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Geography and Economic Development in Colombia: A Municipal Approach

by

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Geography and Economic Development in Colombia: A Municipal Approach

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Abstract

The object of this paper is to determine the relationship between geographical variables and income per capita, income per capita growth, population density and population growth in Colombian municipalities. In order to carry out econometric estimations at the municipal level we constructed a set of geographical variables based on soil, climate and road maps. We obtained some other geographical variables from the Colombian Institute of Geography (IGAC) homogeneous zone statistics.

We found that geography affects both the level of municipal income per capita and its growth, being responsible for between 36% and 47% of the variance in municipal income per capita, and between 35% and 40% of the variance in municipal income per capita growth. It was established that, among the geographic variables, distance to domestic markets and soil type exercise the greatest influence on income per capita and its growth. Furthermore, geographical variables seem to be more significant for poor municipalities than rich ones. In poor municipalities, geography is responsible for between 25% and 32% of income per capita variance, and between 24% and 27% of income per capita growth variance. In contrast, in rich municipalities, geography is less important, being responsible for between 18% and 25% of income per capita variance and between 16% and 17% of income per capita growth variance. Thus, geography affects income and income growth via the productivity of the land, the availability of natural resources (such as water and rivers), the presence of tropical diseases, and agglomeration.

Although geography influences the fate of a region, that is not the end of the story. Human factors, both public policy and private intervention, also play an important role. Education, infrastructure and more efficient public institutions can boost regional economic growth, and can help poor regions to overcome the poverty trap of low income and low economic growth.

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1. Introduction

Recent economic debate has reopened the old question of the wealth and poverty of nations. The answer to this question involves all aspects of human life: education, religion, institutions, technology, the diffusion of knowledge and, more recently, geography. The latter, it is said, has contributed to shaping the destiny of nations and their people (although not inescapably). For instance, Diamond (1999) states "History followed different courses for different peoples because of differences among people's environments."

The idea that geographical and environmental factors have influenced social development is not new. Landes (1999) argues that European economic advantages are the result, in part, of the favorable rainfall patterns and mild seasonal differences that allowed Europeans to raise bigger and better animals than those of other lands. Larger animals brought the agricultural, transport and military advantages that reinforced Western European economic leadership for several centuries. Geography has clearly had some effect on the shaping of the economic history of countries and regions. However, the amount by which geographical factors affect current income per capita and economic development variations is a question that is beginning to be answered. In this paper we will attempt to establish an answer to this question in terms of Colombian inter-regional income per capita variations.

The purpose of this paper is to examine the impact of geographical and other social and economic variables (human capital, infrastructure and living standards) on income per capita, income per capita growth, density of population and population growth at the municipal level. This reasons for this approach include the following:

a) The geographical differences within Colombian departments are many, making departmental averages of certain variables meaningless. For example, the temperature of Cundinamarca (a department located in the center of the country, and one of its richest regions) varies from very hot in some places to freezing cold in others.
b) The great differences in the provision of social services and infrastructure across the departments.

c) The localization of particular types of business (manufacturing, mining, coffee, etc.), which may have important effects on income level variations among municipalities of the same department or region.

Furthermore, given the considerable number of Colombian municipalities, it was possible to include a large set of explanatory variables in the econometric exercises, the variables being taken from economic literature related to income and growth. Generally, many of these variables are absent from departmentally based Colombian regional growth studies due to both small sample size (22 to 30 observations) and free access problems.

This paper attempts to explain the root cause of the differences, both for the level and rate of growth of income per capita, and for the population density of Colombian municipalities between 1973 and 1995. The paper is divided into nine sections. The first is the introduction. Section Two describes some of Colombia's geographical characteristics. Section Three presents the data sources and explains the construction process of the geographical variables. Section Four analyzes the econometric studies of income and population growth rates. Section Five examines the effects of geography on municipal income per capita; Section Six its effect on municipal income per capita growth; and Section Seven its importance in terms of population density and growth. Section Eight determines the effect of geography on inter-regional income differences and municipal income inequalities. Section Nine concludes.

2. Colombian Geographical Features and Statistics

Geography and Fragmented Markets

Colombia is a country of great geographical differences, profound variations in economic and social development among regions (as well as within regions), and regional markets dependent on the so-called intermediate cities. Colombia's economic history is marked by the existence of geographical barriers, some of them not overcome until the end of the twentieth century. These barriers made inter-regional trade very difficult, brought about the non-integration of some regions with world markets and gave origin to an extremely fragmented domestic market (Bushnell, 1996). Furthermore, the roads and railroads built at the end of the nineteenth century were designed to connect towns and villages within the

same region; they did not interconnect regions due to high construction costs in the Colombian *cordilleras*. This reinforced the regional economic fragmentation of the country.

At the beginning of the nineteenth century the journey from the sea and river port of Barranquilla, on the Caribbean, to the inland river port of Honda was via the Magdalena River, and lasted around eighty days. To reach Bogotá (2,600m above sea level) took about eight more days by mule. It was almost impossible to make the trip from the Caribbean coast to Bogotá by land because of the mountains, the lack of roads and the high incidence of tropical diseases. In 1930, eighty years after steamboats were introduced, the trip from Barranquilla to Bogotá was reduced to twelve days.[1] The lack of roads in Colombia is still a problem–the country has one of the lowest road densities in Latin America.[2]

Since colonization, the population of Colombia has been concentrated in the west and north of the country where, in the late nineteenth century, coffee production flourished and early manufacturing industries were born. From the nineteenth century until the 1970s, most of the population lived in rural areas near small towns and villages whose primary source of income was agriculture and livestock. In the second half of the nineteenth century coffee production established itself, in the mountainous center of the country, as Colombia's main agricultural and export product. In addition, an urban population grew in the four principal cities.

Among these cities, Barranquilla had its golden age as Colombia's main sea and river port during the late nineteenth century and the first half of the twentieth century. It became the largest city on the Colombian Caribbean, with intense commercial activity caused, in part, by foreign immigration (Posada, 1998). Following the construction of the seaport of Buenaventura on the Pacific coast, Barranquilla lost a great deal of its economic importance. The new port was located near Cali, which became the largest and richest city in the west of the country. Medellín became the most important city in central Colombia, and it is at the center of the so-called coffee axis. During the nineteenth century Medellín was the center of the gold trade until, at the beginning of the twentieth century, it became a manufacturing center. Bogotá, located in the eastern cordillera, has historically been

[1] A history of navigation on the Magdalena River is presented in Poveda (1998).

[2] The impact of roads (or the lack of them) on per capita income, income growth and variation, as well as on GDP per area and population distribution amongst the Colombian municipalities will also be analyzed in this paper.

Colombia's largest city, although not necessarily the most dynamic. Some authors have stated that, until the 1980s, Colombian urban development was a four-headed beast, (Cuervo and Gonzalez, 1998; Gouesset, 1998).

Spatial Income Concentration towards Bogotá

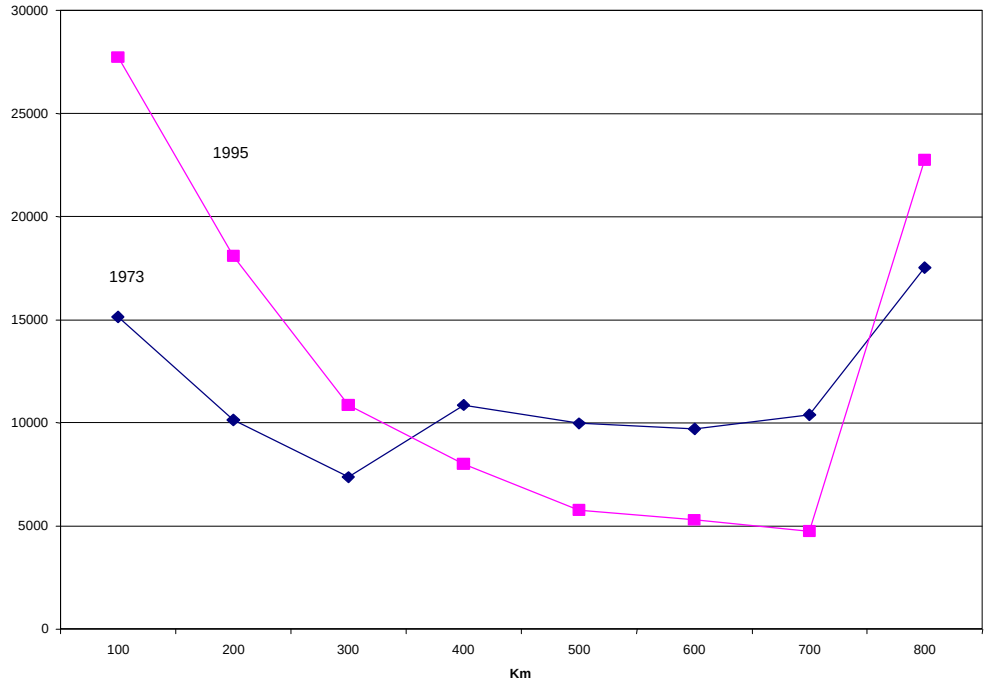
At the beginning of the 1980s, Bogotá's economic growth and development left the rest of the principal Colombian cities behind. As Colombian economic activity moved towards Bogotá in the 1980s, major changes in the spatial variation of average municipal per capita income resulted.

These changes represented a major shift in a relatively short period. In the early 1970s being farther away from Bogotá did not necessarily mean lower income In fact, as shown in Graphs 1 and 2, although in the early 1970s income was already higher around Bogota, it was not lower in the periphery. Income per capita even went up slightly as municipalities moved toward the periphery. Thus, in 1973 per capita income of the municipalities located 200 kilometers from Bogota was two-thirds that of Bogotá, while per capita income of those located 300 kilometers away was half. However, per capita income of municipalities located between 400 and 700 kilometers increased back to two-thirds that of the capital.

But this situation changed dramatically in a few decades. As depicted in Graphs 1 and 2, in 1995 per capita income of municipalities decreased according to their distance from Bogota. Only a few municipalities far away from Bogotá (more than 700 kilometers) rich in oil and other minerals had per capita income as high as that city's. This change is explained by economies of scale, transportation costs and the integration of Colombia's widely separated regions.

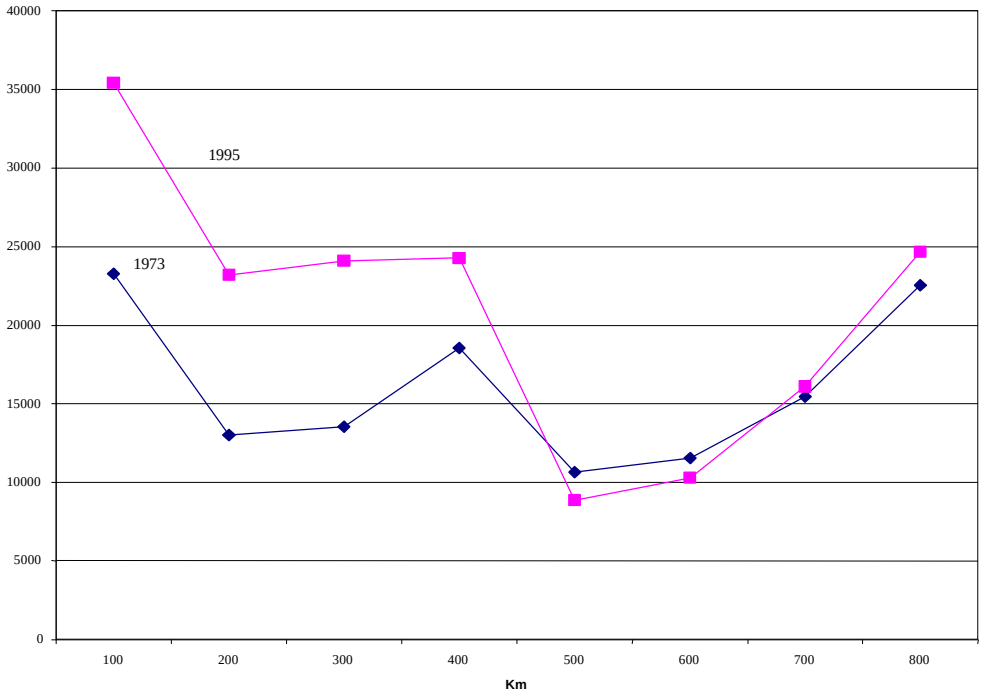
Graph 1

Per Cápita Income and Distance form Bogotá, 1973-1995
(Simple average - Col$ 1975)



Graph 2

Per Cápita Income and Distance from Bogotá, 1973-1995
(Weighted average - Col$ 1975)



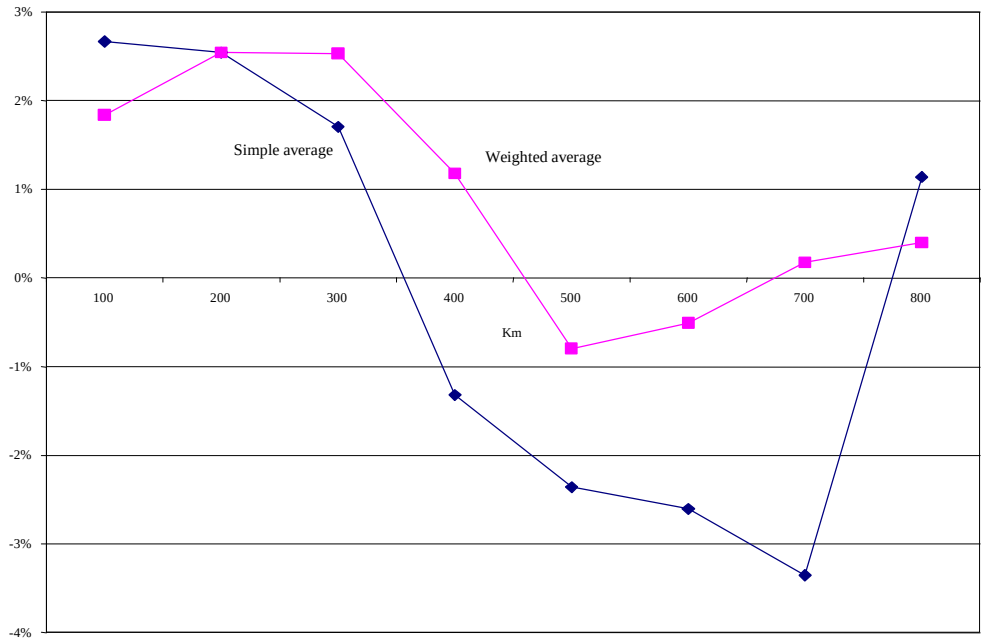
In the 1950s, a consensus emerged in Colombia on the urgency of massive investments in transportation infrastructure[3] that would integrate the dispersed Colombian national market and allow many industries to take advantage of scale and scope economies. In the 1950s and 1960s, as many roads were built and others completed, firms were increasingly able to compete nationally, and many firms located near Bogotá in order to take advantage of the large local markets. Economic activity thus began to move toward the country's center, in the process creating many casualties among the municipalities located in the periphery. Thus, economic growth of the municipalities closer to Bogotá was much more dynamic as shown in Graph 3.[4] Although, there are some differences between the simple average of per capita income growth and weighted (by population) average of per capita income growth the pattern is similar. The difference between the two indicators suggests that economic growth was on average much lower (in fact negative) in the less populated municipalities farther from Bogotá. As we will show in the next section, the concentration of income towards Bogotá hit badly some municipalities, in particular those located 400 kilometers from Bogotá and beyond, reducing their average living standards. The municipalities hardest-hit by the spatial income concentration towards Bogotá in the last decades have belonged to the Caribbean region.

[3] According to Currie (1950), the "lack of a unified transportation system in Colombia is one of the main factors contributing to the high costs of manufacturing goods." Currie additionally calls the limitations imposed by transportation on industrial markets "a primary characteristic of Colombian industry."

[4] Figure 2 shows the variation of per capita income growth as we move from municipalities close to Bogotá to municipalities located in the periphery of the country. The leftmost dot shows the average growth of municipal per capita income for all municipalities located within 100 kilometers of Bogotá (including Bogotá itself). The next dots shows the corresponding average for all municipalities located within 200 kilometers of Bogotá but outside the first circle, and so on in a sequence of concentric circles.

Graph 3

Per Capita Income Growth and Distance from Bogotá, 1973-1995



The spatial income concentration trend towards Bogotá continued in the 1990s, in spite of the opening up and liberalization of trade processes that were supposed to prompt the economic development of ports and border regions (Fernandez, 1999).

As stated above, economic development in Colombia has often been described as a four-headed beast. Clearly, Colombia's geography gave birth to a divided territory; rural-urban population flows were fragmented, and directed towards the core cities of the regional markets, especially Barranquilla, Cali, Medellín and Bogotá. Poor road networks also contributed to curbing early population concentrations and fragmenting economic activity and markets (Gouesset, 1998).

Colombian soils and climates are highly heterogeneous. For instance, in the warm thermal floor there are eighteen different homogenous zones; in the medium thermal floor, four; and in the cold thermal floor, seven. In each of these zones, the characteristics of the land, humidity, temperature and soil quality all interact in a variety of ways.

How and by which channels do geographical factors determine the course of development of different regions in the same country? The links between geography and economic development are related to the productivity of the land, technology, the incidence of tropical diseases, access to markets, urbanization and geographical fragmentation (Lora,

1999). The influence of these geographical features on income and income growth, GDP per land area and population distribution and growth in Colombian municipalities will be examined.

Regional Economic Differences in Colombia

There have been important differences in the economic and social development of the Colombian regions. Some of these differences have grown, whereas others have decreased considerably.[5] The departmental income per capita variation coefficient was 0.22 in 1975, increasing to 0.28 in 1988 and 0.38 in 1995. This dramatic increase may imply that departmental income per capita differences have increased, which has led many authors to conclude that the Colombian regions have not experienced income per capita convergence (Meisel *et al*., 1999. Birchenall *et al*., 1998. Rocha *et al.*, 1998).[6] For example, in 1960 income per capita in Bogotá was 1.8 times that of the Caribbean region, and the difference had increased to 2.6 by 1995.

Departmental population growth has also varied greatly. Bogotá is the region whose population has grown the most, with population density increasing from 824 to 3,597 people per square kilometer between 1960 and 1995. In the Pacific region, population density increased by 2.4 times, and in Antioquia, 2.3 times. The population density of the Central and Caribbean regions has experienced the lowest growth rate (multiplying by 1.86 and 1.42, respectively).

Within these regions, however, there has been no attempt to explain municipal income levels and their growth (income, taxes or other). This study utilizes a large set of municipal variables, which may explain the differences in income per capita and income growth. Some were obtained from public sector statistics and others constructed by the authors from maps (soil, erosion, road, etc) and other primary sources.

Municipal income per capita varies considerably in Colombia. In 1995, the non-weighted average municipal income per capita was COP$12,731 (around US$1,500), average income per capita was COP$7,139 and the standard deviation COP$18,929 (1975

[5] Differences in access to social and public services have decreased considerably (Sanchez *et al.* , 1999)
[6] Cardenas *et al.* (1992) were the first to conclude that the Colombian regions have experienced convergence. However, this hypothesis was soon challenged by Meisel (1992), Meisel *et al.* (1999), Birchenall *et al.* (1997), Rocha y Vivas (1998), Soto (1998) and Montenegro y Suárez (1998).

prices), figures that show a high level of income disparity between municipalities. Municipal income per capita growth has also experienced disparities; a non-weighted annual rate of close to 1% is obtained using taxes as the proxy, or of around 0% using per capita GDP as the proxy. Income growth was, however, positive for most of the municipalities, fluctuating between -5% and 5%.

Regional income per capita differences are also important. As can be seen in Table 1, the 1973 average income per capita of the Caribbean and the Andean regions was similar (around COP$16,000 in 1975 pesos), and that of the Pacific region around 20% lower. The 1995 income per capita of the Caribbean region was similar to its 1973 level. The Pacific region's income per capita, however, grew faster than the national average (2.3% versus 1.92%) and came closer to the Andean[7] region's income level. Thus, according to these results, there has been a convergence between the Pacific and Andean regions, while the Caribbean region has lagged behind. Income disparities within the regions are also important (Table 1). The income per capita variation coefficient in 1995 was 0.62 in the Andean region, 0.75 in the Pacific region and 0.76 in the Caribbean region.

[7] Excluding Bogotá.

Table 1

Weighted Descriptive Income Statistics

Total Country	Mean	Standard Deviation
Per Capita Income Growth, 1973-1995	0.019	0.025
Per Capita Tax Growth, 1973-1995	0.045	0.030
Per Capita Income 1973	16,043.2	9,873.5
Per Capita Income 1995	24,397.3	15,323.8
Per Capita Tax 1973	138.6	13.7
Per Capita Tax 1995	367.3	317.5

Andean Region	Mean	Standard Deviation
Per Capita Income Growth, 1973-1995	0.018	0.107
Per Capita Tax Growth, 1973-1995	0.029	0.373
Per Capita Income 1973	16,402.6	10,701.5
Per Capita Income 1995	24,321.7	15,965.2
Per Capita Tax 1973	141.9	117.2
Per Capita Tax 1995	264.1	191.9

Caribbean Region	Mean	Standard Deviation
Per Capita Income Growth, 1973-1995	-0.001	0.030
Per Capita Tax Growth, 1973-1995	0.039	0.035
Per Capita Income 1973	16,272.5	12,561.6
Per Capita Income 1995	16,081.5	12,246.0
Per Capita Tax 1973	59.1	32.6
Per Capita Tax 1995	138.3	113.2

Pacific Region	Mean	Standard Deviation
Per Capita Income Growth, 1973-1995	0.024	0.033
Per Capita Tax Growth, 1973-1995	0.042	0.081
Per Capita Income 1973	13,241.1	9,650.7
Per Capita Income 1995	22,258.9	16,142.2
Per Capita Tax 1973	122.9	121.7
Per Capita Tax 1995	305.3	262.0

Orinoco Region	Mean	Standard Deviation
Per Capita Income Growth, 1973-1995	0.023	0.032
Per Capita Tax Growth, 1973-1995	0.054	0.032
Per Capita Income 1973	23,732.7	9,843.0
Per Capita Income 1995	38,974.0	26,477.6
Per Capita Tax 1973	65.3	37.0
Per Capita Tax 1995	208.0	137.4

Table 1, *continued*		
Amazonia Region	**Mean**	**Standard Deviation**
Per Capita Income Growth, 1973-1995	-0.008	0.038
Per Capita Tax Growth, 1973-1995	0.035	0.044
Per Capita Income 1973	19,258.9	10,619.9
Per Capita Income 1995	16,199.9	14397.0
Per Capita Tax 1973	23.5	23.5
Per Capita Tax 1995	50.0	32.8

Bogotá, D.C.	**Mean**
Per Capita Income Growth, 1973-1995	0.011
Per Capita Tax Growth, 1973-1995	0.061
Per Capita Income 1973	27,561.6
Per Capita Income 1995	35,417.2
Per Capita Tax 1973	286.1
Per Capita Tax 1995	1,058.2

The Orinoquia and Amazonia regions have experienced very different growth patterns. Although income in Orinoquia grew above the national average, in part due to oil exploitation, income in Amazonia stagnated. These regions make up more than half of Colombia's land area, but only contain a small (although growing) part of its population.

3. Data Sources and the Construction of Variables

The results of the research project presented in this paper are the result of a set of municipal variables including income, economic activity, social conditions, education, health, infrastructure, crime, and geography. This set of variables is related to local (municipal) income levels, growth rates, GDP per area and population and population growth. The way in which the variables were constructed is crucial to understanding and interpreting the results.

Income Variables

The income variables used in this paper are municipal property, industry and commerce tax revenues. We used these variables as they reflect both wealth and the level of economic activity in a municipality. Based on municipal tax revenues we calculated income per capita by working out each municipality's share of the total municipal tax revenue of the

respective department and then multiplying that share by the department's GDP. We calculated the figures for 1973 and 1995.

Geographical Variables

Geographical variables were calculated based on soil, river and road maps and tables of municipal homogeneous zones. For example, the process of obtaining the soil suitability index, used in the econometric exercises, was as follows:

a) The digitalization of soil maps.
b) The calculation of the total area of each type of soil in every Colombian municipality. We used classifications of soil by fertility, agro-ecological zone and degree of soil erosion, found in Colombian Institute of Geography[8] soil maps.
c) An estimation of a soil index for each municipality for each type of soil classification. In order to calculate the index we ranked soil according to its suitability, and then calculated a weighed average of such a ranking.[9] The weighting used was the share[10] of each type of soil in each municipality.

We also calculated the density of rivers in the municipality by type (primary, secondary and tertiary) and the density of roads by type (in 1970 the types were primary, secondary, under construction and railroads). We also used homogeneous zone characteristics, obtained from municipal maps, to construct soil suitability, water availability, land slope and road quality indexes. It should be noted, however, that the number of homogeneous zones in each municipality depends on the physical differences within the municipality (IGAC, 1998). We calculated indexes for more than 600 municipalities, based on more than 20,000 homogeneous zones.

We also calculated the distance between each municipality and the main Colombian markets (the four principal cities of Bogotá, Medellín, Cali and Barranquilla) and most important seaports (Barranquilla, on the Caribbean coast, and Buenaventura, on the Pacific coast). The calculations were made according to available cartographic information.

[8] The Instituto Geográfico Agustín Codazzi.
[9] Soil types and their rankings are presented in the appendices.

Population and Human Capital Variables

Demographic and human capital variables were calculated from 1973 Census data. The demographic variables calculated were municipal population, migration, and the percentage of the population between 0 and 6, 7 and 17, 18 and 65 and over 65 years old. The human capital variables calculated were primary and secondary school enrollment, college graduates as a percentage of the labor force, average years of schooling of the labor force and its variance, and indexes of poverty and absolute poverty (both based on unsatisfied basic needs). As a measure of income distribution, we calculated a personal income logarithm variation for each municipality.

We also calculated a tropical disease index, defined as the percentage of total tropical disease deaths. The National Statistics Department has recorded cause of death and mortality rates for each municipality since 1979.

Segregation of New Municipalities

One of the main difficulties in the elaboration of this paper was deciding how to classify new municipalities, more than 120 of which were created between 1973 and 1995. The solution was to maintain the municipal political division of 1973: new municipalities were considered as part of their original municipality.

4. Municipal Population and Per Capita Income Growth

Population Growth

Between 1973 and 1995 the Colombian population grew by an average annual rate of 2.4% (from 1973 to 1985 the average rate was 3.4%, falling to 2.1% between 1985 and 1995). The population growth rate differs between towns and regions. The non-weighted rate in the Andean Region is 1.24%, in the Pacific 3.4%, in the Caribbean 3.8% and in the Orinoquia region 4.7%. Between 1973 and 1995 population growth rates show persistence[11] when the whole national sample is considered. At the regional level, however, only the Andean region displayed a degree of population growth rate persistence. Thus,

[10] The share was calculated by running Auto Cad software on the digitalized maps and the grid of Colombian municipalities.

[11] The regions and municipalities with the highest population growth between 1973 and 1985 also have the highest population growth between 1985 and 1995.

when considering the 1985-1995 growth rate in terms of the 1973-1985 yield for the whole country, a coefficient of 0.13 with an R-square of 0.019 is obtained. The same process for the Andean region yields a coefficient of 0.13, for the Caribbean 0.39 and for the Pacific 0.025, although the coefficients of the last two regions are not significant (see Table 2).

Table 2
Municipal Growth Process

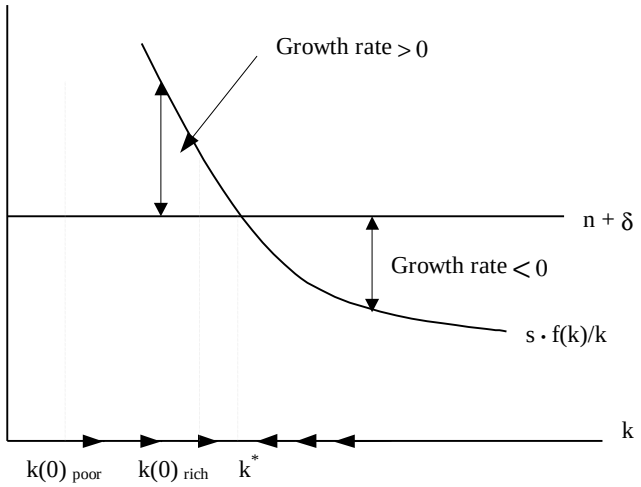
Persistence of Population Growth					
Dependent variable: Population Growth 1985-95	**Total Country**	**Andean Region**	**Caribbean Region**	**Pacific Region**	**Ori**
Constant	0.0185 (12.653)***	0.0136 (13.862)***	0.0159 -1.5411	0.0331 (13.983)***	(
Population Growth 1973-85	0.1368 (4.239)***	0.1327 (4.5913)***	0.3966 (1.2516)	0.0253 (0.7125)***	
No.of Observations	914	575	140	146	
R2	0.0193	0.0354	0.0112	0.035	
Density of Population Convergence 1973-95					
Dependent variable: Population Growth 1973-95	**Total Country**	**Andean Region**	**Caribbean Region**	**Pacific Region**	**Ori**
Constant	0.0414 (9.476)***	0.0005 (0.1342)	0.0315 (2.7226)***	0.0686 (7.365)***	(
Population Density 1973	-0.0072 (-6.4437)***	0.0017 (1.758)*	-0.0032 (-1.177)	-0.011 (-5.062)***	(-
No.of Observations	915	576	140	146	
R2	0.0435	0.0053	0.0013	0.2065	
Density of Population Convergence 1973-85					
Dependent variable: Population Growth 1973-85	**Total Country**	**Andean Region**	**Caribbean Region**	**Pacific Region**	**Ori**
Constant	0.0181 (3.804)***	0.01052 (1.500)	0.0359 (2.8080)***	0.0912 (5.800)***	(4
Population Density 1973	0.0005 (0.446)	-0.0025 (-1.3445)	-0.0036 (-1.1266)	-0.0194 (-4.944)***	(-
No.of Observations	914	576	140	146	
R2	0.0002	0.0020	0.0239	0.1941	
Per Capita Income Convergence					
Dependent Variable: Income Growth 1973-95	**Total Country**	**Andean Region**	**Caribbean Region**	**Pacific Region**	**Ori**
Constant	0.1319 (7.7592)***	0.1175 (5.1144)***	0.0548 (1.2082)	0.1375 (3.9638)***	(3
Per Capita Income Growth 1973	-0.0147 (-7.673)***	-0.0118 (-4.5337)***	-0.0099 (-2.038)**	-0.0171 (-4.1983)***	(-3
No.of Observations	914	576	139	146	
R2	0.093	0.0817	0.0297	0.1186	

Apart from low persistence of the population growth rate, there is a convergence of population density growth rates amongst the Colombian municipalities. Comparing the 1973-1995 population density growth rate with initial population density yields a coefficient of -0.0072 with an R-square of 0.043. If the same exercise is performed on the 1973-1985 period, a coefficient of -0.012 with an R-square of 0.08 is obtained. However, the coefficient for the period 1985-1995 is 0.00053, and it is statistically insignificant. This implies that in the mid-1980s population growth rate convergence dynamics decreased strongly (see Table 1). Although some of the population regression coefficients are significant, the "unconditional density of population convergence model" explains some of the population dynamics. The forces of regional and local densification must, therefore, be linked to other sources.

Income Growth

The municipal income growth rate can be explained by a simple version of the Solow-Swan model. According to this model the economy reaches a "steady state" at the point at which the rate of capital/labor ratio growth *(k)* is equal to zero. This occurs when saving, *sf(k)/k*, equals the effective (including technological changes) depreciation line, *(n+g)* (Aghion and Howitt, 1998; Barro and Sala-i-Martin, 1995). If $k<k^*$, then the growth rate of *k* is positive and k increases towards k^*. If $k>k^*$, the growth rate is negative, and *k* falls towards k^*. The Solow-Swan model leads to the conclusion that as long as the economy begins close enough to a steady state k^*, the greater the shortfall of the actual capital/labor ratio below k^*, and the higher the growth rate of capital per person. Thus, the country or region that begins with a lower level of per capita output will have a higher per capita output growth rate, and their per capita output will tend to converge with the income per capita of other economies (with higher income), as shown in Graph 4.

Graph 4
Growth Rate Dynamics



To test the Solow-Swan model, authors often estimate the following equation:

$$\gamma_i = \alpha_0 + \beta * y_{i,0} + \varphi * X_{0,i} + \varepsilon_i \qquad (1)$$

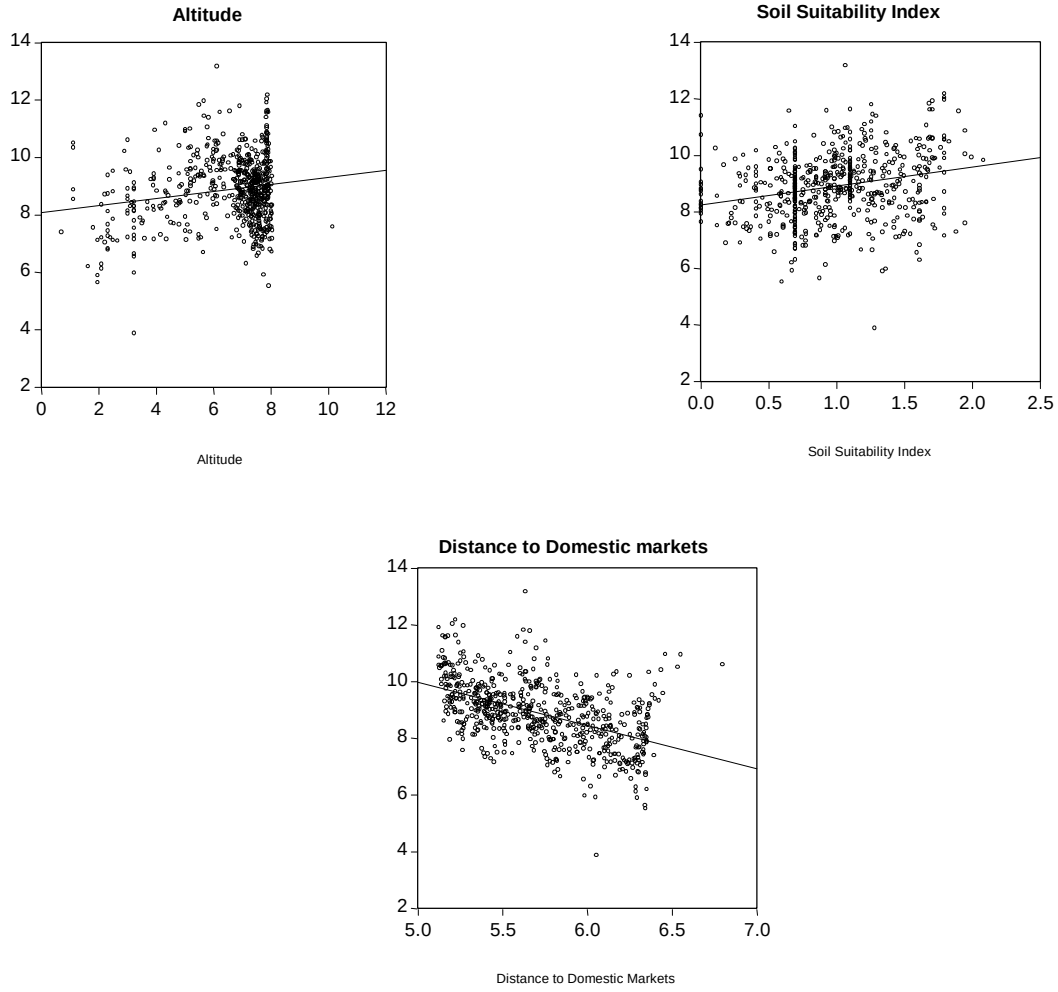
Where γ_i is the income per capita growth rate of a country, region or municipality between *0* and *t*, *y* is output per capita at *t*, and *X* is a vector of control variables, such as saving rate *s* and population rate *n*. We assume, in this model, that the value of the control variables is the same for all municipalities. The above equation was estimated for the Colombian municipalities. Basing the income per capita growth rate on the 1973 per capita level yields a negative, and statistically significant, coefficient of -0.014 and an R-square of 0.09 (Table 2). The results imply that there is unconditional income per capita convergence among the municipalities and, to a certain extent, explain income growth.[12]

[12] The negative coefficient of initial income in the growth regression implies that if we take two municipalities with the same rates of investment and the same level of efficiency, the poorer one will grow more quickly for a transitional period. The reason for these "transitional dynamics" is that relatively poor municipalities have lower stocks of physical and human capital. Hence the marginal product of extra capital is higher. See Temple (1999) for a discussion of growth estimates.

If we examine income per capita growth by region, similar results are obtained. For instance, the econometric exercise for the Andean region yields a coefficient of -0.012, for the Caribbean region, -0.01; for the Pacific region, –0.017; and for the Orinoquia region, –0.028 (see Table 2 and Graph 5).

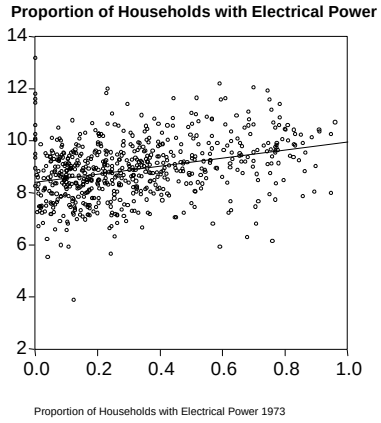
Graph 5

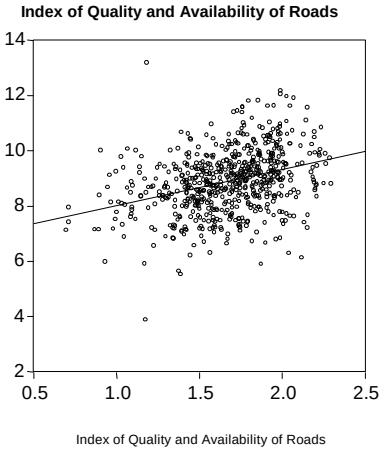
The Relationship between Per Capita Income and Several Explanatory Variables: Geographical Variables*



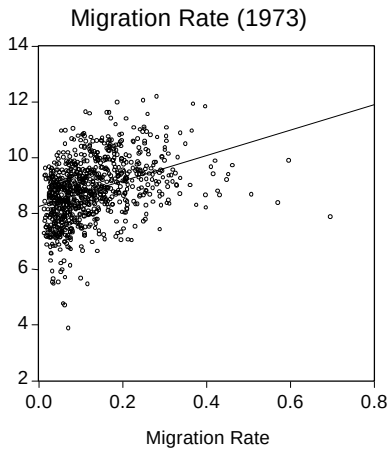
Graph 5 (continued)

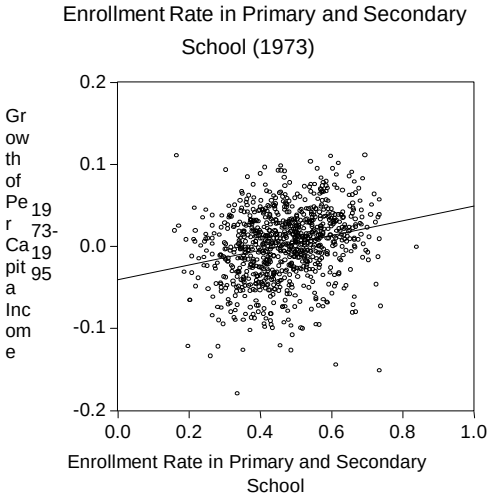
Infrastructure Variables





Human Capital





**Note*: With the exception of the figure "Enrollment Rate in Primary and Secondary School (1973)," the vertical axis represents axis denotes 1995 per capita income in thousands of COP$ at 1975 value. The vertical axis of the enrollment figure denotes growth in per capita income from 1973 to 1995.

5. Geography and Per Capita Income

General Considerations

In this section we examine the role of geographical and other variables in explaining income per capita differences among Colombian municipalities. As can be seen in Table 1, the differences in income per capita among municipalities and regions are significant.

In 1995 Bogotá's income per capita was COP$35,427, in contrast with the Caribbean region's level of COP$7,250, the Andean Region's level of COP$14,490 and the Pacific region's level of COP$7,272 (1975 pesos). We will attempt to answer several questions related to municipal income per capita disparities: How can the income per capita differences among Colombian municipalities be explained? How much do geographical factors affect these differences? How much do other factors (education, health, infrastructure, municipal government transfers, proximity to domestic markets, etc.) contribute to the differences?

A clear relationship exists between geographic variables and income, as was pointed out by Gallup and Sachs (1998). An overview of this relationship, using Colombian municipal data, is found in Graph 6. It can be seen that the level of income per capita in 1995 is positively linked to the soil suitability index and negatively linked to the distance to domestic markets index. Additionally, municipal income per capita is positively correlated with 1973 human capital variables such as years of schooling of the labor force, school enrollment rates and migration rates, and with 1973 infrastructure variables such as the road index and electricity coverage.

Global Results

The model we use to explain income per capita disparities among Colombian municipalities is based on Gallup and Sachs (1998) and Rappaport (1999). To explore the impact of geography on income per capita differences between the Colombian municipalities we carried out two econometric exercises. The first was the regression of municipal income per capita based on geographical variables, which are clearly exogenous to income. These variables are altitude, precipitation, distance to domestic markets and seaports, soil suitability, flatness of land, availability of water and proximity to principal rivers. The

second included the addition of variables linked to income: infrastructure, human capital and standard of living and institutional features.

Table 3 presents the results of the income per capita regressions. Column (1) shows that by far the most significant coefficient is proximity to the principal domestic markets. This variable has a negative coefficient (the greater the distance from markets, the lower the income per capita). Other geographic variable coefficients are as expected. Precipitation (cubic centimeters of rain per year, an indicator of unhealthiness) has a negative influence on income per capita. The altitude coefficients, quadratically introduced, are also as expected. The lineal specification is positive, and the quadratic specification is negative. Thus, not only the hot lowlands, but also the cold highlands, have, *ceteris paribus*, lower income per capita than moderate tropical lands. The soil suitability index, constructed by the authors, has the expected positive signs; the better the soil, the higher the income. The Cauca and Magdalena variable, which takes the value of 1 for the municipalities along these rivers, is negative, although Magdalena is never significant. This may be due to the decreasing importance of these rivers in the economic life of the country in recent decades.

Table 3

Determinants of Municipal Per Capita Income (1995)

Dependent Variable	**Total sample**	**Total sample**	**IGAC Sample**	**IGAC Sample**	**Per CapitaTaxes**	**Per CapitaTaxes**
					Total Sample	Total Sample
Constant	17.5143	10.5135	13.0179	6.8585	12.1485	8.5568
	(13.877)***	(7.953)***	(8.764)***	(3.741)***	(10.494)***	(6.680)***
Geographical Variables						
Precipitation	-0.5892	-0.3413	-0.5706	-0.2072	-0.3672	-0.1238
	(-8.155)***	(-5.694)***	(-5.758)***	(-2.554)**	(-5.185)***	(-1.992)**
Altitude	0.4264	0.3602	0.8099	0.5636	0.3849	0.2197
	(2.683)***	(2.780)***	(3.698)***	(2.992)***	(2.467)**	(1.785)*
Altitude^2	-0.0391	-0.0329	-0.0714	-0.0491	-0.0356	-0.0189
	(-2.734)***	(-2.800)***	(-3.703)***	(-3.020)***	(-2.496)**	(-1.644)
Soil Suitability Index	0.6720	0.4817	0.5934	0.4525	0.6863	0.3170
	(8.1546)***	(5.148)***	(6.241)***	(3.990)***	(7.996)***	(3.531)***
Distance to Domestic Markets	-1.4968	-1.1054	-1.6105	-1.1151	-1.6452	-1.3290
	(-12.724)***	(-10.368)***	(-14.192)***	(-9.178)***	(-14.202)***	(-12.719)***
Cauca River			4.7933	3.6813		
			(3.654)***	(2.897)***		

Table 3, *continued*						
Magdalena River			-2.3645	-2.0001		
			(-3.995)***	(-3.510)***		
River (in kilometers)			0.6987	0.5539		
			(4.393)***	(4.298)***		
Water Availability Index	-0.5077	-0.4130	-0.4771	-0.4255	-0.0303	-0.1155
	(-2.213)**	(-2.678)***	(-1.438)	(-2.013)**	(-0.146)	(-0.820)
Water Availability Index^2	-0.0991	-0.0337	-0.1617	-0.0730	-0.0486	-0.0621
	(-0.684)	(-0.267)	(-1.013)	(-0.505)	(-0.326)	(-0.490)
Proportion of Flat Land	0.2673	0.1707	0.3952	0.2008	0.2209	0.0438
	(3.942)***	(2.896)***	(3.976)***	(2.513)**	(3.557)***	(0.813)
Infrastructure Variables						
Proportion of Households		0.8170		0.6794		1.4117
with Electricity 1973		(3.947)***		(2.789)***		(7.239)***
Road Density 1970		0.0570		0.0291	0.0806	0.0738
		(2.052)**		(0.818)	(3.439)***	(2.771)***
Road Density Growth		0.6623		0.5804		0.9073
		(1.838)*		(1.427)		(2.576)**
Index of Quality and Availability of Roads				0.2019		
				(1.794)*		
Human Capital						
Migration Rate 1973		2.6361		3.2323		2.4658
		(5.919)***		(6.091)***		(6.192)***
Primary and Secondary School Enrollment 1973		1.9812		1.5525		1.1716
		(5.195)***		(3.536)***		(3.208)***
College Graduates per 1,000 of		0.0370		0.0583		0.0357
the Labor Force 1973		(2.851)***		(4.511)***		(3.285)****
Deaths from Tropical Diseases		-0.0964		-0.0759		-0.1153
per 1,000 (1979)		(-2.729)***		(-1.915)*		(-3.126)***
Institutions and Living Standards						
Interaction Between Soil and Degree		-0.1123		-0.1726		-0.0411
of Urbanization (1973)		(-2.055)**		(-2.745)***		(-0.796)
Proportion of Land with Coffee Crops 1980		-0.0116		-0.0125		-0.0134
		(-4.522)***		(-3.963)***		(-5.606)***
Income Inequality 1973		0.0069		-0.1840		-0.2723
		(0.092)		(-1.855)*		(-3.843)***
Annual Per Capita Municipal Transfers		0.4398		0.4484		0.2317
(Average 1973-95)		(5.224)***		(4.085)***		(2.815)***
Number of Observations	873	872	625	612	897	872
Pseudo R2	0.3530	0.5542	0.4571	0.6313	0.3680	0.6006
*Significant at 90%						
**Significant at 95%						
***Significant at 99%						

Overall, geographic variables explain 36% of municipal income per capita differences. Most of the coefficients are significant, have the expected sign and confirm what Gallup and Sachs (1998) found worldwide. The results also validate the strong effect that proximity to markets has on income, as seen in Section 2. Proximity to large markets facilitates the supply of intermediate goods, makes it easier to find the right workers and allows information exchange between firms in the same industry which are clustered together (Krugman, 1991).

Column (3) presents the econometric results for the IGAC sample,[13] which includes the variables of availability of water (expressed quadratically) and proportion of flat land in the municipality. The water coefficients are as expected and are highly significant; low availability of water is linked to low income, but so is high availability. The proportion of flat land coefficient is positive; Colombia's mountainous terrain has not brought economic advantages. In fact, it has made transport, agriculture and the construction of cities difficult. According to the results presented in column (3), geographic variables account for 46% of income per capita differences.

Colombian historians have stressed the importance of geography in inter-regional trade, referring to the mountainous terrain and the difficulties of road construction. The Magdalena River was, until 1930, the main transport route between the Caribbean Sea and the hinterland (Bogotá and the coffee zone). Besides Bogotá, the other important cities were, as previously mentioned, Medellín (a coffee and mining center), Cali (an agro–industrial center) and Barranquilla (Colombia's oldest port, on the Caribbean). From the beginning of the century, the domestic market was formed around these cities, away from the coast. Moreover, the import substitution policies adopted during most of the century contributed to directing the production of tradable goods towards the domestic market (Jaramillo y Cuervo, 1987). Thus, proximity to domestic markets represented an important factor in the differences in income per capita between municipalities.[14]

In columns (2) and (4) of Table 3 we present the determinants of 1995 income per capita, using a large set of variables. In terms of infrastructure variables, we included kilometers of roads per square kilometer (1970 figures). Other infrastructure variables are

[13] The IGAC sample excludes Antioquia, Bogotá and Cali.
[14] An explanation of domestic market formation can be found in Gouesset (1998).

the rate of road density growth, the 1973 percentage of households with electricity and an index of road quality (IGAC sample).

The road variable coefficients are positive and significant, as are those of households with electricity. The human capital variables used were the 1973 primary and secondary school enrollment rate, years of schooling, the 1973 migration rate, the number of college graduates per thousand people and the number of deaths from tropical diseases in 1979. The results of the study show that the municipalities that had higher primary and secondary school enrollment rates in 1973 had higher levels of income in 1995. The same result is obtained for the migration rate and college graduate variables. The tropical disease indicator is, as expected, negatively related to income per capita.

The econometric results for institutional and standard of living variables show that the coefficient of interaction between the soil suitability index and the degree of urbanization is, as expected, negative; the quality of soil is more important to income in rural municipalities. Income inequality is also negatively associated with income. According to Dinninger *et al*. (1999) and Leibovich *et al*. (1999), poverty and inequality restrict the accumulation of human capital in the long term, which affects income.

Finally, intergovernmental transfers per capita between 1973 and 1995 are significant in explaining the 1995 level of income. This is an important result, given the heated debate on the decentralization process and its effects in Colombia, and indicates that, on average, transfers to municipalities are not a waste of money and that they have somehow contributed to increasing municipal income. The econometric studies also show that our model is robust, not only in terms of sample size,[15] but also in terms of the introduction of other variables. Similar results are obtained if we use municipal taxes per capita as an income proxy, as presented in column (5) and (6). In Appendix 1 the results of the same exercise are presented, with good results obtained using GDP by land area as the dependent variable.

[15] The regressions are based on information from homogeneous zones and do not include Antioquia since the information from this department is incomplete.

Geography and Income of Rich and Poor Municipalities

Table 4 presents the results of an econometric exercise[16] aimed at determining if the impact of different income variables differs between poor and rich municipalities. Although there are not great differences in the magnitude of the coefficients, some results are worth highlighting. Columns (1) and (2) contain estimates for the regression of income per capita for rich and poor municipalities, based only on geographic variables. Although the coefficients are very similar, and are the same for the two sub-samples, geographical variables explain 24% of the income per capita variation in poor municipalities and 19% in the richest. The greatest difference is the significance and magnitude of the distance to domestic markets coefficient, which is largest and most statistically significant for the poorest municipalities (-1.9 as opposed to -1.4 in the richest municipalities).

[16] For the rich and poor estimation we used the quantile regression methodology. See Appendix 2.

Table 4

Quantile Regressions of Municipal Per Capita Income

Dependent Variable	TotalSample		Total Sample		IGAC Sample		IGAC Sample	
	poorest 25%	richest 25% richest	poorest 25%	richest 25% richest	poorest 25%	richest 25% richest	poorest 25%	richest 25% richest
Constant	20.4273	14.9455	11.2505	10.3756	15.2920	11.2163	9.1375	8.0232
	(14053)***	(10.906)***	(9.033)***	(6.752)***	(7.036)***	(4.965)***	(3.200)***	(2.996)***
Geographical Variables								
Precipitation	-0.6258	-0.4952	-0.3830	-0.2755	-0.5586	-0.5445	-0.1573	-0.1885
	(-6.934)***	(-5.181)***	(-6.465)***	(-3.405)***	(-4.751)***	(4.213)***	(-1.159)	(-1.251)
Altitude	0.4003	0.3886	0.3394	0.0819	0.8168	0.6999	0.5595	0.4824
	(2.703)***	(2.399)**	(3.643)***	(0.361)	(4.213)***	(3.249)***	(2.670)***	(2.046)**
Altitude^2	-0.0357	-0.0357	-0.0309	-0.0081	-0.0704	-0.0619	-0.0473	-0.0425
	(-2.444)**	(-2.360)**	(3.357)***	(-0.649)	(-3.904)***	(-3.115)***	(-2.431)**	(-1.998)**
Soil Suitability Index	0.6678	0.7582	0.3360	0.5942	0.5309	0.7090	0.3018	0.5063
	(5.786)***	(6.950)***	(3.240)***	(4.965)***	(3.916)***	(5.582)***	(1.549)	(2.972)***
Distance to Domestic Markets	-1.8408	-1.1976	-1.2062	-0.9910	-1.7882	-1.4004	-1.2024	-1.0111
	(-12.460)***	(-9.237)***	(-12.212)***	(-7.869)***	(-11.321)***	(-9.506)***	(-6.157)***	(-5.160)
Cauca River					4.5810	4.7089	0.8844	2.6278
					(2.340)**	(1.770)*	(0.441)	(1.376)
Magdalena River					-2.0893	-2.2688	-0.7104	-1.4649
					(-2.396)**	(-1.946)	(-0.795)	(-1.663)*
River (in kilometers)					0.6641	0.5189	0.5876	0.5223
					(3.052)***	(2.758)***	(2.503)**	(2.514)**
Water Availability Index	-0.1897	-0.4480	-0.4860	-0.4459	-0.1769	-0.2534	-0.3368	-0.6040
	(-0.763)	(-1.954)*	(-3.123)***	(-2.206)	(-0.540)	(-0.862)	(-0.909)	(-2.018)**
Water Availability Index^2	-0.1676	0.0398	-0.0409	0.0683	-0.0009	-0.0829	0.0183	-0.0769
	(-0.851)	(0.235)	(-0.339)	(0.464)	(-0.005)	(-0.431)	(0.083)	(-0.362)
Proportion of Flat Land	0.1387	0.3428	0.1376	0.1329	0.1846	0.5187	0.1030	0.1293
	(1.610)	(4.461)***	(2.416)**	(1.886)*	(1.636)	(5.227)***	(0.841)	(1.116)

Table 4, *continued*								
Infrastructure Variables								
Proportion of Households			0.9057	0.4401			0.5266	0.5200
with Electricity 1973			(4.354)***	(1.946)*			(1.361)	(1.528)
Road Density 1970			0.0882	0.0125			0.0696	-0.0133
			(3.603)***	(0.445)			(2.695)***	(-0.476)
Road Density Growth			1.0157	0.0320			2.0907	-0.3439
			(3.221)***	(0.086)			(2.955)***	(-0.468)
Index of Quality and Availability of Roads							-0.0163	0.3613
							(-0.080)	(1.772)*
Human Capital								
Migration Rate 1973			2.8228	2.6113			2.8399	2.3355
			(6.645)***	(6.105)***			(3.276)***	(3.091)***
Primary and Secondary School Enrollment 1973			1.8844	2.3017			1.4631	1.7333
			(5.266)***	(5.295)***			(2.020)**	(2.437)**
College Graduates per 1,000 of			0.0191	0.0628			0.0716	0.0723
the Labor Force 1973			(1.711)*	(7.127)***			(3.523)***	(3.824)***
Deaths from Tropical Diseases			-0.4485	-0.1834			-0.2702	-0.1611
per 1,000 (1979)			(-7.924)***	(-3.978)***			(-2.785)***	(-2.736)***
Institutions and Living Standards								
Interaction Between Soil and Degree			-0.1181	-0.1452			-0.1220	-0.1550
of Urbanization (1973)			(-1.900)*	(-2.380)**			(-1.036)	(-1.766)*
Proportion of Land with Coffee Crops 1980			-0.0125	-0.0106			-0.0055	-0.0165
			(-4.487)***	(-2.880)***			(-0.867)	(-2.370)**
Income Inequality 1973			0.0757	-0.1142			-0.0127	-0.2865
			(1.126)	(-1.285)			(-0.069)	(-1.771)*
Annual Per Capita Municipal Transfers			0.4679	0.5676			0.4520	0.4633
(Average 1973-95)			(5.320)***	(5.853)***			(2.590)***	(2.693)***
Number of Observations	873	873	872	872	613	613	612	612
Pseudo R2	0.2362	0.1846	0.3636	0.3461	0.3144	0.2562	0.4203	0.4055
*Significant at 90%								
**Significant at 95%								
***Significant at 99%								

The same results are obtained using columns (5) and (6) of the IGAC sample, with geographic variables explaining 32% of the income per capita variations in the poorest municipalities and 25% in the richest. Altitude, availability of water and topography seem to be most important for the income of the poor. The poor municipalities are small, and are located in rural areas where the main sources of income are agriculture and livestock, both of which depend, to a large extent, on the availability of the previously mentioned natural resources and geographical characteristics. Paradoxically, soil suitability seems to be more important in richer municipalities, which may be due to historical reasons. They are rich, in part, precisely because the old settlements were built on good soils while more recent ones were built on soils of lower quality.

The impact of 1973 electrical coverage seems to be very important for the income of both the poor and the rich, and the coefficient is fairly significant for both. However, the impact of road density and growth rates is higher in poor municipalities. Of the human capital variables, the education coefficients (enrollment rates and number of college graduates) seem to be of greater magnitude in rich municipalities when the total sample is used. However, when the IGAC sample is used, the coefficients are broadly similar.

Finally, the institutional and standard of living variables do not seem to perform well in the quantile regressions. This may be because poor and rich municipalities are fairly homogeneous with respect to these variables. The econometric studies of the determinants of income by land area for rich and poor municipalities are presented in Appendix 2.

6. Geography and Income Per Capita Growth

Geography and Growth in Colombia

Although geography has been neglected in regional and municipal economic growth models and estimations in Colombia, historians and travelers have long noted the important role of geographical factors in Colombian development. John Hamilton, a British colonel travelling in Colombia in the nineteenth century, highlighted in 1829 the heavy burden that nature and climate imposed on trade and human transportation. The trip down the Magdalena River from Barranquilla to Honda, the only access to Bogotá, lasted more than 100 days. During such a long journey, many passengers fell ill or died of malaria, yellow

fever, diarrhea and cholera. High freights costs, moreover, made trade expensive, impeding the import of goods and machinery to the hinterland (Hamilton, 1970).

James Parsons, a sociologist who studied in depth the colonization of Antioquia, suggested that the long and effective geographical isolation of mountainous inner Colombia had defined the traditionalism, and peculiar cultural features, of the Antioquians (Parsons, 1997). The scarcity of an indigenous labor force and the near non-existence of flat lands meant that, by the nineteenth century, the rural population of Antioquia was composed mainly of smallholders. This, according to Parsons, prompted the early democratic tradition of the Antioquian labor force, in contrast with the classist social structure found in the south and west of Colombia, where there was a higher indigenous population. The special characteristics of this society, the result of geographical features, determined in part the early industrialization of the region.

The geography of the Caribbean coast likewise brought about a distinctive pattern of development, as Posada (1998) points out. The sea, rivers and swamps determined the position of the main settlements on the coast, in terms of access and sources of water and food. Life was not easy: land and towns suffered periodic floods that destroyed houses and crops and altered the geography of the region. Floods and high temperatures encouraged the proliferation of diseases, infections and plagues, and made the establishment of long-term mining or manufacturing activities difficult.[17]

The lack of economic opportunities and the high level of disease on the coast resulted in migration, death and slow population growth, which generated labor scarcity. The latter, along with low productivity of labor, out of date technology and poor transport, hampered the rise of commercial plantations (*haciendas*), limiting the development of agriculture until very late in the twentieth century. In contrast, the region's land characteristics and market conditions facilitated the rise and consolidation of cattle-raising.

Leading historians, economists and sociologists have recognized the crucial role of geography in shaping regional development patterns in Colombia. The main factors by which geography has directly conditioned economic development are transport costs, health

[17] Striffler, a French engineer, came to work for a mining company in the Sinu Valley in the mid-nineteenth century. In the beginning he and his colleagues were enthusiastic. However, mosquitoes and floods made work impossible, and Striffler and his colleagues soon abandoned the mine and left the country (Posada, 1998).

factors and natural resources (land suitability, water, closeness to rivers, etc.). If these factors influence population density and creation of markets, they also have indirect effects on growth dynamics through agglomeration economies and other feedback mechanisms (Gallup and Sachs, 1998). We will consider these factors in a simple growth model.

Geography and Municipal Economic Growth: Theory

The inclusion of geographical variables in the growth equation can be interpreted as a simple modification of the conditional convergence model. To test for conditional convergence we should drop the assumption that all economies share the same parameters and, therefore, the same steady state positions. The principal idea is that an economy grows faster the further it is from a steady state. To illustrate this point we considered two economies, one rich and one poor, that differ in their initial capital stocks $k(0)_{poor} < k(0)_{rich}$ and saving rates, $s_{poor} < s_{rich}$. If their savings rates were the same, then per capita growth rates would be higher for the poor economy, and $\gamma_{poor} > \gamma_{rich.}$, but if not, and $s_{poor} < s_{rich}$ then $\gamma_{rich} > \gamma_{poor}$. In a neoclassical example, the steady state value, k^*, depends on the savings rate, s, the level of the production function, $f(k)$, and the various government policies and productivity factors that shift the position of the $f(k)$ (Graph 5). Thus, the saving rate in the Solow-Swan model can be expressed as:

$$s=(n+\delta)k^*/f(k^*) \qquad (2)$$

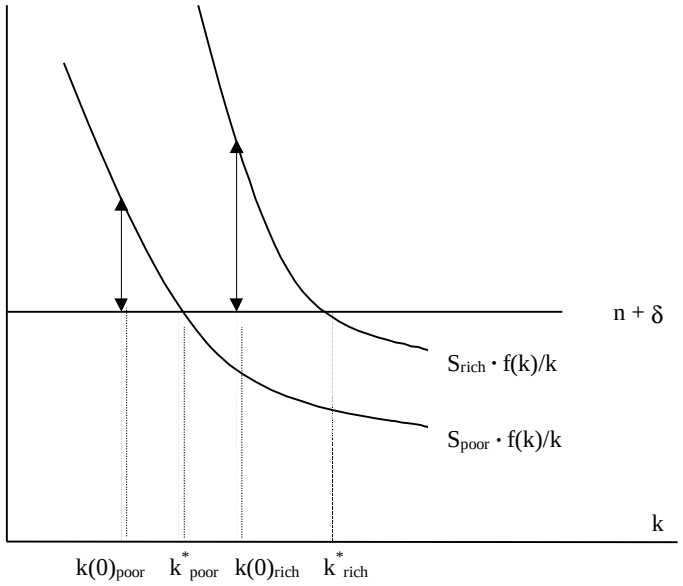
and the capital growth rate g as:

$$g=(n+\delta)[(f(k)/k)/(f(k^*)/k^*)-1] \qquad (3)$$

Equation (3) is consistent with $g = 0$ when $k=k^*$ of the Solow-Swan model. For a given k^*, the formula implies that a reduction in k, which raises the average product of capital, $f(k)/k$, increases g. But a lower k is consistent with a higher g only if the reduction is relative to the steady state value, k^*. Thus, a poor country or region would not be expected to grow rapidly if its steady state value, k^*, is as low as its current value, k (Barro and Sala-i-Martin, 1995).

Graph 6

Conditional Convergence



Equation (3) implies that we should look empirically at the relation between the per capita growth rate, γ_y, and the initial income level, *y(0)*, after controlling for the variables that account for differences in the steady state position, *y**. The large differences in geographical endowments between Colombian municipalities are likely to be related to a different level of *y**. We can see in the above econometric estimations that geography affects growth via land quality, health (tropical diseases), water availability, land slope, and productivity growth. Additionally, access to markets, which facilitates the functioning of the factor and goods markets, and the diffusion of technology and knowledge are clearly beneficial to productivity growth.

In this section we are going to explore, at the municipal level, the forces of income per capita convergence and divergence by estimating a cross-municipal growth regression, highlighting the role of geographical variables in growth. Thus, we estimated models of annual average income per capita (or municipal per capita taxes) growth for 1973-1995, relative to income per capita (or municipal per capita tax level) in 1973. We will test whether growth is affected by the initial income level (negatively if there are convergence

forces) and by geographical variables, controlling for the initial level of infrastructure indicators, human capital, and living standards.

As can be seen in Table 1, in 1973 the differences in income per capita between municipalities and regions were smaller than in 1995. Bogotá's income per capita was COP$27,561, the Caribbean region's COP$11,769, the Andean region's COP$9,097 and the Pacific region's COP$6,854. Thus, income per capita differences between municipalities and regions seem to have increased during the 1970s and 1980s. The average (non-weighted) income per capita of municipalities decreased in the Caribbean region, increased a little in the Pacific region (around 5%) and increased significantly in the Andean region (more than 40%). The changes in the average income per capita of the different regions suggest uneven growth rates between municipalities and regions. How did this occur?

Geography and Economic Growth: Results

In Section 3 we showed that there is an unconditional convergence amongst the Colombian municipalities, although its ability to explain income per capita growth is limited. In Table 5, columns (1) and (2), regressions of income per capita growth between 1973 and 1995, based on 1973 income and geographical variables, are presented. The results obtained are quite interesting and lead us to conclude that geographical variables, in the Colombian case, play an important role in explaining income per capita growth.

Table 5

Determinants of Municipal Per Capita Income Growth 1973 –1995

Dependent Variable	**Total Sample**	**Total Sample**	**IGAC Sample**	**IGAC Sample**	**Per Capita Taxes**	**Per Capita Taxes**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	0.4951	0.4560	0.3267	0.2917	0.3080	0.3126
	(11.236)***	(8.603)***	(4.892)***	(4.088)***	(6.225)***	(6.074)***
Per Capita Income 1973	-0.0216	-0.0281	-0.0214	-0.0281		
	(-14.725)***	(-14.798)***	(-11.393)***	(-10.270)***		
Per Capita Tax 1973					-0.0166	-0.0273
					(-6.936)***	(-11.851)***
Geographical Variables						
Precipitation	-0.0138	-0.0092	-0.0173	-0.0093	-0.0080	-0.0022
	(-4.823)***	(-3.584)***	(-4.594)***	(-2.600)***	(-2.808)***	(-0.869)
Altitude	0.0085	0.0110	0.0243	0.0212	0.0085	0.0080
	(1.885)*	(2.039)**	(4.145)***	(2.737)***	(1.527)	(1.586)
Altitude^2	-0.0006	-0.0009	-0.0020	-0.0017	-0.0007	-0.0007
	(-1.540)	(-1.847)*	(-3.746)***	(-2.633)***	(-1.518)	(-1.466)
Soil Suitability Index	0.0169	0.0125	0.0175	0.0140	0.0204	0.0115
	(4.975)***	(3.077)***	(4.492)***	(3.003)***	(5.872)***	(2.875)***
Distance to Domestic Markets	-0.0567	-0.0498	-0.0577	-0.0475	-0.0457	-0.0464
	(-14.166)***	(-11.054)***	(-12.566)***	(-9.437)***	(-9.0912)***	(-9.882)***
Cauca River	-0.0141	-0.0116	-0.0222	-0.0183	-0.0061	-0.0035
	(-1.953)*	(-1.715)*	(-2.367)**	(-2.004)**	(-0.690)	(-0.5738)
Magdalena River	-0.0051	-0.0013	-0.0040	-0.0001	-0.0067	-0.0034
	(-0.948)	(-0.254)	(-0.673)	(-0.031)	(-1.161)	(-0.644)
River (in kilometers)	0.0085	0.0048	0.0107	0.0067	0.0051	0.0007
	(3.663)***	(2.083)**	(3.458)***	(2.225)**	(2.079)**	(0.305)
Water Availability Index			0.2369	0.1954		
			(3.702)***	(3.624)***		
Water Availability Index^2			-0.1139	-0.1021		
			(-3.996)***	(-4.211)***		
Proportion of Flat Land			0.0190	0.0189		
			(3.087)***	(3.324)***		
Infrastructure Variables						
Proportion of Households		0.0215		0.0130		0.0376
with Electricity 1973		(2.770)***		(1.447)		(4.788)***
Road Density 1970		0.0004		-8.64E-05		0.0009
		(0.589)		(-0.233)		(1.192)
Index of Quality and Availability of Roads				0.0085		
				(1.736)		

Table 5, *continued*						
Human Capital						
Migration Rate 1973		0.0920		0.1305		0.0953
		(5.777)***		(6.042)***		(6.335)***
Primary and Secondary School Enrollment 1973		0.0811		0.0673		0.0637
		(5.254)***		(3.6488)***		(4.336)***
College Graduates per 1,000 of		0.0011		0.0016		0.0012
the Labor Force 1973		(3.309)***		(3.248)***		(3.892)***
Deaths from Tropical Diseases		-0.0041		-0.0028		-0.0046
per 1,000 (1979)		(-2.671)***		(-1.654)*		(-2.948)***
Institutions and Living Standards						
Interaction Between Soil and Degree		-0.0030		-0.0058		-0.0017
of Urbanization (1973)		(-1.299)		(-2.119)**		(-0.724)
Proportion of Land with Coffee Crops 1980		-0.0004		-0.0003		-0.0005
		(-3.927)***		(-2.335)**		(-5.113)***
Income Inequality 1973		-0.0025		-0.0093		-0.0124
		(-0,808)		(-2.302)**		(-4.103)***
Number of Observations	873	872	613	612	873	872
R2	0.3502	0.4860	0.3955	0.5256	0.1799	0.3844
*Significant at 90%						
**Significant at 95%						
***Significant at 99%						

The variable level of initial income per capita is, as expected, negative, which confirms the existence of income per capita convergence forces in Colombian municipalities. The econometric results show that distance to markets was a key determinant of income per capita growth between 1973 and 1995. The coefficient is as expected and is highly significant. The municipalities closer to domestic markets grew more than those farther away.[18] These results also imply that economic activity should have been concentrating around these markets and suggest that there has been an important development of economies of scale around Colombian domestic markets that also reinforces growth.

According to Krugman (1991) geographic concentration of production is "clear evidence of the pervasive influence of some kind of increasing returns...and these increasing proximate industries promote innovation and growth" (p. 5). In fact, Colombian

[18] The distance to domestic markets was weighted by the city's population; it is not the same to be close to Bogotá as to be close to Barranquilla. The weightings used were 0.52 for Bogotá, 0.19 for Medellin, 0.18 for Cali and 0.11 for Barranquilla. These weightings correspond to the proportion of total population of each city.

domestic markets are highly diversified in terms of their production structure. Thus, municipalities closer to domestic markets, as seen in Section 2, and under the influence of principal cities, have been able to exploit the knowledge spillovers coming from them and have therefore grown faster (Jacobs, 1969 and Gleaser, 1992).

Natural geographical variables also play an important role in explaining income per capita growth between 1973 and 1995. Precipitation has had a negative impact, while altitude has had a positive impact up to a certain level, beyond which its impact on growth becomes negative. The soil suitability index has also had a positive impact on growth. Regions or municipalities with good soils not only have higher income per capita, but also grew faster during 1973-1995. The regressive results indicate that municipalities located near or on the Cauca River experienced lower economic growth. According to column (1), geographic variables explain 34% of the income per capita growth variations. The IGAC sample results of column (3) and (4) show that both water availability and the proportion of flat land also affect growth.[19] Geographic variables and initial income levels explain 40% of the income per capita growth variations in Colombian municipalities.

Initial levels of infrastructure density have also determined income per capita growth. The municipalities with a higher number of kilometers of roads and railroads in 1970[20] grew faster from 1973 to 1995.[21] Although the same calculations were made for railroad density, the coefficients obtained were not significant (and were not reported). This result was, however, expected, as railroad development had effectively stopped by the end of the 1960s. According to Ramirez (1999) the number of railroad kilometers grew quite fast from the end of the nineteenth century to the end of the 1950s, then moderately until the end of the 1970s and subsequently halted, or even grew negatively. Thus, the contribution of railroads to Colombian economic development, and to domestic market integration, occurred before the 1970s. The other infrastructure variable used, electricity coverage of households at the start of the period, is also positive.

[19] Water availability matters until certain point, as indicated by the positive and significant coefficient of this variable in its linear specification and the negative and also significant coefficient of its quadratic specification.
[20] This year is used as existing road and rail maps date back to 1970.
[21] The initial year values are used for the variables to avoid endogeneity problems. See Fedderke *et al*. (1998) for a discussion of this theme.

All the 1973 human capital variable coefficients are fairly significant and are as expected. For example, had the number of college graduates per thousand of labor force in 1973 been higher by one person, the average growth rate between 1973 and 1995 would have been 0.08% higher. Similar results are obtained for enrollment rates in primary and secondary education in 1973. The municipalities with higher enrollment rates in 1973 grew faster during 1973-1995, as did the municipalities with a higher 1973 migration rate. Although the mechanism is not entirely clear, recent studies of Colombia (Leibovich, 1996) have shown that migrants reach a higher level of income than people with the same socio-economic characteristics who already live in the destination area. In contrast, municipalities with higher rates of deaths from tropical diseases experienced lower growth between 1973 and 1995. The effect on growth of this variable is quite strong; had this variable been 1% lower, income per capita would have grown at a rate 1% higher.

The standard of living and institutional variables also have an impact on the economic growth of municipalities. As shown in Table 5, the negative variable of interaction between soil and the degree of urbanization implies that the importance of soil quality on growth decreases as the municipality becomes more urbanized. The presence of coffee also has a negative effect on growth; although the coefficient of this variable is low, it is negative and is fairly significant. This may be the result of the decreasing importance of coffee as a source of national income, the loss of its comparative advantage compared with other sectors and its low current price compared with that of the 1970s (Ocampo, 1987).

Levels of income inequality in 1973 (measured as the variance of the logarithm of income at municipal level) have had a negative impact on municipal growth. The effect of initial income distribution on income per capita growth is negative, in concordance with results obtained by recent cross-country studies (Denninger and Squire, 1998). The transmission mechanism from distribution to lower growth is the credit constraint channel. A more unequal distribution of assets would imply that, for a given level of income per capita, a greater number of people suffer credit constraints, restricting the accumulation of education and human capital and producing lower aggregate growth. Columns (5) and (6) show the income per capita regression using other income proxies and municipal taxes. The

results are quite similar to those shown in columns (1) and (2) of the same table. The determinants of income per land area growth are shown in Appendix 3.

7. Geography, Population and Population Growth

This section of the paper presents some of the determinants of population density in Colombian municipalities.[22] Population density reflects in part settlement decisions made in the past and historical demographic trends, and settlement decisions were presumably influenced by soil quality, proximity to rivers, seaports and main roads, quality of climate, and other geographically related factors. Equally, once a settlement was sited, that site determined the future economic growth of the region through the creation of an economy of agglomeration, along with goods and factor markets. Additionally, changes to production structure, demographic trends and access to social services can influence population density. Just thirty years ago, more than 70% of the Colombian population lived in poverty (measured by unsatisfied basic needs), largely in rural areas. By 1995 this figure had decreased to less than 30%, and the urban population had increased to 70%, with greater access to public and social services.

Table 6 shows the determinants of population density in Colombian municipalities for 1973 and 1995. According to the results, the Colombian regions with a high incidence of heavy precipitation indices are the least populated, as expected. Altitude has a quadratic specification in the equation, which means that, ceteris paribus, the most densely-populated areas are those with temperate weather.

[22] Jaramillo (1998) and Florez (1998) have studied the structure of Colombian population and migration patterns.

Table 6

Geography, Municipal Population Density and 1973-1995 Population Growth

Dependent Variable	1973 Population	1973 Population	1995 Population	1995 Population	Populatio Growth
Constant	16,1558 (14,0847)***	13,6500 (13,043)***	14,7055 (11,929)***	12,7027 (8,845)***	0,9099 (26,108)**
Geographical Variables					
Population Density 1973					-0.0070 (-4.843)**
Precipitation	-0.6821 (-8.378)***	-0.5403 (-7.032)***	-0.4133 (-4.805)***	-0.2009 (-2.974)***	0.0020 (0.8019)
Altitude	-0.8161 (-5.738)***	-0.6049 (-4.796)***	-0.5480 (-3.981)***	-0.3071 (-3.180)***	-0.0060 (-1.700)
Altitude^2	0.0836 (6.213)***	0.0790 (6.566)***	0.0683 (5.141)***	0.0328 (3.369)***	0.0007 (1.491)
Soil Suitability Index	0.0607 (5.983)***	0.4231 (4.656)***	0.7910 (8.085)***	0.2508 (2.748)***	0.0160 (3.988)**
Distance to Seaports		-2.7398 (-11.056)***	-2.1851 (-7.147)***	-0.6037 (-2.451)**	0.0105 (1.507)
Distance to Domestic Markets	-0.9777 (-8.046)***	0.1702 (1.343)	0.1635 (1.209)	0.0347 (0.310)	0.0148 (4.655)**
Erosion Index	-0.6507 (-4.743)***	-0.5145 (-4.186)***	-0.3597 (-2.440)**	-0.1331 (-1.122)	
Cauca River		0.1448 (0.763)	0.1621 (0.657)	0.0014 (0.007)	0.0045 (1.047)
Magdalena River		0.1833 (1.249)	0.0893 (0.577)	0.1667 (1.642)	0.0017 (0.325)
River (in kilometers)			-0.3624 (-3.966)***	-0.3478 (-5.219)***	

Table 6, *continued*					
Infrastructure Variables					
Proportion of Households with Electricity 1973				1.5070 (6.069)***	
Road Density 1949		0.0136 (1.248)			
Railroad Density 1970		0.0745 (8.080)***			
Road Density 1970				0.2687 (9.604)***	
Road Density Growth				1.9134 (5.872)***	
Human Capital					
Primary and Secondary School Enrollment 1973				0.7944 (1.977)**	
College Graduates per 1,000 of Labor Force 1973				0.0532 (2.962)***	
Institutions and Standards of Living					
Interaction Between Soil and Degree of Urbanization (1973)				-0.1486 (-2.767)***	
Proportion of Land with Coffee Crops 1980		0.0187 (5.106)***		0.0187 (5.266)***	
Per Capita Municipal Transfers (Average 1973-95)				-0.8620 (-8.317)***	
Number of Observations	894	894	893	869	898
R2	0.2575	0.4471	0.3086	0.6245	0.078

*Significant at 90%
**Significant at 95%
***Significant at 99%

The coefficient of the soil suitability index indicates that Colombian population centers were also shaped by quality of soil and erosion indices. However, at least for 1973, the municipalities located near or along the principal Colombian rivers (the Magdalena and the Cauca) did not have a higher population density. In contrast, municipalities with coffee crops were, in 1973, more densely populated. Finally, population density in 1973 was determined by availability of transport (density measured in 1949), especially railroads.

Column (2) of Table 6 shows the determinants of 1995 population density. The geographical, infrastructure and public and social services variables are important to population distribution. Among the geographical variables, precipitation, temperature and distance to seaports have a negative impact on population density. In contrast, altitude and suitability of soils have a positive effect.

All the infrastructure variables have a positive effect on population density; 1970 road density and road density growth and 1973 electrical coverage have the largest t-statistics in the regression. 1973 primary and secondary school enrollment rates also have an important impact on 1995 population density, as does the number of college graduates per thousand people.

Table 6 also presents the geographical determinants of population growth between 1973 and 1995. The 1973 population density coefficient is negative, which indicates that there is convergence in population density between Colombian municipalities. The other results show that the population of municipalities distant from the main domestic markets and seaports has grown faster in the presence of better soil suitability, greater density of roads (1970), greater household electric coverage and a higher density of coffee. The altitude of the municipality seems to have had a quadratic effect on population growth. Very high and very low altitudes discourage population growth.

The quantitative results obtained from the population regressions imply that geographical factors affect both the location and growth of the population center, which, at the same time, have indirect effects on economic growth through agglomeration, the creation of markets and related mechanisms.

8. The Sources of Differences in Per Capita Income and Economic Growth

Decomposition of Per Capita Income

In this section we will explore the impact of different variables on income per capita differences between municipalities by using the decomposition methodology, based on the coefficients obtained. In order to carry out the study presented in Tables 7 and 8, we took the income per capita average difference between the Andean region (excluding Bogotá) and the other Colombian regions. In order to calculate how much each variable contributes to the difference in income per capita we multiplied the regression coefficient of the variable by the difference between the average of the variable in the Andean Region and the average of the variable in the other region. Thus, if Y_A is the average income per capita of region A and Y_K the average income capita of region K, the difference of average income can be calculated as follows

$$\bar{Y}_A - Y_K = \sum_{1}^{n} b_i (X_{iA} - X_{iK}) + e \quad (4)$$

where $b_i (X_{iA} - X_{iK})$ is the contribution of variable *i* to the difference in income per capita between region A and region K.

Tables 7 and 8 show the results of the decomposition of average income per capita between the Andean region and the rest of the regions. The income per capita difference between the Andean region and the Caribbean is 0.75 (logs). Geographical variables account for 0.62 (82%) of this difference, although the magnitude and value of the contribution of each variable vary considerably. However, the variable that contributes the most (in favor of the Andean region) to the income per capita difference is distance to domestic markets. Infrastructure variables favor the Caribbean region, but only because of the 1973 stock variable (density of roads and electricity coverage). In contrast, the growth of road density has favored the Andean region.

Table 7

Per Capita Income - Differences by Region (Total Sample)

Andean Region vs	**Caribbean**	**Pacific**	**Orinoco**	**Amazonia**	**Caribean**	**Pacific**
Difference	0.7523	0.8642	-0.6331	-0.1758	100.00%	100.00%
Geography	**0.4934**	**0.4874**	**-0.0833**	**0.8232**	**65.59%**	**56.40%**
Precipitation	-0.0912	0.0690	0.2329	0.1966	-12.12%	7.98%
Altitude	1.2653	0.2059	0.5035	0.4805	168.19%	23.83%
Altitude^2	-1.2214	-0.1682	-0.6051	-0.5680	-162.36%	-19.46%
Soil Suitability Index	-0.1924	-0.0460	-0.2126	-0.0305	-25.57%	-5.32%
Distance to Domestic Markets	0.7425	0.4579	0.1574	0.9797	98.70%	52.99%
Cauca River	0.0067	0.0121	-0.0087	-0.0087	0.89%	1.40%
Magdalena River	0.0035	-0.0017	-0.0017	-0.0017	0.47%	-0.20%
Rivers (Kilometers)	-0.0196	-0.0416	-0.1490	-0.2247	-2.61%	-4.81%
Infrastructure	**-0.0138**	**0.0041**	**0.0726**	**0.0169**	**-1.83%**	**0.47%**
Road Density 1970	-0.0146	0.0299	0.0608	0.1556	-1.94%	3.46%
Road Density Growth	0.0213	0.0028	-0.0055	-0.0024	2.83%	0.32%
Proportion of Households with Electricity 1973	-0.0205	-0.0286	0.0173	-0.1363	-2.72%	-3.31%
Human Capital	**0.0030**	**0.0921**	**-0.4518**	**-0.4714**	**0.40%**	**10.66%**
Primary and Secondary School Enrollment 1973	0.0760	0.0337	0.0356	-0.2198	10.10%	3.90%
Migration Rate 1973	0.0373	-0.0055	-0.5422	-0.3004	4.96%	-0.64%
College Graduates per 1,000 of Labor Force 1973	-0.0529	0.0073	-0.0322	-0.0765	-7.03%	0.84%
Deaths from Tropical Disease per 1,000 (1979)	-0.0574	0.0566	0.0870	0.1253	-7.63%	6.55%
Institutions and Standards of Living	**0.1379**	**0.1062**	**0.0183**	**-0.0872**	**18.33%**	**12.29%**
Interaction between Soil and Degree of Urbanization 1973	0.1069	0.0259	0.1043	0.1148	14.21%	3.00%
Proportion of Land with Coffee Crops 1980	-0.0687	-0.0137	-0.0614	-0.0713	-9.13%	-1.59%
Income Inequality 1973	0.0005	-0.0013	0.0011	0.0004	0.07%	-0.15%
Annual Per Capita Municipal Transfers (1973-1995)	0.0992	0.0953	-0.0257	-0.1311	13.19%	11.03%
Total Explained by the Regression	**0.6205**	**0.6898**	**-0.4442**	**0.2815**	**82.48%**	**79.82%**
Residual Unexplained by the Regression	**0.1318**	**0.1744**	**-0.1889**	**-0.4573**	**17.52%**	**20.18%**

Note: Andean region excludes Bogotá

Human capital variables also favor the Caribbean region, mainly because of its greater initial stock of college graduates. However, the contribution of school enrollment rates favors the Andean region. It is worth highlighting, however, that the overall contribution of human capital to average income per capita differences between the Andean region and the Caribbean is quite small (-0.038 or 5% of the difference, as shown in Table 7). The contribution of institutional and standard of living variables to income per capita differences between the Andean region and the Caribbean is moderate. The interaction of soil suitability and urbanization, the 1973 proportion of households living in poverty and the 1973-1995 average per capita municipal transfers favor the Andean region. The proportion of land with coffee crops negatively affects income in the region. As a whole these variables account for 0.16 (logs) of the income per capita difference (or about 22%). The decomposition exercise explains 97% of the income per capita differences between the Andean region and the Caribbean, 75% of the difference between it and the Pacific region and 103% of the difference with the Orinoco region.

In Table 8 we present the results of the income per capita difference decomposition based on the IGAC sample (excluding Antioquia, Bogotá and Cali). The estimates are similar to the ones obtained using the whole sample, which is an indication of their robustness. The decomposition exercise performs even better with the IGAC sample. In fact, it explains 100% of the income per capita difference between the Andean region and the Caribbean, and 80%, 120% and 117% of the difference with the Pacific, Orinoco and Amazonia regions respectively. Appendices 5 and 6 present the decomposition exercises for GDP by area, with similar results.[23]

[23]It is worth pointing out that although the decomposition exercise shows that the differences in *regional* per capita income are mostly explained by distance to domestic markets, this does not imply that *global* income differences are also explained by this variable. In fact, if the sample is divided not into regions but into poor and rich municipalities, the variable distance to domestic markets loses part of its relevance.

Table 8

Per Capita Income - Differences by Region (IGAC Sample)

Andean Region vs	**Carib-bean**	**Pacific**	**Orinoco**	**Amazon-ia**	**Carib-bean**	**Pacific**
Difference	0.8429	0.8539	-0.6351	-0.2295	100.00%	100.00%
Geography	0.6149	0.5769	-0.0647	0.5391	72.95%	67.56%
Precipitation	-0.0391	0.0110	0.1840	0.2040	-4.64%	1.29%
Altitude	1.9845	-0.1118	0.7599	0.8753	235.44%	-13.09%
Altitude^2	-1.8362	0.1394	-0.8846	-1.0085	-217.84%	16.33%
Soil Suitability Index	-0.1776	-0.0791	-0.2344	-0.1869	-21.07%	-9.26%
Distance to Domestic Markets	0.7619	0.5201	0.0341	0.8806	90.39%	60.91%
Cauca River	0.0114	0.0212	-0.0032	-0.0032	1.35%	2.48%
Magdalena River	0.0082	-0.0037	-0.0037	-0.0037	0.97%	-0.43%
Rivers (Kilometers)	-0.0246	-0.0110	-0.1305	-0.3460	-2.92%	-1.29%
Water Availability Index	-0.1654	-0.0653	-0.8772	-0.9658	-19.62%	-7.65%
Water Availability Index^2	0.1922	0.1068	1.1439	1.2540	22.80%	12.51%
Proportion of Flat Land	-0.1004	0.0493	-0.0530	-0.1607	-11.91%	5.77%
Infrastructure	-0.0249	-0.0656	0.0479	0.0035	-2.95%	-7.68%
Road Density 1970	-0.0051	-0.0050	0.0415	0.0122	-0.61%	-0.59%
Road Density Growth	0.0141	0.0072	-0.0170	0.0427	1.67%	0.84%
Proportion of Households with Electricity 1973	-0.0259	-0.0557	0.0347	-0.0799	-3.07%	-6.52%
Index of Quality and Availability of Roads	-0.0080	-0.0121	-0.0113	0.0285	-0.95%	-1.42%
Human Capital	-0.0146	0.0799	-0.5564	-0.6234	-1.73%	9.36%
Primary and Secondary School Enrollment 1973	0.0699	0.0165	0.1293	-0.0056	8.29%	1.93%
Migration Rate 1973	0.0337	-0.0124	-0.6817	-0.6321	4.00%	-1.45%
College Graduates per 1,000 of Labor Force 1973	-0.0797	0.0069	-0.0595	-0.0552	-9.46%	0.81%
Deaths from Tropical Disease per 1,000 (1979)	-0.0385	0.0689	0.0555	0.0695	-4.57%	8.07%

Table 8, *continued*						
Institutions and Standards of Living	0.1807	0.1546	0.0881	0.1382	21.44%	18.11%
Interaction between Soil and Degree of Urbanization 1973	0.1728	0.0714	0.1674	0.1846	20.50%	8.36%
Proportion of Land with Coffee Crops 1980	-0.0682	-0.0094	-0.0544	-0.0708	-8.09%	-1.10%
Income Inequality 1973	-0.0228	0.0043	-0.0468	0.0053	-2.70%	0.50%
Annual Per Capita Municipal Transfers (1973-1995)	0.0989	0.0883	0.0219	0.0191	11.73%	10.34%
Total Explained by the Regression	**0.7561**	**0.7458**	**-0.4851**	**0.0574**	**89.70%**	**87.34%**
Residual Unexplained by the Regression	**0.0868**	**0.1081**	**-0.1500**	**-0.2869**	**10.30%**	**12.66%**

Decomposition of Income Per Capita Growth

Tables 9 and 10 present decomposition exercises of income per capita growth. The non-weighted growth difference between the Andean and Caribbean regions is 4.89 percentage points. Geographical variables account for 3.02 percentage points or 61.2% of the difference. Distance from domestic markets explains most of the difference in income per capita growth rates between the Andean and Caribbean regions. The same variable also explains most of the growth difference between the Andean and Pacific regions. This is a novel and important result, which may indicate that agglomeration economies and large market externalities are the leading forces driving average income growth in Colombian regions. Other geographical variables that account for growth differences are precipitation and soil suitability, although both less than distance from domestic markets.

Table 9

Per Capita Income Growth - Differences by Region (Total Sample)

Andean Region vs	**Carib-bean**	**Pacific**	**Orinoco**	**Amazonia**	**Caribean**	**Pac**
Difference	0.0489	0.0228	0.0161	0.0453	100.00%	100.
Per Capita Income 1973	0.0096	-0.0097	0.028	0.0336		
Geography	**0.0302**	**0.0220**	**0.0017**	**0.0409**	**61.76%**	**96.6**
Precipitation	-0.0024	0.0018	0.0063	0.0053	-4.91%	7.8
Altitude	0.0388	0.0063	0.0154	0.0147	79.35%	27.6
Altitude^2	-0.0343	-0.0047	-0.0170	-0.0159	-70.14%	-20.
Soil Suitability Index	-0.0050	-0.0011	-0.0055	-0.0007	-10.22%	-4.8
Distance to Domestic Markets	0.0334	0.0206	0.0070	0.0441	68.30%	90.3
Cauca River	0.0001	0.0003	-0.0002	-0.0002	0.20%	1.3
Magdalena River	0.0001	-7E-05	-7.22E-05	-7.22E-05	0.20%	-0.3
Rivers (Kilometers)	-0.0005	-0.0011	-0.0042	-0.0063	-1.02%	-4.8
Infrastructure	**-0.0006**	**-0.0005**	**0.0009**	**-0.0022**	**-1.23%**	**-2.1**
Road Density 1970	-0.0001	0.0002	0.0005	0.0013	-0.20%	0.8
Proportion of Households with Electricity 1973	-0.0005	-0.0007	0.0004	-0.0035	-1.02%	-3.0
Human Capital	**0.0004**	**0.0038**	**-0.0148**	**-0.0165**	**0.82%**	**16.6**
Primary and Secondary School Enrollment 1973	0.0031	0.0013	0.0014	-0.0090	6.34%	5.7
Migration Rate 1973	0.0013	-0.0001	-0.0189	-0.0104	2.66%	-0.4
College Graduates per 1,000 of Labor Force 1973	-0.0016	0.0002	-0.0010	-0.0024	-3.27%	0.8
Deaths from Tropical Disease per 1,000 (1979)	-0.0024	0.0024	0.0037	0.0053	-4.91%	10.5

Table 9, *continued*						
Institutions and Standards of Living	**0.0003**	**0.0008**	**0.0002**	**0.0005**	**0.61%**	**3.5**
Interaction between Soil and Degree of Urbanization 1973	0.0029	0.0007	0.0028	0.0031	5.93%	3.0
Proportion of Land with Coffee Crops 1980	-0.0024	-0.0004	-0.0022	-0.0025	-4.91%	-1.7
Income Inequality 1973	-0.0002	0.0005	-0.0004	-0.0001	-0.41%	2.1
Total Explained by the Regression	**0.0303**	**0.0261**	**-0.0120**	**0.0227**	**61.96%**	**114.**
Residual Unexplained by the Regression	**0.0186**	**-0.0033**	**0.0281**	**0.0226**	**38.04%**	**-14.**
Note: Andean region excludes Bogotá						

The effect of infrastructure on regional growth differences is small, as observed in Table 9. Enrollment rates in primary and secondary education, and the incidence of tropical diseases, account for a little more of the regional growth differences. Enrollment rates and tropical diseases explain 5.7% and 10.7% of the growth differences between the Andean and Pacific regions, respectively. Similar results are obtained when using the IGAC sample, as can be seen in Table 10. A decomposition of GDP growth per land area, using both total and IGAC samples, is found in Appendices 7 and 8.

Table 10

Per Capita Income Growth - Differences by Region (GAC Sample)

Andean Region vs	**Carib-bean**	**Pacific**	**Orinoco**	**Amazonia**	**Carib-bean**	
Difference	0.0440	0.0247	-0.0115	0.0438	100.00%	1
Per Capita Income 1973	0.0041	-0.0082	0.0106	0.0335		
Geography	0.0308	0.0253	0.0047	0.0331	70.06%	1
Precipitation	-0.0017	0.0005	0.0083	0.0092	-3.86%	
Altitude	0.0747	-0.0042	0.0286	0.0329	169.77%	-
Altitude^2	-0.0665	0.0050	-0.0320	-0.0365	-151.14%	
Soil Suitability Index	-0.0055	-0.0024	-0.0073	-0.0058	-12.50%	
Distance to Domestic Markets	0.0325	0.0222	0.0014	0.0375	73.86%	
Cauca River	0.0004	0.0009	-0.0001	-0.0001	0.91%	
Magdalena River	2.74E-05	-1.23E-05	-1.23E-05	-1.23E-05	0.06%	
Rivers (Kilometers)	-0.0008	-0.0003	-0.0043	-0.0114	-1.82%	
Water Availability Index	-0.0087	-0.0034	-0.0464	-0.0511	-19.77%	-
Water Availability Index^2	0.0098	0.0054	0.0583	0.0639	22.27%	
Proportion of Flat Land	-0.0034	0.0016	-0.0018	-0.0055	-7.73%	
Infrastructure	-0.0008	-0.0015	-0.0001	-0.0004	-1.72%	
Road Density 1970	4.42E-05	4.36E-05	-0.0003	-0.0001	0.10%	
Proportion of Households with Electricity 1973	-0.0005	-0.0010	0.0006	-0.0015	-1.14%	
Index of Quality and Availability of Roads	-0.0003	-0.0005	-0.0004	0.0012	-0.68%	
Human Capital	0.0007	0.0028	-0.0215	-0.0246	1.59%	
Primary and Secondary School Enrollment 1973	0.0030	0.0007	0.0056	-0.0002	6.82%	
Migration Rate 1973	0.0013	-0.0005	-0.0275	-0.0254	2.95%	
College Graduates per 1,000 of Labor Force 1973	-0.0022	0.0001	-0.0016	-0.0015	-5.00%	
Deaths from Tropical Disease per 1,000 (1979)	-0.0014	0.0025	0.0020	0.0025	-3.18%	

Table 10, *continued*						
Institutions and Standards of Living	0.0028	0.0024	0.0019	0.0045	6.36%	
Interaction between Soil and Degree of Urbanization 1973	0.0058	0.0024	0.0057	0.0062	13.18%	
Proportion of Land with Coffee Crops 1980	-0.0019	-0.0002	-0.0015	-0.0019	-4.32%	
Income Inequality 1973	-0.0011	0.0002	-0.0023	0.0002	-2.50%	
Total Explained by the Regression	**0.0336**	**0.0290**	**-0.0150**	**0.0126**	**76.30%**	**1**
Residual Unexplained by the Regression	**0.0104**	**-0.0043**	**0.0035**	**0.0312**	**23.70%**	**-**

Effects of Geography on Municipal Income Inequality

Table 9 shows the effect of the different geographical variables on income per capita inequality between municipalities. To carry out the study we had to calculate the original income per capita Gini coefficient of the Colombian municipalities, using municipal population as a weighted variable. Then, in order to calculate the effect of each variable on the Gini coefficient, we estimated income per capita under the assumption that this variable is equal to the average in every municipality; by using the new income estimation we calculated a new Gini coefficient. Thus, estimated income is as follows:

$$Y_{iN} = Y_i - b_i(X_{ik} - X_{Ak}) \quad (5)$$

Where Y_{iN} is the new municipal income per capita, Y_i is the original income per capita and $-b_i(X_{ik} - X_{Ak})$ is an expression that the municipal value of X subtracts from income and adds to it the average value of this variable. A new Gini coefficient is then calculated, based on Y_{iN}. Table 11 shows the result of the exercise. The original Gini coefficient is equal to 0.606; after accounting for geographical variables a Gini of 0.609 is obtained. Although that is the compound effect of all geographical variables, some of these variables have an important impact on municipal inequality. For instance, if it is assumed that either distance to domestic markets or altitude are equal for all municipalities, the Gini coefficient reaches 0.63 in the first case and 0.647 in the second.

Infrastructure variables have a greater impact on Gini than geography does, although this impact depends basically upon 1973 household electrical coverage. Thus, had this variable been equal (in 1973) the 1995 income per capita Gini coefficient would have been 0.482 (Table 11). Human capital variables have the strongest impact on the Gini coefficient (Table 11). Had the 1973 value of this variable been equal for all municipalities, the 1995 Gini coefficient would have been just 0.388. Both 1973 enrollment rates and 1973 college graduates per thousand people have a large impact on the Gini coefficient. Finally, the institutional and standard of living variables as a whole have a moderate impact on the municipal Gini coefficient. The effect of the 1973 poverty rate is, however, considerable: had the rate been equal in all municipalities (in 1973), the 1995 Gini coefficient would have

been 0.514. The same exercise was carried out using the IGAC sample and the results obtained were fairly similar to those obtained when using the whole sample (Table 11).

Table 11

EFFECTS OF DIFFERENT VARIABLES ON MUNICIPAL INCOME INEQUALITIES

	Total Sample		IGAC Sample	
	Gini	**% Change**	**Gini**	**% Change**
Initial Gini	**60.62**		**60.11**	
Recalculated after acounting by:				
Geography	**59.20**	**-2.34%**	**59.43**	**-1.12%**
Precipitation	59.25	-2.25%	59.87	-0.39%
Altitude	61.46	1.39%	60.75	1.07%
Soil Suitability Index	59.95	-1.10%	59.49	-1.03%
Distance to Domestic Markets	60.90	0.47%	64.22	6.85%
Cauca River	60.27	-0.57%	60.28	0.29%
Magdalena River	60.55	-0.11%	60.20	0.15%
Rivers (kilometers)	61.43	1.34%	58.70	-2.35%
Water availability index			61.08	1.62%
Proportion of flat land			59.06	-1.74%
Infrastructure	**47.55**	**-21.56%**	**52.57**	**-12.53%**
Road Density 1970	60.30	-0.53%	60.11	0.02%
Road Density Growth	60.78	0.26%	60.19	0.14%
Proportion of Households with Electricity	47.87	-21.03%	53.15	-11.57%
Index of Quality and Availability of Roads			59.68	-0.71%
Human Capital	**34.13**	**-43.70%**	**39.50**	**-34.28%**
Primary and Secondary School Enrollment 1973	49.63	-18.12%	53.51	-10.97%
Migration Rate 1973	60.07	-0.90%	55.47	-7.71%
College Graduates per 1,000 of the Labor force	43.42	-28.37%	48.73	-18.93%
Deaths from Tropical Diseases per 1,000 (1979)	61.11	0.81%	61.38	2.12%
Institutions and Standards of Living	**68.23**	**12.56%**	**69.51**	**15.64%**
Interaction between Soil and Degree of Urbanization 1973	65.77	8.50%	65.79	9.46%
Proportion of Land with Coffee Crops 1980	59.97	-1.07%	59.13	-1.62%
Income Inequality 1973	60.59	-0.05%	60.67	0.93%
Per Capita Municipal Transfers (average 1973-1995)	64.10	5.74%	64.53	7.36%

The results of the municipal income inequality exercises, however, may be flawed in that the division of the country into the traditional regions could hide the real sources of income differences. A global analysis based, for instance, on the Gini coefficient, shows that education and infrastructure explain most of the municipal income per capita differences. A regional analysis, on the other hand, shows that the differences come mainly from distance to markets. This implies that the use of the traditional regions may not be the

most suitable approach to the study of growth and development, at least in the Colombian case.

9. Conclusions

The objective of this document was to determine the relationship between geographical variables and income per capita, income per capita growth, population density and population growth in Colombian municipalities. In order to carry out econometric estimations at the municipal level we constructed a set of geographical variables based on soil, climate and road maps. Additionally, we extracted some other geographical variables from the homogeneous zone statistics of the Colombian Institute of Geography (IGAC).

We found that geography affects both the level of municipal income per capita and its growth, explaining between 36% and 47% of municipal income per capita variation and between 35% and 40% of municipal income per capita growth variation. It was established that, amongst the geographical variables, distance to domestic markets and soil suitability have the largest influence both on income per capita and income per capita growth. The distance to domestic markets is quite important. The evidence shows that in the last decades there has been a spatial income concentration towards Bogotá, the main Colombian market.

Another important finding was that geographical variables seem to be more significant for poor municipalities than for rich ones. In poor municipalities, geography explains between 25% and 32% of income per capita variation and between 24% and 27% of income per capita growth variation. In contrast, in rich municipalities, geography is less important, explaining between 18% and 25% of income per capita variation and between 16% and 17% of income per capita growth variation.

Thus, geography affects income and income growth through the productivity of land, the availability of natural resources such as water and rivers, the presence of tropical diseases and agglomeration. While geography influences the fate of a region, that is not, however, the end of the story. Human factors play an important role, either through public policy or private intervention. Education, infrastructure and better institutions can boost regional economic growth and help poor regions to overcome the poverty trap of low income and low economic growth.

Geography also affects population density. It was found that this variable is determined by precipitation levels, altitude and soil suitability. The more densely populated municipalities are also closer to domestic markets and further from seaports. Population density is also influenced by the availability of infrastructure and access to social services.

In the last section of the paper we carried out some decomposition studies to determine the role of geography in explaining income per capita differences between the Colombian regions. The exercises show that geography accounts for more than 70% of income per capita differences between the Andean and Caribbean regions. A similar figure is evident with respect to the rest of Colombian regions. Human capital and infrastructure variables were found to be much less important when explaining income differences.

Finally, we measured the impact of geography on municipal income inequalities. The studies found that, as a whole, geography is neutral in terms of municipal income inequalities. However, precipitation levels and distance from seaports have a moderate effect on this variable. Differences in infrastructure and human capital variables seem to affect municipal inequalities much more.

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Appendix 1
Determinants of Municipal GDP Per Land Area

Dependent Variable: GDP per Area	Total Sample (1)	Total Sample (2)	IGAC Sample (3)	IGAC Sample (4)
Constant	31.2176 (17.657)***	23.3983 (14.690)***	23.1622 (9.491)***	18.8403 (8.458)***
Geographical Variables				
Precipitation	-0.9847 (-8.098)***	-0.5369 (-6.2803)***	-1.0257 (-7.079)***	-0.4970 (-4.406)***
Altitude	-0.0522 (-0.222)	0.1269 (0.957)	0.4067 (1.785)*	0.4337 (2.614)***
Altitude^2	0.0100 (0.462)	-0.0112 (-0.867)	-0.0271 (-1.303)	-0.0390 (-2.539)**
Soil Suitability Index	1.4384 (10.332)***	0.7021 (5.652)***	1.2119 (8.099)***	0.7670 (5.764)***
Distance to Domestic Markets	-1.8431 (-10.967)***	-1.2898 (-10.287)***	-1.5605 (-8.952)***	-1.1450 (-7.889)***
Water Availability Index			6.4698 (2.587)***	3.3947 (1.926)*
Water Availability Index^2			-2.8728 (-2.578)**	-1.8544 (-2.367)**
Proportion of Flat Lands			0.4892 (2.037)**	0.4191 (2.431)**
Cauca River	-0.0278 (-0.082)	-0.3354 (-1.584)	-0.1952 (-0.530)	-0.3695 (-1.374)
Magdalena River	-0.1633 (-0.675)	0.0480 (0.307)	-0.3044 (-1.310)	-0.0872 (-0.522)
River (in Kilometers)	-0.2060 (-1.816)*	-0.1767 (-2.430)**	-0.0268 (-0.223)	-0.1135 (-1.257)
Infrastructure Variables				
Proportion of Households with Electricity 1973		2.5174 (10.107)***		2.2508 (8.276)***
Road Density 1970		0.3281 (10.646)***		0.2201 (5.649)***
Road Density Rate of Growth		2.6573 (6.448)***		1.6575 (3.266)***
Index of Quality and Availability of Roads				
Human Capital				
Migration Rate 1973		1.1248 (2.246)**		1.4280 (2.351)**
Primary and Secondary School Enrollment 1973		2.5344 (5.729)***		2.6828 (5.209)***
College Graduates per 1,000 of the Labor Force 1973		0.0916 (8.281)***		0.1114 (7.016)***
Deaths from Tropical Diseases per 1,000 (1979)		-0.0741 (-1.806)*		-0.0330 (-0.724)

Appendix 1, *continued*				
Institutions and Living Standards				
Interaction Between Soil and Degree of Urbanization (1973)		-0.2214 (-3.194)***		-0.3228 (-4.454)***
Proportion of Land with Coffee Crops 1980		0.0106 (2.666)***		0.0181 (3.597)***
Income Inequality 1973		0.0259 (0.273)		-0.1259 (-0.9679)
Per Capita Municipal Transfers (Yearly Average 1973-95)		-0.4683 (-4.488)***		-0.3021 (-2.421)**
Number of Observations R2	873 0.3422	872 0.6955	613 0.3548	612 0.6875

*Significant at 90%
**Significant at 95%
***Significant at 99%

Appendix 2

Quantile Regressions of GDP Per Land Area

Dependent Variable	Total Sample		Total Sample		IGAC Sample	
	poorest 25%	richest 25%	poorest 25%	richest 25%	poorest 25%	richest 25%
Constant	31,2073	28,3463	21,6468	23,9899	24,2121	21,8126
	(21,075)***	(10,612)***	(17,121)***	(10,877)***	(9,529)***	(4,993)***
Geographical Variables						
Precipitation	-0.8059	-0.9590	-0.5427	-0.5952	-0.7879	-0.9666
	(-7.821)***	(-4.877)***	(-7.789)***	(-5.292)***	(-5.180)***	(-3.052)***
Altitude	0.2101	-0.1765	0.4008	-0.0807	0.4693	-0.0656
	(1.323)	(-0.563)	(3.577)***	(-0.472)	(2.020)***	(-0.127)
Altitude^2	-0.0150	0.0251	-0.0376	0.0044	-0.0350	0,0153
	(-0.967)	(0.842)	(-3.380)***	(0.270)	(-1.640)	(0,330)
Soil Suitability Index	1.3707	1.6440	0.5757	0.7033	1.2627	1.4576
	(11.306)***	(7.074)***	(5.310)***	(4.386)***	(8.083)***	(4.442)***
Distance to Domestic Markets	-1.9250	-4.3498	-1.5104	-1.1272	-1.7107	-1.3055
	(-13.186)***	(-4.981)***	(-14.873)***	(-6.356)***	(-9.645)***	(-3.610)***
Water Availability Index					6.3558	5.9675
					(2.579)***	(1.437)
Water Availability Index^2					-2.8220	-2.5619
					(-2.554)**	(-1.367)
Proportion of Flat Lands					0.2819	0.6090
					(1.102)	(1.330)
Cauca River	-0.1440	0.2517	-0.3195	-0.1470	-0.3159	0.3475
	(-0.527)	(0.533)	(-1.783)*	(-0.544)	(-0.828)	(0.483)
Magdalena River	-0.3360	0.1078	-0.0884	0.0675	-0.3819	-0.0444
	(-1.688)*	(0.305)	(-0.676)	(0.341)	(-1.658)*	(-0.099)
Rivers (kilometers)	-0.4411	-0.1471	-0.1067	-0.2302	-0.3036	0.0986
	(-5.603)***	(-0.928)	(-1.888)*	(-2.422)**	(-2.596)***	(0.415)

Appendix 2, *continued*						
Infrastructure Variables						
Proportion of Households			2.0709	2.7089		
with Electricity 1973			(9.032)***	(8.593)***		
Road Density 1970			0.4173	0.2629		
			(17.165)***	(6.276)***		
Road Density Rate of Growth			3.3873	2.0428		
			(10.294)***	(3.627)***		
Index of Quality and Availability of Roads						
Human Capital						
Migration Rate 1973			0.6813	1.1260		
			(1.527)	(1.729)*		
Primary and Secondary School Enrollment 1973			2.3770	2.4113		
			(6.059)***	(4.320)***		
College Graduates per 1,000 of			0.1064	0.1367		
the Labor Force 1973			(9.264)***	(10.608)***		
Deaths from Tropical Diseases			-0.5600	-0.2361		
per 1,000 (1979)			(-9.188)***	(-3.444)***		
Institutions and Living Standards						
Interaction Between Soil and Degree			-0.1248	-0.2910		
of Urbanization (1973)			(-1.903)*	(-3.436)***		
Proportion of Land with Coffee Crops 1980			0.0126	0.0094		
			(3.471)***	(1.875)*		
Income Inequality 1973			0.1295	-0.0213		
			(1.465)	(-0.187)		
Per Capita Municipal Transfers			-0.2406	-0.2919		
(Yearly Average 1973-95)			(-2.650)***	(-2.086)**		
Number of Observations	873	873	872	872	613	613
R2	0.2430	0.1751	0.4368	0.4794	0.2348	0.2019
*Significant at 90%						
**Significant at 95%						
***Significant at 99%						

Appendix 3

Determinants of Municipal GDP Per Land Area Growth

Dependent Variable	**Total Sample**	**Total Sample**	**IGAC Sample**	**IGAC Sample**
	(1)	**(2)**	**(3)**	**(4)**
Constant	0.1218	0.3065	-0.0083	0.2073
	(2.063)**	(5.625)***	(-0.101)	(2.725)***
GDP Per Land Area 1973	-0.0037	-0.0141	-0.0038	-0.0151
	(-3.268)***	(-11.487)***	(-2.569)***	(-9.486)***
Geographic Variables				
Precipitation	-0.0058	-0.0066	-0.0171	-0.0103
	(-1.698)*	(-2.171)**	(-3.831)***	(-2.532)**
Altitude	-0.0021	-0.0029	0.0138	0.0097
	(-0.412)	(-0.641)	(2.019)**	(1.625)
Altitude^2	0.0004	0.0003	-0.0007	-0.0007
	(0.925)	(0.855)	(-1.175)	(-1.259)
Soil Suitability Index	0.0194	0.0155	0.0247	0.0210
	(4.752)***	(3.536)***	(5.360)***	(4,296)***
Distance to Domestic Markets	-0.0323	-0.0321	-0.0284	-0.0275
	(-6.621)***	(-7.307)***	(-5.233)***	(-5.412)***
Water Availability Index	-0.0077	-0.0069	-0.0176	-0.0171
	(-0.912)	(-0.930)	(-1.598)	(-1.766)*
Water Availability Index^2	-0.0085	-0.0065	-0.0017	-0.0044
	(-1.332)	(-1.186)	(-0.247)	(-0.741)
Proportion of Flat Lands	0.0149	0.0029	0.0149	0.0020
	(5.278)***	(1.145)	(4.078)***	(0.627)
Rivers (kilometers)			0.2320	0.1542
			(3.090)***	(2.425)**
Cauca River			-0.1037	-0.0822
			(-3.101)***	(-2.910)***
Magdalena River			0.0087	0.0126
			(1.218)	(2.015)**
Infrastructure Variables				
Proportion of Households		0.0724		0.0685
with Electricity 1973		(8.245)***		(6.907)***
Road Density 1970		0.0027		-0.0001
		(2.915)***		(-0.329)
Index of Quality and Availability of Roads				0.0149
				(2.584)***
Human Capital				
Migration Rate 1973		0.0865		0.0789
		(4.969)***		(3.584)***
Primary and Secondary School Enrollment 1973		0.0719		0.0696
		(4.604)***		(3.686)***
College Graduates per 1,000 of		0.0016		0.0018
the Labor Force 1973		(4.010)***		(3.125)***
Deaths from Tropical Diseases		-0.0012		0.0030
per 1,000 (1979)		(-0.384)		(1.809)*

Appendix 3, *continued*				
Institutions and Living Standard				
Interaction Between Soil and Degree		-0.0075		-0.0105
of Urbanization (1973)		(-3.161)***		(-4.026)***
Proportion of Land with Coffee Crops 1980		-0.0001		4.01E-05
		(-1.248)		(0.214)
Income Inequality 1973		-0.0043		-0.0131
		(-1.298)		(-2.798)***
Number of Observations	873	872	613	612
R2	0.1209	0.3739	0.1997	0.4320
*Significant at 90%				
**Significant at 95%				
***Significant at 99%				

Appendix 4

Quantile Regressions of Municipal GDP Per Land Area Growth

Dependent Variable	Total sample		Total Sample		IGAC Sample		IGAC Sample	
	25% poorest	25% richest	25% poorest	25% richest	25% poorest	25% richest	25% poorest	25% richest
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	0.0842	0.2012	0.1913	0.3319	-0.0630	0.0783	0.0481	0.3254
	(1.325)	(2.377)**	(2.884)***	(4.283)***	(-0.634)	(0.825)	(0.655)	(4.688)***
GDP Per Land Area 1973	-0.0031	-0.0031	-0.0111	-0.0138	-0.0031	-0.0021	-0.0144	-0.0161
	(-2.680)***	(-1.746)*	(-7.519)***	(-7.688)***	(-1.737)*	(-1.041)	(-8.444)***	(-10.304)***
Geographic Variables								
Precipitation	-0.0028	-0.0060	-0.0062	-0.0079	-0.0054	-0.0235	-0.0058	-0.0133
	(-0.759)	(-1.227)	(-1.665)*	(-1.923)*	(-0.966)	(-3.938)***	(-1.472)	(-3.538)***
Altitude	0.0023	-0.0129	0.0025	-0.0109	0.0150	0.0165	0.0093	0.0079
	(0.412)	(-1.692)*	(0.435)	(-1.766)*	(1.795)*	(1.178)*	(1.504)	(1.392)
Altitude^2	0.0001	0.0011	-0.0000	0.0011	-0.0008	-0.0011	-0.0005	-0.0005
	(0.269)	(1.564)	(-0.050)	(1.923)*	(-1.082)	(-1.323)	(-1.001)	(-1.081)
Soil Suitability Index	0.0161	0.0245	0.0153	0.0159	0.0184	0.0322	0.0170	0.0237
	(3.499)***	(4.328)***	(2.509)**	(2.708)***	(3.031)***	(5.374)***	(3.042)***	(6.022)***
Distance to Domestic Markets	-0.0369	-0.0325	-0.0328	-0.0270	-0,0396	-0.0270	-0.0298	-0.0220
	(-6.554)***	(-4.778)***	(-6.082)***	(-4.209)***	(-5.644)***	(-4.009)***	(-5.873)***	(-4.618)***
Water Availability Index					0.2423	0.0819	0.2517	0.0584
					(2.537)**	(1.185)	(4.424)***	(1.328)
Water Availability Index^2					-0.1037	-0.0299	-0.1202	-0.0343
					(-2.395)**	(-0.959)	(-4.754)***	(-1.779)*
Proportion of Flat Lands					0.0238	-0.0004	0.0200	0.0028
					(2.376)**	(-0.051)	(3.108)***	(0.550)
Rivers (kilometers)	0.0144	0.0124	0.0067	0.0024	0.0126	0.0174	0.0039	-0.0027
	(4.352)***	(3.035)***	(1.946)*	(0.653)	(2.550)**	(3.879)***	(1.126)	(-0.965)
Cauca River	0.0068	0.0076	-0.0054	-0.0025	-0.0058	0.0058	-0.0186	-0.0190
	(0.674)	(0666)	(-0.589)	(-0.259)	(-0.395)	(0.448)	(-2.063)**	(-2.327)**
Magdalena River	-0.0075	-0.0037	-0.0059	0.0003	0.0018	0.0020	-0.0023	0.0029
	(-0.995)	(-0.435)	(-0.878)	(0.052)	(0.194)	(0.242)	(-0.388)	(0.564)

Appendix 4, *continued*								
Infrastructure Variables								
Proportion of Households			0.0665	0.0512			0.0638	0.0579
with Electricity 1973			(5.513)***	(4.288)***			(5.472)***	(6.842)***
Road Density 1970			0.0028	0.0018			-0.0000	-0.0005
			(2.478)**	(1.414)			(-0.100)	(-1.168)
Index of Quality and Availability of Roads							0.0190	0.0215
							(3.090)***	(4.783)***
Human Capital								
Migration Rate 1973			0.0941	0.1255			0.0762	0.1201
			(4.185)***	(5.412)***			(3.106)***	(6.942)***
Primary and Secondary School Enrollment 1973			0.0719	0.0731			0.0865	0.0601
			(3.505)***	(3.427)***			(4.263)***	(3.525)***
College Graduates per 1,000 of			0.0016	0.0019			0.0028	0.0023
the Labor Force 1973			(3.345)***	(4.229)***			(4.173)***	(5.089)***
Deaths from Tropical Diseases			0.0039	-0.0010			0.0056	0.0081
per 1,000 (1979)			(1.177)	(-0.335)			(2.460)**	(3.582)***
Institutions and Living Standards								
Interaction Between Soil and Degree			-00099	-0.0061			-0.0124	-0.0103
of Urbanization (1973)			(-2.824)***	(-2.013)**			(-3.884)***	(-5.095)***
Proportion of Land with Coffee Crops 1980			-0.0001	-0.0001			0.0002	-0.0000
			(-0.997)	(-0.929)			(1.601)	(-0.203)
Income Inequality 1973			-0.0025	-0.0078			-0.0053	-0.0163
			(-0.660)	(-1.687)*			(-1.004)	(-4.196)***
Number of Observations	873	873	872	872	613	613	612	612
R2	0.0885	0.0549	0.3321	0.2274	0.1195	0.1169	0.2574	0.2806
*Significant at 90%								
**Significant at 95%								
***Significant at 99%								

Appendix 5

Decomposition of GDP Per Land Area by Region (Total Sample)

Andean Region vs	**Carib-bean**	**Pacific**	**Orinoco**	**Amazonia**	**Caribean**	**Pacific**	**O**
Difference	0.5633	0.9365	0.9258	1.5361	100.00%	######	#
GDP Per Land Area 1973	**0.4929**	**0.6464**	**0.3610**	**1.6120**	**87.50%**	######	**3**
Geography	-0.1435	0.1085	0.3663	0.3093	-25.47%	11.59%	3
Precipitation	0.4460	0.0725	0.1774	0.1693	79.18%	7.74%	1
Altitude	-0.4162	-0.0573	-0.2062	-0.1935	-73.89%	-6.12%	-2
Altitude^2	-0.2804	-0.0670	-0.3099	-0.0444	-49.78%	-7.15%	-3
Soil Suitability Index	0.8664	0.5344	0.1837	1.1432	153.81%	57.06%	1
Distance to Domestic Markets	0.0054	0.0098	-0.0071	-0.0071	0.96%	1.05%	-
Cauca River	-0.0050	0.0025	0.0025	0.0025	-0.89%	0.27%	(
Magdalena River	0.0202	0.0430	0.1543	0.2327	3.59%	4.59%	1
Rivers (kilometers)	**-0.0619**	**0.0954**	**0.3814**	**0.4662**	**-10.99%**	######	**4**
Infrastructure	-0.0841	0.1722	0.3503	0.8960	-14.93%	18.39%	3
Road Density 1970	0.0855	0.0114	-0.0223	-0.0097	15.18%	1.22%	-
Proportion of Households with Electricity 1973	-0.0633	-0.0882	0.0534	-0.4201	-11.24%	-9.42%	5
Human Capital	**-0.0621**	**0.1025**	**-0.1987**	**-0.5027**	**-11.02%**	######	**-2**
Primary and Secondary School Enrollment 1973	0.0972	0.0431	0.0456	-0.2812	17.26%	4.60%	4
Migration Rate 1973	0.0159	-0.0023	-0.2313	-0.1282	2.82%	-0.25%	-2
College Graduates per 1,000 of the Labor Force (1973)	-0.1311	0.0182	-0.0799	-0.1896	-23.27%	1.94%	-
Deaths from Tropical Diseases per 1,000 (1979)	-0.0441	0.0435	0.0669	0.0963	-7.83%	4.64%	7
Institutions and Living Standard	**0.1702**	**-0.0430**	**0.2939**	**0.4333**	**30.21%**	**-4.59%**	**3**
Interaction Between Soil and Degree of Urbanization 1973	0.2108	0.0511	0.2058	0.2264	37.42%	5.46%	2
Proportion of Land with Coffee Crops 1980	0.0630	0.0126	0.0563	0.0654	11.18%	1.35%	(
Income Inequality 1973	0.0020	-0.0052	0.0044	0.0019	0.36%	-0.56%	(
Per Capita Municipal Transfers (yearly 1973-1995)	-0.1056	-0.1015	0.0274	0.1396	-18.75%	######	2
Total Explained by the Regression	**0.5391**	**0.8013**	**0.8376**	**2.0088**	**95.70%**	######	**9**
Residual Unexplained by the Regression	**0.0242**	**0.1352**	**0.0882**	**-0.4727**	**4.30%**	######	**9**

Note: Andean region excludes Bogotá.

Appendix 6

Decomposition of GDP Per land Area by Region (IGAC Sample)

Andean Region vs	**Caribbean**	**Pacific**	**Orinoco**	**Amazonia**	**Caribean**	**I**
Difference	0.8429	0.8539	-0.6351	-0.2295	100.00%	1(
GDP Per Land Area 1973	0.5135	0.5540	0.3008	1.3924	60.92%	6
Geography	-0.0789	0.0223	0.3714	0.4117	-9.36%	
Precipitation	1.6223	-0.0914	0.6215	0.7159	192.47%	-1
Altitude	-1.5539	0.1180	-0.7487	-0.8535	-184.35%	1
Altitude ^2	-0.2537	-0.1131	-0.3348	-0.2670	-30.10%	-1
Soil Suitability Index	0.7663	0.5231	0.0343	0.8858	90.91%	6
Distance to Domestic Markets	0.0104	0.0194	-0.0029	-0.0029	1.23%	
Cauca River	0.0059	-0.0026	-0.0026	-0.0026	0.70%	-
Magdalena River	0.0206	0.0092	0.1091	0.2893	2.44%	
Rivers (Kilometres)	-0.1455	-0.0575	-0.7718	-0.8497	-17.26%	-
Water Availability Index	0.1773	0.0985	1.0556	1.1572	21.03%	1
Water Availability Index^2	-0.0573	0.0281	-0.0303	-0.0918	-6.80%	
Proportion of Flat Lands	-0.1135	-0.2406	0.2752	0.0155	-13.47%	-2
Infrastructure	-0.0301	-0.0297	0.2432	0.0714	-3.57%	-
1970 Road Density	0.0314	0.0161	-0.0380	0.0955	3.73%	
Proportion of Households with electricity 1973	-0.0844	-0.1812	0.1128	-0.2596	-10.01%	-2
Index of Quality and Availability of Roads	-0.0304	-0.0458	-0.0428	0.1082	-3.61%	-
Human Capital	-0.0571	0.0769	-0.1159	-0.2892	-6.77%	
Primary and Secondary School Enrollment, 1973	0.1073	0.0254	0.1986	-0.0087	12.73%	
Migration 1973	0.0116	-0.0043	-0.2351	-0.2180	1.38%	-
College Graduates per 1,000 of the Labor Force 1973	-0.1522	0.0132	-0.1137	-0.1055	-18.06%	

Appendix 6, *continued*						
Deaths from Tropical Diseases per 1,000 (1979)	-0.0238	0.0426	0.0343	0.0430	-2.82%	4
Institutions and Standards of Living	0.2951	0.0704	0.3170	0.3925	35.01%	8
Interaction Between Soil and Degree of Urbanization 1973	0.3018	0.1247	0.2924	0.3224	35.80%	1
Proportion of Land with Coffee Crops 1980	0.0792	0.0109	0.0631	0.0821	9.40%	1
Income Inequality 1973	-0.0107	0.0020	-0.0219	0.0025	-1.27%	(
Per Capita Municipal Transfers (yearly 1973-1995)	-0.0752	-0.0672	-0.0166	-0.0145	-8.92%	-
Total Explained by theRegresion	**0.6380**	**0.4607**	**0.7771**	**1.5112**	**75.69%**	**5**
Residual Unexplained by theRegresion	**0.0868**	**0.1081**	**-0.1500**	**-0.2869**	**10.30%**	**1**

Appendix 7

Decomposition of GDP Per Land Area Growth by Region (Total Sample)

Andean Region vs	**Caribbean**	**Pacific**	**Orinoco**	**Amazonia**	**Caribbean**
Difference	0.0308	0.0026	-0.0174	-0.0195	100.00%
GDP Per Land Area 1973	0.0016	-0.0121	-0.018	-0.027	
Geography	**0.0168**	**0.0126**	**0.0019**	**0.0301**	**54.55%**
Precipitation	-0.0018	0.0013	0.0046	0.0039	-5.84%
Altitude	-0.0107	-0.0017	-0.0042	-0.0040	-34.74%
Altitude^2	0.0134	0.0018	0.0066	0.0062	43.51%
Soil Suitability Index	-0.0064	-0.0015	-0.0071	-0.0010	-20.78%
Distance to Domestic Markets	0.0218	0.0134	0.0046	0.0288	70.78%
Cauca River	0.0001	0.0002	-0.0001	-0.0001	0.32%
Magdalena River	0.0007	-0.0003	-0.0003	-0.0003	2.27%
Rivers (kilometers)	-0.0003	-0.0006	-0.0022	-0.0034	-0.97%
Infrastructure	**-0.0024**	**-0.0011**	**0.0043**	**-0.0046**	**-7.79%**
Road Density 1970	-0.0006	0.0014	0.0028	0.0073	-1.95%
Proportion of Households with Electricity 1973	-0.0018	-0.0025	0.0015	-0.0119	-5.84%
Human Capital	**0.0022**	**0.0007**	**-0.0184**	**-0.0225**	**7.14%**
Primary and Secondary School Enrollment 1973	0.0027	0.0012	0.0012	-0.0080	8.77%
Migration Rate 1973	0.0011	-0.0001	-0.0171	-0.0095	3.57%
College Graduates per 1,000 of the Labor Force 1973	-0.0023	0.0003	-0.0014	-0.0033	-7.47%
Deaths from Tropical Diseases per 1,000 (1979)	0.0007	-0.0007	-0.0011	-0.0017	2.27%
Institutions and Living Standard	**0.0064**	**0.0025**	**0.0060**	**0.0070**	**20.78%**
Interaction Between Soil and Degree of Urbanization 1973	0.0077	0.0018	0.0076	0.0083	25.00%
Proportion of Land with Coffee Crops 1980	-0.0010	-0.0002	-0.0009	-0.0010	-3.25%
Income Inequality 1973	-0.0003	0.0009	-0.0007	-0.0003	-0.97%
Total Explained by the Regression	**0.0230**	**0.0147**	**-0.0062**	**0.0100**	**74.68%**
Residual Unexplained by the Regression	**0.0078**	**-0.0121**	**-0.0112**	**-0.0295**	**25.32%**

Note: Andean region excludes Bogotá.

Appendix 8

Decomposition of GDP Per Land Area Growth by Region (IGAC Sample)

Andean Region vs	**Caribbean**	**Pacific**	**Orinoco**	**Amazonia**	**Caribbean**	
Difference	0.0260	-0.0273	-0.0264	0.0050	100.00%	1
GDP Per Land Area 1973	**-0.0013**	**-0.0063**	**-0.0202**	**-0.0127**		
Geography	0.0165	0.0131	0.0072	0.0269	63.46%	-
Precipitation	-0.0020	0.0005	0.0095	0.0105	7.33%	
Altitude	0.0357	-0.0020	0.0136	0.0157	-130.77%	
Altitude ^2	-0.0272	0.0020	-0.0131	-0.0149	99.63%	
Soil Suitability Index	-0.0080	-0.0036	-0.0106	-0.0085	29.30%	
Distance to Domestic Markets	0.0188	0.0128	0.0008	0.0217	-68.86%	-
Cauca River	0.0004	0.0008	-0.0001	-0.0001	-1.47%	
Magdalena River	0.0003	-0.0001	-0.0001	-0.0001	-1.10%	
Rivers (Kilometers)	-0.0003	-0.0001	-0.0018	-0.0049	1.10%	
Water Availability Index	-0.0070	-0.0027	-0.0374	-0.0411	25.64%	
Water Availability Index^2	0.0080	0.0044	0.0476	0.0522	-29.30%	-
Proportion of Flat Lands	-0.0022	0.0011	-0.0012	-0.0036	8.06%	
Infrastructure	-0.0032	-0.0065	0.0047	-0.0055	11.72%	
1970 Road Density	-0.0002	-0.0002	0.0020	0.0005	0.73%	
Proportion of Households with Electricity 1973	-0.0025	-0.0055	0.0034	-0.0079	9.16%	
Index of Quality and Availability of Roads	-0.0005	-0.0008	-0.0007	0.0019	1.83%	
Human Capital	0.0028	-0.0021	-0.0160	-0.0209	-10.26%	
Primary and Secondary School Enrollment, 1973	0.0030	0.0007	0.0056	-0.0002	-10.99%	
Migration 1973	0.0008	-0.0003	-0.0175	-0.0163	-2.93%	
College Graduates per 1,000 of the Labor Force 1973	-0.0025	0.0002	-0.0019	-0.0017	9.16%	
Deaths from Tropical Diseases per 1,000 (1979)	0.0015	-0.0027	-0.0022	-0.0027	-5.49%	
Institutions and Standards of Living	0.0091	0.0046	0.0070	0.0117	-33.33%	-
Interaction Between Soil and Degree of Urbanization 1973	0.0105	0.0043	0.0101	0.0112	-38.46%	-
Proportion of Land with Coffee Crops 1980	0.0002	3.99E-05	0.0002	0.0002	-0.73%	
Income Inequality 1973	-0.0016	0.0003	-0.0033	0.0003	5.86%	
Total Explained by the Regression	**0.0252**	**0.0091**	**0.0029**	**0.0122**	**-92.31%**	-
Residual Unexplained by the Regression	**0.0868**	**0.1081**	**-0.1500**	**-0.2869**	**-317.95%**	-4

Appendix 9

The aim of quantile regression is to estimate the median of the dependent variable. However, this method could also be used to estimate any quantile of the dependent variable. This method is very similar to ordinary least squares, but quantile regression looks for a line through the data that minimizes the sum of the absolute residuals rather than the sum of the squares of the residuals.

This method is very useful when the data display heteroskedasticity. The quantile regression methodology estimates the variance-covariance matrix of the coefficients using the Koenker and Basset (1982) and Rogers (1993) methodology. This methodology turns the problem of finding a minimum absolute deviation into a linear programming problem. Thus, an iteration process is performed until the coefficients that minimized the residuals are found. The covariance matrix is:

$$\text{cov}(b) = R_2^{-1} R_1 R_2^{-1}$$

Where $R_1 = X^{'} W W^{'} X$, $R^2 = X^{'} X$ and W is a diagonal matrix with elements W_{ii} equal to:

$$\begin{array}{ll} q / f_{residuals}(0) & if \quad r > 0 \\ (1-q) / f_{residuals}(0) & if \quad r < 0 \\ 0 & otherwise \end{array}$$

Where q is the quantile to be estimated.

Appendix 10

Example of a table with information on Homogeneous Physical Zones

INSTITUTO GEORÁFICO AGUSTÍN CODAZZI
1998

SECCIONAL: **CUNDINAMARCA** **CÓDIGO: 25**	**MAPA DE SUBZONAS HOMOGÉNEAS FÍSICAS**	**MUNICIPIO: TAUSA** **CÓDIGO: 793**

No.	Área (Has)	Clima	V.P.	Pend.	Aguas	Vías	Usos	Puntos Investigados
1	93	F.H	49	a	Suficientes	3	9 - 6	1
2	2780	F.H	55	c	Escasas	1 - 2	9 - 6	2-3-4-5-6-15-24-29-2A
3	450	F.H	55	c	Escasas	3	12	12B
4	115	F.H	55	c	Escasas	4	9 - 6	17
5	598	M.F.H	49	c	Escasas	4	9 - 6	30
6	526	F.S.	44	c	Escasas	1	9 - 6	20-25
7	78	F.S.	44	c	Escasas	2	9 - 8	23
8	2008	F.S.	38	d	Escasas	1 - 3	9 - 6	19-26-27
10	2026	M.F.H	38	d	Escasas	4	9 - 6	11-11A-32-33-36-37
11	291	M.F.H	38	d	Escasas	4	7/9	13-31
12	488	F.H	30	e	Escasas	4	12	12
13	489	F.H	30	e	Escasas	4	9 - 6	16-10A
14	112	F.H	30	e	Escasas	4	12/9	10
15	160	F.H	30	e	Sin	6	7/9	14
16	260	F.S.	30	e2p	Sin	5	9 - 6	43
17	460	F.S.	17	fr	Sin	6	7/9	9
18	119	F.H	23	fr	Sin	1	9 - 6	21
20.1	367	M.F.H	17	fr	Escasas	4	9 - 6	34
20.2	2274	M.F.H	17	fr	Sin	6	7/9	8-3-47-35-39
21	386	M.F.H	17	fr	Sin	6	12	12A
22	790	M.F.H	17	fr	Sin	6	12/9	7-12C
23	218	M.F.H	6	fr	Sin	7	8	11B
24	1888	M.F.H	6	er	Sin	8	8	12D-34B
25	934	M.R.	6		Sin	7	8	38
26	398	M.F.H	6	e	Sin	6	8	40
27	652	M.F	6		Sin	7	8	22-28
Aguas	830							
Total	19881							