model is also considerable, since the values of the principal variables will fluctuate considerably depending on the scenario.

Whatever the scenario, the values of trade and the level of infrastructures (price) are always lower (higher) in the monopoly model than in the average cost pricing case. In addition, the first model shows that the profit for the first period is higher when the \( \sigma \) term is weak, since its strategy consists in applying a very high price (48.33) for a low output level. However, graphic (1.2e) shows that from the sixth (second) period, the profit made in scenario 1 (scenario 3) exceeds that of the second scenario.

Scenario 3 of the unit cost pricing model (graphic 1.2.b) shows that it is necessary to impose a constraint preventing the country from importing for a value which would exceed its income. This constraint modifies the shape of the curve, which becomes parallel to the x-axis from the seventh period, translating that the importer's entire revenue is used to purchase the goods produced by the partner.

For this to be the case, it is necessary for the adjustment variable to be stabilized. This variable is the transport price. In this context, from the seventh until the last period, the company sets its price at 11.1 (graphic 1.2.d). Consequently, the higher the substitution elasticity, the more sensitive the import demand will be to the trade resistance ratio.

When \( I_j \) passes from 35 to 45 in the first period, the quantities increase respectively by 173.26% and 224.95% within the framework of the monopoly and unit cost pricing model. If the production costs decrease by half (change from scenario 3 to scenario 2), the \( x_{ij} \) term will be multiplied by 4.91 in the first table and 6.05 in the second. For the two parameters, the variation between scenarios 2 and 3 increases over time, whatever the selected model.

---

13 Rate of growth for the three scenarios are 258.32%, 258.74% and 275.96% respectively for the unit price model, and 194.06%, 162.74% and 224.72% for the monopoly model.
For the multilateral resistance parameter, the best situation corresponds to the scenario 3 (graphics 1.3.a and 1.3.b), whereas for the production costs it is the opposite. As for the elasticity of substitution, the income constraint prevents the import level from being higher than the country's resources. From the sixteenth period in scenario 2 (graph 1.4.b), the country imports only goods provided by the partner.

As regards the three variables of the supply function, two have a significant impact on trade. The first corresponds to the initial level of infrastructures, which has a positive influence on trade. For a level of 15, whatever the model, the company's expected profit would be negative; therefore the bilateral trade would not occur. When this level exceeds the threshold of 17.5, the expected profit becomes positive and thus trade can take place. As this level increases, trade becomes more and more intense. Unlike the other parameters, the difference in the initial level of infrastructures, will lead to the convergence of the values for the three scenarios (Appendix 1.5).

The second variable, Z, has a negative influence on bilateral trade, whatever the model (graphics 1.6.a and 1.6.b). Whereas the last variable (fixed cost), has only a marginal or no impact on trade according to whether the monopoly applies average cost pricing or that which maximizes its profit.

One of main criticisms of this model resides in the fact that the transport price decreased through the time, contributing to a reduction in bilateral resistance between the partner countries, while multilateral resistance remains unchanged. What leads us to assume that the only "route" which profited from this investment in infrastructures is the one that connects country i to country j, leading therefore, to a reduction in this service price and therefore to an increase in their trade.

The trade resistance ratio determines the positioning of the partner country in relation to the rest of the world in terms of supplying the domestic market of the importing country. The combined effect of a reduction of the numerator whilst maintaining a constant denominator, is equivalent to assuming that the partner country became much more efficient than the other countries. However, there is a higher probability that all others partners which have exported in the first period invest in infrastructure. Consequently, the multilateral trade resistance of importing country should be reduced, which would moderate the effect obtained by this model. This perspective will be taken into account in the next section.

3.2. Model with a decrease multilateral resistance

The objective of this model is to show the incidence of a reduction in multilateral resistance in the determination of bilateral trade. In the preceding models this term remained constant, which leads us to postulate that only the partner has increased its efficiency in supplying the importing country market. In certain scenarios, this improvement was such that all imports came from the partner. This extreme situation can be attenuated by increasing competition between countries to satisfy this market, and this can be represented in the model by a reduction in multilateral trade barriers ($I_j$). In this context it becomes possible to identify the variables which can contribute to the maintenance of a competitive position.

By way of simplification, the multilateral trade resistance will be taken to decrease in an exogenous way, with a constant rate beta ($\beta = 2\%$). The previous models have shown the effects of investment function shape on the negative and convex form of the transport price function. So this model shows a phase for which the reduction in the service price is higher than that of the multilateral resistance, and another where this situation is reversed.

14 Providing this initial level is sufficient for the country to engage in trade
Consequently, the sensitivity of the models in relation to the different parameters will be modified, mainly during this second phase. In addition, it seems essential to introduce a constraint on profit, in order to prevent trade from occurring while the company's profit is negative (Monopolist's Profit Variations Annexe 2 and 3). The values of the first period are identical to those in the previous models. In addition, certain observations are also similar, since in the monopoly case the quantities transported by the company are smaller and the price is higher than those in the average cost pricing model.

When multilateral resistance is decreasing, the model's sensitivity to the parameter $s_i$ changes. There are two phases, one when trade increases and the other when it decreases. In this second case, the model will react differently depending on whether the monopoly applies unit cost pricing or the profit maximization pricing.

If the objective is to maximize profit, then second phase does not occur (graphic 2.1.a) since the company's expected profit would be negative (graph 2.1.e). When the objective consists in maximizing transported quantities, trade continues in this second phase (graphic 2.1.b), even though with lesser magnitude. Consequently, trading periods are longer in the case of average costs pricing than in the monopoly situation. According to graph 2.1.a, trade stops from the eleventh, thirteenth and fourteenth period in scenarios two, one and three of the model of monopoly respectively. In the case of unit costs pricing (graphic 2.1.b), trade continues until the eighteenth and the twenty-eighth period for scenarios two and one, respectively and until the end in the last scenario.

Progressing into the second phase will affect the accumulation of infrastructures, since the investments will be zero in the case of an absence of trade. Furthermore, the infrastructures function takes into account the deterioration of its stock induced by the delta parameter. The combined effect of these two phenomena will result in infrastructure stock depreciation in all scenarios, except for the third one with the unit cost pricing model. This reduction in the level of infrastructures will be reflected in the shape of the transport price, which increases in the last trade periods with average cost pricing (graphic 2.1.d).

Finally, the company's profit decreases over time and if it decided to continue its production beyond the first stage, it would incur large and large losses (graphic 2.1.e). This perspective encourages the company to leave the market, which was not the case when the multilateral resistance was constant.

The influence of substitution elasticity on the model can be summed up in three points; firstly, this parameter plays a decisive role in the duration as well as in the amount of trade. The maximum trade volume in a given period is achieved in scenario 3 (graphics 2.2.a and 2.2.b), as was the case when the multilateral trade barrier was constant. However, this is the situation where the trade period is the shortest. Consequently, the trade growth phase will be shorter when sigma is high.

Secondly, the share of imports from the partner is not as high as when Ij was constant. Indeed, in scenario 3 of the second model, the partner became the only supplier of the domestic market from the eighth period; in the case of decreasing resistance, the value of imports reaches a maximum of 190.655, and then decreases (graphic 2.2.b).

Thirdly, the only scenario in which these countries throughout all periods is the one where sigma is lower. Moreover, the value of imports is relatively constant over time, which makes it possible to continue to accumulate infrastructures (graphic 2.2.c and 2.2.d). In the monopoly case, the company sets a higher price which guarantees profit throughout all periods (graphic 2.2.e), whereas in unit costs pricing this price is almost twice as low (graph 2.2.d).
When the initial trade resistance value varies, the values of the main variable will differ. This resistance takes into account three factors, one of which, the transport cost, is endogenous. As regards the two other factors, they are exogenous and their effects in the models will have opposing signs. As the $I_j$ index increases, country $j$ will be encouraged to increase the partner's share of imports in relation to rest of the world (graphs 2.3.a and 2.3.b), whereas an increase in the production costs will lead to the opposite result (graphics 2.4.a and 2.4.b).

In the case of $I_j$ variation, scenario 3 has the highest import value, although it represents the worst situation in the transport cost variation. In addition, the reduction in production costs is more effective in stimulating trade than the possible increase in the term $I_j$.

This sensitivity analysis shows that trade quantities increase in relation to the importer's and the exporter's income, and to multilateral resistance, while these volumes decrease in relation to production and transport costs. Regarding the substitution elasticity, it influences the intensity of the role played by the resistance ratio in determining bilateral trade. On the other hand, the exchange probability falls when multilateral resistance decreases.

In order to mitigate the impact of this phenomenon, it is possible to increase the level of investment. In the monopoly model, a doubling of investment (appendix 3) not only makes it possible to increase the value of the imports, but also to continue to trade for one additional period. In the case of unit cost pricing, trade continues until the last period, with the exception of scenario 3 of the sensitivity analysis in relation to the production cost (graphic 3.4.b).

**Conclusion**

The introduction of a transport sector into the bilateral trade model, made it possible to show that the economy of scale, the level of infrastructures and the market structure play a decisive role in trade development. Moreover, the sensitivity analysis of these different models leads us to consider the conditions required for trade to take place.

Indeed, the existence of important fixed costs in this sector induced that this could become a loss-making activity, while the demand level remains under the threshold. Thus, the richest countries have a greater probability of meeting this criterion. Moreover, if there is a relatively high level of trade, the resulting investment will also be higher and thus the accumulation of infrastructures will be accelerated. This will result in a marginal cost reduction and consequently a reduction in the transport price. On the other hand, the countries with low-incomes will produce a limited number of outputs. These quantities may not generate enough profit to render the transport activity profitable, thus leading to an absence of trade.

The bilateral barrier must be either lower or slightly higher than the multilateral resistance. In other words, the exporting country must be relatively well placed to export to this market, since as this ratio increases, the probability that this country can export to its partner decreases. The sensitivity of the model to this ratio depends on the value of the elasticity of substitution.

In addition, the variable cost must not be too high. There are two factors that have a bearing on this cost. The first is term $Z$ and the second is the level of infrastructures. These two factors could lead to an absence of trade. Indeed, the marginal cost can be regarded as a constant for a given period, since it does not depend on quantities but on the term $Z$ and on:

---

15 Set of graphics relating to import variations, in a monopoly market structure (Appendix 3).

16 If the exporter's share of income in relation to world income decreases from 5% to 1%, then whatever the pricing rule, the profit becomes negative.
the level of infrastructures. Consequently, the marginal cost function could be represented by a parallel line in relation to the x-axis and its position in the plane depends on this relationship between term Z and the level of the infrastructures.

The lower (higher) the infrastructures (Z) the higher the marginal cost; so that the intersection between revenue and marginal cost will determine a low output level, which could lead to the activity being unprofitable. In the average cost pricing, the price also depends on the marginal cost.

Finally, the fixed cost must not be too high. If this is the case, the countries could be in a “fixed cost trap” which makes transport activities impossible, unless the quantities the countries wish to trade are so high that the average fixed cost becomes relatively low.

If all these criteria are complied with, then bilateral trade becomes possible, whatever the type of monopoly (private or public). In addition, the volume of trade is greater in the average cost pricing model than in that of a private monopoly.

These conditions point to the existence of a vicious circle, which leads the poorest countries to be burdened with a double handicap which may exclude them from international trade. Indeed, on one hand their production level is relatively low and on the other, their resources are too limited to allow them to carry out the required infrastructure investment. Even if they manage to trade, the volume of trade will be of a low magnitude, not generating enough resources to finance measures to facilitate trade and transport. This situation may result in a deterioration of their international competitiveness. Nevertheless, this model also showed that an increase in investment could contribute to an improvement in their export performance. For these countries, it is fundamental to undertake reforms in this area, in order to profit from the domino effect between the transport cost and the volume of trade.
References


Hummels, D. (1999). Toward a Geography of Trade Costs: Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.
Hummels, D. (2001). Time as a Trade Barrier: Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.


Appendix 1: Impact of transport structure market on bilateral trade

Perfect Competition

- Import function
- Marginal cost Pricing
- Infrastructure function
- Profit evolution

Monopoly

- Import function
- Monopoly price
- Infrastructure function
- Profit evolution

Average cost pricing

- Import function
- Average cost pricing
- Infrastructure function
Appendix II : Constant multilateral resistance.

1.1. Sensibility Analysis : Exporting country revenue in relation to world revenue (s).

1.2. Sensibility Analysis : Substitution elasticity (σ).

1.4. Sensibility Analysis: Production cost ($c_i$).

- **Import value evolution: Monopoly model**
- **Import value evolution: Marginal cost pricing**
- **Transport price evolution: Monopole**
- **Transport price evolution: Average cost pricing**
- **Monopole profit evolution**

1.5. Sensibility Analysis: Initial infrastructure level ($G_t$).

- **Import value evolution: Monopoly model**
- **Import value evolution: Marginal cost pricing**
- **Transport price evolution: Monopole**
- **Transport price evolution: Average cost pricing**
- **Monopole profit evolution**


- **Import value evolution: Monopoly model**
- **Import value evolution: Marginal cost pricing**
- **Transport price evolution: Monopole**
- **Transport price evolution: Average cost pricing**
- **Monopole profit evolution**
Appendix III : Multilateral resistance decreasing \( (\ln v_t = 0.5 \ln (v_{ijt}) \).  

2.1. Sensibility Analysis : Exporting country revenue in relation to world revenue \( (s_i) \).

2.2. Sensibility Analysis : Substitution elasticity \( (\sigma) \).

2.3. Sensibility Analysis : Multilateral resistance \( (I_{ij}) \).
2.4. Analyse Sensibility Analysis : Production cost (c).

Appendix IV : Multilateral resistance decreasing ($ln(v_{ijt-1})$).

3.1. Sensibility Analysis : Exporting country revenue in relation to world revenue (s).

3.2. Sensibility Analysis : Substitution elasticity ($\sigma$).

3.4. Sensibility Analysis : Production cost (c).