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Agglomeration and Trade: The Case of Colombia

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he purpose of this paper is to analyze the relationship between trade and agglomeration in the case of cities located far from the coast. In a modified version of the Krugman and Elizondo model, trade should make industries move to the coast in order to reduce internal freight costs. However, empirical evidence suggest that this has not been the case of Colombia.

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I. INTRODUCTION

Industries located in cities as Bogota, Madrid and Mexico have to incur in high internal transportation cost in order to trade with foreign countries. Therefore, trade liberalization should have an important effect in the localization of these industries. The purpose of this paper is to determine the influence of trade and internal freight cost over industry agglomeration in the case of Colombia. For this purpose, I use a general equilibrium model, which provides the hypothesis that are tested econometrically.

Main cities in Latin America are considerably more populated than in developed countries. For example, Buenos Aires accounts for 31% of the Argentinean population, Santiago for 35% of the Chilean population, Mexico City for 17% of the Mexican population, Bogota for 15% of the Colombian population, and Montevideo for 41% of the Uruguayan population. Meanwhile, cities as New York, Milan, Rome, Madrid and Berlin do not exceed 10% of the population of their respective countries[1].

The literature has widely explored this issue. In particular, Krugman and Elizondo (1996) (henceforth *KE*) claimed that the import substitution policy was partially responsible for the large city size in Latin America. In fact, in a relatively closed economy with high tariffs, industries seek to be localized in big cities where consumers and inputs are easily available. However, in the presence of trade, it becomes less important to be near the local consumers and the domestic production of intermediate goods (since products are more likely to be exported and inputs are more likely to be imported). Therefore, entrepreneurs tend to move their industries towards locations with lower rents and less commuting costs.

Following the same argument, in the case of Colombia, the relationship between trade and agglomeration should be even stronger. In fact, Bogota is located relatively far from the coast (approximately 900 kilometers or 16-hours drive)[2] and both inputs and final products incur high internal freight charges. According to Garay (1998), in some cases this charge can be equivalent to a 37.7% tariff.

This intuition is clarified and supported with an adapted version of the *KE* model to the Colombian case. Also, an econometric test is proposed in order to verify it

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1 Source: United Nations Statistics Division from the World Statistics Pocketbook and Statistical Year Book.

2 Approximate time for a 3-4 axis trunck. Source: Invias.

empirically. However, the evidence suggests a strong positive relationship between agglomeration and trade. These results contradict the theory in the sense that trade liberalization should lead to a lower level of agglomeration. Nevertheless, both the theoretical and the econometrics models support the strong influence of internal freight charge over the agglomeration process.

The conclusions obtained may be of interest for policy-making decisions. In particular, this paper may be applied to issues such as city planning, industry incentive policies, infrastructure investment, and in considering a more aggressive trade policy. In fact, the present administration is orienting its government plan towards the development of the Caribbean Coast in order to reduce overall transportation costs.

The structure of the paper is as follows: Section II reviews the literature on trade and agglomeration; section III, extends the Krugman and Elizondo model to study the Colombian case; and the last section contains an econometric approach to the problem. Finally, conclusions, contradictions and future lines of research are presented.

II. TRADE AND AGGLOMERATION: A SURVEY

Urbanism and in particular, city size is a widely explored issue in the Urban and Economics literature. Early contributions such as Henderson (1974) and Losch (1952) claimed that industries tend to be localized according to cities' comparative advantages. These comparative advantages have been recently explained as differences in amenities[3] (see Roback, 1982 and Gyuorko and Tracy,1991), public infrastructure (Martin and Rogers, 1995), fiscal conditions (Gyourko and Tracy, 1991) and political facts[4] (Ades and Glaeser, 1994), among other variables.

A relatively new literature has changed the line of research, including history as an important determinant of city size (Henderson, 1994)[5]. The main implication of this incursion is that it leaves small room for firms' mobilization, at least in the short run. These papers develop models that include endogenous variables as

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3 For example: wheather, violence and pollution.

4 The effects of dictatorship regimes, political instability and centralization processes.

5 As it will be explained later, history seems to be an important determinant in the localization of cities in Latin America. In fact, Spanish settle down in high regions in order to avoid diseases, and have an adecuate temperature.

determinants of agglomeration. The endogenous variables that are usually analyzed are local competition (Glaeser, Kallai, Scheinkman and Shleifer, 1992), availability of a labor force with specific acquired skills (see Beenson, 1991, Rauch, 1993 and Segal, 1976), diversity in the industrial base (Henderson, 1974) and the presence of specialized input suppliers (Wheeler and Mody, 1991).

A third approach reconciles both streams, through dynamic general equilibrium models. This approach appeared as a line of research of the Economic Geography and Trade Models. According to this type of models, firms tend to agglomerate because they find profitable to be geographically close to both the consumers and the inputs supply (centripetal forces). In fact, if firms are not located in the city, they have to pay internal freight charges in order to get the inputs and to sell the final products. The availability of inputs creates backward linkages that reinforce agglomeration, the availability of demand causes forward linkages that also induce agglomeration. However, there are forces that prevent agglomeration (centrifugal forces) such as congestion cost, high rent, pollution, localization of agricultural supply (Krugman, 1993) and the desire of firms to move away from competitors.

Following this approach, *KE* develop a model to explain agglomeration in Mexico City. In this case, the included centripetal forces are the availability of demand and intermediate products (backward and forward linkages, respectively) and the included centrifugal forces are high land rent and expensive commuting cost.

According to the authors, the openness of the economy should lead to a reduction in city size. In fact, industries oriented to the export market will show lower backward linkages (since internal demand is replaced by external demand), and lower forward linkages (since domestic inputs are replaced by imported ones).

Hanson (1997) and Ades and Glaeser (1994) have tested the *KE* hypothesis using econometric models. Hanson uses a three dimensional panel data (state, industry and year) for the case of Mexico. According to his hypothesis, wages should decrease with distance to industrial conglomerates and trade liberalization should increase the importance of transportation cost to the outside and decrease the importance of transportation cost to Mexico city[6]. His empirical results suggest that distance from industrial conglomerates is important to agglomeration, but he does not find any strong evidence in favor of the trade and agglomeration relationship.

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[6] In fact, in addition to the trade hypothesis, he claimed that if wages decrease with distance to industrial conglomerates it should be induced by increasing returns to scale (since fixed amenities matter for wages but this relationship should not be affected by distance to industrial conglomerates).

On the other hand, Ades and Glaeser (1994) use a cross-section of countries to test the *KE* hypothesis. They argue that this relation is not obvious since cities as London and Buenos Aires have grown through commerce and therefore the relationship between trade and agglomeration might be positive[7]. Moreover, they question the causality between trade and agglomeration, claiming that it may be that urban concentration is causing low levels of trade, and not that low levels of trade are inducing concentration. They conclude that there exists a positive relationship between trade and agglomeration but they did not find any evidence for a causal connection between trade and city size.

III. A GENERAL EQUILIBRIUM MODEL FOR COLOMBIA

This section presents a version of the *KE* model that is suitable for Colombia. In particular, the model emphasizes the importance of internal freight costs. Also, simplifying assumptions of the model are removed in order to obtain a more realistic description of the economy. For example, the model considers an export transportation cost which was not considered in the original model, and provides interesting implications.

The first subsection presents some particularities of the Colombian case, the second subsection proposes a Geography and Trade model for Colombia, the third is focused in the parameters used in the simulations and the last one explains the simulation results.

A. PARTICULARITIES OF THE COLOMBIAN CASE

In order to understand the adaptations of the *KE* model to the case of Colombia, this subsection presents some generalities and particularities of the agglomeration and trade process in Colombia.

As other countries in the region, Colombian population and industry are rather concentrated in the capital. In fact, Bogota accounts for 17% of the population and produces a third of industrial production of the country[8]. In terms of trade, the

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7 In this case, Ades and Glaeser (1994) are critizing the Krugman and Elizondo model. However, theirs critique should not affect the model I am proposing here since London and Buenos Aires are located by the coast.

8 Sources: Encuesta Anual Manufacturera (1996) y Encuesta Nacional de Hogares 1996.

tariff liberalization in Colombia also follows the general case in Latin America: during this decade, Colombian industry tariffs were lowered from levels of 43% in 1988 to 11.9% in 1992, and quantitative restrictions were also fully dismantled.

However, there are two particularities of the agglomeration process that make Colombia a special case of analysis (see Figure 1) .The first one is the fact that Bogota is localized in the center of a mountainous country, the other one is the existence of 6 cities with more than half a million habitants in a country with a population of 39 million.

The localization of Bogota means that imported inputs, as well as final export products, are subject to 14 hours of ground transportation in order to have the production process sited in Bogota. Garay (1998) calculated this cost as an equivalent tariff for some products, and his results are showed in Table 1. On top of this, is important to take into account the security problem: an average of 6 trucks are assaulted every day in Colombian roads[9].

Figure 1

[9] Source: El Transporte en Colombia. May 1997. Ministerio de Transporte (draft).

Table 1
Effect of Transportation Cost in Main Colombian Imports

		Total effect %	
		External transportation	Internal transportation
1.	**Agricultural goods**		
	Wheat	9,5	20,3
	Corn	11,3	25,2
	Rice	4,0	11,5
	Soy	7,5	15,4
	Cotton	5,8	2,7
2.	**Intermediate goods**		
	CKD	4,9	0,5
	Soy oil	8,2	7,8
	Gasoline	5,4	22,7
	Gasoils	9,1	25,0
	Oil Base for lubricants	8,6	13,1
	Vinyl Chloride	11,5	10,0
	Potasium chloride	16,6	37,2
	Polythene	7,6	4,8
	Chemical Paste for wood	11,1	7,4
	Newspaper paper	12,1	6,4
	Copper wire	3,2	1,7
3.	**Final goods**		
	Books	8,6	0,6
	Fish Flavor	6,3	8,5

Source: Garay et al (1998).

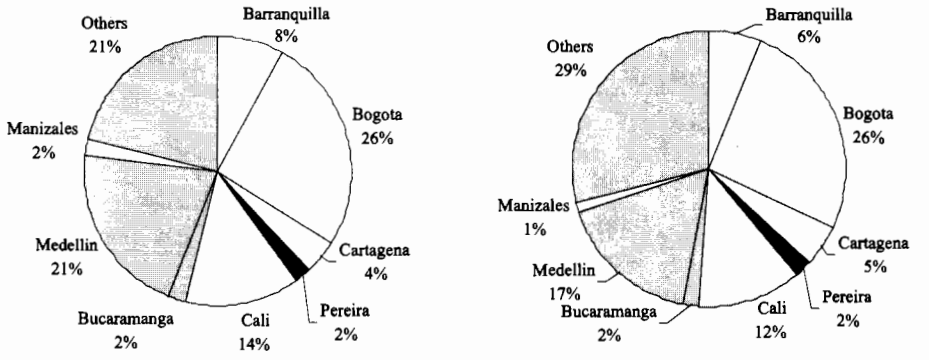
Another particularity of the country that may be a consequence of the localization of Bogota, is the existence of relatively large intermediate cities other than the metropolis, a rather rare occurrence in Latin America. In fact, cities such as Medellin, Cali and Barranquilla account for 6.7%, 5.1% and 3.6% of the population, respectively[10]. Meanwhile, in other countries as Peru, Lima accounts for 31% of the population, and the share of the next biggest cities (Arequipa and Trujillo) reaches only 2 to 3%, approximately[11].

Taking this fact into account, it is possible to argue that the Colombian population is concentrated in the interior rather than in Bogota. As it is shown in Figure 2, the

10 Source; Encuesta Nacional de Hogares (1996).

11 World on line. World statistitcs.

Figure 2
Gross industrial production 1994 and 1996



Source: Encuesta Anual Manufacturera. *DANE.*

main "interior" cities of Colombia: Bogota, Medellin and Cali account for 69% of the industrial production, and 66% of the industrial employment. Meanwhile, the main cities of the coast (Barranquilla and Cartagena) produce only 11% of the product and employ 9% of the workers[12].

In the model presented in the next section, I considered the problem of Bogota's geographic localization, and the high internal freight charges that this implies. Nevertheless, I simplify the existence of large intermediate cities by assuming that Bogota and Barranquilla are the only locations in the country. However, for future research it would be interesting to add intermediate locations both in the theoretical and the econometric model, in order to have a better understanding of the country. For example, it may be easy and appealing to consider the interior and the coast as the relevant locations for the model, but this exercise is out of the scope of this paper.

B. A COLOMBIAN VERSION OF THE KRUGMAN AND ELIZONDO MODEL

This subsection presents a Colombian version of the *KE* model, which emphasizes the importance of internal transportation cost, and adds an export transportation cost. In others words, it includes the fact that goods produced in Bogota have to be

[12] Source: Encuesta Anual Manufacturera. *DANE.*

transported to the coast in order to be exported, and that imported goods once in the coast have to be transported to Bogota for processing.

In fact, the original model considers a system with three different locations: one located in the interior, a second in the border and a third one in a foreign country. However, the same transportation costs from local cities to abroad are assumed. In order to make this model suitable to Colombia, I considered that the transportation cost from the interior to the foreign location is equal to the internal transportation plus the external transportation cost. Also, I included an export transportation cost. As it will be shown next, these two modifications to the *KE* model add a new centrifugal force, making stronger the original trade and agglomeration results.

As it was explained before, the *KE* model belongs to the new Economic Geography and Trade literature, which explains agglomeration as a result of market imperfections. In particular, forward and backward linkages generate concentration of firms, that is only attenuated by the existence of congestion costs.

The structure of the model is as follows. It includes three different areas: the rest of the world, a domestic internal location (e.g. Bogota), and a domestic border location (e.g. Barranquilla). (These locations are going to be respectively referred in the model as 0, and 1, and 2 or as $j = 0, 1, 2$ when generalization is possible).

Activities use only one factor of production (labor), which is mobile between regional locations and immobile between domestic and foreign locations. It is also assumed that employees in the city occupy some space (a measure named one worker), and that they are located in a row. This implies that the distance between the "middle" and the "border" worker is half of the total amount of workers in that location.

$$(1) \qquad \delta_j = \frac{1}{2} l_j$$

where δ_j is the distance between the border and the middle of the local city and l_j is the amount of workers is location j.

Also it is assumed that workers face a commuting cost of γ per unit of distance, which is measured in terms of labor. γ can be explained as the cost that workers are willing to pay in order to live one unit of distance closer to their job. This means that the total cost of a round trip from the outskirts to the center of the city is $2\gamma\delta_j$. Therefore, if each worker is endowed with one unit of work, we have that the net supply of labor hours (s_j) of the "border worker" is:

(2) $s_j = 1 - 2\gamma\delta_j$

However, workers that live in the center not only receive a higher wage bill but also pay higher rent. This trade-off and competition ensures that the net wage rate is the same in any living place of the city. In fact, workers that live in the center of the city pay high rents but low commuting cost, and workers that live in the outskirts pay high commuting cost but less rents. Consequently, each worker receives $w_j(1 - 2\gamma\delta_j)$ where w_j is the wage rate.

Therefore, the total supply of labor net of commuting cost (z_j) is the aggregation over all the individuals supply (s_j),

(3) $$z_j = \int_0^{l_j} (s_j)\, d\, l_j = \int_0^{l_j} (1 - \gamma r_j)\, dr_j = l_j - \frac{1}{2}\gamma l_j^2$$

(where r_j is an integration variable), and the location total income (y_j) is:

(4) $$y_j = w_j z_j$$

Additionally, a Dixit and Stiglitz (1977) framework is used in order to model imperfect competition and to include a reason for agglomeration in the analysis. According to this approach, on the consumer side a *CES* utility function is assumed $\left(U = \left(\Sigma c_j^{\frac{(\sigma-1)}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}\right)$ where c_i is a consumption good of industry $i = 1 \ldots n$ and $\sigma > 1$ is the constant elasticity of substitution between goods[13]. On the production side, a cost function with economies of scale $(z_{ij} = \alpha + \beta Q_{ij})$ is assumed, where z_{ij} is the labor used for production of good *i* at location *j*, α is the fixed cost of production, β is the variable cost, and Q_{ij} is the total output of good *i* at location *j*[14].

As usual in this kind of models, the maximization problem[15] results in the fact that prices are charged as a mark up over marginal cost and the zero profit condition[16] ensures that the output is constant for each variety. Then,

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13 It is assumed bigger than one, because if not it would mean that goods are inelastic and competidors may increase revenues by decreasing production.

14 The cost function with economies of scale takes this form because the zero profit and the market clearing conditions are held. Therefore, the total consumtion $c_i z_{ij}$ equals total production, and total production equals total cost $c_i(\alpha + \beta Q_{ij})$ Therefore, $(z_{ij} = \alpha + \beta Q_{ij})$.

15 Max $(p_{j1}x_{j1} + p_{j2}x_{j2} - w(\alpha + \beta(x_{j1} + x_{j2})))$.

16 $p_j x_j = (\alpha + \beta x_j) w_j$.

(5) $$p_j = \frac{\sigma}{\sigma - 1}\beta w_j$$

(6) $$Q_{ij} = Q = \alpha^{\frac{\sigma - 1}{\beta}}$$

where Q_{ij} does not depend on any specific characteristic of the locality or the firm and therefore the number of goods is proportional to the net labor input after commuting $\left(n_j = \frac{z_j}{\alpha\sigma}\right)$ These two results make possible a choice of units such that $p_j = w_j$ [17] and $n_j = z_j$ [18].

Finally, the original model uses an iceberg transportation cost $\tau > 1$ between locations, and $\rho > 1$ between the rest of the world and both regions[19]. According to this, if x goods are sent abroad only x/ρ of them will arrive to its final destination. Thus, the iceberg transportation cost (ρ) can be considered as the ratio between *CIF* and *FOB* prices.

For the case of Colombia, the use of the same transport cost between local sites and abroad is not very realistic. In fact, the merchandise is generally imported to the port (e.g. Barranquilla) by ship, where there is then sent by ground transportation to the inland (e.g. Bogota)[20]. Therefore, in this new version of the model, I will assume an iceberg import transportation cost of $\rho\tau > 1$ for Bogota and $\rho > 1$ for Barranquilla. This assumption adds an additional centrifugal force to the model[21].

Another modification that is introduced at this point, is that export costs are different from zero. Therefore, another parameter for export transportation cost $\theta > 1$ must be included and used in the same way that ρ is used in import transactions (the parameter can not be the same since it not only includes freight charge cost but

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17 It is possible to choose units of measurement such that $\beta\sigma = \sigma - 1$.

18 Firms can be scaled such that the size at which they earn zero profits is 1. Therefore $\alpha = 1/\sigma$.

19 τ is equal to the advalorem transportation cost (*CIF/FOB* -1) plus one.

20 Assuming that imports use maritime or ground transportation rather than air transportation. This is pretty fair for Colombia since, according to the Ministery of Transportation 86% of the total imported weigth was transportated by ship, 11% by road and only 2% by air. The percentages for exports are 96%, 3.5% and 0.5% respectively.

21 In the original paper the considered centrifugal forces were the rent and the congestion cost but not the lower transportation cost to foreign countries.

tariffs, and usually tariffs are not symmetrical between countries)[22]. This fact affects the output of the model by increasing the centrifugal forces. In fact, if export activities become costly, it is less attractive to be located in the port.

The next step is to maximize the utility function subject to the budget constraint. The budget constraint states that income in location j should be equal to expediture in goods imported from abroad, plus expediture in local goods, plus expenditure in goods produced in the other local region. In sum, the restriction can be written as:

$$y_j = n_0 p_{0j} c_{0j} + n_1 p_{1j} c_{1j} + n_2 p_{2j} c_{2j}$$

where p_{10} is the price of location 1 goods at location 0 (i.e., production cost, plus tariffs, plus transportation cost), and c_{10} is the consumption of a typical good from 1 at location 0 (recall that 1 refers to Bogota, 2 to Barranquilla and 0 to the rest of the world).

This maximization process enables to find the price indexes (t_j), the net real wages (ω_j) and the net real wage difference (ϖ) for each locality, according to the following equations:

(7) $$t_j = \left(n_0\, p_{0j}^{1-\sigma} + n_1\, p_{1j}^{1-\sigma} + n_2\, p_{2j}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

(8) $$\omega_j \frac{w_j\left(1-\gamma l_j\right)}{t_j}$$

(9) $$\varpi = \omega_1 - \omega_2$$

Other results form the former maximization problem are: $p_{0j}c_{0j} = y_j\left(\frac{p_{0j}}{t_j}\right)^{1-\sigma}$, $p_{1j}c_{1j} = y_j\left(\frac{p_{1j}}{t_j}\right)^{1-\sigma}$ and $p_{2j}c_{2j} = y_j\left(\frac{p_{2j}}{t_2}\right)^{1-\sigma}$. These results and the fact that expenditure equals income $\left(y_j = n_j p_{j0} c_{j0} + n_j p_{j1} c_{j1} + n_j p_{j2} c_{j2}\right)$ allow us to obtain the following income equations:

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[22] In strict terms, internal freight charges are not symmetrical neither. In fact, the freight transportation cost fram Bogota to Barranquilla in 1998 was 57% of the trip from Barranquilla to Bogota (according to the resolution 1020, 1998 from the Ministry of Transportation). Therefore it would be wise to include a new parameter to describe internal freight charges in the Bogota to Barranquilla direction.

$$(10)\quad y_0 = n_0 p_0^{1-\sigma}\left(y_0\left(\frac{1}{t_0}\right)^{-\sigma} + y_1\left(\frac{\rho\tau}{t_1}\right)^{-\sigma} + y_2\left(\frac{\rho}{t_2}\right)^{-\sigma}\right)$$

$$(11)\quad y_1 = n_1 p_1^{1-\sigma}\left(y_0\left(\frac{\theta\tau}{t_0}\right)^{-\sigma} + y_1\left(\frac{1}{t_1}\right)^{-\sigma} + y_2\left(\frac{\tau}{t_2}\right)^{-\sigma}\right)$$

$$(12)\quad y_2 = n_2 p_2^{1-\sigma}\left(y_0\left(\frac{\theta}{t_0}\right)^{-\sigma} + y_1\left(\frac{1}{t_1}\right)^{-\sigma} + y_2\left(\frac{\tau}{t_2}\right)^{-\sigma}\right)$$

where, prices were disaggregated into original prices plus transport cost (for example if a good is imported from the rest of the world to Bogota (p_{01}) the price is going to be the original price (p_0) times the transportation cost to Barranquilla (ρ) times the transportation cost to Bogota (τ) according to the following table:

$p_{00} = p_0$	$p_{10} = p_1\theta\tau$	$p_{20} = p_2\theta$
$p_{01} = p_0\rho\tau$	$p_{11} = p_1$	$p_{21} = p_2\tau$
$p_{02} = p_0\rho$	$p_{12} = p_1\tau$	$p_{22} = p_2$

Finally, if it is assumed the same choice of units than in *KE* model: $n_j = z_j$, $p_j = w_j$, and w_0 is normalized to one. Using equations (1) to (13) it is possible to obtain the following system of equations:

$$(13)\quad w_1 = \left(n_0\left(\frac{\theta\tau}{t_0}\right)^{-\sigma} + n_1 w_1\left(\frac{1}{t_1}\right)^{-\sigma} + n_2 w_2\left(\frac{\tau}{t_2}\right)^{-\sigma}\right)^{\frac{1}{\sigma}}$$

$$(14)\quad w_2 = \left(n_0\left(\frac{\theta}{t_0}\right)^{-\sigma} + n_1 w_1\left(\frac{\tau}{t_1}\right)^{-\sigma} + n_2 w_2\left(\frac{1}{t_2}\right)^{-\sigma}\right)^{\frac{1}{\sigma}}$$

$$(15)\quad t_0 = \left(n_0 + n_1(w_1\theta\tau)^{1-\sigma} + n_2(w_2\theta)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

$$(16)\quad t_1 = \left(n_0(\rho\tau)^{1-\sigma} + n_1 w_1^{1-\sigma} + n_2(w_2\tau)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

$$(17)\quad t_2 = \left(n_0(\rho)^{1-\sigma} + n_1(w_1\tau)^{1-\sigma} + n_2 w_2^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

As the analytical solutions are very complex[23], the numerical results are presented using different simulations. A Gauss program used to perform both models as well as the complete results are available under regrest[24].

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23 Scientific Workplace solve it for determinated values of *L*, but does not give a complete analitycal solution.

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C. PARAMETERS OF THE MODEL

In order to obtain a solution of the model some value for the parameters σ, τ, ρ, θ, n_0, L and γ should be adopted. I calculated these parameters for the case of Colombia and the results are the following:

- $\sigma = 0.75$. The model that was described in the previous chapter lies in the existence of monopolistic competition to allow the combination increasing returns and zero profit condition. However, the monopolistic competition model implies that firms operate in a point where the marginal income is positive (to increase the amount sold they should decrease prices). In turn, marginal income is positive only if the elasticity of substitution is larger than one (goods are elastic to prices). And it can be shown that this only occurs when $\sigma > 1$.

  However in the case of Colombia the evidence suggest that the elasticity of substitution is less than one[25], which do not support the existence of a model of monopolistic competition in the country. Nevertheless, and in favor of the simplification, I will assume this firm behavior in Colombian economy and adopt the same parameter that *KE* used for Mexico ($\sigma = 4$).

- $\tau = 1.04$. This value is calculated as the internal transportation cost reported by Colfecar plus a 10% commission to the transportation companies plus the load and unload charge, over the total value of the export and import charge (*FOB* prices of Bogota exports). On top of this approximately 0.08% of the value of goods is stolen, therefore internal freight charges are increased in this value.

- $\rho = 1.2$. This parameter not only includes the external freight charge but the tariffs. In the first set of results, it will be assumed that the economy is close. Therefore, goods will show a prohibitive tariff ($\rho = 4$). In the open economy case, the external freight charge (*CIF/FOB*) is 1.064, and the average tariff is 11.4%. Therefore the external freight charge plus tariffs (ρ) in an open scenario is approximately 1.2. In the close economy the average tariff was near 40%, and therefore ρ should be near 1.5.

- $\theta = 1.1$. Theta is calculated as the external freight charge for Colombia 1.064 plus an average world tariff of 3%[26].

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25 According to Manuel Ramirez (*DANE* Boletin de estadistica #540) the price elasticity of demand is 0.09 for food, 0.125 for beverages and tobacco, 0.216 for clothing, 0.194 for housing, 0.23 for furniture, 0.24 for health, 0.34 for transportation, 0.36 for recreation, 0.29 for education, 0.26 for others, 0.51 for financial payments and 0.57 for savings in the 4 biggest cities of Colombia.

26 Transportation Cost and the Growht of World Trade. David Hummels (1988).

- $n_0 = 13$, $L = 1$. United States is approximately 13 times bigger than Colombia, then assuming that the foreign location is *USA*, the total number of workers abroad is 13 and in Colombia is assumed to be one. Therefore, given that $L = l_1 + l_2$, the shares of Bogota and Barranquilla are $l_1 = 0.8$ and $l_2 = 0.2$, respectively.

- $\gamma = 0.25$. The excess in terms of rent that a person that lives in the center has to pay over has to be equal to the excess in terms of transportation cost that a person has to pay in order to live in the outskirts $(\gamma w_j l_j)$. Therefore,

$$(18) \quad \gamma = \frac{rent_{center} - rent_{outskirts}}{w_j l_j}$$

According to *DANE* the average worker spends 10% of his income in transportation[27]. Assuming that people that live in the center should not pay anything in transportation and taking into account the symmetry of the model, it should be the case that the person that lives further spends 20% of his income in transportation. Therefore, given that $l_j = 0.8$ in this case, $\gamma = 0.25$.

However, in order to allow comparisons with other models I will adopt the parameters usually adopted by the literature: (see Krugman and Elizondo, 1996 and Puga, 1996) $n_0 = 10$, $\sigma = 4$, $L = 1$, $\tau = \frac{14}{10}$ and $\gamma = \frac{2}{10}$. The parameters ρ and θ are changed according to the simulation.

D. GENERAL RESULTS

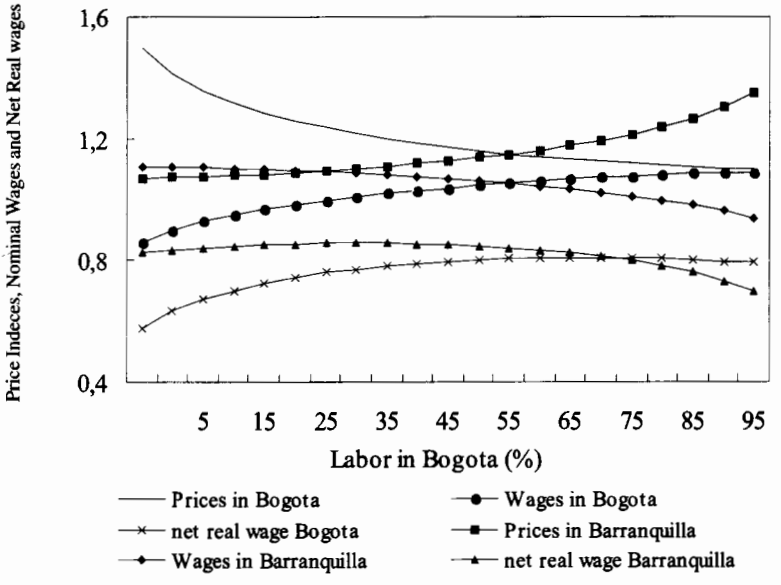
In this subsection, it is presented how the model works and how each variable is adjusted in the limit. The behavior of the labor market can be seen in Figure 3. If the percentage of labor in Bogota is high, this location produces goods at a relatively lower cost (because of increasing returns) and therefore charges lower prices. Analogously, with a low degree of agglomeration, Barranquilla produces costly goods and therefore charges higher prices. On top of this, as labor rises the marginal productivity of labor becomes higher and wages increase relatively to Barranquilla.

The effect of labor in real wages tend to increase the agglomeration in the metropolis, but at the same time the increase in population rises congestion which reduces the

[27] *DANE*. Boletin de Estadistica 140.

Figure 3

Price Indeces, Nominal Wages and Net Real Wages



tendency for agglomeration. The combination of the labor and congestion effects results in a inverted U-shape behavior of the net real wages for both localities.

The wage difference (net real wage in Bogotá minus net real wage in Barranquilla) that is presented in Figure 4 allows for two major conclusions. The first one is that the wage differential is negative for most of the values of L, showing that living standards are in general, higher in the port than in the inland.

The second major conclusion is related to stability. According to the graph, when wages in Bogota are higher than in Barranquilla, and more specifically more than 77% of the population lives in Bogota[28] higher agglomeration is induced until all the workers are concentrated in Bogota. The same dynamics are generated in Barranquilla when more than 23% of the population is located there (the asymmetry is a consequence of the introduction of trade internal freight charges). Therefore, the dispersed labor equilibrium (wage differential is 0) is not stable since a small movement induces agglomeration either in Barranquilla or in Bogota.

[28] This is the case of Colombia. In fact, if only it is taking into account Bogota and Barranquilla 80% of the population is located in Bogota and 20% in Barranquilla.

Figure 4

Net Real Wage Difference

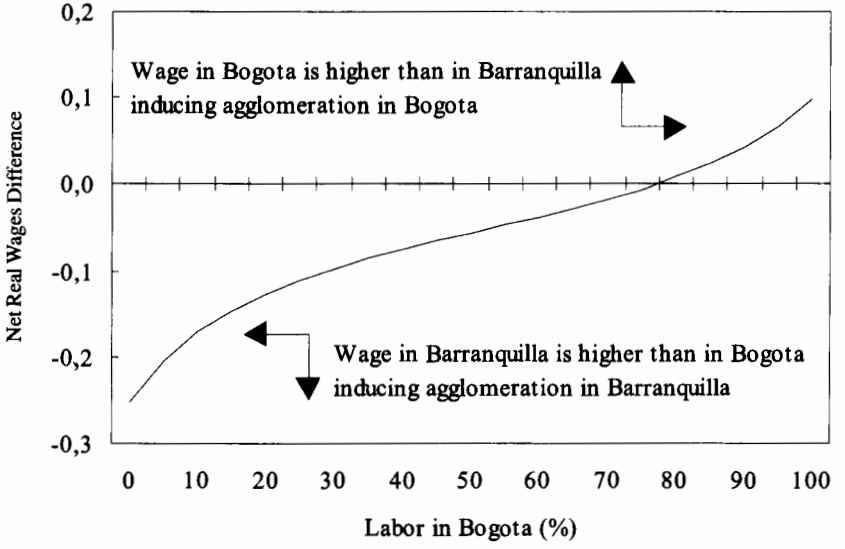
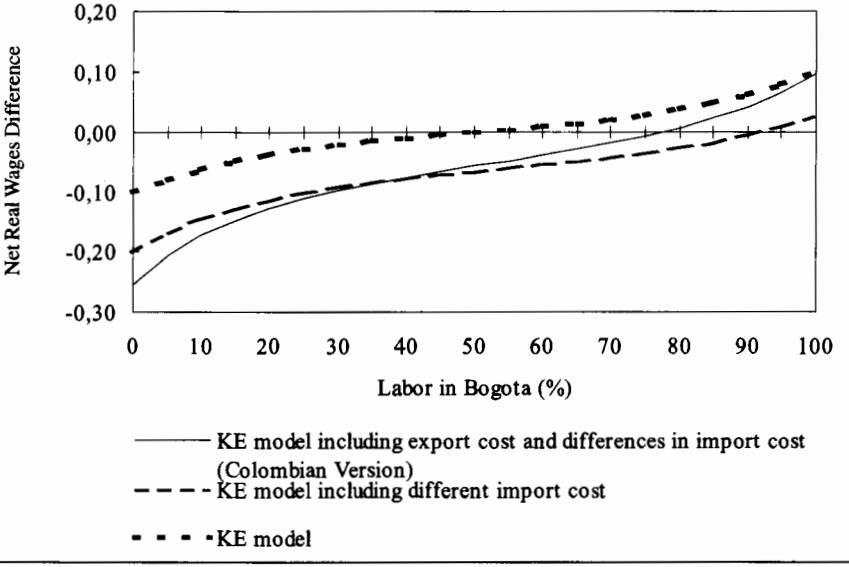


Figure 5

Net Real Wage Difference in Three Different Models



In sum, the agglomeration process in Colombia may result in a concentrated population in Bogota or Barranquilla depending on the parameters.Nevertheless the inclusion of trade internal import and total export freight charges, makes more likely agglomeration in Barranquilla.

In order to understand the Colombian version of the model it is useful to separate each modification to the *KE* model. Figure 5 presents the net real wage in three different versions of the Krugman and Elizondo model. The effect of include a different transportation cost for each region, just moves in a parallel way the original line. Intuitively what happens is that the lower freight charge in the coast implies lower prices and higher wages for this region, increasing the attractive to be located in port.

The inclusion of an export cost, changes the slope of the curve. In fact, if it becomes costly to export, the external market becomes less important and the internal market more important, therefore industries prefer to be located near the biggest cities and enjoy the backward linkages.

E. TRADE EFFECT

In the previous sections it was explain that the trade effect in Colombia should be stronger than in other countries according to the fact of Bogota being located far from the coast. The model designed to the Colombian case clearly illustrates this hypothesis.

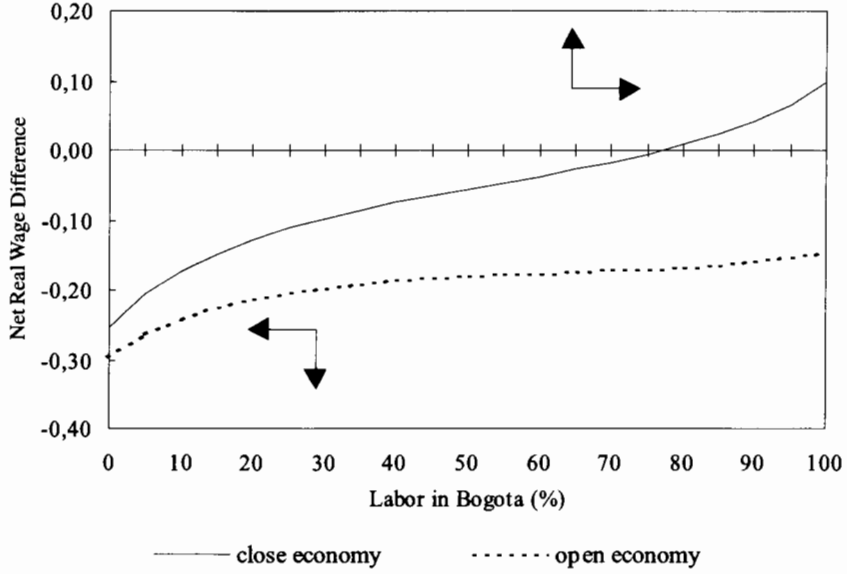
The cases of openness and closeness of the economy are presented in Figure 6. This is done by reducing the values of ρ from 4 to 2. In fact, tariffs may be viewed as an extra external freight cost for imports. As a result of trade liberalization, both nominal wages and prices become lower (imports become less expensive decreasing prices, and exports become more competitive increasing marginal productivity, and therefore wages). Moreover, Barranquilla's geographic advantage becomes more important, working in favor of lower prices and higher wages it this locality. As a result in the open economy, only if Bogota concentrates at least 60% of the population, increasing returns will compensate the advantages of the coast and real wage will be higher in the interior[29]. However, if congestion cost are taking into account, industries will prefer to be located in the coast at any level of L (this is the corner solution where all the population is concentrated in the border location).

[29] This is the value of L at which the real wage difference (that does not include congestion cost) becomes positive.

Therefore, the only possibility for total concentration of labor in Bogota, is when the economy is relatively close (ρ is bigger than 3). Otherwise, the total population will be completely agglomerated in Barranquilla. In fact, the net real wage is higher in Barranquilla, no matter how much increasing returns advantages are offered by Bogota. Therefore, in the limit, a strong trade liberalization will not develop in an equal division of population between localities (symmetric equilibrium) but in a complete agglomeration in Barranquilla.

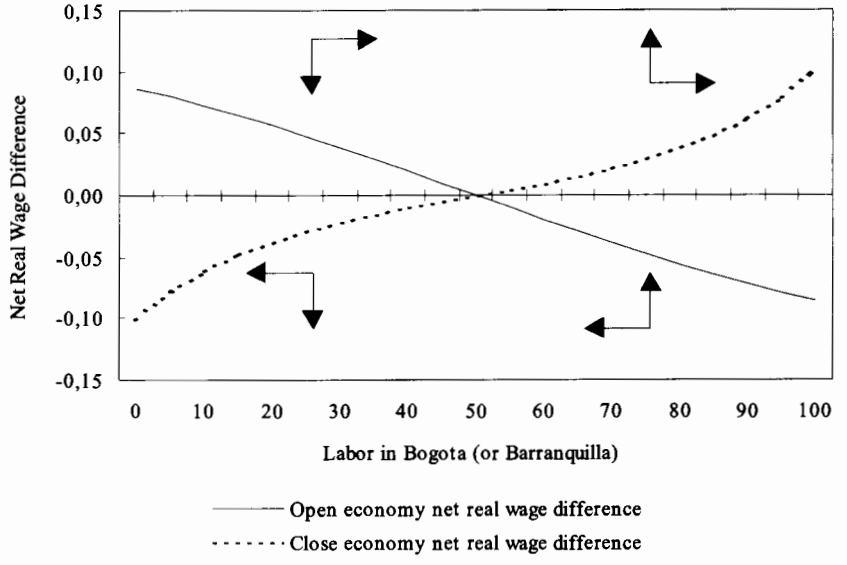
The model developed by Krugman and Elizondo (1996) works in the same way than the one presented in this section. The only difference is that the model is symmetrical. However, in the open economy the difference in real wages is much lower than in the closed economy[30]. Therefore, in the open economy the congestion effect is stronger that the labor effect, and workers tend to avoid agglomeration. In other words, trade liberalization introduces the possibility of a stable symmetric equilibrium (see Figure 7).

Figure 6
Trade Effect in the Colombian Model



30 In fact, the biggest wage difference in the close economy between Barranquilla and Bogota wos 0.31 meanwhile in the open economy it reaches 0.18.

Figure 7
Trade Effect in the Krugman Model



F. MORE COMPARATIVE STATICS EXERCISES

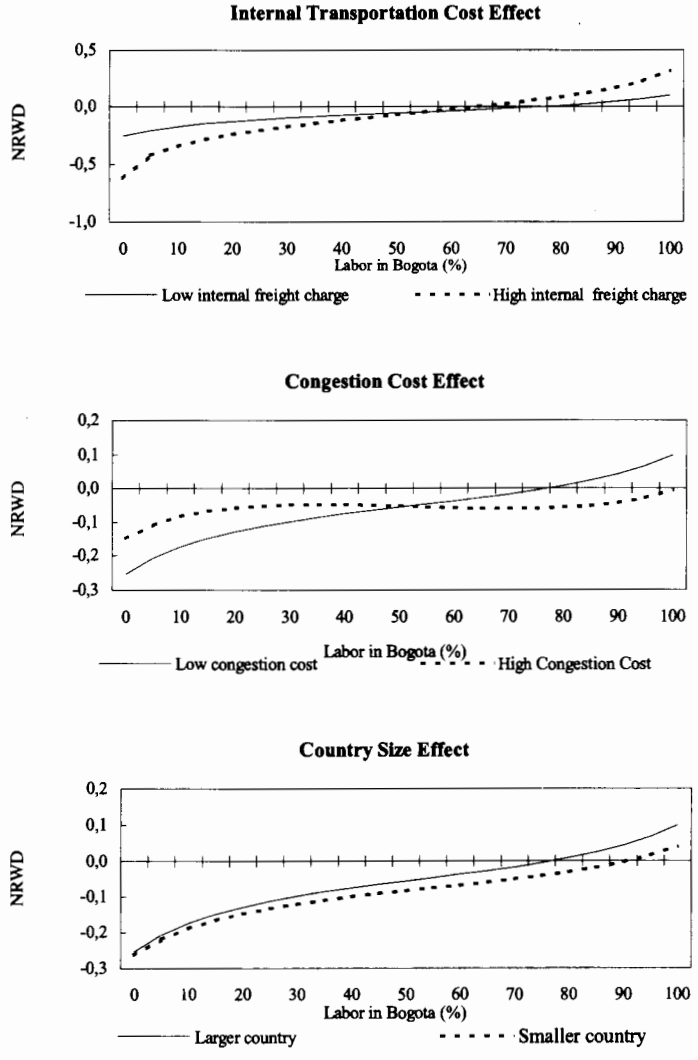
The previous subsection presented how the results change with tariffs (or with external import freight charges). This subsection deals with the sensibility of the model to changes in other parameters, as the congestion cost, the internal freight charge and the country size (see Figure 8).

A decrease in the congestion cost reduces the centrifugal forces, therefore the model is more sensible to the forward and backward linkages effect, and the net real wage graph becomes steeper. This modification has the same effect over both cities. Therefore, the slope changes at the point when the population is equally distributed between both cities.

The internal transportation cost has two effects. The first one is to make Bogota less open to the country. As a consequence of this, the economy becomes more vulnerable to the centripetal forces (forward and backward linkages). The second one, is to make preferable to locate industries in Barranquilla rather than in Bogota due to its geographic position.

The size of the country (L size) is important in determining agglomeration. In fact, if the country is smaller it is more exposed to the international trade and offers less

Figure 8
Comparative Statics Exercises



Note: NRWD: Net Real Wage Difference.

increasing returns advantages. Therefore a small country industry would prefer to be located closer to the international market, and it will move to the coast.

According to this static comparative exercises it is possible to conclude that if trade liberalization is not as strong as in Mexico, and we assume less congestion cost, it is possible to still have agglomeration in Bogota if population in this city exceed 80%.

IV. REGRESSION ANALYSIS

The objective of this section is to test the implications of the theoretical model. The first subsection presents the econometric model that Hanson (1997) performed for Mexico. The second subsection presents an econometric model designed for Colombia. Finally, the third section presents the results and the main contradictions between the theoretical predictions and the empirical results.

A. HANSON'S MODEL

There is little empirical work on trade and agglomeration. However one of the most important contributions (Hanson, 1997) is very related to this paper.

The model proposed by Hanson explains the wage differential between the metropolis and another location as a result of transportation cost inside and outside the country, and the degree of openness of the economy. This is done through a cross-section using disaggregated industries (which are indexed by *j*), and different locations (which are indexed by *i*).

According to the model, the regression for each location is the following:

$$\ln\left(\frac{w_{ijt}}{w_{cjt}}\right) = \beta_0 + \beta_1 \ln(MX_i) + \beta_2 \ln(US_i) + \delta_t\theta \ln(MX_i) + \delta_t\phi \ln(US_i) + \varepsilon_{ijt}$$

where, w_{ijt} is the wage in the border city (Barranquilla in this case), w_{cjt} is the wage in the capital city, MX_i is the average distance from location *i* to Mexico city (Bogota in this case), US_i is the distance from the state *i* to US, δ_t is a dummy variable that takes value of 1 if year *t* falls after the date of trade liberalization, and, ε_{ijt} is an error term that has modeled in order to include fixed effects[31] $(\varepsilon_{ijt} = w_i + k_j + v_t + n_{it})$ where w_i, k_j, v_t and n_{it} are respectively the fixed effects for location, industry, year and location at a determined time.

The coefficients β_1 and β_2 are expected to be negative according to the hypothesis that claims that wages tend to be equalized as the transportation cost inside and outside the country are reduced. Also, an structural change in both parameters is expected with the openness of the economy, since in this case local transportation

[31] Given by a regional specific attractive.

cost becomes less important than international transportation cost to the wage differential. The structural change in these parameters is tested by checking whether θ and ϕ are significantly equal to zero.

Another important contribution of Hanson (1997) is his claim that if the concentration of government activities is sufficiently large, metropolis wages will bid up in the same way than in the case of agglomeration due to increasing returns. However, it should be less resistant to changes in the trade regime than increasing returns based agglomeration.

Hanson empirical evidence suggest that wage difference is sensible to distance to industrial conglomerates. However he did not find any good evidence to suggest the effects of the trade reform. Although, wages have increase in other localities relative to México City, but this change has begun before the trade liberalization.

As I mentioned before, Hanson's work is one of the most important contributions in empirical geography and trade. However, he uses nominal instead of real wages, only takes into account some few years, does not use cost of transportation but distance to conglomerates, and does not use a continuous variable to approximate openness but a dummy. The model presented in the following chapter solves the previous problems, but as a trade-off it only operates with two locations: Bogota and Barranquilla.

B. AN ECONOMETRICS MODEL FOR COLOMBIA

This subsection tests the hypothesis derived form the theoretical model with two different sets of data. The first set of regressions is performed for the aggregate manufacturing sector and the second is performed for a 25 industry panel data[32]. Most of the variables are available for the period 1974-1996, except the internal freight charge.

The first type of regressions consider the total manufacturing and include three main variables: internal transportation cost, external transportation cost and a measure of the degree of openness of the economy. The dependent variable is the net real wage ratio between an internal city (Bogota) and a port (Barranquilla).

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[32] Tobbaco (314), oil refinery (353), oil and coal derivities (354) and pottery products (361) were excluded since Barranquilla does not produce this type of products over the analyzed period of time.

$$(19) \quad \frac{w_{it}^{Bog}}{w_{it}^{Barr}} = f(cons_i,\ itck_t,\ etck_{it},\ open_{it})$$

where, i refers to industry, t refers to time, *cons* to constant and *itck*, *etck* and *open* are measures of the internal freight charge per kilo between Bogota and Barranquilla; the external freight charge per kilo between Barranquilla and an average destination in the rest of the world; and the openness of the economy, respectively. *itck* is the same across sectors of production, so it works in the model as a time-specific characteristic.

The net real wages are defined in the same way as in the theoretical model:

$$(20) \quad \omega_{ij} = \frac{w_{ij}(1-\gamma_{ij})}{t_j}$$

where, subscript j denotes location[33], and i denotes industry.

C. RESULTS

This subsection presents the main results obtained in the panel data regressions with constant and moving coefficients. The Annex presents a complete description of the variables used in the model. As was explained before, the industry net wage difference is regressed against internal and external transportation costs, and an outward orientation indicator. It was used the random effects estimador since the Hausman test predicted that the hipothesis of no correlations between the random effects and the independent variable was not rejected. In the same way, regressions were performed with moving an common coefficients (common coefficients using gls). I am going to present the common coefficients results first, (see Table 2).

- The measures of internal and external transportation costs present the predicted sign (positive). In fact, as internal and external freight charge are going up, the economy is less integrated to the world and net real wages increase in Bogota relatively to the port. However, if the external freight charge is divided by kilo, the sign is negative. This can be explained because the increase in the freight charge by kilo is an indicative of external charges independenly of the volume that the industry has to transport. Therefore this charge generally coincides with an increase in the overall world demand. The external freight charges

[33] Results do not vary significantly using the real wages ratio as the dependant variable.

Table 2
Panel Data Results (Common Coefficients-Random Effects-*GLS*/Pool)

Dependent variable: Net real wage differential (Bogota / Barranquilla)

Regression number	(0)	(1a)	(1b)	(1c)	(2a)	(2b)	(3)
Type	R.E	POOL	R.E.	POOL	R.E.	R.E.	R.E
Constant	-4,16	-2,07	-1,24	-2,38	-2,05	-3,88	
	(-9,17)	(-1,76)	(-2,29)	(-1,88)	(-3,66)	(-7,24)	
Internal freight charges							
Log (FIE)		0,34			0,35		
		(4,19)			(4,63)		
Log (FII)			0,13				0,11
			(2,67)				(2,28)
Log (FI2)	0,45			0,50		0,46	
	(4,85)			(4,28)		(4,94)	
External freight charges							
Lof (FXT)	0,12	0,06	0,06	0,05	0,06	0,11	0,06
	(7,10)	(1,18)	(2,88)	(1,06)	(2,68)	(5,08)	(2,52)
Openess							
Log (ARANCEL)		-0,06	-0,16	-0,13			
		(-1,16)	(-5,27)	(-2,80)			
Log (PROTEFEC)					-0,06		
					(-2,16)		
Log (XMP)						0,03	
						(1,04)	
Log (ARANCEL (-1))							-0,17
							(-5,43)
Number of observations	425	425	425	425	425	425	425
Chi2	82,7	43,0	86,9	41,1	103,6	84,3	88,8
p-value	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hausman	1,1	5,1	7,2	5,2	22,1	15,9	6,4
p-value	0,00	0,16	0,06	0,16	0,00	0,00	0,09
R-sq within	0,19		0,20		0,22	0,20	0,20

Note: t-statistics in parenthesis.

increase has a positive effect in the net real wage differential, and an overall world demand augment has a negative one, (probably sectors are more sensible to external demand than to external freight charges).

- The significance of internal freight charge is high and robust. The significance of external total freight charge is weaker but still being an important variable in explaining net real wage differentials.

- However, contrary to the predictions of the theory, the trade liberalization variables show the opposite sign, and always appear to be strongly significant. In fact, it was expected that with trade liberalization industries tend to move to the coast and that wages in Barranquilla should increase relatively to Bogota.

- Moreover, this contradiction remains even when a 3 years lag are used in order to capture the fact that agglomeration may respond to trade liberalization with some delays. In fact, the opening variable lagged one period has a positive and significant coefficient. The same result is obtained with two and three lags and with all the approximations to the variable *openess*.

- The χ^2 statistic reflects the possibility that all coefficients are equal to zero. According to the values there is a high probability that at least one coefficient is different from zero.

The panel data regressions performed using moving coeffients are presented in the next table (see Table 3)[34].

- Similarly to the aggregate industry results, the overall fit of the regression is good, and the internal freight charge appears as an important explanatory variable of the net real wage differential.

- The external freight charge has the right sign only for some industries, and in most of the cases it is not significant. As before, this can be explained because the increase in the freight charge generally coincides with an increase in the overall world demand. The external freight charges increase has a positive effect in the net real wage differential, and an overall world demand augment has a negative one. Therefore, some sectors more sensible to world demand than to external freight charge may show a negative coefficient. On the other hand it could be that the external freight charge is very stable over time and what really affects exports is not the external freight charge but the tariffs imposed by other countries.

- Similarly, the trade liberalization variable only appears to be significant and shows the right sign in some few sectors: Food (311), Beverages (313) and Chemical Substances and Industries (351-352). Results that are fairly understanding since the Colombian value added of these products is relatively small and therefore the coast has become specialized in these products (specially chemicals). When this variable is lagged one period the results do not change significantly.

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[34] The results does not change significantly using another proxies for internal freight charge and for trade reform, therefore I just present the results of one regression.

Table 3
Panel Data Results (Variable Coefficients)

Dependent variable: Net real wage differential (Bogotá / Barranquilla)

	Internal freight charge		External freight charge		Tariffs	
	coef	t-stat	coef	t-stat	coef	t-stat
311- Food	0,09	0,43	0,00	0,10	0,09	1,64
312- Food (others)	1,03	5,22	-0,08	-2,34	-0,25	-3,49
313- Beverages	0,90	3,54	-0,12	-2,59	0,13	2,77
321- Fabrics	0,63	2,35	-0,04	-1,00	-0,14	-2,50
322- Clothes (no shoes)	0,52	3,91	-0,03	-1,25	-0,04	-1,28
324- Shoes	-0,42	-1,12	0,19	3,43	-0,29	-3,41
331- Wood and products	0,73	2,51	-0,07	-1,67	-0,23	-3,20
332- Furnitures	0,40	2,40	0,00	-0,09	-0,07	-1,40
341- Paper and products	-0,09	-0,35	0,04	1,06	-0,17	-2,79
342- Prints	-0,31	-0,63	0,12	1,53	-0,24	-2,53
351- Chemical substances	0,84	3,40	-0,12	-3,54	0,13	2,11
352- Chemicals (others)	0,90	4,14	-0,11	-2,98	0,26	3,63
355- Rubber	0,87	1,47	-0,09	-1,07	0,14	1,28
356- Plastics	0,21	1,39	0,00	0,01	0,05	1,19
362- Glass	-1,43	-3,91	0,33	5,86	-0,62	-7,79
369- No metalics minerals	0,22	1,17	0,04	1,10	-0,36	-6,47
371- Steel and iron	0,89	2,08	-0,02	-0,41	-0,34	-2,76
372- Non iron metals	0,66	1,99	-0,09	-1,61	-0,18	-2,37
381- Non metalic products	1,08	2,46	-0,08	-1,26	-0,33	-4,39
382- Non electric machinary	1,15	3,80	-0,09	-2,10	-0,24	-3,11
383- Machinary	0,99	2,70	-0,09	-1,78	-0,15	-1,86
384- Transportation equipment	0,64	2,76	-0,05	-1,40	0,02	0,44
385- Profesional equipmnent	-0,11	-0,35	0,04	0,92	0,00	0,00
390- Others	-0,03	-0,13	0,04	1,14	0,02	0,36
Constant	-0,75	-1,62				
Number of observations	408,00					
F-statistic	50,43					
Prob(F-statistic)	0,00					
Durbin-Watson stat	1,94					

V. AGGLOMERATION AND TRADE IN COLOMBIA: A CONTRADICTION

This section tries to give an explanation to why industries do not seem to move to the coast after trade liberalization in Colombia. It also provides some empirical exercises.

A. SOME POSSIBLE INTERPRETATIONS

In Colombia, import tariffs in manufacturing were lowered from levels of 43% in 1988 to 11.9% in 1992. Also quantitative restrictions were fully dismantled. According to the *KE* model, this by itself should have implied a dissagglomeration of manufacturing activities from Bogota to the coast, due to the excessive costs that a big city implies. If, on top of this, the distance from Bogota to the port is taken into account, the geographic reallocation of industries should be imminent (as it has been shown in the model presented in section III).

However, the Colombian manufacturing sector does not seem to have moved to the coast after the trade liberalization. In fact, the ratios between Bogota's and Barranquilla's total production, employment, value added and net real wages have increased significantly until 1994 (see Figure 9). Moreover, the empirical evidence presented in section IV suggest the existence of a positive and strong relationship between trade and agglomeration. In other words, it seems that trade liberalization is increasing the size of Bogota.

There can be several interpretations to this contradiction between the theoretical model and the empirical evidence: excessive assumptions in the theory, the inclusion of Bogota and Barranquilla as the only cities in Colombia, or that the effects of changes in trade liberalization in agglomeration take longer to be seen. Although it exceeds the scope of this paper, I would present some possible explanations of the contradiction, and test it empirically. The inclusion of these new elements in the model is left for future research.

The model developed in chapter three is a very simplified one, and it is not expected any country to have such specifications, there are three critical assumptions that may not hold for the Colombian economy: The first is the existence of imperfect competition; the second is presumption of labor mobility inside the country; and the third is the assumption that agglomeration is the only source of backward and forward linkages.

The assumption of imperfect competition implies that the competitors produce in the elastic section of the demand curve. Therefore, the elasticity of substitution should be larger than one. However, most of the empirical evidence in Colombia suggest that the elasticity of substitution is less than one[35], thus there is no sufficient evidence for imperfect competition (at least at this level of aggregation).

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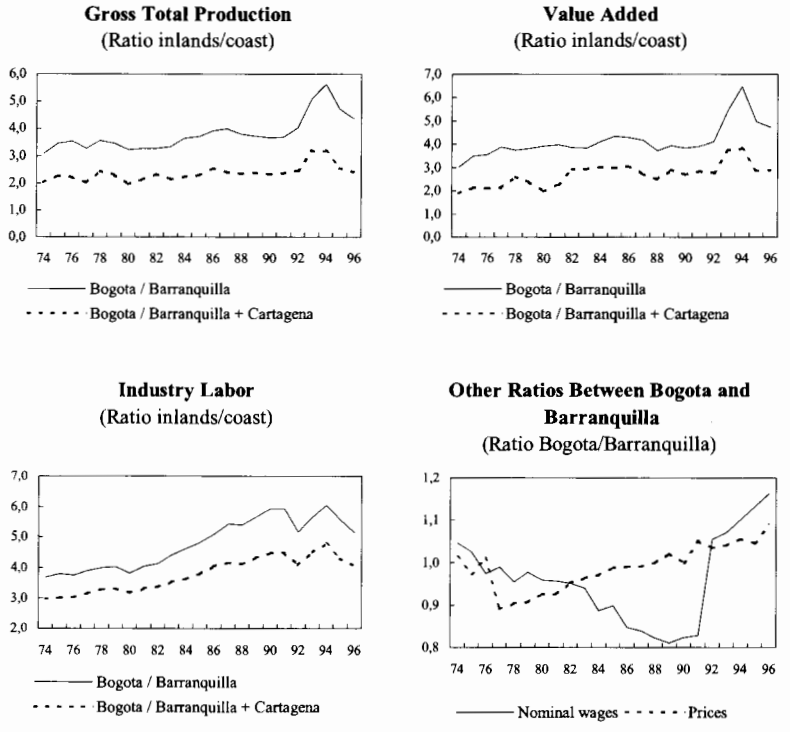
[35] According to Manuel Ramirez, (Boletin de Estadistica #540) the elasticity of substitution in Bogota and Barranquilla is less than one for all goods excepting savings. *DANE*, Boletin de estadistica 540.

Figure 9
Bogotá and Barranquilla. Some Statistics



Source: Encuesta Anual Manufacturera.

The second problem is related with labor mobility. In fact, the lack of labor mobility inside the country in addition to important differences in education may be the cause of the increasing net real wage in Bogota relatively to Barranquilla. This interpretation will be tested in the next subsection by adding education as a determinant of the net real wage differential.

The third interpretation is very related to the last one (moreover, it may be a cause of the lack of mobility of labor) and is the existence of exogenous amenities. In contrast to endogenous amenities such as the number of restaurants, child education, and cultural life; the exogenous amenities do not depend on agglomeration but generate backward and forward linkages, that in turn generate agglomeration.

A good example of this amenities is the importance of Bogota being the center of political power. A large government size in Bogota generates high demand (backward

linkages) and input supply[36] (forward linkages) which induces agglomeration. In fact, Hanson (1997) argues that if the concentration of government activities is sufficiently large, metropolis wages will bid up in the same way than in the case of agglomeration due to increasing returns. However, agglomeration based in government size should be less resistant to changes in the trade regime than increasing returns based agglomeration. Therefore, if agglomeration is not elastic to trade liberalization it may be because of the government size in the metropolis.

Another example of amenities is the differences in infrastructure between cities. The lack of infrastructure in the coast may be another cause of the increasing importance of Bogota at the expense of the coast. In fact, the interior of the country has much more infrastructure services than the coast, and this difference has increased during the last few years. As an example, Table 4 shows how the number of telephone lines per capita were 3 times more in Bogota than in Barranquilla in 1988, and this parameter increased to almost 5 times in 1992.

In the overview of agglomeration and trade in Colombia, it is also possible to include some factors that can be hardly adopted in the model, such as the effects of narco-trafficking and the oil boom. In fact, the period of trade liberalization in Colombia has coincided with an increase in the revenues derived from the drug trade, and oil exports. This two factors increased the internal consumption, generating important forward and backward linkages in Bogota, deviating attention from the external to the internal market and therefore, orienting industry to Bogota instead of Barranquilla. Finally, as was explained by Henderson (1994), history is an important determinant of the city size and therefore agglomeration is not very sensible to changes in the short run. It should be taken into account that the mobilization of industries from Bogota to the coast is a long run process and perhaps short run effects are offsetting the long run ones. In fact, as it was notice before, industry in Barranquilla has increased relatively to Bogota in 1995 and 1996.

B. EMPIRICAL VERIFICATION OF SOME INTERPRETATIONS

This subsection tests some of the interpretations of the positive relationship between agglomeration and trade, that were explained before. In order to perform such test the empirical model was augmented in the following way:

$$(21) \quad \frac{w_{it}^{Bog}}{w_{it}^{Barr}} f(cons_{it},\ itck_t,\ etck_{it},\ educ_t,\ gob_t,\ lines_t,\ propcon_t)$$

[36] For example bureocratic facilities and infraestructure may be view as an important input supply.

Table 4
Telephone Lines per Capita

	Bogota	Barranquilla
1976	0,13	0,05
1977	0,14	0,06
1978	0,14	0,06
1979	0,15	0,06
1980	0,16	0,07
1981	0,17	0,06
1982	0,18	0,06
1983	0,18	0,06
1984	0,19	0,06
1985	0,20	0,06
1986	0,20	0,06
1987	0,21	0,06
1988	0,20	0,06
1989	0,22	0,05
1990		
1991	0,24	0,05
1992	0,25	0,06
1993	0,27	0,07
1994	0,30	0,09
1995	0,31	0,09

Source: Departamento Nacional de Planeación.

where *gob* is the size of Bogota's government, *lines* is the availability of communication facilities, *educ* is the relative number of schooling years of the labor force between Bogota and Barranquilla, and *propcon* is the coefficient of consumtion over income.

The inclusion of education will test the mobility of labor force between Bogota and Barranquilla: if the net real wage gap is due to differences in education, this means that the labor mobility is low. The inclusion of government size and communication facilities will test the importance of external amenities. Finally, the inclusion of the coefficient of consumption over income will test the hyphothesis of the internal consumtion boom.

Table 5 presents the random effects results with common coeffiecients. This evidence suggest that there are some signs of lack of labor mobility in Colombia (the coefficient of *educ* lagged two periods is relatively large in equation 2), of the importance of the consumption boom in explaining agglomeration, and some indication of the importance of government size in determining wage differentials. In fact, the coefficient of government size is relatively large (*gototbb* in equation 1a). This result highlights the importance of consumption generated by government employees in determining industry localization.

In relation with infrastructure, the results are ambiguous and not significant. Therefore, results with *gkbb* and *lines* are not presented here.

Table 5

Panel Data Results (Common Coefficients – Random Effect)

Dependent variable: Net real wage differential Bogota/ Barranquilla					
	(1a)	**(1b)**	**(2)**	**(3)**	**(4)**
Constant	-4,27	-4,48	-3,66	-2,03	-2,61
	(-8,90)	(-8,29)	(-7,60)	(-5,78)	(-3,65)
Internal freight charges					
Log (FI2)	1,03	0,69	0,46		0,68
	(6,32)	(3,05)	(5,00)		(3,45)
External freight charges					
Log (FXT?)	0,07	0,12	0,10	0,09	0,04
	(3,06)	(5,83)	(5,76)	(5,66)	(1,88)
Government					
Log (GOTOTBB)		0,13			
		(1,24)			
Log (GFUNBB)	0,23				0,08
	(4,52)				(1,04)
Education					
Log (EDUC(-2))			1,12		0,62
			(2,90)		(1,54)
Consumtion					
Log (PROPCON)				0,09	
				(5,66)	
Tariffs					
Log (AR?)					-0,09
					(-2,63)
Observations	375	375	425	500	375
Chi2	95,9	72,8	92,8	40,5	107,3
p-value	0,0	0,0	0,0	0,0	0,0
Hausman	7,4	13,9	11,6	8,9	13,9
p-value	0,06	0,00	0,01	0,01	0,02
R-sq within	0,19	0,20	0,21	0,09	0,25

Note: t-statistics in parenthesis.

The results presented in Table 6 suggest that only the lack of labor mobility and the importance of government current expenses in increasing relative wages are possible explanations of the trade and agglomeration contradiction in Colombia. As mentioned before stronger effort should be performed in order to find a valid explanation to the problem.

Table 6
Panel Data Results (Variable Coefficients)

Dependent variable: Net Real Wage Differential (Bogota / Barranquilla)

	Internal freight charge		External freight charge		Tariffs		Government		Education (-2)	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
311- Food	0,34	1,29	-0,14	-2,14	0,04	0,57	-0,64	-0,83	1,11	1,64
312- Food (others)	0,57	1,95	0,03	0,25	-0,22	-2,36	2,87	1,70	1,28	1,51
313- Beverages	0,56	2,27	-0,06	-1,03	0,07	1,41	2,10	3,40	0,54	0,68
321- Fabrics	0,64	1,87	-0,09	-1,16	-0,18	-2,23	0,61	0,58	2,22	2,38
322- Clothes (no shoes)	0,48	2,76	-0,14	-2,13	-0,08	-2,10	-0,54	-0,54	1,42	2,16
324- Shoes	-0,72	-1,73	0,18	1,99	-0,34	-2,91	1,03	0,84	-0,37	-0,25
331- Wood and products	0,30	1,42	0,11	2,18	-0,21	-3,88	4,54	5,44	0,06	0,06
332- Furnitures	0,13	0,84	0,00	0,21	-0,11	-2,28	1,37	2,99	0,12	0,20
341- Paper and products	-0,13	-0,35	-0,06	-0,51	-0,19	-2,64	-0,27	-0,17	0,13	0,12
342- Prints	0,02	0,05	-0,07	-0,80	-0,22	-2,61	-0,99	-1,28	0,23	0,20
351- Chemical substances	0,31	1,16	-0,01	-0,11	0,05	0,82	3,12	2,27	0,03	0,03
352- Chemicals (others)	0,44	1,58	-0,06	-0,69	0,16	2,57	1,61	1,39	-0,98	-1,35
355- Rubber	1,87	2,76	-0,43	-2,75	0,17	1,66	-2,29	-1,46	3,01	1,98
356- Plastics	-0,12	-0,55	0,00	0,03	0,00	-0,05	1,07	1,30	-0,30	-0,58
362- Glass	-0,98	-2,92	0,02	0,25	-0,80	-11,93	-3,12	-2,94	-2,75	-2,82
369- No metalics minerals	0,01	0,05	0,01	0,15	-0,40	-5,67	0,86	0,78	0,59	0,65
371- Steel and iron	0,62	1,15	0,02	0,11	-0,35	-2,28	1,98	0,97	2,45	1,35
372- Non iron metals	0,91	1,92	-0,27	-2,01	-0,10	-0,97	-0,79	-0,57	0,13	0,11
381- Non metalic products	0,67	0,85	-0,03	-0,17	-0,34	-3,80	1,84	1,07	1,10	0,79
382- Non electric machinary	0,93	2,45	-0,09	-0,98	-0,28	-3,29	1,23	0,93	0,40	0,33
383- Machinary	0,52	1,03	0,00	0,01	-0,14	-1,69	2,62	1,64	1,71	1,34
384- Transportation equipment	0,58	1,94	-0,09	-1,46	0,01	0,16	0,82	1,16	1,27	1,68
385- Profesional equipmnent	-0,31	-0,70	0,05	0,35	0,00	-0,02	1,39	0,83	1,86	1,48
390- Others	0,29	0,88	-0,10	-1,38	-0,11	-1,35	-0,40	-0,50	1,62	2,10
Constant	1,48	2,11								
Number of observations	408									
F-statistic	36,8									
Prob (F-statistic)	0,00									
Durbin-Watson stat	2,28									

VI. CONCLUSIONS

This paper presented a Colombian version of the Krugman and Elizondo model (1996). The main innovation of this model is that it includes, as a centrifugal force for agglomeration, the fact that Bogota is located at a considerable distance from the port.

According to this model, forward and backward linkages induce agglomeration in Bogota. This agglomeration is mitigated by congestion cost and by the geographical localization of Bogota. In fact, the localization of Bogota far from the port implies large internal freight costs in order to transport imports to the port, and exports to the inland.

The results of this model suggest that intuition is right in the sense that agglomeration in Bogota should decrease with trade liberalization and with lower freight charges. In fact, if tariffs and freight charges are lower, the country is more integrated to the world and industries should move to the port in order to face lower congestion and transportation costs.

The importance of internal freight charge is supported by the empirical evidence. In fact, when internal and external freight charges are lower, industries tend to move to the coast. Moreover, this result suggest that internal freight charge should be taken into account not only in agglomeration and trade studies but in all work related with Colombian trade.

However, contrary to the predictions of the theory, the empirical evidence suggest a positive relationship between agglomeration and trade for most sectors excluding: food, beverages and chemicals, that showed a negative relationship. This fact, suggest that further work should be performed in order to make the model more suitable for the Colombian case or that the effects of changes in trade liberalization in agglomeration take longer to be seen.

Among the further adaptations to the theoretical model that might be performed I suggest the inclusion of government as a sector of production with fixed labor (in the same way that agriculture is included in the Krugman model, 1993), or the inclusion of some other immobility of labor force (see Puga, 1995). Also I suggest the inclusion of different transportation cost between Bogota-Barranquilla and Barranquilla-Bogota. In the econometric model, my suggestion is to enlarge the panel data, including not only Bogota and Barranquilla as the only locations of the country but including a location dimension in the panel data (see Hanson 1997).

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ANNEX

Description of the data

wdif: The wage differential between Bogota and Barranquilla is computed as:

$$(A.1)\quad \frac{\omega^{i}_{Bog}}{\omega^{i}_{Barr}} = \frac{\frac{tw^{i}_{Bog}+ben^{i}_{Bog}}{to^{i}_{Bog}\times ipc_{Bog}}\times\left(1-2\gamma_{Bog}\right)}{\frac{tw^{i}_{Barr}+ben^{i}_{Barr}}{toi_{Barr}\times ipc_{Barr}}\times\left(1-2\gamma_{Barr}\right)}$$

where,

i denotes industry, *tw* wage bill, *ben* benefits bill, *to* number of employees and *ipc* total price index by city.

The source of *tw, ben* and *to* is the Encuesta Anual Manufacturera and the source for *IPC* is Dane. However as total *IPC* is calculated only since 1979, the index 1974-1978 is built as 30% of low income price index by city and 70% of medium income price index (participation that is more or less sustained after 1979).

- *itck:* The internal freight charge is approximated using the following sources:

  1. Federacion Nacional de Cafeteros: The total bill paid by the Federation in internal mobilization of coffee is divided by the number of 70kg bags that is bought to the peasants in that year. This variable is called FII. In the same way, the total bill paid by the Federation to internal mobilization of export oriented coffee is divided by the number of 70kg bags that is exported in that year, and this variable is called FIE. The sum of both variables is called FI2. Unfortunately, this information is only available from 1980. The serie is presented in Kg.

  2. Almacafe: The amount paid by Almacafe to transport 1 ton of coffee from Bogota to Barranquilla is called bogbarr. This is only available for 1981 and, 1984-1996.

  Both measures were deflated using *IPP* (Product Price Index 1990). Note that this measure is the same across the sectors, and therefore it works as time effects for sectors.

- *etck:* The external transportation cost per kilogram is calculated as *CIF-FOB* import prices reported to customs and collected by *DANE*. The total cost is divided by the number of kilograms imported by the sector and is available for all years and all sectors.

- *open:* The degree of openness of the economy is approximated in three different ways:

  1. *xmpib:* Value of imports and exports as a percentage of production. This variable is available or all years and all sectors. The problem is that it does not take into account smuggling.

  2. *tariffs:* Major import tariffs reforms are available for all sectors. Years in between are assumed to be the same since changes are few.

  3. *effective protection:* This variable is calculated taking into account protection over inputs. It is also available for all years and all sectors. The problem with these last two variables is that they do not take into account real exchange movements.

- *gob:* Bogota's Government size is calculated in two different ways:

  1. Production of Government Services (*gob*): This variable is calculated as the government services of Bogota over the government services of Colombia using *DANE* data 1980-1995. This is combined with data from Fedesarrollo (1970-1988) through growing rates.

  2. Government Expenses (*gtot*): The source of this data is the Finance Ministry and the Capital Government of Colombia. The variable is built as Bogota's expenses in effective operations divided by total expenses of the country. This is available for the period 1981-1996 and can be divided in current expenses (*gfun*), and capital expenses (*gk*).

- *Educ:* This is calculated as the average years of education of a worker in Bogota over the same statistic in Barranquilla.

- *lines:* This variable is calculated as the ratio between the number of telephone lines percapita in Bogota and Atlantico. It is important to be aware that Atlantico includes rural areas and is not strictly comparable with Bogota.

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