5. THE EFFECT OF TRADE ON AGGLOMERATION WITHIN REGIONS

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Abstract

This paper assesses for the first time the effect of regional trade openness on spatial distribution of population within regions by using a database on exports and imports of sub-national regions of Colombia from 1999 to 2010. Studies using such type of data are of significant relevance because the concentration in large cities of regions can be reinforced by trade. The results of our panel model show that the effect of trade on the spatial concentration of population depends upon the characteristics of regions. On the one hand, trade enhances the spatial agglomeration within regions with large home market and location advantages. On the other hand, trade induces dispersion within regions that lack access to international trade or historical disadvantage. These results hold when controlling for the natural course of agglomeration, congestion effects in cities, road infrastructure and historical factors.

Keywords: trade openness, spatial concentration, congestion, Economic Geography, regional data

JEL Classification: R12, F10, O54

1. Introduction

Spatial concentration is a ubiquitous process in territories, being not only an interregional but also an intra-regional phenomenon. It has been widely argued that trade is one of the factors that influences such spatial configurations.

The understanding concerning spatial differences between regions induced by trade has been addressed largely in the New Economic Geography and in urban economics literature. Openness to trade influences the distribution of production factors at both the regional and city level. (Krugman, 1991; Krugman and Livas Elizondo, 1996; Krugman and Venables, 1995; Venables, 2005; Monfort and Nicolini, 2000; Rauch, 1991; Alonso-Villar, 1999; Paluzie, 2001).

Frequently, NEG models are indifferently applied to the international context, to the national context and to the regional context, because there is a lack of explicit distinction between regions and countries (Behrens *et al.,* 2007) and a lack of information on sub-

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national regions. At the national level, the distinction between the inter-regional and intra-regional levels is not trivial. Trade openness differently affects regions to the extent that trade costs are industry and region-specific (Head and Mayer, 2004). Then, specialized regions will meet different costs depending on tariff policies and regional conditions to trade. Thus, the spatial configuration of the economic activity between regions is likely to be modified. Moreover, the spatial configuration *within* regions is also affected to the extent that agglomeration forces can be very localized (Head and Mayer, 2004). Because agglomeration originates in cities (Hansen, 1990), trade will mainly affect these units of concentration already established in each region. Therefore, the analysis at the sub-national scale makes sense both from a theoretical and an empirical point of view.

Empirical studies about trade and spatial concentration use two types of datasets: cross-country data and within-country data. In the former, external trade of countries is examined to disregard the different levels of trade of domestic regions.

Reference studies using cross-country data are Ades and Glaeser (1995) and Henderson (2000). They analyze the factors influencing the level of spatial agglomeration which is measured by urban primacy in each country. The effect of trade openness seems to be unclear in those models. In Ades and Glaeser (1995), the estimate of openness becomes insignificant in the instrumental variable model. In Henderson (2000), the effect of trade openness is generally negative but not always. Similarly, Brülhart and Sbergami (2009) found inconclusive results regarding the effect openness in the growth-agglomeration relationship. Ramirez-Grajeda and Sheldon (2009) show that main cities reduce in size meanwhile secondary cities grow when trade openness increases.

Using within country data, the effect of trade is clearer. The fact that manufacturing would locate in the core of the country with geographical advantage leading to regional concentration has been verified for China (Ge, 2006; Kanbur and Zhang, 2005). On the basis of the methodology of location choices, Henderson and Kuncoro (1996) conclude that trade liberalization enhances the degree of spatial concentration of manufacturing in large metropolitan areas but centralization is difficult to alter due to historical patterns in Indonesia.

Many studies have been conducted for Mexico which has attracted the attention of the research community. The evidence generally shows that after the process of trade liberalization in Mexico, border regions (US frontiers) have gained attractiveness, leading to dispersion of activities that were initially concentrated in Mexico City (Hanson, 1997; Madariaga *et al.,* 2014; Chiquiar, 2005; Aroca *et al.,* 2005; Jordaan and Rodriguez-Oreggia, 2012). Likewise, in the Argentinean case, Sanguinetti and Volpe-Martincus (2009) have noticed that the high concentration of manufacturing industries has decreased between 1974 and 1994. The authors relate this process of de-concentration to trade reforms. The econometric results confirmed that employment grew more than proportionately in regions far away from the economic center, namely the region of Buenos Aires. The reason is the congestion effects derived from over-concentration in this economic center. By examining regional inequality over time, Daumal (2010) also showed that trade openness contributes to regional convergence in Brazil. Overall, the empirical literature has been focused on the inter-regional analysis. However, as Venables (2005) states, spatial concentration occurs much more at an inner-spatial level than at the state or province level. The empirical analysis at finer geographical scales, as conducted in this paper, is compelling, providing interesting insights to be considered in theoretical studies.

Besides the geographical scope of the effect of trade, another important aspect that deserves special attention is the study of developing countries because according to Esfahani (1991); Balassa (1978); Coe and Helpman (1995), trade can boost development[2]. In this paper, we aim at exploring the influence of trade on intra-regional agglomeration in a developing country, Colombia. We employ a database whose richness relies on information on the international imports and exports of each region. Using such data together with complementary regional information on infrastructure, we contribute to assess for the first time the effect of regional trade openness on the spatial configuration within regions.

In Colombia, the pattern of spatial concentration is a recurrent process at various geographical levels. At the national level, few regions prevail, and at the regional level, few cities stand out. Indeed, more than half of national production is concentrated in only four regions that occupy 10% of the territory. Within regions, spatial concentration is also observed. On average, the most populated cities of regions are 4 times as large as secondary cities.

In the context of globalization, Colombia has experienced an increasing trend of trade liberalization. In the last decade, trade[3] has rapidly increased at an annual growth rate of 11%, from US$21 billion in 1999 to US$78 billion in 2010. Concerning regions, trade has also been increasing (8.2% annually on average). Such a trend of trade openness might affect the spatial distribution of population. As discussed in more detail in Section 2, openness to trade could enhance concentration within regions through two effects: the home market effect and the location advantage effect. However, as far as Colombia, a developing country, is concerned, one may think that the patterns of concentration can be reversed with trade because export specialization in the agricultural goods of this country might reduce spatial disparities through an increase in income of primary-sector specialized regions (De-Ferranti *et al.,* 1998).

This paper is organized as follows. Section 2 reviews the literature about the effect of trade on spatial concentration. Section 3 describes the stylized facts about regional concentration and trade openness in Colombia. Section 4 presents the data and Section 5, the methodology of estimation. Section 6 discusses the results. Section 7 concludes.

2. The Effect of Trade on the Internal Geography

The role of trade openness in the spatial configuration of countries has been largely studied. Most theoretical studies have been based on the New Economic Geography

[2] Trade can promote growth through efficiency gains from economies of scale of exporting firms (Esfahani, 1991; Balassa, 1978). In addition, trade facilitates the diffusion of technology, embedded in tradable goods, from developed to developing countries (Coe and Helpman, 1995).

[3] It is computed as the sum of exports and imports. The data are obtained from the Statistic System of International Trade (SIEX is the acronym based on the Spanish name).

(NEG). This literature addresses the issue of the influence of openness on concentration of activities by distinguishing between two hypotheses: homogeneous and heterogeneous regions. The latter is of particular interest here because heterogeneity of domestic regions involves specific mechanisms (different production functions of each region) that can be neglected at the national scale.

In the general set-up of NEG models, regions differ in terms of their location within a country, one region located deep inland, which is related to the rural area, and one region close to the sea, which is related to the urban area (Nishikimi, 2008). Theoretical predictions indicate that trade integration increases the concentration in the region with good international accessibility. Domestic firms locate close to the foreign market to spend less in transportation costs. Thus, trade enhances disparities between geographically advantaged and disadvantaged regions (Nishikimi, 2008; Alonso-Villar, 1999; Crozet and Koenig, 2004). Nevertheless, Alonso-Villar (1999), Brülhart *et al.* (2004) and Crozet and Koenig (2004) establish that if agglomeration prior to openness allocates in the interior region, there will be no relocation toward the borders. The main reason is that historical factors more than offset the effect of trade. If foreign countries are small, firms will not be interested in locating in border regions; the firms will instead follow historical factors, i.e., the extant pattern of agglomeration (Alonso-Villar, 1999). Moreover, being near to the foreign market implies more competition for domestic firms, so these firms search to locate as far as possible from foreign competitors. In that case, trade integration favors agglomeration toward internal regions (Alonso-Villar, 1999; Crozet and Koenig, 2004).

Another factor that could induce dispersion when trade increases is congestion effects in cities Krugman and Livas Elizondo (1996). High urban costs (congestion) in the local market discourage exporting and importing firms from agglomerating. Thus, backward linkages (the demand in the home market) and forward linkages (inputs of other firms) become weaker, which in turn, induces firms to relocate outside the over-agglomerated region. Based on the predictions, explicit dispersion forces (transportation costs) appear to play a secondary role compared with the negative externalities produced in cities.

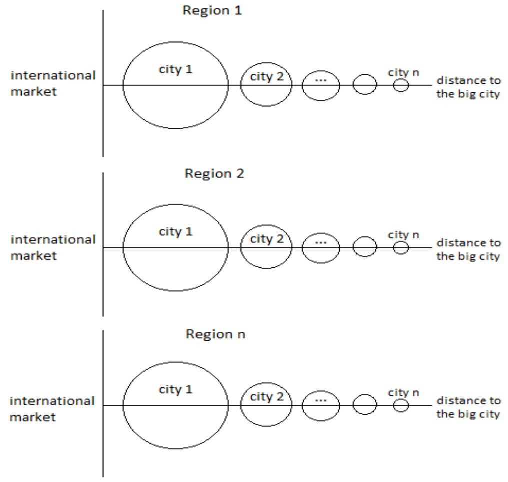
Thus, trade openness also has implications for the development of cities because economic activities commonly concentrate in urban areas. The closest approach concerning this perspective was undertaken in the early nineties through the analysis of urban systems examining the distribution of cities in an open economy (Henderson, 1982; Rauch, 1991).

Rauch's (1991) model shows that population agglomerates around the centers of cities. One central business district (CBD) exists in each city. Workers that live far away from the CBD must pay high commuting costs but lower land rents. They have the incentive to go to the CBD to interact with other workers and shopping. Cities produce goods ranked according to their comparative advantage. As in NEG models, cities differ in terms of their distance to the coast, and they are located along a river (straight line). The price of imported goods from foreign cities is higher in domestic inland cities than in domestic coastal cities because inland cities face higher transportation costs. The higher prices lead to low purchasing power in inland cities, which induces people to move to coastal cities. In the presence of prohibitive trade costs, purchasing power in all cities is constant; thus, all cities have the same size. As trade costs decrease, cities engage in international trade, and their sizes will be higher depending on their closeness to the coast.

In Figure 1, we present a modified structure of the Rauch's model. The distance to the coast is transposed to the distance to the international market. Larger cities are more close to the international market in the sense that they have a higher degree of access to the international market because of their large home market. Main cities will concentrate further population when trade increases because the production of small cities must be transported to/from the main city to be exported/imported. Moreover, the notion of the distance to the coast has to be retained in the analysis.

Figure 1

Distribution of Cities within Regions



Source: Elaboration by the author based on Rauch (1991).

Thus, cities of inland regions have one single centripetal force, whereas cities of regions near the coast have two centripetal forces. The force affecting both types of regions is the home market effect corresponding to city sizes. The additional force of coastal cities is the location advantage effect corresponding to their geographical position with respect to the international market. Hence, the expected effect of trade on intra-disparity would be greater for coastal regions. Therefore, two hypotheses are tested in this empirical study:

1. the effect of trade openness on the internal geography of regions close, in terms of geographical location, to the international market is higher than in distant regions, and
2. trade openness increases the population concentration of regions close, in terms of market size, to the international market than distant regions.

Moreover, the effect of openness on spatial concentration can be ambiguous. Two distinct effects may arise. On the one hand, the coefficient estimate would be positive according to the prediction that trade openness leads to concentration of population in cities with better access to the international market. On the other hand, if main cities face congestion diseconomies, exporting and importing firms will prefer to locate outside the main city to avoid high labor and land costs. Furthermore, firms undertaking exporting/importing activities would not be interested in locating near the largest local market because their inputs and demand come from abroad, *i.e.*, weak backward and forward linkages.

For practical purposes, the consideration of cities in the models of Rauch (1991), Krugman and Livas Elizondo (1996) and Alonso-Villar (1999) merits special attention in this study. The relocation of activities is assumed to occur between contiguous cities. Then, the results of these models might be transposed to lower geographical scales than the national one.

3. The Spatial Concentration of Population in Colombia

In Colombia, spatial agglomeration is not only an inter-regional but also an intra-regional phenomenon. This section describes the mechanisms that have led to both structures.

Globalization has been one of the key factors that shaped the spatial distribution of population in the country. The starting point of the spatial organization was first given by pre-colonial settlements, which established in fertile lands (comparative advantage). Based on that, four cities become the main centres to trade in the international market, two in the mountainous region, Bogota and Medellin, and two on the Coast, Cali and Baranquilla. Currently, the production of Colombia (GDP of 548.3 thousands of millions of pesos, equivalent to US$ 291 billion in 2010) remains highly concentrated. Bogota Capital District, with a surface area corresponding to 0.14% of the total territory (1776 km2 out of 1,141,748 km2) records 26% of the national production. Excluding Bogota Capital District, three other regions, Antioquia (capital city Medellin), Valle (capital city Cali) and Santander (capital city Bucaramanga) account for 31% of the national production and occupy 10% of the national territory. The 12 regions with land shares less than 1%, all together reached only 4% of the total GDP. However, they occupy 51% of the total national surface.

The pattern of development of cities in the territory has also gone hand in hand with geographical characteristics, which is, in turn, a determinant for transport infrastructure across the country. To observe such a configuration, the elemental structure based on geographical characteristics of Colombia is considered. That structure divides the national territory in 6 large elemental regions as shown in Figure 2.

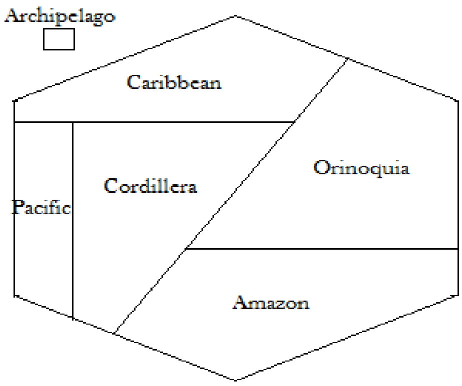
The Cordillera elemental region gathers most of the cities, 735, which concentrate 62% of the national population. The Caribbean elemental region has 237 cities and concentrates 31% of the total population. The Pacific elemental region has 30 cities with 1% of the total population. The rest of the elemental regions (Orinoquia, Amazonas and Archipelago) record 120 cities with only 6% of the total population, despite the fact that Orinoquia and Amazonas occupy 50% of the territory, approximately.[4] Thus, population

[4] *Note that some regions can be classified in two elemental regions because they are in the Cordillera and have either the Pacific coast or the Caribbean coast. We classify regions according to the location of the main city to avoid duplicates.*

is highly concentrated. Differences in transport and communications infrastructure migh be the explanation for not only inter-regional but also intra-regional disparities.

Figure 2

Elemental Structure of Colombia



Source: Massiris-Cabeza et al. (2012) on the basis of Deler (1991) and Florez (2003).

Within regions, some cities constitute the cores of attraction because they provide better standards of living, whereas other intermediate cities assist those centers through production. The other cities remain unconnected, accentuating poverty issues. The main centers of agglomeration have developed communications, transport infrastructure and urban conditions, which have prompted internal migrations, particularly from rural to urban areas, fostering the agglomeration within regions. The laggard cities/regions face low-quality infrastructure that prevents them to access to large domestic markets and eventually to foreign markets.[5] Thus, the concentration in main cities/regions continues to rise. Examining population shows that most regions have predominant cities that account for more than 50% of the regional population. On average, the most populated cities within regions are 4 times as large as secondary cities. The density[6] (traffic per kilometer) on roads surrounding capital cities is on average 3 times greater than the density on roads far from capital cities. This fact confirms that small cities assist the largest cities to the degree that production and population commute more often toward them, enhancing the concentration within regions.

After all, Colombia presents not only spatial disparities between regions but also within them. To measure both types of regional disparity, we apply the Theil index using population of cities. It is computed with the following formula:

[5] *Nowadays, three Colombian regions (Vaupes, Guania and Amazonas) are not connected with the rest of the country through primary and secondary roads. (Mesquita et al., 2013).*

[6] *The information was obtained from the National Institute of Roads of Colombia, which collects the information about traffic volumes during the year.*

$$T = \sum_{c=1}^{C} \frac{A_c}{A} \log \frac{A_c}{A/C}$$

where: *A* is the total population in the country, A_c is the population in city *c*, *C* is the total number of cities in the country. It is noteworthy that A/C is the counterfactual, in which cities are equipopulous. This index can be decomposed in disparity between regions and disparity within regions as follows:

$$T = Tintra + Tinter$$

$$Tintra = \sum_{i=1}^{R} \frac{A_i}{A} \left(\sum\nolimits_{c}^{C_i} \frac{A_c}{A_i} \log \frac{A_c}{A_i/C_i} \right)$$

$$Tinter = \sum_{i=1}^{R} \frac{A_i}{A} \log \frac{A_i/C_i}{A/C}$$

where: A_i is the population in region *i* and C_i is the number of cities in region *i*.

The overall Theil index of Colombia indicates that the spatial concentration of population is high, having increased from 1.68 in 1999 to 1.75 in 2010. The share of inequality within regions measured using the Theil intra-index (52%) was slightly greater than the inter-regional inequality measured using the Theil inter-index (48%). This result confirms that spatial agglomeration in Colombia arises at both inter-regional and intra-regional levels.

In 2010, five regions of Colombia accounted for 39% of total exports and 83% of imports, approximately[7]. There has been no major change with respect to these shares since 2003. However, in 1984, the four main regions recorded 70% of total exports (Mesquita *et al*., 2013). Thus, the level of disparity has decreased over twenty years, but it has been stable during the last decade. The regions concentrating most of the export activity are primarily Antioquia and Bogota, followed by Cesar, Guajira and Bolivar. Import activities are primarily concentrated in Bogota, followed by Antioquia, Valle, Cundinamarca and Bolivar. Most regions have experienced an increase in international trade during the last decade. The five regions with the highest average annual growth rates of trade are Quindio (27%), Huila (25%), Choco (22%), Cesar (20.6%) and Norte de Santander (19%). Only a few regions, particularly those located in the Amazon and Orinoquia, had negative average growth rates of trade in the period 1999-2010.

The simple correlation between disparity within regions (Theil intra) and regional trade is significantly positive (0.58). The higher the level of trade, the higher the level of disparity within regions. Thus, we might think that spatial configuration within Colombian regions is related to trade openness.

[7] *Export statistics exclude oil and coffee. The source of information is the Taxes and Customs National Service, DIAN.*

4. Data

In terms of data sources, the information on exports and imports in FOB prices was obtained from the Statistic System of International Trade (SIEX for the acronym in Span ish) developed by the Taxes and Customs National Service (DIAN acronym in Spanish) of Colombia. Data on population of cities were obtained from the National Administrative Department of Statistics (DANE acronym in Spanish). The information on urban transportation in capital cities was obtained from the Survey of urban transport of passengers (ETUP acronym in Spanish) of Colombia, which accounts for information of 23 capital cities. The sample is reduced from 32 regions to 22 regions[8] when using this variable. Road traffic is obtained from the Report of the National Institute of Roads (INVIAS, 2012), which records the traffic volume in the main road network of the country. Finally, the classification of regions according to their elemental geography is based on the propositions of Deler (1991) and Florez (2003). The historical regions were based on municipalities data kindly provided by IDB[9].

Concerning data issues, our sample contains information of 32 regions instead of 33 regions. Bogota Capital District is excluded in this analysis for one main reason. The value of inequality within this region cannot be computed because the region has only one city. Eliminating Bogota, an important district in Colombia, does not constitute a problem because the interest of our study is to analyze the intra-disparity of regions. Doing so would have been problematic in the case of the analysis about inter-regional inequality.

Another possible data issue is related to the destination of imports. One can think that imports are registered in main city ports and then re-distributed to other regions. Thus, the destination of imports would be misleading. According to the Taxes and Customs National Service (DIAN acronym in Spanish) of Colombia[10], import forms record the main address (region and municipality) of the importer. The fact that import goods are registered in sub-national regions (not only in ports) reduces the uncertainty about import destinations within the country. Hence, this problem would be minor in our database.

5. Model

Colombia records trade data at the regional level, allowing us to assess for the first time the effect of regional trade openness on agglomeration within regions. We use panel data of 32 regions over the period 1999-2010.

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[8] Capital cities of the ETUP survey include Bogota Capital District. In our sample, we exclude Bogota; therefore, the resulting sample when using this variable records 22 regions. Regions without information are Amazonas, Arauca, Casanare, Cundinamarca, Guainia, Guaviare, Putumayo, San Andres, Vaupes and Vichada.

[9] I am thankful to Juan Blyde who provided data on the historical character of municipalities.

[10] We have requested such information from DIAN and we have received formal response N. 100210226 2401.

As shown in Section 3, the patterns of concentration depend upon the natural or other characteristics of regions that are present but not always observable. To control for unobserved heterogeneity, we use panel data techniques.

The specification of the panel model is the following:

$$\text{agglom}_{i,t} = \alpha + \lambda \text{openness}_{i,(t-s)} + X_{i,t}\beta + \theta_t + \rho_i t + \eta_{i,t} \quad (1)$$

$$\eta_{i,t} = \mu_i + \varepsilon_{i.t}$$

where: $\text{agglom}_{i,t}$ is the level of agglomeration within region i at time t, $\text{openness}_{i,(t-s)}$ is the trade openness of region i at time t-s, $X_{i,t}$ is the row vector containing control variables, μ_i represents region-specific effects, θ_t corresponds to time-specific effects, $\rho_i t$ represents region-specific time trends and $\varepsilon_{i.t}$ is the well behaved independent identically distributed error. Since unique characteristics of regions would be correlated with trade openness and control variables, the assumption of the OLS estimator that $cov(\eta_{i,t}, X_{i,t}) = 0$ is violated. Then, OLS estimates are biased and inconsistent. The fixed effects estimator is therefore appropriate if μ_i is assumed fixed and the remaining disturbances are stochastic with $\varepsilon_{i.t}$ independent and identically distributed with mean zero and a constant variance. The second case is to assume that individual effects, μ_i are random. To choose between fixed effects model or random effects model, the Hausman test will be used. In the sequel, the variables used in the model are described in detail.

Dependent Variable

Agglomeration is measured with the Theil index of population[11] proposed by Theil (1967). As presented previously, the Theil index can be decomposed into two indexes distinguishing intra-regional and inter-regional concentration. To capture the concentration of population within regions, we use the Theil intra-index. The formula is as follows.

$$agglom_i = \sum_{c=1}^{C_i} \frac{A_c}{A_i} \log \frac{A_c}{A_i / C_i}$$

where: A_c is the population in city c at time t, A_i is the total population of region i at time t and C_i is the number of cities of region i at time t. The index is computed at each period t. The term A_i/C_i is the counterfactual or situation of reference in which all cities are equipopulous. A higher value of the index indicates a higher degree of concentration within a region.

The Theil index comprises information of approximately 1122 municipalities[12] spread over 32 regions of Colombia. The number of cities by region ranges from 2 cities (San

[11] *In this case, we consider inequality a mere demographic phenomenon. Spatial inequality also involves differences in the standard of living between localities. Data on income of cities would solve this issue. However, obtaining such information for large periods is complicated.*

[12] *In this study, cities are defined by municipalities, which correspond to the second level of the administrative division in the country.*

Andres) to 124 cities (Antioquia). Because the Theil index[13] is computed using the administrative division, economic agglomerations could be artificially separated and the so-called Modifiable Areal Unit Problem (MAUP) could arise. However, the Theil index appears to consider implicitly the economic agglomeration of cities. Moreover, population might not locate in city frontiers because of infrastructure barriers.

As shown in Table 1, the variation of the population Theil index comes largely from heterogeneity across regions. For instance, Valle del Cauca, which has 42 cities, concentrates more than 50% of its total population in one city only. An example of regions with low levels of concentration is Putumayo, whose cities exhibit population shares around the counterfactual. The (within) variation across time is small, which shows that the pattern of inequality is permanent over time.

Table 1

Variation of the Theil-intra Index

Variable	Variation	Mean	Std. dev.	Min.	Max.
Tr	Overall	0.77	0.3799	0.20	1.60
	Between		0.3849	0.21	1.59
	Within		0.0208	0.69	0.89

Explanatory Variables

Trade openness (*$Open_{t-2}$*) is computed as the logarithm of the sum of imports and exports[14]. Another interesting measure of openness is the level of import duties. However, we do not account for such data. As in Henderson (2000) and Ades and Glaeser (1995), we use a two-year lag of openness. The effect of openness on regional disparity is likely to be delayed because the re-organization of exporting and importing firms responding to trade policies takes time. We have estimated different specifications using different time lags of openness[15], and a two-year lag of openness is chosen because it fits the data better. Moreover, we do not lose observations using such a lag. As shown previously in Section 3, regional trade differs in terms of exports and imports. Therefore, we distinguish trade openness in exports (*$Exports_{t-2}$*) and imports (*$Imports_{t-2}$*). Both variables are also in logarithm form.

[13] *We also considered other indexes to measure agglomeration intra-regions such as primacy, the standard deviation and the coefficient of variation. However, those measures have limitations. For instance, primacy disregards the weight of secondary cities in regions. The standard deviation measure does not consider a reference distribution of cities. These measurement issues are solved when using the Theil index.*

[14] *Other alternative measures that we use are the sum of imports and exports as share of GDP, the share of exports over GDP, the share of imports over GDP and the volume of exports plus imports. The estimation results are available upon request to the author.*

[15] *The results of estimations using different lags are available if requested of the author. According to the results, the coefficient estimates of the interaction terms between Open and Cordillera and the Coast are stable across regressions. Because the agglomeration pattern is not very sensitive in a short time, we do not use the first lag of openness. The estimation's results using the third lag of openness are similar to the estimations using the second lag of openness. Finally, the estimation using the fourth lag of openness loses observations. Overall, we choose the second lag of openness for the estimations.*

By recalling the statistics shown in Section 3, we presume that inland regions will also experience more concentration induced by trade because the largest cities of the country are interior (Fernandez, 1998) and trade would reinforce them. This presumption holds for regions in the Cordillera because of historical factors. Most of their cities have been historically favored in the national configuration. Then, asAlonso-Villar (1999), Brülhart *et al*. (2004) and Crozet and Koenig (2004) state, the effect of openness would depend upon the initial agglomeration of these regions. On the other hand, regions in the Amazon and Orinoquia are presumed to experience a lower effect of trade because their geographical characteristics comprising the rain forest and the countryside impede, to some extent, agglomeration. Moreover, the presence of illegal armed forces related to narco-traffic is another factor that could discourage economic activities from concentrating in these regions.

To test whether the effect of trade depends upon the geography of regions, we introduce interaction terms between trade openness and region types following the elemental geography of the country[16]: 1) Cordillera[17], 2) The Coast (The Caribbean and the Archipelago)[18] and 3) Orinoquia and Amazon[19].

Based on the above-mentioned intuitions, we expect the interaction term between trade and the Cordillera dummy ($Cordillera * Open_{t-2}$) and the interaction term between trade and the Coast dummy ($Coast * Open_{t-2}$) to be positive for concentration of population within regions, and to be greater than the interaction term between trade and the Amazon and Orinoquia dummy[20].

The coefficient estimates would be negative according to the prediction that backward and forward linkages become weaker when trade costs decrease. The presence of congestion effects in main cities might be another factor that could entail a decreasing effect of trade on spatial concentration (Krugman and Livas Elizondo, 1996).

Note that openness could be endogenous by reverse causality. High levels of population concentration in one region may influence its level of trade. When population concentrates in a few cities within regions, export and import activities increase in those cities because of labor availability and forward and backward linkages. To reduce the endogeneity problem, we consider the historical dimension of regions by interacting them with a dummy variable of history. One can think that historic regions predate

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[16] Regions are classified in one of the categories according to the position of their main city. In this manner, the issue of a region sharing two elemental regions is solved.

[17] The regions classified in the Cordillera are Antioquia, Boyaca, Caldas, Cauca, Cundinamarca, Huila, Narino, Norte de Santander, Quindio, Risaralda, Santander and Tolima.

[18] The regions classified in the Coast are Atlantico, Bolivar, Cesar, Cordoba, La Guajira, Magdalena, San Andres, Sucre and Valle del Cauca.

[19] The regions classified in the third group are Amazonas, Arauca, Caqueta, Casanare, Choco, Guainia, Guaviare, Meta, Putumayo, Vaupes and Vichada. The region Choco of The Pacific is classified in this group because its capital city is far away from the coast. Furthermore, it has problems of menace that lead to low levels of agglomeration of population. Hence, it is not expected to experience concentration.

[20] Note that including a dummy variable for Amazonian regions allows, to some extent, controlling for unobserved narco-traffic activities in these regions. We think that the presence of such activities could inhibit agglomeration of population because of restrictions imposed by drug-dealers.

location decisions influenced by trade (Mesquita *et al*., 2013). Then, looking at the differences between regions with respect to their historical characteristics, allows us to separate to some extent the endogenous part of the effect of trade on spatial concentration. As in Mesquita *et al.,* (2013), our historical dummy takes the value 1 if capital cities of regions have been created before 1800, and 0 otherwise. Because our dependent variable is an index, one might think that it is unlikely to exhibit a feedback effect. To be sure, we test whether this variable must be considered endogenous in our estimation.

Concerning other control variables of our specification 1, we include time-invariant factors that affect inequality through region-specific effects (μ_i). Those factors reflect specific geographical characteristics of regions. For instance, the centrifugal force of foreign markets in border regions near Ecuador, Peru, Venezuela, Brazil and Panama is controlled by these effects. Moreover, we control for factors that change over time but not across regions through time-specific effects (θ_t). These effects could be related to national regulations, which are likely to affect all regions to the same degree. More importantly, we include region-specific time trends ($\rho_i t$) to control for the natural growth of population. One can reasonably believe that concentration of population in main cities of regions would have an increasing trend because the native population increases regardless of the level of migration from other cities. The increase of population would be larger in the main city than in other cities because the main city already has a large population. Including time trends of each region allows determining the effect of trade net of such a natural course of agglomeration.

In the X vector of control variables, we introduce other key variables that change over time and might affect the level of agglomeration. One of them is congestion effects (*congestion*) in the main city of a region. These effects are measured by the annual growth rate of the daily average public urban transportation in service in the capital city of each region. In this manner, we are able to consider the key element of Krugman and Livas Elizondo's (1996) model, congestion. In the presence of this element, the prediction of such a model is that trade openness will incentivize firms to relocate far away from congested cities because their interest is no longer the local market but instead the foreign market. Once we control for congestion in the main city, we are able to determine whether congestion effects are sufficiently strong to influence the effect of trade.

Additionally, we control for internal transport infrastructure (*traffic density*$_{t-2}$), which is proxied by the traffic density in region i, the logarithm of the number of vehicles per kilometer within each region. As discussed in Section 3, road traffic seems to reinforce spatial disparities within regions. According to Puga (2002), an improvement in communications between two cities is not only beneficial for small cities but also for large ones. The small city would have better access to inputs and main markets, but the large city would also extend its market and more easily supply the small one. Then, the expected effect in the intra-inequality of regions is ambiguous. We use a two-year lag of transport infrastructure because economic interconnections driven by road infrastructure would develop over time.

6. Results

To estimate equation 1 presented in the previous section, the fixed effect (Least Square Dummy Variable, or LSDV) estimator is used. The motivation to use such a technique is the presence of region-specific effects that may be correlated with trade openness and control variables. In that situation, the fixed effects estimator is consistent. In addition, we use robust standard errors that allow for intra-group correlation. Robustness checks concerning stability[21] and endogeneity[22] are also conducted.

In Table 2, we present the estimations of model 1. These estimations include all the variables, region-specific effects, time-specific effects ($\theta \neq 0$) and region-specific time trends ($\rho \neq 0$). We also run other specifications of the model 1, shown in Appendix: i) $\theta = 0$ and $\rho = 0$, i.e., without time-specific effects and region-specific time trends; ii) $\theta \neq 0$ and $\rho = 0$, i.e., without temporal trends of regions. Although the differences are minor, we rely on the results of estimations shown in Table 2 because they is more precise and separate the effects related to trade and those related to pre-determined trends of concentration of regions.

To avoid losing observations, we exclude congestion in main cities as explanatory variable in models of columns (2)-(6). In columns (5) and (6), openness is measured by the level of imports and exports, respectively.

First, note that our coefficient of trade openness is interpreted as a function of the three elemental regions. The coefficient of $lnOpen_{t-2}$ corresponds to the region of reference Amazon and Orinoquia; the coefficient of $Cordillera*lnOpen_{t-2}$ corresponds to the effect of trade openness in regions of the Cordillera with respect to the region of reference. Finally, the coefficient of $Coast*lnOpen_{t-2}$ corresponds to the effect of trade openness in Coastal regions with respect to the region of reference. The net effect of trade openness in the regions of the Cordillera/Coast is the sum of the coefficients of $lnOpen_{t-2}$ and $lnOpen_{t-2}*Cordillera/Coast$.

Given the expected effects discussed previously, two hypotheses are tested:

1. Trade openness increases less strongly the disparity of population within regions of the Amazon and Orinoquia compared with the other two types of regions, and
2. The effect of trade openness on the spatial concentration of population is higher in regions close to the international market (Coast) than in inland regions (Cordillera).

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[21]Concerning the stability of our results, different measures of openness are used. The estimations with alternative measures (exports plus imports over GDP, exports' share of GDP, imports' share of GDP and the volume of exports plus imports), show qualitatively similar results.

[22]We test whether openness is endogenous using a time lag as the instrument. According to the test, Chi-sq.(1)= 0.88 and P-value=0.3469; openness can be treated as exogenous in the equation. The concern of endogeneity is thus ruled out. We also use a measure of ad-valorem transport costs as an instrument. Such a measure was kindly provided by Mesquita et al. (2013) who calculated them for years 2004, 2005 and 2006. However, this instrument was not valid according to the first stage estimation (F=0.07). Another instrument that might work better than the lagged trade could be the distance to external markets (Redding and Venables, 2004). Unfortunately, we do not account for such information.

Hypothesis 1: Amazon and Orinoquia regions experience a lower effect of trade openness on their spatial concentration of population

All regressions (1-6) show that the effect of trade openness is significantly greater in the Cordillera regions and Coastal regions than in regions of the Amazon and Orinoquia. In fact, the latter experience a negative effect of trade on their disparity of population distribution. This result indicates that inland regions in the Amazon and Orinoquia are more dispersed because of trade openness. Main cities of these regions do not attract further population driven by trade, perhaps because their size is not sufficiently large with respect to other cities in the same region. Dispersion is instead the resulting effect that arises from a weak home market effect of main cities in those regions. In particular, the Amazon regions: Vaupes, Guania and Amazonas do not account for national primary and secondary roads, so that their potential markets cannot develop, which is, in turn, the main obstacle to trade. Another explanation could be related to the intuition of Krugman and Livas Elizondo(1996). Because exporting and importing-oriented firms do not need to be located near the large market, forward and backward linkages vanish in the main city. However, note that the dispersion in these regions is less likely to be induced by congestion effects in main cities.

Table 2

Panel Models

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
Population Theil index	(X+M)	(X+M)	(X+M)	(X+M)	(M)	(X)
$Open_{i,t-2}$	-0.0109	-0.0142	-0.0144	-0.00953		
	(-4.014)***	(-3.493)***	(-3.473)***	(-1.806)*		
$Coast*Open_{i,t-2}$	0.0322	0.0394	0.0388	0.0326		
	(3.477)***	(3.268)***	(3.153)***	(2.518)**		
$Cordillera*Open_{i,t-2}$	0.0174	0.0168				
	(5.987)***	(3.328)***				
$Cordillera'*Open_{i,t-2}$			0.0173			
			(3.569)***			
$Hist*Cordillera'*Open_{i,t-2}$				0.00978		
				(1.605)		
Cundinamarca*$Open_{i,t-2}$			-0.0934	-0.101		
			(-8.213)***	(-8.4)***		
$Imports_{i,t-2}$					-0.00811	
					(-1.188)	
$Cordillera*Imports_{i,t-2}$					0.00935	
					(1.183)	
$Cundinamarc*Imports_{i,t-2}$					-0.0697	
					(-9.69)***	
$Coast*Imports_{i,t-2}$					0.0265	
					(2.224)**	
$Exports_{i,t-2}$						0.000791
						(0.108)
$Cordillera*Exports_{i,t-2}$						0.00311
						(0.395)
$Cundinamarc*Exports_{i,t-2}$						0.197

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
						(14.033)***
*Coast*Exports$_{i,t-2}$*						0.0291
						(2.234)**
Traffic density$_{i,t-2}$	0.0142	0.0238	0.0265	0.0291	0.0304	0.0182
	(2.176)**	(2.481)**	(2.346)**	(2.583)**	(2.668)**	(1.813)**
Congestion	-0.0177					
	(-0.981)					
Constant	3.665	1.173	1.330	0.806	0.378	1.478
	(6.069)***	(2.264)**	(2.564)**	(1.691)	(1.181)	(2.096)**
N	220	275	275	275	275	275
F statistic	57.61	5.92	6.65	6.23	7.70	6.029
p-value	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.869	0.602	0.619	0.602	0.588	0.624
t statistics in parentheses						
*p<0.10, ** p<0.05, *** p <0.01						

Conversely, when trade increases in the Cordillera and Coastal regions, their main cities gain relevance in the regional economy and attract more population. Exporting and importing activities in search of good access to the international market locate in large cities which allow increasing returns to scale and stronger backward and forward linkages. In the case of the Cordillera regions, the size of the main cities representing their home market effect is the centripetal force enhanced by trade openness. Because we control for trends of agglomeration, the positive estimate is solely due to trade openness. Thus, historical factors can be discarded. In the case of Coastal regions, two centripetal forces are enhanced by trade: the home market of main cities and the location advantage.

According to the coefficient estimates of model (2), an increase of 100% in trade of the Cordillera and Coastal regions increases their population concentration in 0.0394 points and 0.0168 points, respectively, more than in the Amazon and Orinoquia regions.

Over the period 2000-2010, trade in Cordillera regions has increased 172%, which has induced a 2.7% increase in their population Theil index. This increase corresponds to 43% of the increment of the Theil index in those regions. On the other hand, the 132% increase of trade in Coastal regions between 2000 and 2010 has increased their spatial concentration of population by 8%.

However, the effect of trade is not similar across Cordillera regions. We presume that the effect in Cundinamarca, the main region in the country, will be different because its municipalities have been better integrated in terms of transport infrastructure. In column (3), we then differentiate the effect of trade in Cundinamarca[23]. The result shows that trade openness in this region reduces in 0.09 points its level of population concentration with respect to Amazon and Orinoquia regions. However, this result seems to change when analyzing the level of imports (column (5)) and the level of exports (column (6)). On the one hand, an increase of exports of Cundinamarca will induce to a higher level of its internal regional disparity. On the other hand, a high level of intra-regional disparity in this region is due to a decrease of imports. It is noteworthy that the positive impact of

[23] *Recall that Cundinamarca in this analysis excludes Bogota.*

exports is much higher than the negative impact of imports. Thus, one can believe that the level of intra-inequality in Cundinamarca is mostly related to its level of exports. In fact, Alfonso (2013) shows that the gap among municipalities in Cundinamarca, including Bogota, is widening. Moreover, there is a great flow of vehicles carrying cargo and passengers (Mayoralty Colombia, 2014) through Cundinamarca towards main cities.

The differences across regions might be related to their levels of trade. The logarithm of trade in the Amazon and Orinoquia regions is 14.64 on average; in Coastal regions, it is 19.71, and in Cordillera regions, it is 19.35, including Cundinamarca and 19.08 excluding Cundinamarca. According to the mean-comparison test, the difference between Amazon and Orinoquia regions with respect to both Cordillera and Coastal regions is significant. Thus, we observe that the effect of trade on inequality is negative in regions with a low level of trade. Moreover, the effect becomes positive in regions with a high level of trade. Based on this result, a U-shaped relationship between the level of trade and its effect on inequality can be inferred. In particular, Cundinamarca follows such a relationship when considering its level of exports.

The concentration effect of trade is significant after controlling for local factors that affect agglomeration, namely traffic density in regions and congestion in main cities. These two variables allow distinguishing their effects from the effect of trade openness.

The variable of traffic density allows controlling for the effect of road infrastructure, which is generally of better quality close to the capital city. Hence, road density would be given in great part by the importance of the main city of each region. In fact, the estimate of this coefficient is positive and significant, suggesting that traffic flows are higher on roads close to the main city, inducing further agglomeration.

As mentioned previously, main cities are the centers from/to which exports and imports of other cities are transported. Thus, the effect of traffic density is very likely to be linked to trade. This aspect, which can disguise the effect of trade, is somehow controlled in our specification by including this traffic density variable.

The other key element that is controlled in our models is the effect of congestion in main cities measured by the growth rate of daily urban transportation in service. Although the estimate is negative, it is not significant. According to Krugman and Livas Elizondo (1996), the effect of trade openness is influenced by strong congestion effects that lead firms to relocate far away from the main city. Nevertheless, the results of our model demonstrate that even in the presence of congestion effects in main cities, trade openness increases concentration toward them, inducing further spatial inequality within regions. Whereas congestion does induce dispersion in our model, external trade still provokes a concentrating effect, which could be because firms require a large market to trade. Thus, these results do not support the Krugman and Livas-Elizondo's (1996) hypothesis.

Hypothesis 2: Coastal regions experience a higher effect of trade openness in their inequality than do Cordillera regions.

Until now, we have provided empirical evidence on the first hypothesis, that is, that trade generates a concentration-enhancing effect in Coastal regions and Cordillera regions, whereas regions in the Amazon and Orinoquia experience not only less concentration of population but a negative effect of trade, inducing dispersion of population within them.

To test the second hypothesis, that is, that the effect of trade openness is greater in Coastal regions than in Cordillera regions, we assess the significant difference of their corresponding coefficient estimates. In the model in column (3) using the sum of exports and imports as a measure of trade openness, the effect of trade in the Cordillera is slightly lower than that of the Coast. According to the test of equality of coefficients, the difference is significant at 7% level (F statistic=3.41, p-value=0.0773). In addition, one could argue that these regions would have a higher impact of trade in their internal concentration due to historical factors, which causes a problem of endogeneity. Regions already highly concentrated in traditional cities would experience further concentration induced by trade because their infrastructure and urban conditions have been developed for a long time. In order to reduce the endogenous character of concentration within these regions, we separate the effect of historical regions in the estimation of column (4). To do so, we take into account the main cities of regions created before 1800 which are mainly located in the Cordillera and any in the coast. We then observe a significant change in the Cordillera coefficient in model (4) with respect to model (3). When considering historical advantages of Cordillera regions, the effect of trade on their level of spatial concentration is not significant with respect to Amazon and Orinoquia regions.

To understand better the differences in trade effects across regions, we examine their differences in terms of exports and imports. Concerning imports (column 5), the null hypothesis of the equality of the coefficients is not rejected at 12% (F statistic=2.54, p-value=0.1238). In terms of exports (column 5), the effect in Cordillera regions is much lower than that in Coastal regions. Such a difference is significant at the 3% level (F statistic=5.34, p-value=0.0298).

The different effect of trade in terms of exports might be because the level of exports between the two groups is different. The average of the logarithm of exports from Coastal regions is 19.26, whereas the average of interior regions in the Cordillera is 18.18. According to the test, we reject the equality of those means (t-statistic=4.04, p-value=0.0001). Coastal regions export more than Cordillera regions do, suggesting that the centripetal force coming from the location advantage prevails in the former. Moreover, the main cities of the Cordillera face higher internal transport costs (Nishikimi, 2008; Alonso-Villar, 1999; Crozet and Koenig, 2004), which limit their exports. The only centripetal force for them is then the size of their market, which might constitute the main reason why spatial inequality within Coastal regions increases more than in Cordillera regions with trade openness.

Conversely, the level of imports is almost similar between the two types of regions. Despite the large distance to ports, inland regions of the Cordillera import as much as do regions on the Coast. The first group of regions (Cordillera) records a mean of imports in logarithm of 18.24, whereas the second group (Coast) records a mean of 18.28. The mean-comparison test is not rejected (t-statistic=0.14, p-value=0.89). Main cities, no matter their location (Coast or Cordillera), are appropriate environments to produce positive externalities of diversity and attract more population, enhancing the inequality within their respective regions. Moreover, main cities become much larger because the importing activity is likely to be devoted to the development of the local industry. To determine to what extent industry is affected, analyzing imports by type of products would be useful. However, such an analysis is outside the scope of this study. Overall, the effect of trade remaining significant for Coastal regions indicates that trade is sufficiently strong to shape their spatial configuration, a phenomenon that rarely changes. On the other hand, the pattern of concentration in Cordillera regions seems to come exclusively from their historical relevance.

7. Conclusions

This study underscores that spatial disparities within countries come not only from inter-regional disparity but also from intra-regional disparity. In the Colombian case, the pattern of agglomeration is indeed revealed across geographical levels. Although this analysis focuses on Colombia, such a characteristic might be considered a general fact for all countries. Given that intra-regional inequality exists, this paper seeks to determine to what extent regional trade reinforces such a pattern.

The results show that the effect of trade is different across types of regions. Overall, the Amazon and Orinoquia regions experience negative effects, i.e., trade induces dispersion within these regions. Conversely, regions of the Cordillera and the Coast tend to experience higher internal concentration induced by trade openness. The literature suggests two possible explanations behind these results: home market effect and location advantage effect.

Furthermore, because the level of trade of the Amazon and Orinoquia regions is lower than that of the Cordillera and Coastal regions, we could deduce a U-shaped relationship between the level of trade and its effect on inequality. Overall, this empirical analysis, which demonstrates that spatial configuration of cities is shaped by trade openness, is a key finding that calls for the development of theoretical models considering a finer geographical level of analysis.

The analysis using the sub-national geographical level has provided interesting and clear insights about the role of trade in the spatial configuration of cities within regions. By contrast, the results of the aforementioned studies (Ades and Glaeser, 1995; Henderson, 2000; Brülhart and Sbergami, 2009) analyzing the effect of trade at the national scale were rather inconclusive, possibly suggesting that the effect of trade is more explicit within regions than between regions. Thus far, this observation has not been directly addressed in theoretical studies, thus calling for further research, particularly in urban economics, given that trade openness affects the configuration of cities.

Finally, this study can be extended by differentiating the level of trade by type of products, which would provide promising results. For instance, such an analysis would shed light on the role of imports of manufacturing goods in bearing benefits for local innovation (Coe and Helpman, 1995; Coe *et al.*, 1997) which, in turn, could affect spatial agglomeration.

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Appendix

OTHER SPECIFICATIONS

In Table 3 we present different specifications of model 1. In column (1), In column (1), the specification of the model 1 with $\theta = 0$ and $\rho = 0$, i.e., without time-specific effects and region-specific time trends, is estimated. In column (2), the specification with $\theta \neq 0$ and $\rho = 0$, i.e., without temporal trends of regions, is estimated. In column (3), the specification of the model with $\theta \neq 0$ and $\rho \neq 0$, i.e., with time-specific effects and the temporal trends of regions, is estimated. We make emphasis on the variable of congestion. It is only significant when time fixed effects and region specific trends are not taken into account. In Table 2, we present the estimations excluding congestion but including all types of fixed effects.

Table 3

Trade Effect in Agglomeration within Colombian Regions

Dependent variable	(1)	(2)	(3)
Population Theil index	(X and M)	(X and M)	(X and M)
$Open_{t-2}$	-0.0123	-0.0119	-0.0109
	(-10.486)***	(-5.539)***	(-4.014)***
$Cordillera*Open_{t-2}$	0.0187	0.0139	0.0174
	(4.159)***	(3.160)***	(5.987)***
$Coast*Open_{t-2}$	0.0198	0.0116	0.0322
	(1.367)	(0.702)	(3.477)***
traffic $density_{t-2}$	0.0280	0.0232	0.0142
	(2.313)**	(2.334)**	(2.176)**
Congestion	-0.0513	-0.0217	-0.0177
	(-1.882)*	(-0.698)	(-0.981)
Constant	0.675	0.800	0.0322
	(6.198)***	(6.514)***	(6.069)***
N	220	220	220
F (p-value)	689.2 (0.000)	7.804 (0.000)	56.40 (0.000)
Region effects	Y	Y	Y
Time effects	N	Y	Y
Region time trend effects	N	N	Y
R2	0.285	0.394	0.869
t statistics in parenthesis			
*p<0.10, ** p<0.05, *** p <0.01			