A spatial profile of the economy of Boyacá

Perfil espacial de la economía boyacense

Perfil do espaço na economia de Boyacá

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Resumen

Se intenta describir la economía boyacense en términos espaciales con la identificación de conjuntos de municipios, que por su contigüidad, pueden compartir algunas características productivas y geográficas comunes. Con las variables económicas georreferenciadas disponibles se aplican algunas herramientas de análisis espacial para determinar la tendencia de localización de las actividades agrícolas, industriales y de servicios. El desarrollo del tema corrobora las intuiciones teóricas que destacan la conformación de núcleos urbanos centrales que concentran actividades económicas y de zonas periféricas con baja productividad y sumidas en un estancamiento económico a causa de su aislamiento y la precariedad de la conectividad.

Palabras clave: análisis espacial, economía regional, estructura productiva, localización de la producción.

Clasificación JEL: C18, R12, R15

Abstract

This article aims to describe the economy of Boyacá, Colombia in spatial terms, identifying sets of municipalities that, due to their proximity, may share some common productive and geographical features. Using the available georeferenced economic variables, some tools of spatial analysis were applied, in order to determine location trends in the activities of agriculture, industry and services. The development of this topic corroborated with the theoretical assumptions regarding the formation of urban centers that concentrate economic activities, while peripheral zones show low productivity and remain economically stagnant, as consequence of their isolation and poor connectivity.

Keywords: spatial analysis, regional economics, production structure, location of production.

Resumo

Este trabalho tem como objetivo descrever a economia Boyacense em termos espaciais, com a identificação de grupos de municípios que, pela sua contiguidade podem compartilhar algumas características produtivas e geográficas comuns. Com as variáveis econômicas disponíveis algumas ferramentas de análise espacial geo-referenciadas são aplicados para determinar a natureza espacial das atividades agrícolas, industriais e de serviços. O desenvolvimento do tema corrobora conhecimentos teóricos que destacam a criação de centros urbanos centrais que concentram áreas econômicas e periferias, com atividades de baixa produtividade e relegadas na estagnação econômica com resultado do seu isolamento e pobre conectividade.

Palavras-chave: análise espacial, economia regional, estrutura produtiva. localização da produção.

INTRODUCTION

The department of Boyacá is counted among the four principal agricultural producers in the country (UNDP, 2011), thanks to a long-standing tradition of rural economic production and a variety of climates and natural conditions. In other circumstances, when nature does not allow for the exploitation of agriculture in a productive manner, municipalities have sought to survive from services activities, such as tourism, business, crafts or pottery.

In effect, the economy of Boyacá has been characterized for being based predominately on agriculture and mining, although in recent years services have gained greater participation in the production of the department (Rodríguez, 2007). This sectoral change in its productive structure is reflected in the spatial distribution of economic activity that can be seen in cartographic and spatial analysis displays.

This impact on spatial aspects underlines the importance of the analysis of the location of economic variables, and the possible persistence of certain phenomena localized spatially in particular places and their surroundings. According to this, there are common conditions shared by a number of municipalities, which helps to understand the productive vocation of some particular region, and allows the determination of certain geographic or natural conditions that underlie these spatial phenomena.

As is widely known, since the time of Alfred Marshall it has been discussed that the most elemental influence on the location of productive activity came from the natural conditions and the access to

natural resources. The observations of the British author arose from the curiosity sparked by the location of industry in England at the end of the XIX century (Marshall, 2005). In this context, the department of Boyacá possesses fertile soils which accommodate a variety of productive activities, but also, in some regions soil erosion and the deterioration of topsoil has left an imprint on some desertic areas (see map 2). Further on, it will also be seen that in the most fertile zones and with suitable soils, there are some municipalities that stand out for their productivity, especially in certain products.

Regarding the above, this article analyses the spatial distribution of the economic activities of Boyacá, for which some basic spatial analysis tools are applied. The georeferenced information was downloaded from the application SIG-OT, which is available from the webpage of the *Instituto Geográfico Agustín Codazzi* (IGAC)[1], personalizing the data for the department of Boyacá. The information has the virtue of being available for municipalities, although for the same degree of detail, statistics in the fields of manufacturing and services do not exist. Nevertheless, substitute variables were incorporated that, in an indirect manner and with high fidelity, offered directories of what was originally intended to study.

In terms of variables of analysis, the most complete and direct information consulted

in the geographic body corresponded to the agricultural production of municipalities. In the case of the manufacturing industry, statistics on the local level of production, aggregated value or employment do not exist. As a way of approaching this sector, municipal information on the number of productive units was used; which was found to be duly georeferenced. Finally, for the services sector the study included data on the number of units of services for each municipality. Given the advantage of having municipal statistics on the aforementioned terms, it was possible to apply a series of geostatistical tools to determine the characteristics and the spatial patterns of the variables in question and draw very specific and local conclusions.

In this way, the article manages to explore some spatial aspects of the production of Boyacá and attempts to identify the municipalities that play a set role in the location of economic activity in the department. Precisely, in Appendix 1 that accompanies this document, the codification of the municipalities and the political division of the department are presented, to guide the location of the municipal jurisdictions repeatedly mentioned in this analysis.

The structure of the article is comprised of five parts. After this introduction, a section that puts forward some ideas concerning the problem of the location of economic activity are presented

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[1]   Agustín Codazzi Geographic Institute. For further details consult: http://sigotn.igac.gov.co/sigotn/

following a useful classification applied by the Nobel Prize winner Krugman (1995), although emphasis is made on the conceptual schemes of Von Thünen, the usefulness of which comes to light when observing the spatial disposition of the economic variables consulted. In effect, the cartographic display exhibits centers of production and economic activity in the main cities of Boyacá, surrounded by a group of close municipalities, which gravitate in turn to those in accordance with their particular productive vocation. In the third section, some methodological tools are introduced, like a toolbox to interpret the subsequent results. The fourth part presents a basic spatial analysis of the georeferenced variables available for agriculture, the manufacturing industry, and services; and finally, some conclusions are proposed.

THEORETICAL FRAMEWORK

The spatial form that productive activity assumes has caught the attention of geographers as well as economists. From the contributions of the German school of location to the recent developments of the new economic geography, much has been written and researched on the phenomenon of agglomeration and its spatial location. To make an account of the contributions of some magnificent exponents on the topic, the description proposed by Paul Krugman (1995) will be followed. This description is focused on emphasizing the difficulties that arise when incorporating the line of studies of location into the basic theoretical corpus of economic science.

The classification that Krugman (1995) proposes of the traditions of thought, in order to explain location, has as its starting point the recognition of the importance of placing oneself in the context of increasing returns to fully understand the unequal distribution of economic activity in the space. On the contrary, if working in a context of constant returns and if there are transport costs, the world would reveal a panorama dominated by a collection of self-sufficient dwellings in which each producer would do so for their own satisfaction in an autarchic manner, in what has been referred to as *backyard capitalism* (Krugman 1992, 1995; Fujita et al, 2000). This metaphor highlights the fundamental role of economies of scale as a force for location, according to which companies are established in few places where the existence of a large enough market is detected, so as to produce large volumes, exploiting some production conditions dominated by increasing returns.

In this sense, the proven existence of spatial concentrations of economic activity and an unequal distribution of production is an irrefutable sign of the lack of validity of *backyard capitalism*. The objective of Krugman (1995) in identifying the five traditions in the spatial economy demonstrates the intent of this field of science to embed itself in the central core of conventional economic science.

The first proposed tradition corresponds to Germanic geometry[2], developed among German language writers and was known of in the Anglo-Saxon context only until the mid-XX century. In this tradition can be included the model in which companies seek to address various markets, having one or more suppliers, so they have more than three sites to choose a location from. Likewise, the theories of *central-place* are relevant, which end up proposing geometric type solutions with an agricultural population homogenously distributed, the results of which could lead to a hexagonal distribution of the agricultural population or a hierarchical plan of cities.

The issue with these types of models is that they are geometric descriptions of the location, instead of explanations of an economic type according to conventional analysis. They also exhibit a fundamental lack of a micro-founded framework, in which appears an explanation of individual decisions and a definition of the market structure in which context the model develops. In summary, the main lack of these approaches consists of the fact that it is not possible to explain the existence of a central place, disregarding the market power of imperfectly competitive companies (Krugman, 1995).

The second tradition reviewed by Krugman (1995) is known as *social physics* and is identified with developments which occurred in the United States in the mid-XX century, which aimed at elaborating a set of algorithms that represented the relationship between population and range of cities, and the utilization of the market potential. These tools turned out to have a high level of practical precision and sufficient capacity to explain certain empirical regularities in the subject of location.

The definition of the rule of size-rank[3] related functionally the distribution of the size of cities with the rank order following demographic criteria. The aforementioned rule was defined as:

$$N_i = \frac{k}{R^b_j}$$

N being the population of the city *N, R* its rank order according to the demographic criteria and *b* acting as an exponent close to 1.

Continuing with the algorithms associated with social physics, an expression of gravitational type appears in which the populations, their distances, and the volume of the transactions made intervene. A way of representing it is as follows:

$$T_{ij} = k \frac{N_i N_j}{D^b_{ij}}$$

Where *T* represents the transactions carried out between cities, *D* is the distance, and *b* is an exponent.

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[2]   In this category theorists like Weber, Lösch and Christaller are classified.
[3]   Also known as Zipf's Law

A third algorithm was defined in terms of market potential to identify entities that demonstrate that they have a strong market, as vital information for firms at the time of localizing. Therefore, an index was created that incorporated the purchasing power of the markets and the distances, as follows:

$$p_i = \sum_j k \ \frac{Y_j}{D^b_{ij}}$$

With similar parameters to those presented above, but including *Y* representing purchasing power of a certain market. These tools, which are focused on market power, were appropriately adjusted, and coincided in locating with precision the points in which industrial agglomeration and the focus of the market were back-fed.

The third tradition of spatial economy corresponds to *cumulative causation*[4], which made emphasis precisely on the circular dependence that is generated between the market potential and the location of the companies. With these arguments, it was intended to explain the self-reinforced dynamic, which is present in the growth of cities as a response to industrial development, originated, at the same time, in urban growth. This circular process was captured in some empirical works that were consistent with this hypothesis.

This logic applied to the development theory could make predictions of what would happen on a territorial scale of regional scope. In these terms, if a market was big enough so as to promote economies of scale, an import substitution process could begin that would favor local production. Later on, and in the presence of free movement of factors, immigration would increase the number of workers and would give rise to a new expansion cycle of production.

Then, Krugman appeals to technological influence and the spillovers which are at the base of the fourth tradition known as *local externalities*. The economist, whose contribution is most recognized in this respect is Alfred Marshall (2005), with his emphasis on the transfer of knowledge between companies as a result of spatial closeness. Although, in principle, his contributions limited the definition of some purely technological externalities, these were included as one of the centripetal forces of industrial agglomeration.

Finally, in the fifth tradition of the analysis of spatial economy, Krugman alluded to studies based on *land rent and land use*. In order to develop this tradition, he concentrates on the theoretical model of concentric rings around an isolated city[5].

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[4]   Important exponents are Harris, Lowry, Pred and Myrdal.
[5]   The discussion is particularly focused on Von Thünen`s contribution.

In the present analysis, said report will be complemented with a graphic analysis presented in the work of Cabral (2011), in which an illustration of the Von Thünen rings appears in a study of the location of the timber and forestry industry. Similarly, a more formal development of the model of concentric rings will be consulted. This was presented in the magnificent contribution made by Samuelson (1983) who, when approaching the model, develops a remarkable mathematical and analytical refinement.

The starting point of the model is the functionality of the agricultural organization around a central city, addressing various economic and geographic restrictions, such as the distance with respect to an urban center, factorial intensity (land and work) of the crops and transport costs. Under these circumstances, the spatial disposition of the model shows a number of surrounding rings that accommodate agricultural production, according to the uses of the soil in each spatial segment.

Each farmer has similar characteristics to those of their peers, but the differentiating element is the geographical position and the distance with respect to the central place, a circumstance which introduces the cost of transport as a central criterion of the model. Another implication is that the increase of distance has an effect of gradual reduction on the agricultural rent, coinciding with the need to raise wages due to the increase in the price of urban goods. Additionally, the differential nature introduced by the distance affects the agricultural production systems and the type of crop in each ring, keeping intensive agriculture in the central rings and distributing the extensive activities in the zones furthest away.

The model assumes important criteria. In the words of Cabral (2011):

• It is located on flat land with uniform soil quality surrounded by an outer ring of wilderness.

• There are no movements of exportation or importation beyond the forest.

• The farmers are homogenous as regards their cultural level.

• The farmer produces for the market, aiming to maximize profits.

• The only possible market to sell their products is the urban market.

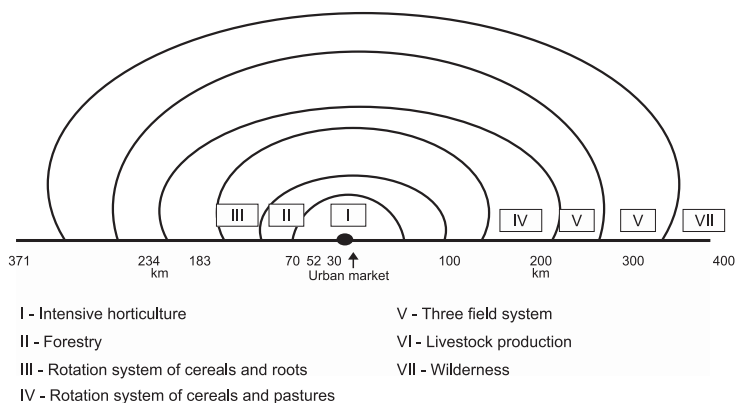• The products are transported to the city by animal-drawn vehicles.

I - Intensive horticulture   V - Three field system
II - Forestry   VI - Livestock production
III - Rotation system of cereals and roots   VII - Wilderness
IV - Rotation system of cereals and pastures

Figure 1. Von Thünen`s rings
Source: Taken from Cabral (2011).

In Figure 1, Cabral graphically develops the configuration of the productive rings which are derived from Von Thünen's model and his "theory of agricultural location." In the spatial distribution it is reasonable that the products that are most expensive to transport are cultivated in the most central rings, applying a criteria of economic efficiency to this decision.

In accordance with the above, the organization of the agricultural production would locate the vegetable, legume and fruit crops in the most central ring; the second ring would be used for the production of timber and firewood; in the third ring would be put the rotation crops of cereals and root vegetables; in the next ring, a rotation system of cereals and grass would be organized; the fifth ring would be adapted to a three field system, composed of winter crops, spring crops and fallow land. Finally, extensive livestock production would be relegated to the sixth ring (Cabral, 2011).

In the model of Von Thünen in Samuelson's (1983) style, it is assumed that the city specializes in the production of clothing, and also in two agricultural crops, which are located in their respective rings. On the one hand, the vegetables that are most delicate to transport and, consequently, that bring about greater costs; and, on the other, grains with low transport costs. In these circumstances, the vegetables will be grown on the limited zones that are contiguous with the city, while the grains will be planted in the plains further away, due to their ease of transport. For reasons of economic efficiency, the production would make more economic use of land the more central the ring. This explains why the production would tend to progressively make more intensive use of the land as the distance increases, given

that land becomes the most relatively abundant factor, while in the more central rings the factor of labor would be most intensively used (the relationship between the factors *L/T* will decrease with the distance from the urban center).
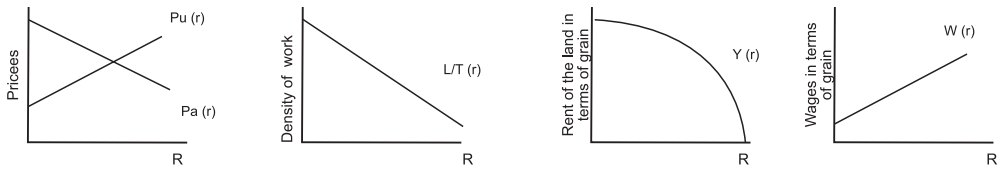

Figure 2. Variables' behavior in the model, according to distance.
Source: taken from Samuelson (1983).

In Figure 2 the functioning of the variables of the location model are represented, in accordance with the distance *R*, from the perspective of the analysis of Samuelson. The first frame represents the fact that the prices of the urban goods delivered to a certain distance from the city should increase linearly. At the same time, the price of the agricultural goods delivered to the city, will experience a continuous reduction to the extent that the distance requires the crossing of the outer ring. In the third illustration, the rent of the land in terms of grain is represented, which has a tendency to decrease. If the land is a static factor, the relative rent of the land in terms of grain will continually reduce in contrast to the rent of the lands located closer to the city. Lastly, the fourth frame represents wages in terms of grain, which have a tendency to increase, so the wages need to adjust to the increase in order to compensate for the higher price of the urban goods; the further the distance from the center, the higher the increase.

The presented model is a master work in assigning the use of land in an efficient way and offers very reasonable criteria for the functioning of an agricultural system, applying a system of differential rent in relation to distance. As Samuelson (1983, p. 1481) pointed out: "…charging competitive land rent is what leads to normative social efficiency."

METHODOLOGICAL ASPECTS

Nearly all of the socioeconomic phenomena are distributed in an unequal way in the space. Some aspects affect some places more intensely than some others, and the maps that represent the simple display of variables are always shaded in different colors or use symbols which denote differences on the geographical plane. The merit of the spatial analysis consists of managing to identify the thematic reasons and the underlying facts which lead to the differentiation of the economic variables within the space.

To the effect of the present analysis, some very basic and standardized tools of spatial analysis are applied with the purpose of identifying location patterns and pointing out the names of the municipalities which have a particular economic and productive characteristic. Given that the spatial behavior of agriculture, industry, and services is intended to be approached, it was considered illustrative to focus on the identification of municipalities that had a specific role in the behavior of some productive variable, proposing an interpretation of the geographic patterns displayed by the cartographic tool.

As was previously noted, the data was taken from the Instituto Geográfico Agustín Codazzi, whom you can consult through their webpage. This data has the advantage of being on a municipal territorial scale, for this reason, a very detailed analysis can be carried out. However, as is logical, not all the desired variables were available and so, other data closely related to the phenomenon in question was used. At the same time, Appendix 1 presents a map of the municipalities and a table with their respective names in order to facilitate the cartographic location of the localities in Boyacá. With respect to the cartographic display and the spatial analysis tools applied, they were processed using the ARCGIS software, ARC MAP 10.1.

The first spatial analysis tool consists of the application of hot spot in which clusters of high values or low values of the variable in spatial neighborhoods are identified; they are characterized by groups of contiguous municipalities. This technique is very useful to efficiently point out where certain behavior of the variable takes place (Universidad Nacional de Colombia, n.d.).

On occasions, a high value of the variable is detected, but it might be isolated from the rest of the high values that belong to other spatial entities. Therefore, the tool seeks certain value in the context of the neighboring entities. In order to form hot spot, the spot must have high values and be surrounded by entities which show equally high values.

Additionally, a widespread contrast of this type of analysis has also been applied. It is known as Moran`s spatial autocorrelation (Ord & Getis, 1995), the purpose of which is to measure the degree of spatial dependence of the values of each variable between neighboring areas and determine if there is a spatial pattern which accompanies the distribution of the variable. In fact, for the spatial analysis, it is essential to detect if the variables follow a spatial pattern or not; in other words, if the variable is distributed randomly or if the data forms a cluster of similar values in a fraction of the plane.

These phenomena of spatial contiguity can be attributed to the existence of a "contagion effect", as a consequence of the geographical vicinity and the transmission of externalities (Chasco, 2008), the final result of which is the display of a group of spatial entities that

show a certain pattern, grouping high values and low values of the variable in question.

This phenomenon of spatial correlation can be contrasted through Moran's test, as Chasco (2008) describes:

$$ I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \left(y_i - \overline{y} \right) \left(y_j - \overline{y} \right)}{\sum_{i=1}^{n} \left(y_i - \overline{y} \right)^2} $$

Where *I* is Moran's index, y_i is the value of the variable in the location i, $\overline{y_i}$ is the average value of the variable y, w_{ij} represents one of the elements of the spatial weights matrix w and where s_0 is a factor of equivalent scale to the sum of all the elements in the matrix w. This last matrix has an n order, where *n* is the number of municipalities in the department (123), which contains information of the contiguity relationships among the observations.

The interpretation of Moran's index is carried out against the contrast of the null hypothesis of no spatial autocorrelation. Therefore, the values of Moran's Index (I) that the test shows are interpreted in comparison to the values that would be expected in case that the null hypothesis was not rejected, reinforced by the respective values z and p of the probability (Chasco, n.d.).

Similarly, the spatial autocorrelation analysis is accompanied by a Gaussian bell-shaped report with the objective of observing the contrast of the hypothesis test, and if the calculated values belong to the area of acceptance or rejection of the null hypothesis. For the present analysis, the purpose is to find out if the spatial distribution of the variables responds to a random distribution in the space or if it is run by some association pattern (Universidad Nacional de Colombia, n.d.).

SPATIAL BEHAVIOR OF THE ECONOMY OF BOYACÁ

Several points of interest stand out in Von Thünen's model, which was superficially presented in the theoretical part. Production demands that in the areas closest to the urban centers, the land be used more efficiently for more productive crops and with technologies that maximize the use thereof, while in the more remote areas the production can be less land-conserving and involve more extensive activities. At greater distances from the urban center, wages in terms of agricultural goods have to be readjusted to the increase, recognizing that the price of the urban goods also increase because of the distance; simultaneously forcing the drop in rent of the land in the more remote rings.

A summarized conclusion of the concentric rings model has been described in the following terms: "….the expensive land close to the center would be reserved for crops with high transport costs and/or crops that gave a high value per hectare; the outer most ring would be dedicated to crops intensive in land use or to harvests of cheap transport" (Krugman, 1995, p. 51).

Below, the layout on the map of some economic variables will be cartographically described, making particular emphasis on the spatial characteristics of the agricultural production, contextualizing the spatial performance of this enterprise with respect to the distribution of other branches of activity.
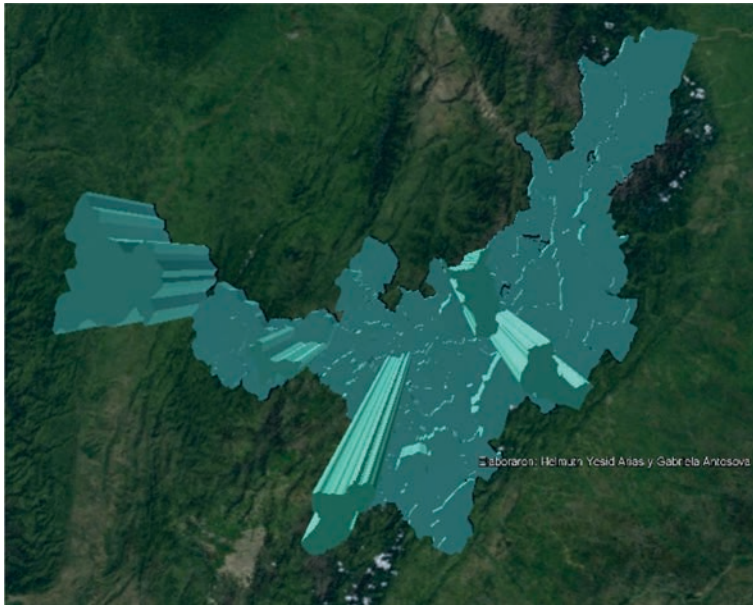
Map 1 . Boyacá Population by municipalities.
Source: elaborated by the authors with data from the system SIGOB of the GIAC
and the National Administrative Department of Statistics (DANE).

Map 1 shows the municipalities with concentrated populations in the department and that, at the same time, act as provincial urban centers and which offer a number of economic services to their surrounding areas. The most prominent figure represents Tunja, the capital, followed by Sogomoso, Duitama, and Chiquinquirá. This last city is considered to be the market center for emeralds from the mining zone and is known as the religious capital of Colombia. Other important populations that also stand out in the region are Paipa and Puerto Boyacá.

From this perspective, as described by Medina and Bermúdez (2007), Boyacá is sociologically characterized by a marked predominance of a rural component in its population, demographic stagnation; and in the economic sphere, the persistence of areas dominated by a widespread rural economy, and with scarcity of capital and

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technology. For his part, Cruz (2007) identifies certain typical characteristics of the rural regions of Boyacá with the outermost rings of Von Thünen's model, which in practice tend to be less productive, with extended periods of inactivity of the land and few crop cycles and little production per year.

The department continues to demonstrate a predominately rural economy with subsistence crops that involve some 200,000 families according to the approximated calculations of Medina and Bermúdez (2007); a phenomenon which is recognized in the small villages and in the focal points of human activity where the countryside meets the city in the departmental centers of Tunja, Sogomoso, Duitama, and Chiquinquirá.

In a recent work, Arias (2011) applied the first stage of the methodology of industrial districts for Boyacá, with data on the movement of *commuters* reported in the 2005 census. There, the municipalities that attracted workers from other jurisdictions to their labor markets were identified. This situation indicated that those municipalities were developing as points of attraction regarding work, either for housing government offices or legal entities, or for being well defined areas of economic exploitation, for example, the emerald zone and some touristic municipalities. As well as the municipalities mentioned in the previous paragraph, others that appear as places of attraction to workers are Tuta, Cómbita, Samacá, Toca, Soracá, Sora, Chivatá, Cucaita, Garagoa, Chiquinquirá, Saboyá, San Pablo de Borbur, Maripí, Otanche, San Miguel de Sema, Muzo, Villa de Leyva, Sutamarchán, Nobsa, Tibasosa, Firavitoba, Santa Rosa, Paz del Río, Tasco and Socotá, among others.

According to the above, the role that the different municipalities have assumed reflects the prevalence of some recent tendencies in the reality of the department, in the sense of maintaining the continuation of agricultural and mining centers, and the force that services have taken, especially governmental services.

The economic structure of the department has produced some recent innovations. Firstly, the upturn in the services sector is observed, mainly in what refers to government services and the financial sector (Rodríguez, 2007). This outsourcing is a phenomenon that belongs to the contemporary economy and coincides with a decline in the involvement of industry and the agricultural sector.

Some municipalities that are conditioned by their natural environment lack agricultural or industrial activities and have dedicated themselves to the development of pottery and tourism, as is the case of the ten municipalities that make up the intersection of the desert of the La Candelaria (Medina & Bermúdez, 2007).
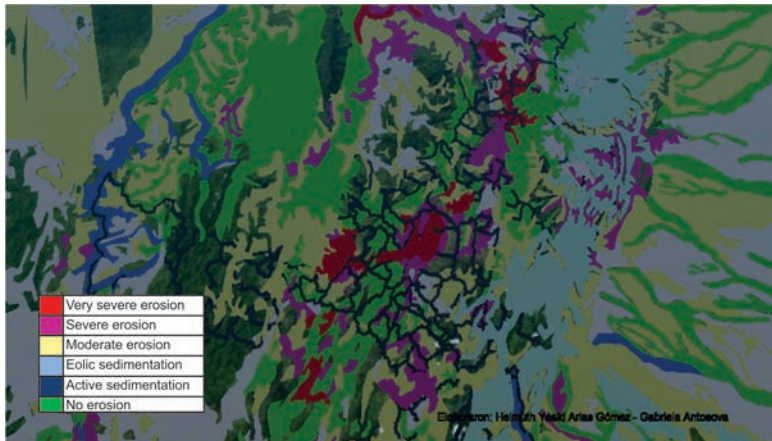
Map 2. Boyacá, degree of erosion by municipality
Source: elaborated by the authors with data from IGAC

Map 2 represents the state of erosion in the municipalities and corroborates the influence of the geographic environment on production. The impact of the erosion of the soil is notorious in municipalities such as Villa de Leiva, Ráquira, Gachantivá, Sotaquirá, Cómbita, among others. A light green coloring is observed in the center of the department in very suitable soils and that correspond with a very productive zone in terms of agricultural production. This green colored area with optimum productive conditions includes the municipalities of Samacá, Cucaita, Chíquiza, Tibaná, Turmequé, among others. These fertile conditions and the access to water determine the location of crops such as potatoes and onions, as they are intensive in water use and fertile land.

This overview of the soils also shows a cleared zone in the west of Boyacá, in the renowned Western Boyacá Province, a territory dedicated to mining, in particular the extraction of emeralds. This zone of emeralds includes the municipalities of Quípama, Maripí, Muzo, Otanche, Coper, Borbur, Coscuez, with a more diverse sociology caused by the population movements stemming from other regions.

Another mining production center is associated with the exploitation of coal in the municipalities of Samacá, Paz del Río, Socha, Tópaga, Mongua and in the surroundings of Sogomoso, the production of which is linked to steelmaking processes and the generation of thermoelectric energy (Medina & Bermúdez, 2007). In other localities, coal serves as an input for the production of brick and lime, particularly in the municipalities of Nobsa, Belencito, and the surroundings of Sogomoso.

Agriculture

In the zones of the department where the land is suitable, agriculture is the basic activity, which causes the high concentration of some specific products and defines the productive specialization of the department. In this way, the Human Development Report 2011 (UNDP 2011) identified some stability in the rates of growth in the departments that participated the most in the national agricultural production, a condition that Boyacá shares with Antioquia, Valle and Cundinamarca. The products that have propelled the sectoral growth in the region of Boyacá have been potatoes and corn. Additionally, the report concludes that Boyacá, Santander and Cesar have experienced a certain evolution in transforming from being purely agricultural regions towards regions with an upturn in livestock activity (UNDP, 2011).

With respect to the national sectoral performance, the report of the UNDP (2011) highlights the behavior of the agricultural activity during the decade of the nineties, a period in which the aforementioned type of production had pro-cyclical behavior and rates of growth close to those of the overall economy, while years later, the development of the sector was more mediocre and represented half of the growth of the economy as a whole.

Medina and Bermúdez (2007) estimate the number of head of cattle as five-hundred thousand. Livestock activity is developed in the flat area that runs parallel to the Oriental mountain-range, in a model of latifundia style, concentrated, extensive production, located in the valleys of Sotaquirá, Sogamoso, Iza, Belén and Cerinza, and in the surroundings of Ventaquemada, Chiquinquirá and Arcabuco. Livestock farming has a presence towards the west in the area of Puerto Boyacá and in the remote territories of Labranzagrande, Pisba and Paya (Medina & Bermúdez, 2007).

The potato, the signature crop of the department, is cultivated in high and cold zones in the majority of cases by smallholders in productive units that, on average, cover less than 3 hectares per farm, rotated in two productive cycles in the year. Together with Nariño y Cundinamarca, the department of Boyacá leads in the production of the tuber, projecting its market to the capital of the country, the Atlantic coast and Bucaramanga (Medina & Bermúdez, 2007).

The portion of the basin of the Suarez river that is within the department of Boyacá is characterized by the production of sugar cane in the municipalities of Moniquirá, Togüí, Santana, Chitaraque and San José de Pare. The milling activity keeps the labor market active and introduces basic elements of a proletariat that works in the elaboration of panela (unrefined whole cane sugar). In the

same region, agricultural production is mixed, simultaneously benefitting from coffee, manioc, plantain and orange crops (Medina & Bermúdez, 2007). As will be appreciated further on, in map 3 of agricultural *hot spots*, this zone appears as a space characterized by high values of agricultural production, particularly for temperate climate crops.

Onion crops are established in the department under two arrangements. There exists a productive commercial crop in the surroundings of Tota lagoon and that supplies the national capital and other urban centers. On the other hand, on small parcels of land, onions are cultivated in the municipalities of Samacá, Sáchica, Sutamarchán, Tinjacá, Villa de Leiva, and in the vicinity of the capital of the department. The crop is water intensive and this explains its specific location in the department

close to bodies of water to facilitate its extraction for the purposes of production.

Fruit-tree areas include the municipalities of Nuevo Colón, Jenesano, Tibaná, Ramiriquí, Sotaquirá, where peaches, apples, plums, pears, banana passion fruit, tamarillo, blackberry, feijoa, among others are cultivated. In the department the production of string beans, cucumbers, and tomatoes also exist which are located in the vicinity of Guayatá and Somondoco (Medina & Bermúdez, 2007).

The following analysis will be based on the spatial characteristics of agricultural production. For this, a tool called hot spot will be applied to the agricultural production data measured in tons, with which it is intended to point out well-defined areas in the map, which show particular characteristics as regards agriculture.
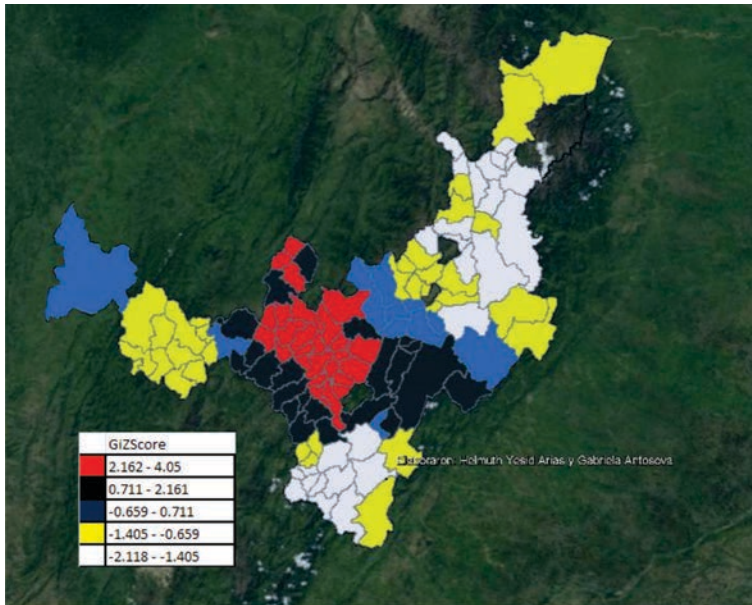
Map 3. Boyacá, *hot spot* of agricultural production.
Source: calculations made by the authors from information elof IGAC
and the Ministry for Agriculture

The representation in the map of the zones with different degrees of intensity of agricultural production indicates the influence of natural, geographical, or weather conditions which favor the exploitation of certain productive varieties in the jurisdiction some municipalities characterized by spatial contiguity.

In these terms, it is convenient to determine if an economic variable is spatially correlated so as to identify the possible formation of clusters, in which case the variable can follow a spatial pattern, disregarding the possibility of a random location (Chasco, n.d.). In what follows, the analysis demands the exact location of the municipalities where agricultural production exhibits high values and additionally the definition of whether the surrounding localities register similar production values.

In map 3 the agricultural production hotspots are represented, that is to say, groups of municipalities with similar values of the variable and depending on which, well defined zones of the department are profiled.

There, in red, appear the municipalities with high values forming a central cluster of cold lands, where the potato and pea crops and pastures play a very

important role. This quite productive zone includes Ramiriquí, Chivatá, Jenesano, Viracachá, Cucaita, Chíquiza, Sáchica, Toca, Oicatá, Sotaquirá, Sutamarchán, Santa Sofía, Gachantivá, Arcabuco, Cómbita, Motavita, and the capital of the department, Tunja. However, without spatial contiguity, further north, three municipalities with high agricultural production are profiled, such as Chitaraque, Santana, and San José de Pare.

Below this first group, agricultural production is distributed with lower values in a ring that surrounds the main group and that is marked in black. The municipalities included there, specialize in the production of onions, and some of them stand out more due to mining production or handicrafts. This group, which forms a circumference, is made up of the municipalities of Pajarito, Aquitania, Tota, Pesca, Zetaquira, Tibaná, Úmbita, Turmequé, Nuevo Colón, Ventaquemada, Samacá, Ráquira, Tinjacá, San Miguel de Sema, among others.

In an intermediate group of agricultural production, there are populations with predominantly urban and industrial activity; and other municipalities, further from the center of the department. The municipalities of Duitama, Paipa, Sogamoso, Chiquinquirá, Labranzagrande, Nobsa, Tibasosa,

Mongüi, appear in blue, and also, in the occident, Puerto Boyacá.

Finally two groups with lower agricultural production are introduced, with two typical characteristics highlighted by the economic geography for the location of production: natural advantage and the transport costs and the distance.

There are a group of municipalities colored in yellow, located in the occident of Boyacá, which stand out more for their mining production than for their agriculture. Others are affected by poor communication over land, while others are located in more central places. In this group of emerald producing municipalities are: Otanche, Quípama, San Pedro de Borbur, Muzo, and Pauna. Along with them appear Buenavista, Caldas, Tununguá and in the north, Chiscas and Cubará. More towards the center of the department are found Belén, Beteitiva, Tasco, Floresta, Gámeza, Tópaga, Santa Rosa, and Cerinza.

The group with least importance in terms of agricultural production is conditioned by the distance with respect to the market centers and clearly marks a peripheral outline in the geography of the department. There appear Miraflores, Macanal, Santa María, Chivor, Guayatá, Garagoa, and Campo Hermoso. In the north, there are Chita, Guacamayas, El Espino, Tipacoque, La Uvita, Sativanorte, Tutaza, Socha, among others.
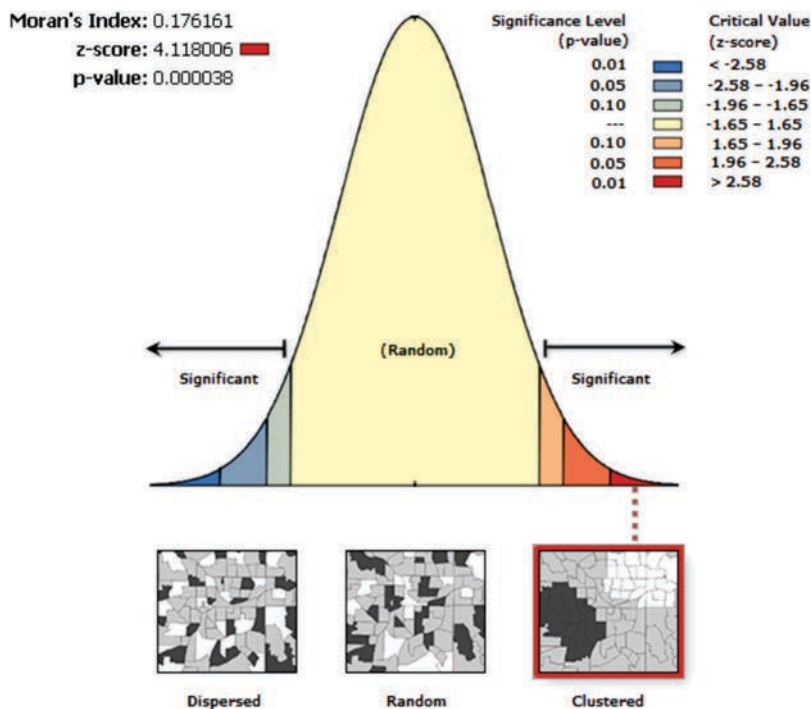
Given the z-score of 4.12, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Figure 3. Moran's Index agricultural production
Source: result of the tool applied in the ArcGis software

The spatial phenomena imply that contiguous or close units possess similar values and that as observations move further in space, said values become more dissimilar. Through the concept of spatial autocorrelation it is evaluated if neighboring jurisdictions have similar values. For such an effect, a standard indicator will be interpreted to detect social autocorrelation, known as Moran's index (Ord & Getis, 1995; Chasco, 2008).

Observing figure 3, according to Moran's index, it's z-score and the P value, the null hypothesis of random distribution is rejected, giving an indication of the definition of the spatial pattern of agricultural production. Additionally, the graphic report locates the z-score of 4.11 on the right of the Gaussian bell curve, so it is confirmed that the values follow a cluster pattern. For this reason, it can be stated that the data of agricultural production shows

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a spatial autocorrelation and that cluster agglomerations are formed, observing the distribution by municipalities of the variable in question.

In fact, considering the agricultural vocation of the department, it is very likely that the natural and weather conditions favor one type of production that is very similar between neighboring municipalities. This is related to the predominant role of this section of the country as regards the production of onions, potatoes, fruit trees among others.

Industry

The manufacturing industry in Boyacá has been characterized as being not very diverse to the standards of other sections of the country. Additionally, the existence of certain specific groups is very limited and, in general, responds to strong linkages to the natural resources, with a marked presence in agro-industry. In Table 1, there appear the most important industrial groups of the department, consulting the data of the Annual Manufacturing Survey carried out by DANE.

Table 1. Boyacá. Participation of each group in manufacturing employment of the department 2009 (%)

Food and Bev.	Textile	Clothing	Chemistry	Rubber	Non-metals and glass	Basic metallurgy	Metallic minerals	Towing vehicles	Furniture and others
13,3	0,9	2,0	1,4	0,4	13,8	48,6	5,3	3,2	1,5

Not all groupings appear and does not necessarily add up to 100.
Source: Calculations of the authors based on Annual Manufacturing Survey (EAM).

In Boyacá, the manufacturing industry has been based in specific locations giving rise to industrial strongholds and fostering agglomeration economies. In the surroundings of Duitama and Sogomoso, they have located factories producing car bodies and other transport material, which have defined the industrial profile of these municipalities. Since the year 1958, the department has welcomed the company *Acerías Paz del Río* (steelworks) in the municipality of Nobsa, which satisfies 30% of the steel market in the country and has become an emblematic establishment of the region. One should also mention the company by the name of *Siderúrgica de Boyacá* (steelworks).

The beer making plants in Tibasosa and drinks factories in the city of Duitama are of importance for the department. The non-metallic minerals group has a cement plant in the municipality of Nobsa and has a series of factories of various sizes dedicated to the elaboration of tiles and bricks throughout the department. Celebrated is the case of the old textile factory in Samacá, which has suffered many ups and downs in its history and dates from the XIX century.

Nevertheless, the most generalized industrial activity is that related to the group of food and beverages that is present in many municipalities of the department and that responds to the traditional agricultural vocation of Boyacá.

In map 4 it is observed that most of the industrial facilities are located in the industrial zone in the surroundings of Duitama, including the municipalities of Nobsa, Firavitoba, Santa Rosa and Paipa, forming a characteristic industrial cluster in the region.

The second group of municipalities, marked in black, appear as industrial zones of lesser intensity, including the municipalities of Sogomoso and Aquitania, and more towards the center of the department, it forms a ring around Tunja.

A third group, colored blue, includes the municipalities of the basin of the Suarez river, such as San Miguel de Sema, Sáchica, Sutamarchán, among others.

Other regions house a lower number of industrial establishments and are located in the extreme peripherals of the department. There appear the municipalities of the occidental zone of the department and of the provinces of Valderrama, Gutiérrez, Neira, and La Libertad.
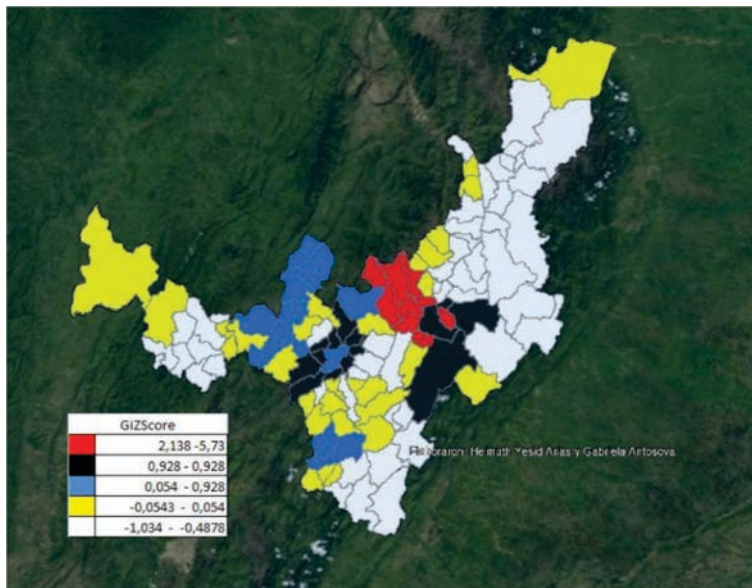

Map 4. Boyacá, hot spot of industrial units by municipality.
Source: elaborated by the authors based on information from IGAC and DANE

If speaking in spatial terms, industry in Boyacá is concentrated in the more urbanized municipalities. The localities that surround the city of Duitama have formed an industrial ring of lesser intensity, the same as other medium-sized municipalities, especially in the basin of the Suarez river. Finally, on the periphery of the department, industry is limited to a reduced number of industrial units with little influence on the local economy.
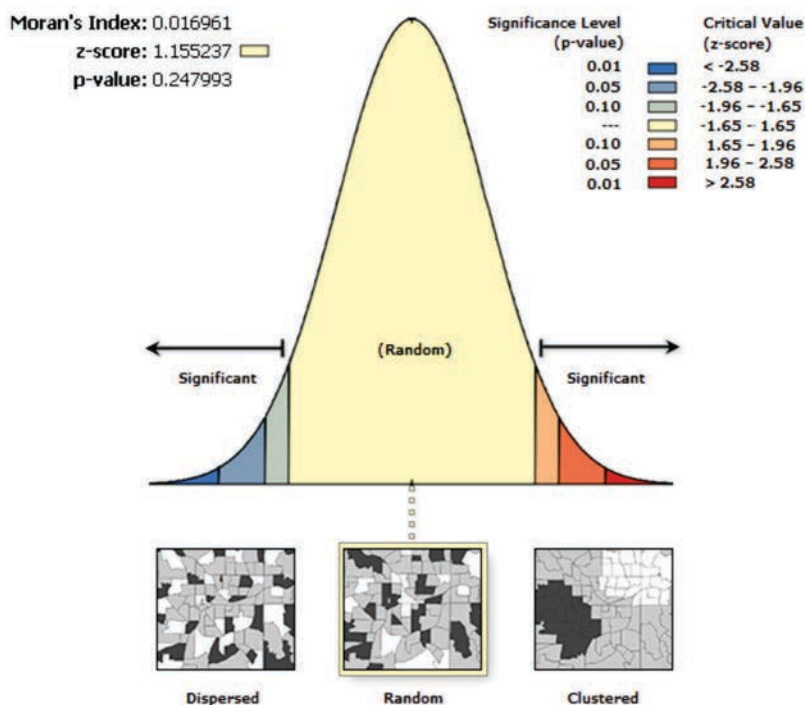
Given the z-score of 1.16, the pattern does not appear to be significantly different than random.

Figure 5. Moran's Index of the number of industrial units
Source: As a result of the application of ArcGis *software*.

According to figure 5, the analysis of spatial autocorrelation by the variable number of industrial units, is accompanied by a probability value that does not allow the null hypothesis of random distribution of the industrial units in the space to be rejected, and equally the Moran index (I) is sufficiently low to approximate itself to the expected value in case that the null hypothesis is not rejected.

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This leads to the conclusion that the variable in question is randomly distributed in the space and that neighboring municipalities do have a strong relationship between them, as regards the number of industrial facilities. This could be understood better if the predominance of agricultural activities was taken into account, but not the industrial ones, in most municipalities. Equally, this reinforces the clustered nature of the manufacturing activities that are commonly located in the surroundings of mineral deposits, as is the case of the steel industry
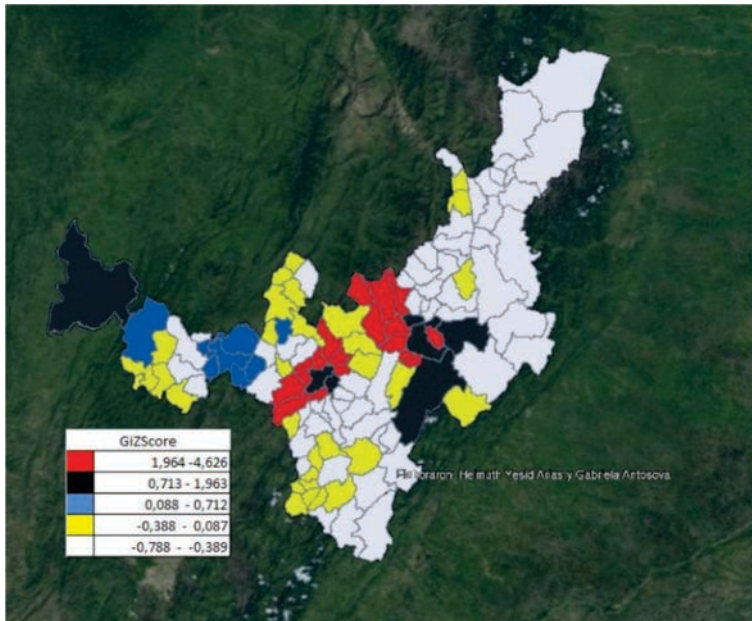
The services sector

In the last few years, the economy of Boyacá has experienced gradual outsourcing in light of the expansion of governmental services, as well as the services market to the detriment of the traditional branches of activity. Rodríguez (2007) insists on the loss of involvement of the primary sector in the department, in light of the growing prominence of the tertiary sector, which, by 2004 already represented 53% the of Boyacá´s GDP. With reference to the national data, the report of the UNDP (2011) also recognizes a step backwards in the participation of the agricultural sector in the total production, as is the generalized phenomenon on an international level, with the aggravating factor that in the case of Colombia a steep decline in the growth of sectoral productivity and competitiveness has been registered.

With respect to tertiary activities, a cartographic representation was made of the placement of the market services sector, which includes businesses, professionals, hotel and restaurant services, among others, according to the information that is captured by DANE and that can be consulted in the georeferenced information of the IGAC. In map 5, *hotspot,* a very logical tendency of the location of services in the department is described, conditioned by the markets of the population with more urban characteristics, namely: Tunja and Duitama, in rings that appear marked in red.

The phenomenon is more evident as regards the city of Duitama, because it has detected important tertiary activity in the municipalities of Santa Rosa, Iza, Belén, Floresta, Firavitoba, and Paipa. This may point out that many suppliers of the service sector gravitate around municipalities which have the characteristics of a city, operating there without necessarily being located in the most urban areas. This may indicate the movements of commuters who offer their services to clients located in other jurisdictions (Arias, 2011).

Sogamoso appears in a second group marked in black along with other municipalities where service activity was detected, such as Aquitania, Mongua and Corrales. Also included in this group are: Villa de Leyva, with activities focused on tourism, Soatá, Miraflores, Garagoa, Muzo, Santa Sofía, among others.

**Map 5**. Boyacá, *hot spot* of the service units by municipality
Source: elaborated by the authors – information extracted from IGAC and DANE

Nevertheless, from the predominance of the yellow and white colors, there exists very little services sector activity in the majority of the municipalities of the department, comprised of the provinces of: Gutiérrez, Valderrama, Neira, some municipalities of the center of the department and in the emerald zone.

Of the special distribution of the services sector it can be concluded that the majority of the activity is concentrated in the main urban areas. However, they have constituted rings of lesser intensity in the municipalities adjacent to the important cities of the department, which makes us think of an "irradiation effect" from the municipalities with urban activity towards their surroundings. It is easy to imagine this type of influence towards surrounding areas: transport, professionals, and the activities of the commuters create economic bonds between localities.

Another aspect to underline is the poor services activity in large regions of the department, particularly those furthest from the center, a phenomenon explained by the lack of human capital, the scarce communication, and the strong specialization in stagnant activities that operate without linkages towards other sectors.

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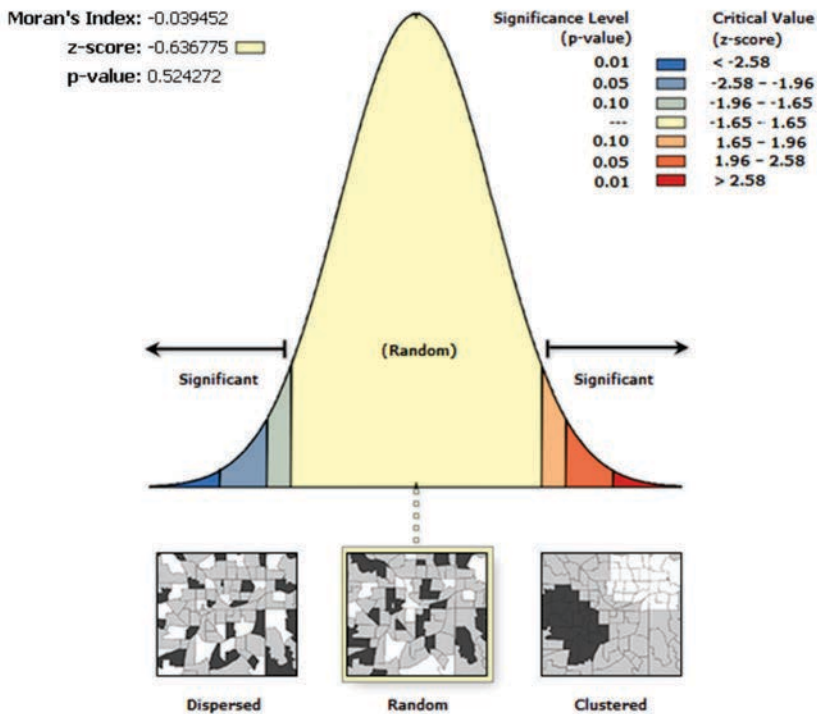
Given the z-score of -0.64, the pattern does not appear to be significantly different than random.

Figure 6. Moran's index of the number of services units
Source: resulting from the tool applied in the ArcGis *software*.

According to Figure 6, in the case of the variable number of units of services, the Moran index does not show signs of rejecting the null hypothesis of random distribution from the variable in the space (Chasco, n.d.; Chasco, 2008). The concentration of service establishments in the most urban areas and their poor presence in peripheral populations form a panorama of reduced spatial autocorrelation of the variable.

CONCLUSIONS

The spatial distribution of the economic activity in Boyacá reveals an interesting cartography of specialization, which coincides with a first sight perception. In the most important cities of the department, industrial and services activities predominate, which are branches of activity that complement one another adequately, reinforced by the size of the urban markets. There is

a geographically central region, highly productive in terms of agricultural goods, dominated by cold land crops, supported in the surroundings of Moniquira by a good production of temperate climate crops. The occident is characterized by its emphasis on mining production that takes advantage of its comparative advantage and overshadows agricultural production. Finally, the peripheries of the department have a predominance of agricultural activities but their performance in terms of productivity is poor.

This is corroborated in the exercise hot spot of agricultural production that very clearly defined some exploitation zones. One very productive region as regards the cultivation of potatoes and other cold land products was identified in the center province and in some municipalities of the province of Márquez. Further north, another highly productive zone is the basin of the Suarez river. The second ring with less intensity of agricultural production was formed around the primary zone covering some municipalities of the provinces of Sugamuxi and Márquez. The most peripheral territories of the department and predominantly mining zone revealed less intensity in agricultural production.

The results of the contrasts of the spatial autocorrelation reveal different characteristics in economic activity. In the case of agricultural production, high degrees of spatial correlation are detected, which can be explained by the natural advantage that contiguous municipalities have in the exploitation of products of an agricultural origin. This indicates that the production values between neighboring populations reflect similarities and allow the visualization of cluster groups of municipalities that are spatially agglomerated. This situation is explicable because the contiguous municipalities can share geographic conditions and common climates that convert them into good places for the cultivation of certain products and with similar productivity characteristics.

On the contrary, in the case of the number of industrial units per municipality, there is a scarce spatial correlation because manufacturing production has clustering characteristics, without effects of spatial dragging on the vicinities and because it depends on the access to natural resources, which are distributed randomly in the territory. Thus, it can be affirmed that this variable responds to a random layout and does not follow a similar pattern with respect to its surroundings.

Likewise, the number of services units does not show a clear spatial autocorrelation among neighboring municipalities, because it is observed that the majority of this activity is limited to bigger cities, although one exception can be made when observing the ring that stands out in the surroundings of Duitama.

The analysis of this economic specialization of the municipalities of the department finds inspiration in different theoretical

approaches. The principal of comparative advantage can explain a spontaneous response of the economy to the climatic restrictions, both natural and of soil, as can be seen in the erosion map of the department. According to Von Thünen's model, the criteria of efficiency lead to a rational use of the soil, which localizes the crops that are relatively more productive and land conserving in areas close to the urban center, while in further away places activities that are intensive in the resource of arable land can be developed.

In summary, the economic production of the department has been spatially set up around central locations that have a marked predominance in agricultural activity and an outstanding presence of units of services. On the other hand, there are peripheral regions that are isolated, with a poor infrastructure and with a predominance of smallholding productive structures, which reduces the productivity of the municipal economy.

The economic backwardness and geographic isolation generate a series of dynamics that are self-sustaining. In effect, it is observed that in more central locations and in the surrounding rings, there is a strong presence of industrial, agricultural and services activities. At the same time, the most peripheral municipalities lack productive variety and are characterized by a reduced presence of the services sector and industrial activities. That is to say, if a dynamic economic sector does not exist, linkages with other productive activities that diversify the local economy do not develop. Thus, the high costs of transport caused by isolation result in loss of productivity and impede adequate development of inter-branch linkages.

It is interesting to realize that Duitama has set up an area of influence that is clearly appreciable if compared to the spatial influence of other cities of the department, particularly by the presence of industrial and services units in the municipalities that surround it, which corroborates a relative similarity in the magnitudes and activities developed in this city with respect to it adjacent areas.

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APPENDIX 1
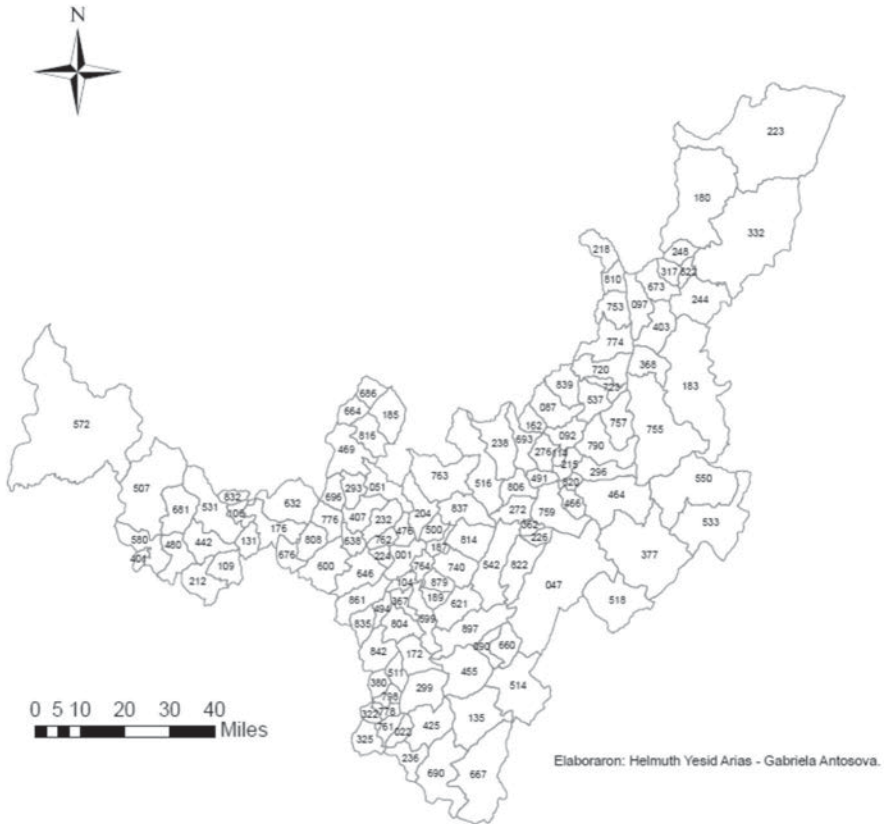
Map 6. Boyacá: polítical-administrative division
Source: IGAC, DANE

Department Code	Municipality Code	Name	Department Code	Municipality Code	Name
15	1	Tunja	15	238	Duitama
15	22	Almeida	15	244	El Cocuy
15	47	Aquitania	15	248	El Espino
15	51	Arcabuco	15	272	Firavitoba
15	87	Belén	15	276	Floresta
15	90	Berbeo	15	293	Gachantivá
15	92	Beteitiva	15	296	Gámeza
15	97	Boavita	15	299	Garagoa
15	104	Boyacá	15	317	Guacamayas
15	106	Briceño	15	322	Guateque
15	109	Buenavista	15	325	Guayatá
15	114	Busbanzá	15	332	Guicán
15	131	Caldas	15	362	Iza
15	135	Campohermoso	15	367	Jenesano
15	162	Cerinza	15	368	Jericó
15	172	Chinavita	15	377	Labranzagrande
15	176	Chiquinquirá	15	380	La Capilla
15	180	Chiscas	15	401	La Victoria
15	183	Chita	15	403	La Uvita
15	185	Chitaraque	15	407	Villa de Leyva
15	187	Chivata	15	425	Macanal
15	189	Cienega	15	442	Maripi
15	204	Cómbita	15	455	Miraflores
15	212	Coper	15	464	Mongua
15	215	Corrales	15	466	Mongui
15	218	Covarachía	15	469	Moniquirá
15	223	Cubará	15	476	Motavita
15	224	Cucaita	15	480	Muzo
15	226	Cuitiva	15	491	Nobsa
15	232	Chíquiza	15	494	Nuevo Colon
15	236	Chivor	15	500	Oicatá
15	507	Otanche	15	740	Siachoque
15	511	Pachavita	15	753	Soata
15	514	Páez	15	755	Socotá
15	516	Paipa	15	757	Socha
15	518	Pajarito	15	759	Sogamoso
15	522	Panqueba	15	761	Somondoco
15	531	Pauna	15	762	Sora
15	533	Paya	15	763	Sotaquirá
15	537	Paz de Rio	15	764	Soracá

Department Code	Municipality Code	Name	Department Code	Municipality Code	Name
15	542	Pesca	15	774	Susacon
15	550	Pisva	15	776	Sutamarchán
15	572	Puerto Boyacá	15	778	Sutatenza
15	580	Quípama	15	790	Tasco
15	599	Ramiriquí	15	798	Tenza
15	600	Ráquira	15	804	Tibaná
15	621	Rondon	15	806	Tibasosa
15	632	Saboya	15	808	Tinjacá
15	638	Sachica	15	810	Tipacoque
15	646	Samacá	15	814	Toca
15	660	San Eduardo	15	816	Togüi
15	664	San Jose de Pare	15	820	Tópaga
15	667	San Luis de Gaceno	15	822	Tota
15	673	San Mateo	15	832	Tununguá
15	676	San Miguel de Sema	15	835	Turmequé
15	681	San Pablo de Borbur	15	837	Tuta
15	686	Santana	15	839	Tutasa
15	690	Santa María	15	842	Úmbita
15	693	Santa Rosa de Viterbo	15	861	Ventaquemada
15	696	Santa Sofia	15	879	Viracachá
15	720	Sativanorte	15	897	Zetaquira
15	723	Sativasur			

Source: DANE - DIVIPOLA