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" Economic and social convergence in Colombia"

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Abstract

GDP has usually been used as a proxy for human well-being. Nevertheless, other social aspects should also be considered, such as life expectancy, infant mortality, educational enrolment and crime issues. With this paper we investigate not only economic convergence but also social convergence between regions in a developing country, Colombia, in the period 1975-2005. We consider several techniques in our analysis: sigma convergence, stochastic kernel estimations, and also several empirical models to find out the beta convergence parameter (cross section and panel estimates, with and without spatial dependence). The main results confirm that we can talk about convergence in Colombia in key social variables, although not in the classic economic variable, GDP per capita. We have also found that spatial autocorrelation reinforces convergence processes through deepening market and social factors, while isolation condemns regions to non-convergence.

JEL classification:. L11, Q4, C25.
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Economic and social convergence in Colombia

1. Introduction

GDP has usually been used as a proxy for human well-being. In this line, GDP has usually been used as a proxy for human well-being. This is how macroeconomic convergence has been looked at in a wide number of studies at different levels: international (Barro and Sala-i-Martin, 1992 and 1997; Mankiw *et al.*, 1992; Quah, 1996), regional (Lopez-Bazo *et al.*, 1999; Bivand and Brunstad, 2005) and even local (Royuela and Artís, 2006). Improving GDP will help to increase life expectancy, provide better access to basic education, etc. As Kenny (2005) argues, "it appears that improving incomes will improve whatever your chosen [quality of life] measure happens to be" (Kenny, 2005, p 1).

Nevertheless, there are other important aspects on the development agenda. The Millennium Development Goals stress eight international development objectives to achieve by the year 2015. They include reducing extreme poverty and child mortality rates, fighting disease epidemics such as AIDS, and developing a global partnership for development. Some previous literature (Easterly, 1999) stresses the fact that many of the improvements in quality of life variables are often not correlated with economic growth rates. Indeed, if some studies fail to find economic convergence at international level - Ram (1992) and others find weighted income convergence but unweighted stagnation, mainly due to big changes in large countries such as China and India - others (Kenny, 2005; Crafts, 2000; Ram, 1992) find convergence in well-being indicators.

The list of social indicators analysed to test convergence is quite long and includes factors such as life expectancy, infant mortality, educational enrolment, literacy, environmental degradation, etc. (Neumayer, 2003; Goesling and Firebaugh, 2004; Bourguignon and Morrisson, 2002; Becker *et al.*, 2005; Dorius, 2008). Usually the results come to mixed conclusions with regard to convergence, depending on the time frame considered and the selection of countries and indicators. These papers usually deal with an international context; only a few of them look at a regional level (Giannias *et al.*, 1999; Liargovas and Fotopoulos, 2009; Marchante and Ortega, 2006) and even fewer at a local level (Royuela and Artís, 2006).

In this paper we focus our attention on multidimensional convergence at a regional level in a single country, Colombia, for the period 1975-2005. There is a wide literature analysing economic convergence in Colombia, but the list of papers focusing on convergence in social indicators is quite short, with ambiguous results.

Additionally, many techniques have been used for finding convergence in living standards: β-convergence, σ-convergence and kernel density estimates among others. Also, spatial distribution matters, particularly at regional level, have attracted special attention to spatial statistics and spatial econometrics. In this paper we try to find robust results on convergence using a wide range of available techniques in our analysis. We look at one question posed in the literature: what is the relationship between convergence and spatial autocorrelation?

Our findings suggest clear convergence paths in four out of six variables considered (disposable household income, the literacy rate, life expectancy at birth and the non-murder rate). This evidence is strong enough to affirm that there is a convergence process at regional level in Colombia, despite the fact that this is not shown by variables such as real GDP per capita. We have also found that spatial autocorrelation reinforces convergence processes through deepening market and social factors, while isolation (such as that experienced by Chocó) condemns to non-convergence.

The structure of this article is as follows. The next section overviews recent research on regional income convergence. Section 3 shows the cases studied and the databases used. The empirical evidence is presented in Section 4. Finally, Section 5 concludes.

2. Convergence concepts

The contribution of Baumol (1986) stimulated a large number of studies examining the convergence hypothesis, being initial followers Barro (1991) and Barro and Sala-i-Martin (1991 and 1992). These works can be derived from the neo-classical model of economic growth by Solow (1956), and use the so-called *β-convergence* approach, where the economic growth of a list of economies depends on their initial level. If a significant coefficient of this *convergence equation* is found, then poor countries grow more than rich countries, and consequently a convergence process exists.

Another indicator of convergence has to see with the distribution of the variable in two different periods of time. The more basic measure is the called *σ-convergence* (Quah, 1993a), usually measured either by the standard deviation or by the coefficient of variation in two different periods of time. Through σ-convergence it is possible to find if a variable is becoming increasingly similar across the studied economies.

As explained by Quah, the first kind of convergence is necessary but not sufficient to achieve the second one, and consequently β-convergence should be complemented by the analysis of σ-convergence (Sala-i-Martin, 1996). Magrini (2007) exposes that the distribution dynamics approach proposed by Quah (1993a and b, 1996a, b and c, and 1997) contends explicitly the σ-convergence point of view, and expands it with the use of stochastic kernels to capture the time evolution of the behaviour of the entire cross-sectional distribution of a variable.

Finally, we remember that several works as Bernat (1996) and Rey and Montouri (1999) were among the first to include spatial effects in growth regressions, with special attention on the spatial distribution of the variable. When inspecting the dynamics of the distribution of a variable, they assume that both the magnitude and spatial distribution of a variable are important. More recently Rey and Janikas (2005) provides a review of methodological approaches with spatial effects of regional growth processes, proposing several research questions for such as "What is the relationship between convergence, inequality and spatial autocorrelation?" (Rey and Janikas, 2005, p. 168).

As our main aim is to analyse convergence and growth patterns in socio-economic variables, we assume that we have to inspect all possible techniques and sources of convergence. Although many works have surveyed these techniques (see the excellent proposal of Magrini, 2007), next we display a brief summary of these alternatives.

2.1. The regression approach: β-convergence approach

The neoclassical growth theory (Solow 1956; Swan, 1956; Cass, 1965; and Koopmans 1965), inspired works on economic convergence such as Baumol (1986) and several hundreds more. The model drives to a saddle-path stability, namely the steady state, where the final driver of income and consumption per capita growth is the rate of technological progress of the economy.

If a Cobb-Douglas production function is assumed, a testable expression for the convergence debate is derived. In particular, Barro and Sala-i-Martin (1991) suggest the following growth equation:

$$\left(\frac{1}{T}\right)\log\left(\frac{y_t}{y_0}\right) = c - \frac{\left(1-e^{-\beta t}\right)}{t}\log y_0 + u_t$$

Where the average growth rate of per capita income depends negatively on its initial level, conditioned on the exogenous growth rate of technology, on the steady state value per effective worker and on the initial level of technology. Parameter c summarises the nobserved parameters, such as the steady state values. The speed of convergence to the steady state, β, is the rate at which the representative economy approaches its steady state growth path, and consequently this procedure of convergence analysis is known as β-convergence.

There has been a huge literature on convergence, but in empirical terms there are three estimation alternatives: cross sectional, panel data and time series analysis.

The more basic analysis is the use of OLS estimation on a ***cross section*** of data. The basic assumption is that the considered economies of the data base belong to a homogeneous system. Of course, it can be the case that this hypothesis does not hold. The solution for this is the use of an additional set of explanatory variables (X) that represent proxies for different steady states in the cross-section regression, capturing different technological levels, saving rates, etc. In this case the growth equation becomes:

$$\left(\frac{1}{T}\right)\log\left(\frac{y_t}{y_0}\right) = c - \frac{\left(1-e^{-\beta t}\right)}{t}\log y_0 + \delta X + u_t$$

As it is not easy to find these explanatory variables proxying the steady state of every economy, a popular empirical alternative is the use of ***panel data*** methods. Through the use of fixed effects one can estimate the steady state of every economy. A simple model can be:

$$\log\left(\frac{y_t}{y_{t-1}}\right) = c_0 + c_1(t) - b\log y_{t-1} + u_t$$

Where c_0 is an unobservable economy-specific effect, and c_1 is a time specific fixed effect affecting all economies. Nevertheless, panel data estimations have also a list of drawbacks: if most of the variation in the key variables is cross-sectional rather than within regions, fixed effect approaches could produce misleading results (Barro, 2000). That is, if the underlying causal factors in the growth process are persistent, the long-run cross-sectional effects will be subsumed into the region fixed effects, which mean the explanatory coefficients of the initial level of the endogenous variable would be much less informative. Additionally, measurement-error bias is worsened by only using within region variation (Barnejee and Duflo, 2000), so that the bias can be more severe than when using simple OLS. Partridge (2005) concludes that fixed effects estimates may produce inaccurate results for measures that mostly vary cross-sectionally. Contrary to fixed effects, random effects and between panel data estimates, will result into closer results to standard OLS when most of variation is cross-sectional.

Consequently, OLS cross-sectional models capture how persistent cross-sectional differences in inequality affect long-run growth rates, which is more relevant to understanding growth disparities, while fixed effects panel techniques capture how time-series changes within a region affect changes in its growth rate over a short period. Therefore, the two methods are complementary and may reflect different responses.

In the panel estimates, both Hausman and the Breusch and Pagan tests can be used to suggest the use of the fixed effects versus random model. Nevertheless, Mairesse (1990) remembers that Hausman test assume that the model's assumptions hold in the fixed effects model (e.g., no measurement error), and violations could seriously affect the test results. Additionally, Hsiao and Sun (2000) argue that as Hausman test has no clear alternative hypothesis, classic sampling theory may not apply, and recommend the use of simple model selection procedures, such as the AIC statistic, much higher in the random effect model. In order to simplify the final results, we finally prefer using OLS cross section rung run estimates together with fixed effects panel short run estimates. We skip then using random effects panel estimates, as it can be potentially non consistent, and the long run information is basically captured in the OLS estimates.

The regression approach can be also operationalised using ***time series*** methods, in which the definition of convergence relies on the notions of unit roots and cointegration. Bernard and Durlauf (1995 and 1996) argue that convergence is defined as the equality across economies of long-term forecasts of per capita income taken at a given fixed date. The main idea is that convergence will exist if the difference between per capita income series of two economies is a mean zero stationary process. This analysis has been rather uncommon in regional analysis.

While the cross section and panel data approaches usually confirm economic convergence around a speed of 2% (depending on the employed technique), the time series way of estimation usually reject convergence, probably due to it uses a stricter notion of convergence. Besides, regressions such as the cross-section approach, is unable to test the neoclassical model implying convergence against alternative and conflicting models. Finally, Friedman (1992) and Quah (1993b) argue that it is possible to observe a negative parameter in the regression approach together in a diverging distribution. This aspect is subsequently analysed under the label of σ-convergence.

2.2. Analysis of the evolution of dispersion: σ-convergence approach and the analysis of inequality

σ-convergence corresponds to the decline of the cross-section dispersion in the variable under analysis. Different measures have been employed to analyse dispersion: standard deviation (Carlino and Mills, 1996) and the coefficient of variation (Bernard and Jones 1996). In order to find σ-convergence there is a necessary but not sufficient condition: to find β-convergence. That's why Sala-i-Martin (1996) suggests complementing the convergence analysis using both procedures.

In any case, the analysis of the cross-section dispersion is again non conclusive. As shown by Quah (1996a), a constant standard deviation can be consistent with very different dynamics. Consequently, it is not fully clear that a decreasing dispersion measurement is the definitive prove of the existence of convergence.

Together with the analysis of the variance, the literature has used inequality statistics in order to see if there is a convergence process. Some examples are the Gini index, the Mehran index, the Piesch index, the Kakwani index, and the Theil index, being the latter one of the more popular ones. This index is based in the notion of entropy, and is computed as follows:

$$Theil\ \ Index = \sum_{i=1}^{N} \frac{y_i}{Y} \log\left(\frac{y_i}{Y} \Big/ \frac{n_i}{N} \right)$$

where: y_i = Total amount of the variable that belongs to individual i.
$Y = \Sigma\, y_i$ = Sum of the whole amount of the variable for all individuals.
n_i = size of individual i
N = total amount of individuals

When there is total equality, every individual has the same amount of the variable. Consequently, $\log\left({}^{y_i}\!/_{Y} \Big/ {}^{1}\!/_{N} \right)$ would be equal to zero, and the total sum would be equal to zero as well. As the inequality rises, the index grows higher and higher, reaching its maximum value at $-\log(n_i/N)$. The Theil index is particularly appropriate when looking at inequality measurements because it has the property of mathematical fractals: it can be decomposed additively between groups, with the total Theil index being equal to sum of the Theil index between groups and the weighted average of the Theil indices within each group. This property greatly simplifies many calculations (as in Royuela and Vargas, 2009).

2.3. The distribution dynamics approach: computing stochastic kernels

This approach analyses the evolution of the cross sectional distribution of a variable by means of computing stochastic kernels to describe the change in the shape of the distribution and also the dynamics of changes within the distribution. As is clearly exposed is Magrini (2007), being $f_{X(t)}$ the probability density function associated to a variable X at time t, then:

$$f_{X(t+s)} = M_{t,s} f_{X(t)}$$

the stochastic kernel, $M_{t,s}$, allows for analysing the dynamics of the entire distribution of a variable between two different periods of time, providing information not only on the change in the external shape of the distribution but also, and more importantly, on the movement of the economies from one part of the distribution to another.

Analysing the shape of a three-dimensional plot of the stochastic kernel or the corresponding contour plot is the way we can inspect the existence of convergence. The main diagonal in these graphs represents persistence, as the elements in the cross sectional distribution remain where they started. We will find perfect convergence if most of the graph is around the average of the time $t+s$ axis and parallel to the time t axis. Finally, the intra distribution analysis can be made searching for the formation of separate modes, a signal of polarization (stratification) in the distribution.

2.4. The relationship between convergence and the spatial autocorrelation

"The problem with aspatial empirical analyses that have ignored the influence of spatial location on the process of growth is that they may have produced biased results, and hence misleading conclusions" (Fingleton and Lopez-Bazo, 2006, p. 178). In other words, the basic assumption of independence between observations was usually violated in the analysis of convergence. Rey and Montouri (1999) checked for σ and β convergence under spatial heterogeneity and spatial dependence, and found that, because of these spatial behaviours, convergence processes may display complicated transitional dynamics, which have to be taken into account.

Two aspects are to be considered here. Firstly, spatial econometrics estimation tools have to be considered, both in the cross-section estimates and in the panel data approach. (Abreu *et al*. (2005) surveys the existing evidence of the empirical evidence).

Basic references of these methods are Anselin (1988), Anselin (1995), Anselin and Bera (1998), Anselin and Florax (1995), Anselin and Rey (1991), Anselin *et al*. (1996), Getis and Ord (1992). In the cross-section approach, several estimation alternatives arise, such as the spatial error model, the spatial lag model, the spatial cross–regressive model, and even autoregressive and spatial error model. In our paper we will consider only two basic models: the spatial error model and the spatial lag model. Thus, we will not consider the autoregressive and spatial error model. Even though it may appear convenient to combine both the spatial lag and the spatial error dependence, it is difficult to disentangle which one is more relevant, and also it is also more difficult to interpret the spatial coefficients:

spatial error model	$\ln\left(\frac{Y_{t+k}}{Y_t}\right) = \alpha + \beta \ln(Y_t) + \varepsilon_t$, where $\varepsilon_t = \lambda W \varepsilon_t + u_t$
spatial lag model	$\ln\left(\frac{Y_{t+k}}{Y_t}\right) = \alpha + \beta \ln(Y_t) + \rho W \ln\left(\frac{Y_{t+k}}{Y_t}\right) + \varepsilon_t$

The panel data approach with spatial effects is more recently developed in Elhorst (2001 and 2003), and recent applications are Arbia and Piras (2005) Arbia, Basile and Piras (2005) Arbia, Elhorst and Piras (2005) and Elhorst (2005).

And secondly, the distribution dynamics of the spatial dimension of the variables also matter. In this line, the use of global and local spatial measurements deserves a particular attention. We consider here three complementary alternatives of global statistics of spatial patterns of a variable *x*: Moran's I, Geary's C, and Getis and Ord's G.[1]

Moran's I	$I = \frac{N}{S_0} \frac{\sum_{ij}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i^N (x_i - \bar{x})^2}, i \neq j$
Geary's C	$C = \frac{N-1}{2S_0} \frac{\sum_{ij}^{N} w_{ij}(x_i - x_j)}{\sum_i^N (x_i - \bar{x})^2}, i \neq j$
Getis and Ord's G	$G = \frac{\sum_i^N \sum_j^N w_{ij}(d) x_i x_j}{\sum_i^N \sum_j^N x_i x_j}, i \neq j$

Where: N: sample size
w_{ij}: spatial weight of the W contact matrix
$S_0 = \sum_i^N \sum_j^N w_{ij}$

Local statistics of spatial patterns: despite there are several local statistics (such as Moran's I_i, Geary's C_i, Getis and Ord's $G1_i$, Getis and Ord's $G2_i$), here we will only consider the local Moran's I statistic for a region *i*:

$$I_i = \frac{z_i}{\sum_i z_i^2 / N} \sum_{j \in J_i} w_{ij} z_i$$

Where: z_i : standardized value of x_i
J_i: amount of regions neighbouring region *i*

3. The case of study: Continental Colombian regions

Colombia is a medium-income nation with some 44 million inhabitants and a land area of about 1,200,000 km2. It is a country located in northwestern South America that shares borders with several countries and has access from the north to the Caribbean Sea and from the west to the Pacific Ocean. It is made up of thirty-two departments and a Capital District that is the country's capital, Bogotá [2]. Departments are country

[1] Moran's I indicates the presence of spatial association between similar values, while Getis and Ord's G informs about the concentration of similar values of the studied variable.

[2] Colombia is politically divided into departments, districts and municipalities. Before the Constitution of 1991, there were also *intendencias* and *comisarías*. The *intendencias* and *comisarías* are the "New Departments", and the departments that existed before 1991 are known as the old departments. The "New Departments" included: Arauca (Ara), Casanare (Cas), Putumayo (Put), the islands of San Andrés and Providencia, and the group we label as Amazonía Group (GA), formed by the following departments:

subdivisions similar to US states and are granted a certain degree of autonomy (see Figure 1).
Until the late twentieth century Colombia had had low but stable economic growth accompanied by high levels of poverty, inequality and violence. The annual growth rate of per capita GDP between 1990 and 2007 was around 2%, but the proportion of people living below the poverty line was 28 percent and the Gini coefficient was 58 percent. The intentional homicide rate was 39 per 100,000 population in 2007 and the conflict and insecurity induced an internally displaced population of more than 3 million persons in 2008 (see Table 1).

Colombia is a country of regions, most of them having idiosyncratic characteristics in geographical, economic and socio-cultural terms (see the map in Figure 1). The geographical characteristics have clearly influenced the others. Most urban centres are located in the highlands of the Andes Mountains or cordilleras. There are three main cities located in the cordilleras: Bogotá (the country's capital), Medellín (capital of Antioquia) and Cali (capital of Valle). These three cities concentrate 41% of the total population and about 80% of economic activity (Galvis, 2001). In contrast, those regions located on the periphery or in hard-to-access geographical areas are the poorest, such as Chocó, the Amazonía, Nariño and La Guajira. Other poor regions are located close to maritime borders, such as Bolivar, Magdalena, Sucre and Cauca.

Figure 1. Map location of Colombia and Departments

Source: Instituto Geográfico Agustín Codazzi – IGAC

Amazonas, Guainía, Guaviare, Vichada and Vaupés. The "Old Departments" included: Antioquia (Ant), Atlántico (Atl), Bogotá (Bog), Bolívar (Bol), Boyacá (Boy), Caldas (Cal), Caquetá (Caq), Cauca (Cau), Cesar (Ces), Córdoba (Cór), Cundinamarca (Cun), Chocó (Cho), Huila (Hui), La Guajira (La Gua), Magdalena (Mag), Meta (Met), Nariño (Nar), Norte de Santander (Nors), Quindío (Qui), Risaralda (Ris), Santander (San), Sucre (Suc), Tolima (Tol) and Valle (Val).

The discovery of important mineral resources in the 1980s and 90s increased the importance of several departments in the national product. This is the case of the departments of Arauca and Casanare, which have the largest oil fields in the country (Caño Limón and Cusiana-Cupiagua respectively), and La Guajira, which has the Cerrejon mines, the largest opencast coal mine in Latin America, and the salt mines in Manaure, the biggest open pan salt mines in the world.

Regional inequality and the geographical location of poverty in the coastal departments are two of the main characteristics of Colombia, and several authors (such as Meisel, 2007) have stressed that economic and social disparities have deepened in the last 15 years. Consequently, the study of these disparities and the search for a potential convergence/divergence process are important issues to be undertaken by researchers, as we will try to do in the following sections.

Table 1. Economics and social indicators in Colombia and other close countries

	Colombia	Brazil	Chile	Argentina	Mexico	United States
Per capita GDP 2007 (US$)	4,724	6,855	9,878	6,644	9,715	45,592
Annual growth rate of per capita GDP 1990-2007 (at constant prices)	1.2%	1.2%	3.7%	1.5%	1.6%	2.0%
Gini coefficient 2007	58.5	55.0	52.0	50.0	48.1	40.8
Population below income poverty line (US$2 a day) 2007	27.9%	12.7%	2.4%	11.3%	4.8%	-
Adult illiteracy rate (% aged 15 and above) 1999-2007	7.3%	10.0%	3.5%	2.4%	7.2%	-
Life expectancy at birth 2007	72.7	72.2	96.5	75.2	92.8	79.1
Intentional homicide rate per 100,000 population (2007-2008)	38.8	22	8.1	5.2	11.6	5.2

Source: UNDP, 2009 and UNODC, 2009.

3.1. Literature review in Colombia

The results found on economic convergence in Colombia are ambiguous. As usual, the final results depend on the period of analysis and the technique applied. The works by Cárdenas (1993) and Cárdenas *et al*. (1993 and 1995) are the first studies on economic convergence in Colombia, concretely, the departmental convergence of GDP in the period 1950-1990. By applying usual β-convergence analysis à-la-Barro and Sala-i-Martin (1991) and with information provided by the National Department of Statistics (DANE), the authors show that Colombia is a successful case of convergence with a convergence rate of GDP of 4.2%. Cárdenas' papers were criticized by many authors. One of the most critical was Meisel (1993) who, with similar GDP database and period of analysis, found that even though in the period 1950-1960 there was convergence, it was not the case for the period 1960-1990. The results by Meisel (1993) suggest that findings by Cárdenas were biased and misinterpreted, among other reasons, by errors in the database.

Birchenall and Murcia (1997) performed the first empirical study of economic convergence in Colombia using the stochastic kernel estimation in per capita income at departmental level. The results for the period 1960-1994 with information provided by

DANE suggest that there is no economic convergence in Colombia, and that any processes of mobilization of poor regions was due to the explosion of the mining industry (oil fields) in the last years. One step forward in the analysis of economic convergence is the work by Rocha and Vivas (1998), who applied an alternative methodology (Exchangeability Priors). They used a database at the departmental (regional) level provided by DANE and Banking Superintendence of Colombia, by measuring alternatively the GDP. They compared the process of regional convergence with regional heterogeneity conditions (socio-political instability, credit restrictions and the low level of education). Their results show that Colombia experienced a process of regional polarization in the period 1980-1994. Finally, the authors stress that there are different regional steady states and the hypothesis of economic convergence is not fulfilled.
Bonet and Meisel (1999) also used the GDP measure from Banking Superintendence of Colombia, and analyzed the regional convergence by applying usual absolute β-convergence and σ-convergence, together with others measures of dispersion and inequality, as the weighted coefficient of variation, the Theil index, the Gamma and Alfa indicators and the Herfindahl-Hirschman concentration index. In this work they analyzed two periods, 1926-1960 and 1960-1995. The results show that in the first period there was economic convergence, while it was not found in the second period. On the contrary: there was a process of polarization in departmental per capita income levels.

Others papers that use an alternative database on GDP at the municipal level are the works by Sánchez and Núñez (2000) and Galvis and Meisel (2000). In these papers they estimated the absolute and conditional β-convergence at the municipal level, using as a list of controls: geographic, infrastructure, human capital and living standard variables. The general conclusion is that there was conditional convergence between the 70s and 90s, while that the evidence of absolute convergence is not very strong.

Several other papers have made additional empirical research on economic convergence for the 80s and 90s. Using data from DANE the works by Acevedo (2003), Barón and Meisel (2003), and Barón (2003), find convergence during the eighties but not during the nineties. The last one, by Barón (2003), by means of spatial dependence techniques (Moran's I and Geary's C) found that the departmental per capita GDP did not show any pattern, so the wealth or poverty in Colombia would be randomly distributed geography.

In the 2004 and 2006 the *Centro de Estudios Ganaderos y Agrícolas* (CEGA) produced new estimates of GDP and income at the departmental level in Colombia for the period 1975-2000. The first authors who used this information for analyzing regional convergence were Gómez (2006) and Bonet and Meisel (2006 and 2008). The first one analyzed absolute and conditional convergence and univariate kernel density estimators, and used the money supply and the regional export rate as controls in conditional convergence analysis. He did not find strong evidence of regional absolute convergence, but he found conditional convergence.

Bonet and Meisel (2006 and 2008), analyzed convergence in gross per capita income and departmental per capita household income using measures of dispersion and inequality, together with kernel density estimators. The results show that there was not convergence in per capita income, but they observed a decrease in sigma convergence in household available income. In their conclusions they stressed the process of polarization in the income between Bogotá and the rest of the nation.

Similarly, the works by Branisa and Cardozo (2009a) and Franco and Raymond (2009) analyze the economic convergence in Colombia with CEGA data. The first one analyzed the convergence of the GDP and income available to household estimating the β-convergence, σ-convergence and stochastic kernels. According to their results there exists evidence of slow convergence in household available income but there is no convergence in GDP. The observed convergence in income can be explained by recent redistributive policies, particularly higher public spending in social sectors and infrastructure. The public spending affected the relative position of some departments, although not the distribution as a whole. The second work, by Franco and Raymond (2009), studied the existence of regional GDP convergence clubs in Colombia. Their results suggest that there are four clubs of convergence, and that there is no convergence between these clubs. In fact, there are big differences between poor and rich regions and there is a persistence of the disparities since the 1970's. Again, the polarization stressed by Bonet and Meisel arises.

All these works focus only on economic convergence (GDP and income). Few studies consider the convergence in non economic social indicators, probably due to the lack of available data. There are only five works dealing with convergence in social indicators: Meisel and Vega (2007), Ardila (2004), Aguirre (2005), Martínez (2006) and Branisa and Cardozo (2009b). The first one studied convergence in the height of Colombians in the last century using absolute β-convergence and σ-convergence. With a wide database the authors showed that the height average of Colombians increased throughout the 20th century in every decade and there is convergence in this indicator also between men and women, a proxy of social development. The second work, Ardila (2004), by using DANE data for period 1985-1996 and by applying stochastic kernel estimation (both conditional and unconditional) looked at the percentage of people with unsatisfied basic needs and the index of living conditions. They found geographical persistence in the social indicators and also the fact that policy variables such as the public expenditure affect the relative position of some departments, although not the dynamic of the distribution as a whole.

Aguirre (2005), Martínez (2006) and Branisa and Cardoso (2009b) used health and education indicators for analyzing social convergence between 1973 and 2005, with DANE data. The two first works, by means of the estimation of β-convergence and univariate kernels, found that while the infant mortality rate converges, education indicators (the illiteracy rate and the basic education variable) did not converge. Similarly, Aguirre (2005) also found convergence in life expectancy at birth. Contrary to these results Branisa and Cardoso (2009b) found convergence in education indicators but not in the health ones. The main difference between both works is the exclusion of outliers in the analysis developed by Branisa and Cardoso (2009b). Besides, in Branisa and Cardozo all variables are expressed as a ratio to the national value and they use literacy rates while that Aguirre uses illiteracy rates.

Overall, we have seen that there are conflicting results in the literature, both in economic and social variables, and consequently some additional work will be helpful to analyze convergence from a multidimensional point of view.

3.2. Data base description

When analysing social indicators a key issue is the selection of the variables considered for the study. Following Sen, a 'good life' is composed of four key elements: material well-being, health and survival, education and personal development and social inclusion / participation. Our selection includes two economic variables (real GDP per capita and real disposable household income), two related to health (life expectancy at birth and infant survival rate), one concerning education (literacy rate), and finally one related to a key aspect of social life in Colombia: crime (murder rate). Next we describe the sources and implementation issues of every variable.

In Colombia there are two different data sources of departmental information of GDP: the National Department of Statistics (DANE) and the *Centro de Estudios Ganaderos y Agrícolas* (CEGA). Both series produced for these two institutions have serious limitations. DANE only provides homogeneous data of GDP between 1990 to 2005 at disaggregate level for all the 33 departments (including Bogotá), while the CEGA even though provides data of GDP and income since 1975, only includes 23 departments, the capital district of Bogotá, and the nine "New Departments" grouped into a single observation (a total of 25 departments). Finally, CEGA database finishes in 2000.

Taking into account that departmental results coincide between CEGA and DANE from 1990 onwards (both use the System of National Accounts of 1993, CEGA, 2006), we try to build a consistent series of GDP that considers the heterogeneity of departments. Two procedures have been followed. The first one consisted in using as baseline the data of CEGA, and then using the GDP computed by DANE (from 2000 to 2005) for calculating department growth rates. Subsequently we applied these growth rates to the CEGA database for updating the series until to 2005. The second procedure consisted in assign values of GDP to each of the nine "New Departments". We used the data computed by DANE of GDP for the period 1990 to 2005 to find the relative position of the new departments, and subsequently we filled the DANE data between 1975 and 1989 maintaining the relative positions between these new departments in 1990 CEGA data. This way we consider a data set ranging from 1975 to 2005 (31 years) for 26 departments, Bogotá and the Amazonía Group (GA) (thus, a total of 28 spatial units)[3].

For income variable we only used the data of CEGA because it is not supplied by DANE, and consequently it is not possible to enlarge the database for "New Departments". Hence, we prefer excluded to the nine "New Departments" to avoid bias by omission of regional heterogeneity. Consequently, for the income variable we have data of 23 departments and Bogotá for the period 1975 through 2000: 24 units during 26 years.

Summarizing, we have two key variables relevant for economic convergence analysis, gross departmental product and gross departmental household available income. The first variable reflects production by residents in each department, while the second

[3] We excluded the islands of San Andrés and Providencia because these are not in continental Colombian regions.

reflects the primary income received by those residents. The latter is the result of households' income after subtracting taxes on property and rental income and net payments to the social security, and adding other net current transfers. As is mentioned in others studies (Bonet and Meisel, 2008) the income variable is a more accurate measure of a population's welfare than merely using GDP. And in our view, in order to analyze well being, it is more useful using household available income, as it considers the net amount of economic flows finally available for people.

Concerning the other social indicators we use literacy rate, life expectancy at birth, infant survival rate and non-murder rate. Our main source of data at department level is DANE. The first variable was taken of Census facts by DANE in the years 1973, 1985, 1993 and 2005. Both health variables were considered for the periods 1985-1990, 1990-1995, 1995-2000 and 2000-2005; and finally the crime variable is computed yearly for the period 1990-2005.

It is noted that the literacy rate, infant survival rate and non-murder rate are defined positively (the higher, the better). Although the results of convergence analysis may change depend upon whether one uses a variable or its complement (Micklewright and Stewart, 1999), we prefer the positive definitions and follow the arguments of Kenny (2005): measurements of convergence toward zero are more sensible to favor very small changes close to zero than very large changes further from zero. Besides, he claims that convergence towards a positive value is the standard in the literature. The same approach is followed in Braniza and Cardozo (2009b).

The literacy rate is defined as the complement of illiteracy rate, so that measure the percentage of literate population greater than age 15 and it is show the level of education of each region. Life expectancy at birth measures the number of years of life remaining at a given age. The infant survival rate is calculated as 1000 minus the infant mortality rate and it measures the number of infants surviving their first year of life over 1000 births. Lastly, the non-murder rate is computed as the complementary measure of the murder rate: violent deaths per 10,000 inhabitants. Consequently it is computed as the amount of people who is not murdered per 10,000 inhabitants. This variable shows the regional safety level, and we use is a proxy of social inclusion.

4. Empirical evidence. Convergence analysis for economic and social variables

As has been highlighted above, there is a wide list of statistical methods to test the existence of convergence. Next we analyse convergence in economic and social variables by means of using a list of techniques. First we look at the distribution of the variables over time, analysing sigma convergence and the spatial behaviour of the variable. These statistics are complemented with stochastic kernels, the Moran's Scatterplot, and the cloropleth and LISA maps. Finally we compute several measurements of β-convergence, cross sectional and panel data fixed effects estimates, using spatial econometric techniques in both cases. In several variables we have census data, what implies working with growth rates between t and t+10 in the panel data approach. In order to have reasonable comparisons, we will work with this time window even if we have annual data. Besides, this way we follow the existing literature (Partridge, 2005). Overall, we expect to obtain a robust picture of the existence of regional convergence in Colombia.

4.1. Analysing economic variables: real GDP per capita and real departmental per capita household income

Next we analyse convergence in economic variables: product and income. The product variable is real GDP per capita, while the income variable is real departmental per capita household income, computed by CEGA.

We firstly look at the **real GDP per capita**. The real production in Colombia during the 31 considered years has grown at an average annual rate of 1.7%. There has been important expansion periods (1986-1987, 1994-1996) and also experienced recessions (end of nineties). This growth has been unequally distributed between regions, what has forced significant changes in the dispersion of the variable. While Annex 1 shows the table with all key statistics of real GDP per capita[4], in Figure 2 we see the evolution of the a σ-convergence measurement, the coefficient of variation (CV), and a spatial autocorrelation statistic, the standardized value of the Moran's I.

Regarding σ-convergence in the period 1975-2005 we see very different paths of the CV.[5] Firstly, since 1975 to 1986 there is a quite stable situation, with low levels of dispersion. In 1986 starts a huge increase in the CV, with maximum values in 1999. After this year we see an important decrease in CV, although in 2000 it is still above its initial level in 1975. Consequently, if we focus only on the sigma convergence path, we cannot talk about sigma convergence (as it is generally found in the existing literature).

And, how about the changes in shape of the distribution? And the dynamics of changes within the distribution? The stochastic kernels help us to answer these questions[6]. Figures 4 to 6 display the Univariate kernel density estimate of relative per capita GDP in the years 1975 and 2005, and the three-dimensional plot of the stochastic kernel and its corresponding contour plot. We see in the kernels shapes (Figure 4) that there are not significant changes of the distribution between 1975 and 2005. We only see a peak in the part left of the distributions which for 2005 is higher than 1975. Figures 5 and 6 show that is peak belongs to the region of Putumayo which shows a process of stagnation in its development: it shows persistence and is very below the national average for both years. On the other hand, the regions of Casanare and La Guajira are located above the 45-degree diagonal which shows a process of mobility in these regions due to mining development since the late eighties. The rest of the distribution is quite away of any convergence path. On the contrary, we see a quite persistent picture, with most of the regions close to the main diagonal of the kernel density estimate, and even a group of regions forming a local mode over average of the distribution. Consequently we see again a non convergence dynamics in Colombian regions, with few exceptions that clearly does not allow generalizing the convergence process.

Spatial autocorrelation is hardly significant in most of the analysed periods: if at a level of significance posed at 10% only 9 out of the 31 considered years are non significant,

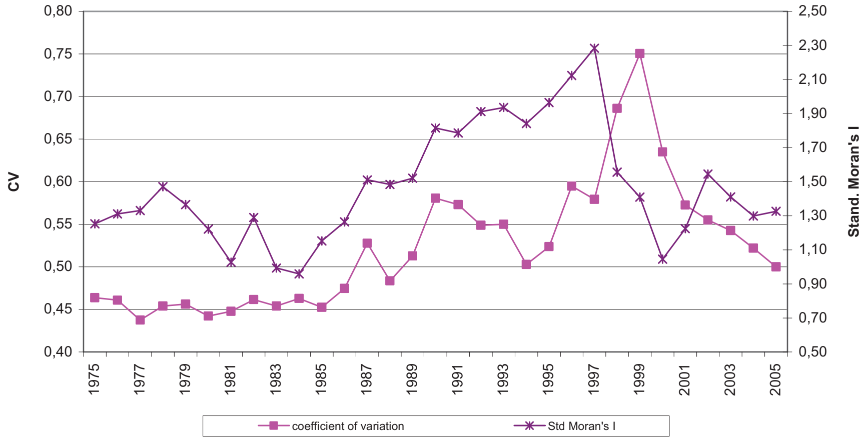
[4] We have computed every year's Mean, Standard Deviation, Coefficient of Variation, Gini Coefficient, Theil Entropy Measure, Moran's I, Geary's c and Getis & Ord's G.

[5] In our case the Theil index display the same behaviour as the CV (see Annex 1), and consequently we focus our analysis in the typical measurement of σ-convergence.

[6] For both univariate and bivariate kernels density estimations we use the Gaussian density function. For univariate kernels we use plug-in methodology to select the bandwidth suggest by Wand and Jones (1994), and for bivariate kernels we use direct plug-in proposed by Sheather and Jones (1991). Results are not very dissimilar using either methodology to select the kernels bandwidth.

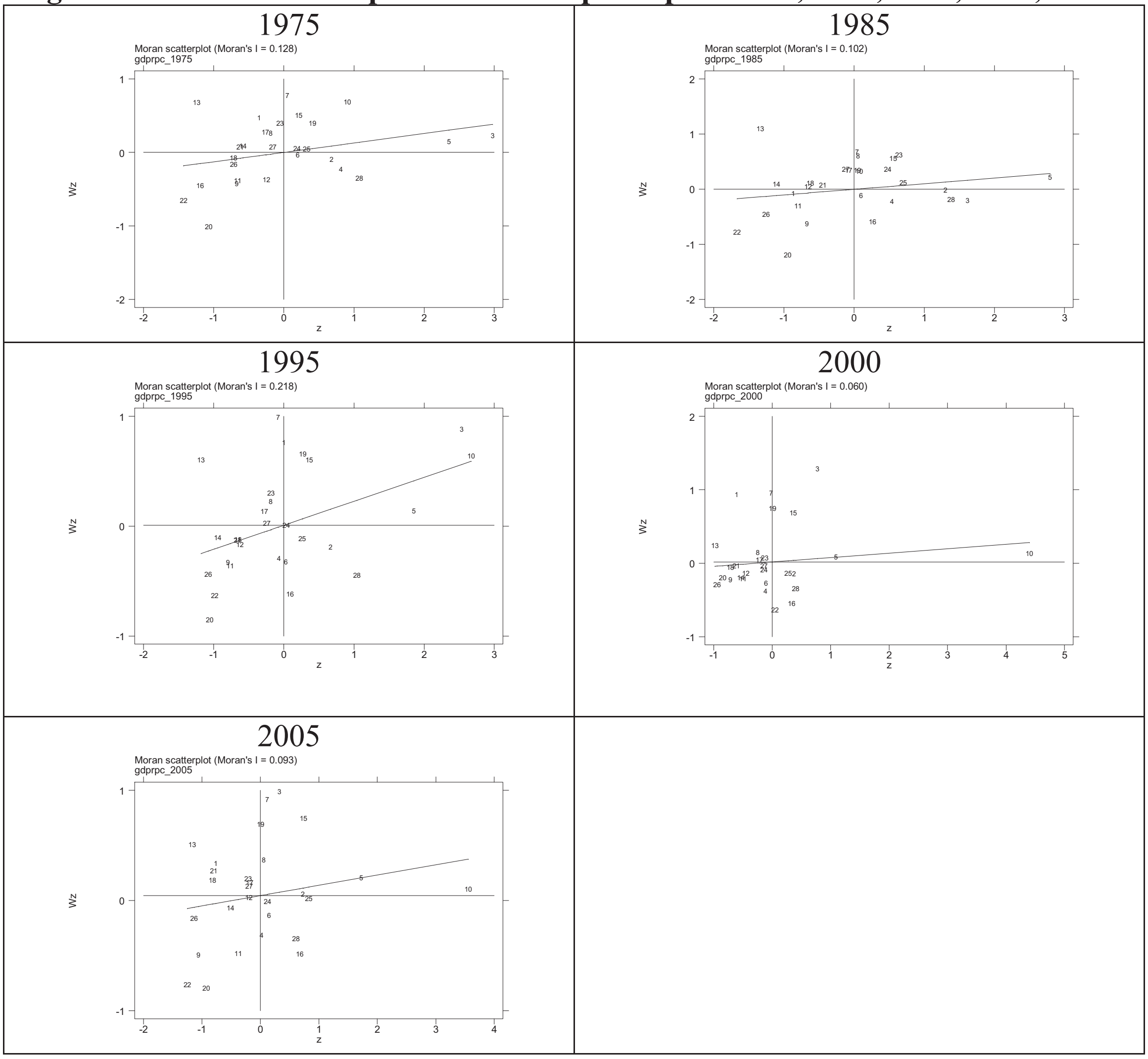
when the significant level is placed at 5%, only the 1990-1997 period display significant Moran's I statistics, as we can see in the 1995 Moran's scatterplot in Figure 3. Regarding spatial autocorrelation evolution, we see in Figure 2 that it follows a path parallel to the CV: small values at the beginning, a huge increase after 1986 (with the start of the works in the oil fields Orinoco River) until 1997, and then an important decrease. Thus, real GDP per capita dispersion and spatial dependence display a positive covariance throughout time (the correlation equals 0.38). Interestingly, we see that moves in spatial autocorrelation statistics are followed by moves in σ-convergence (a 4 years lagged correlation between both statistics is up to 0.71). The Getis and Org's G statistic of spatial concentration is hardly significant (only in 2002 it is significant at 5%) and displays no relationship with the CV statistic.

Figure 2. Real GDP per capita statistics



Note: Moran's I statistic is displayed normalized.

Figure 3. Moran's Scatterplot. Real GDP per capita. 1975, 1985, 1995, 2000, 2005



The positive relationship between σ-convergence and spatial autocorrelation has been investigated in Rey and Montouri (1999), while Rey and Janikas (2005) inspect the relationship between inequality and spatial autocorrelation: "what is the relationship between convergence, inequality and spatial autocorrelation?" (Rey and Janikas, 2005, p 168). The Colombia's evidence is basically the same that the one found in Rey and Montouri (1999) and Rey and Janikas (2005) for the USA case: a positive relationship between σ-convergence and spatial dependence.[7] The consequence of this result is that low levels of dispersion would imply low spatial dependence, and subsequently convergence would drive to low levels of spatial dependence.

With respect to local measures of spatial autocorrelation, figures 7 and 8 display the cloropleth and LISA maps in order to find the spatial distribution dynamics in Colombia. There are interesting changes in the distribution of the variable. Significant clusters with negative values at the beginning of the period, the ones formed by Chocó, Nariño and Putumayo, display (partially) non significant results after 1986, despite arise

[7] Rey and Montouri (1999) report a correlation coefficient of 0.785 over the 1929-94 period for the U.S. regions.

again in 2002. On the contrary, a positive cluster is developed after 1986, formed by Arauca and Casanare, the departments with oil fields, and another one in 2001 (Cundinamarca, a Bogota's neighbouring region). Annex 2 displays a list of tables detailing the significant local spatial autocorrelation measurements of every Department for every considered year. There we see clearly the break that is experienced in 1986, with the creation of the above mentioned positive cluster and the weaken of the negative cluster; and the final break in 2001, where the positive cluster of Cundinamarca arises, plus the rebirth of the negative cluster formed by Nariño, Putumayo and now also Caquetá.

Finally we refer to the beta convergence estimates. Table 2 shows the main results of the developed estimations, and displays both the long run OLS cross section analysis and the short run fixed effects panel estimates.

In the long run cross section estimates we find the low adjustment levels (lower than 10%) and non significant negative parameters, and also a non significant influence of spatial dependence. Both AIC statistics and LM tests drive to the same conclusion: simple OLS estimates are preferred to the ones using spatial autocorrelation techniques. The parameter in the OLS estimation implies the absence of β convergence, what is consistent with the evolution of dispersion over the 31 years under study that we saw above.

Panel data estimates use annualised growth rates of ten years periods as dependent variable. Although not reported, the within dispersion exceeds by large the between dispersion, which is mainly controlled using time series fixed effects, and consequently most of the variation of the endogenous variable in the panel relates to the time series dimension and drives us to think on short run results: regarding every region how time changes in region *X* GDP per capita levels affect economic growth rates of region *X*. In this line, the fixed effects panel estimates suggest a high speed of convergence: 6.5% in the spatial lag model, what implies that every region converges to its steady state in just 7.3 years.

Consequently, overall our analysis of sigma convergence and the kernel estimates was not strongly supportive of convergence for the whole period. The same results are obtained in the long run beta convergence analysis, but not in the fixed effects panel data estimates, which supports the idea of convergence. Previous literature had already pointed to the fact that once mining departments are excluded, convergence disappears (Birchenall and Murcia, 1997). This evidence is supported here with kernel analysis.

Nevertheless, if the correlation coefficient between GDP growth and the log of initial GDP is -0.26, when excluding Amazonía, Arauca, Casanare, La Guajira, and Putumayo, the mining departments (19% of Colombian GDP in 1975 and 22% in 2005), the coefficient drops to -0.04. Consequently, it cannot be argued that any convergence process is due to the neoclassical growth theory, based in factors mobility and decreasing marginal returns, but on changes in the steady state conditions of a list of departments. Precisely because of these aspects is why we find simultaneously a significant beta convergence parameter together with a non decreasing path in the sigma convergence measures and an increase in the spatial autocorrelation.

Table 2. Beta convergence estimates. Real GDP per capita.

	Cross section estimates			Panel data estimates, Cross Section Fixed Effects		
	OLS	OLS	OLS	OLS	ML	ML
	No Spatial Effects	Spatial Lag	Spatial Error	No Spatial Effects	Spatial Autoregressive Model	Spatial Error Model
Log GDP t-1	-0.01563	-0.01515	-0.01421	-0.10680***	-0.06487***	-0.08578***
	0.0105	*0.0100*	*0.0098*	*0.0048*	*0.0043*	*0.0044*
Implicit yearly speed of convergence (divergence)	1.28%	1.04%	1.18%	7.27%	6.47%	6.19%
Half life in years	44.01	56.57	48.44	6.14	7.27	7.73
lambda		-0.24392			0.28698***	
		0.3531			*0.0439*	
rho			-0.2176			0.44698***
			0.3556			*0.0452*
Cross section fixed effects				YES	YES	YES
Time Series fixed effects				YES	YES	YES
R-squared	0.079	0.107	0.079	0.482	0.590	0.545
corr-squared					0.350	0.389
AIC	-126.04	-122.42	-122.52	-3221.53	-3013.38	-3061.63
Observations	28	28	28	588	588	588
LR-test joint significance regional fixed effects				45.64***	484.9***	531.2***
LM test no spatial lag	0.283			1.008		
Robust LM test no spatial lag	0.108			13.508***		
LM test no spatial error	0.231			1.503		
Robust LM test no spatial error	0.056			1.294		

* p<0.05, ** p<0.01, *** p<0.001. Standard errors are displayed in italics.

Figure 4. Univariate kernel density estimate of relative per capita GDP, 1975 and 2005

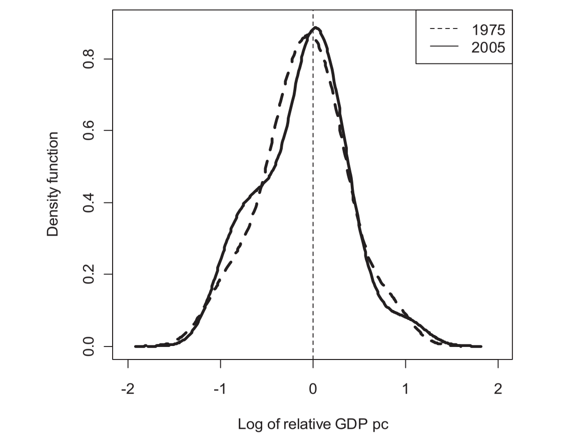


Figure 5. Kernel density estimate 3-dimensional of relative per capita GDP, 1975 and 2005

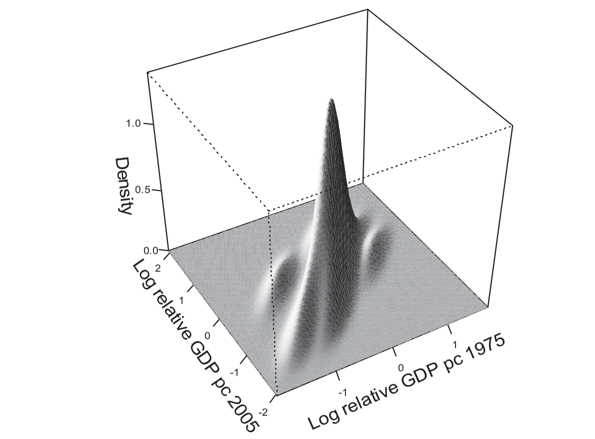


Figure 6. Contour plot of relative per capita GDP, 1975 and 2005

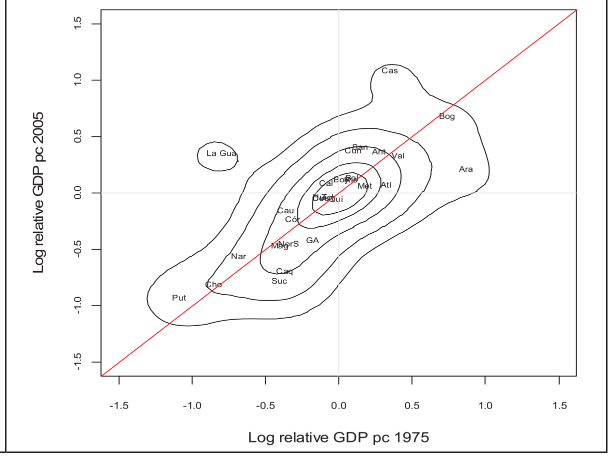


Figure 7. Cloropleth maps. Real GDP per capita

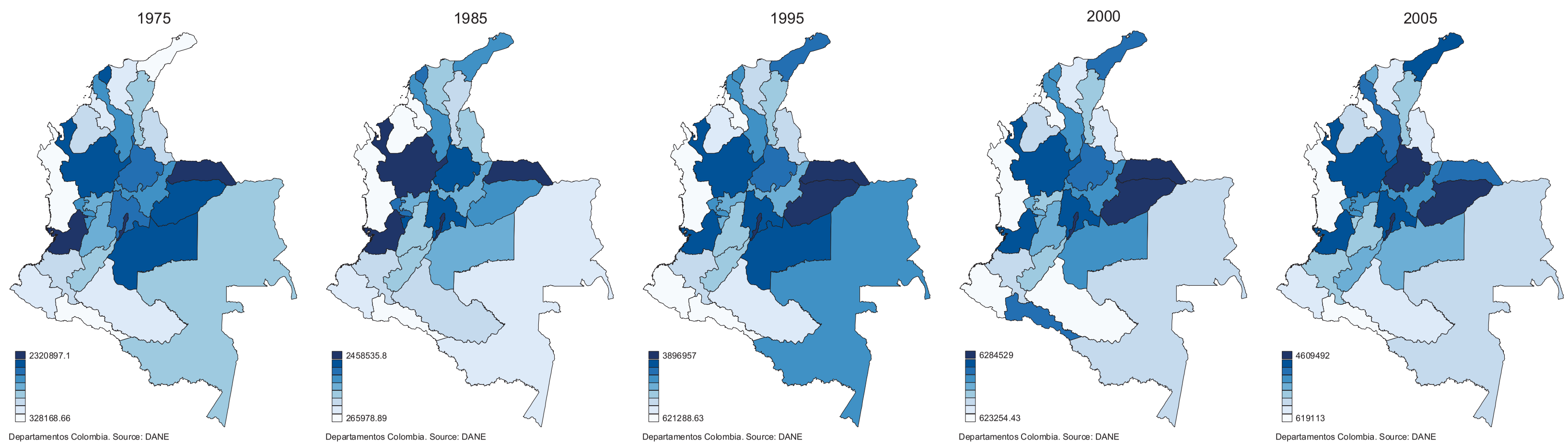
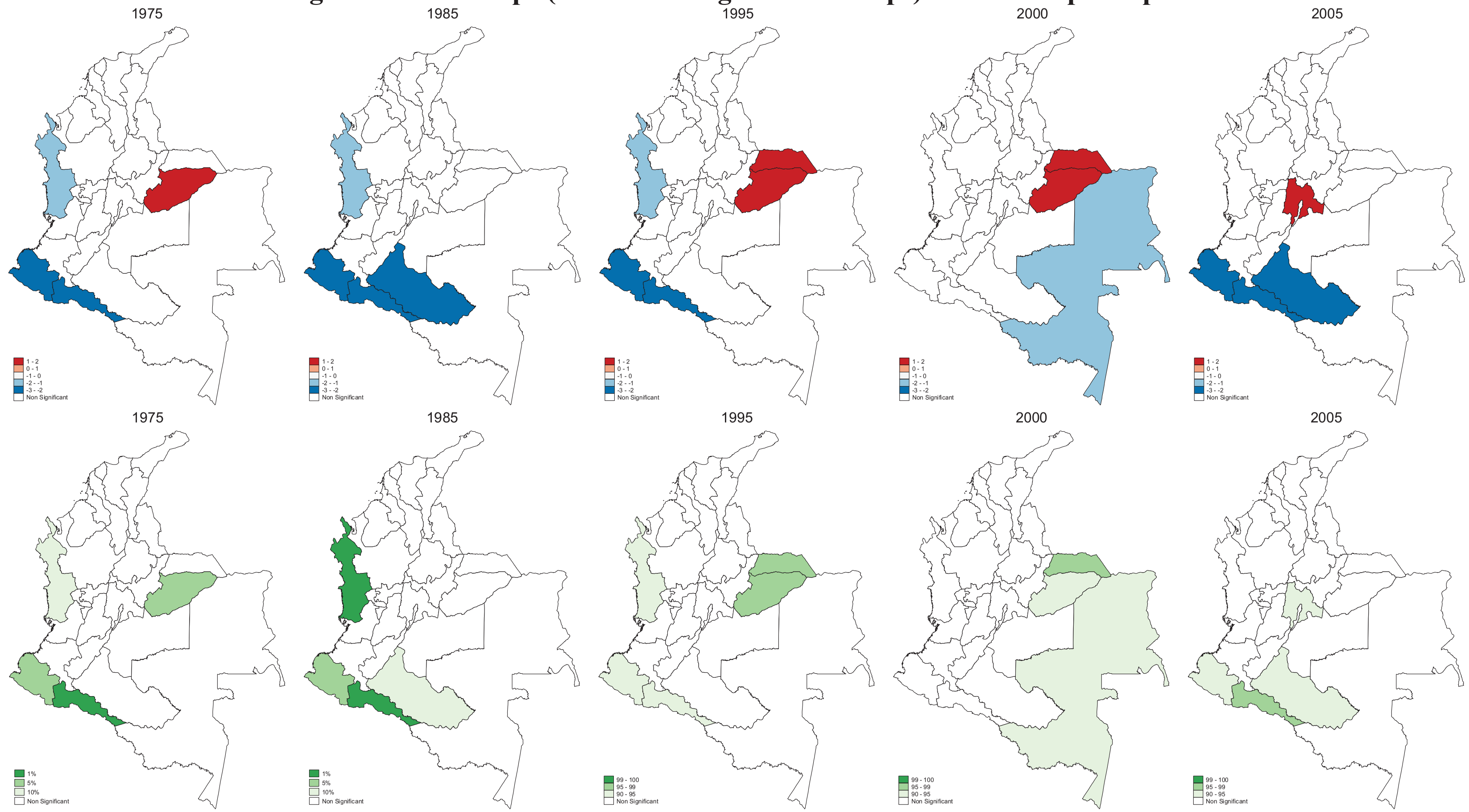


Figure 8. LISA maps (cluster and significance maps). Real GDP per capita



Note: the significance level is posed at 10%.

The second economic variable we face is **real departmental per capita household income**. One of the limitations in the debate the regional convergence in Colombia is that there did not exist, until recently, a direct measurement of departmental per capita household income, until in 2006 CEGA estimated this series. The advantage of income with respect to GDP is that the latter is a measure of the production generated by individuals within a department while the former is an estimate of the received income by individuals residing in this region. In others words, the data on GDP do not reflect well the level of prosperity of the regions (Bonet and Meisel, 2006), while reproduces the portion of the generated production that is captured by individuals, and then it is not affected by the sectoral composition of production. A typical example of the differences between GDP and income is the production of energy, a sector with high apparent productivity (GDP per worker) but its correspondence in personal income is usually quite low. As we have seen above, sectoral composition is a huge aspect to be considered in Colombian departments.

Nevertheless we face a trade off in the use of personal income in Colombia. The available series, computed by CEGA, is available from 1975 to 2000, and is not available for a list of departments (Arauca, Casanare, Putumayo and Amazonía, which are the ones with oil fields). Consequently, the analysis will be at the same time partial but away from the influence of mining activities.

We firstly look at the evolution of dispersion. Inversely to what happened with real GDP, there is a decrease in the coefficient of variation of income, from 0.46 in 1975 to 0.33 in 2000 (see figures 9 and 10). This decrease is particularly important after 1987. Figures 12 to 14 show the kernel estimates and contour plot of the distribution of real departmental per capita household income at the beginning and at the end of the 1975-2000 period. What we see is that any convergence process is observed at the tails of the distribution, both the highest and the lowest. The poorest in 1975 (Chocó, 39% of the national average) was less poor in 2000 (51%), and the richest in 1975 (Bogotá, 275% of the national average) was less rich in 2000 (206%). Additionally, there is an important increase of the density close to the average of the distribution. Part of this result is due to the dataset we are using. In the previous analysis if real GDP per capita we found a positive cluster formed by Arauca and Casanare, two Departments that we are not considering now. Consequently we perform the analysis of real GDP per capita in the narrow data set of 24 departments. The results of the CV and Moran's I are displayed in Figure 10. Contrary to what we observed in the total data set, we observe now a decrease in the CV, particularly after 1999. It implies that convergence in real per capita income can be due to the selection of the data set.

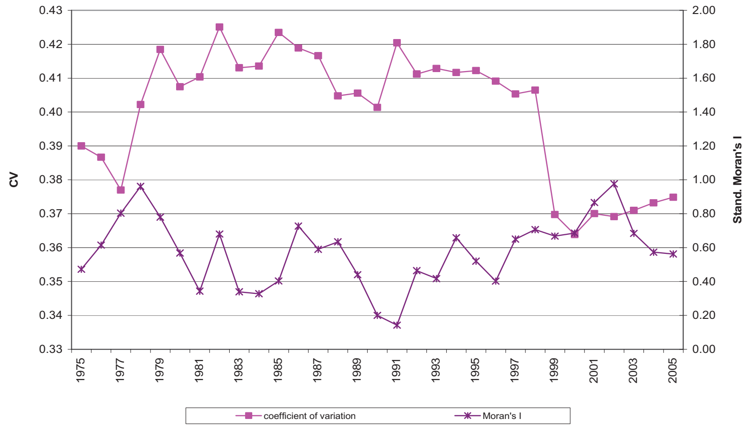
Inversely to what happened with real GDP, spatial autocorrelation in real per capita income is never significant, despite the Moran's I statistic experiences a very small increase in 1992 and 2000 (see also the Moran's scatterplots in Figure 11). On the contrary, the Getis and Org's G statistic of spatial concentration is significant after 1991 (although only at 10%). This concentration is mainly focused in Bogotá and its neighbour Cundinamarca, as we will see later on.

Additionally, we do not find the positive relationship between dispersion (CV) and spatial autocorrelation (Moran's I Statistic) that we found in GDP. On the contrary, if any, we find a negative correlation between both statistics of -0.33. The correlation between the CV and the Moran's I in real GDP per capita of the 24 departments is equal to -0.44 between 1975 and 2005 (and equal to -0.31 between 1975 and 2000). Our conclusion is that the positive relationship in Colombia between CV and Moran's I in economic variables is only due to the birth in 1986 of a positive cluster of small departments related with oil fields. What the rest of the country experiences is an absolute absence of spatial autocorrelation. Inversely to the Moran's I, the Getis and Org's G statistic is inversely correlated with CV: as the CV decreases, the Getis and Org's G increases.

Finally, figures 15 and 16 shows the local spatial autocorrelation measures. There we see permanently a department with low levels of per capita household income and surrounded of richer departments. We talk about Chocó, the 'low-high' department at the west side of the country. This region is at the Pacific coast and has a natural barrier of deep forest that separates it from the rest of the country. The transportation to the main city (Quibdó) of the rest of the country is done by air, for instance, Quibdó only is 136 km away from the Medellín (second city of Colombia) but the access by road takes approximately 18 hours, while that by plane takes only 30 minutes (Bonet, 2007). Its isolation is a key aspect to explain the big difference in departmental per capita household income levels with neighbouring regions. Bogotá displays a significant local autocorrelation measure in 21 out of the 26 considered years. Cundinamarca, a neighbouring region to Bogotá, joints the capital in a positive High-High cluster in 1994.

Figure 9. Real Household Income per capita statistics (24 Departments)

Figure 10. Real GDP per capita statistics (24 Departments)



The beta convergence analysis displayed in Table 3 confirms the previous analysis: we find a significant and negative parameter at all regressions, with a speed of convergence in the log run equal to 1.44% (OLS estimates) and in the short run equal to 7.27% (fixed effects panel estimates), when every department is converging at their own steady state. Spatial estimates are not particularly preferred and different from the previous ones.

Contrary to the GDP estimates, now the estimates enjoy a better adjustment, and consequently, despite the estimates are not so different, they are more reliable and consequently are statistically significant.

The whole evidence is supportive of the idea of convergence: the CV decreases, particularly after 1985, the kernel estimates show that convergence happens particularly at the tails of the distribution, and finally the estimations of beta convergence are significant. And interestingly, this happens with a total absence of spatial autocorrelation.

Figure 11. Moran's Scatterplot. Real Household Income per capita. 1975, 1985, 1995, 2000

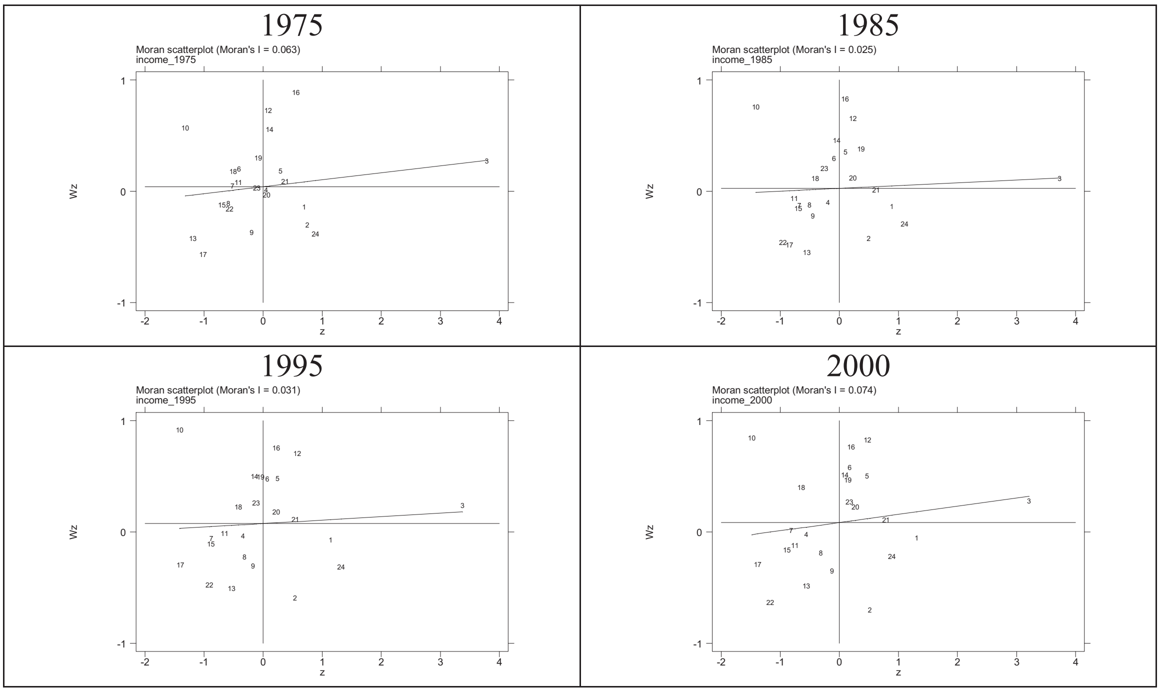


Table 3. Beta convergence analysis. Real Household Income.

	Cross section estimates			Panel data estimates, Cross Section Fixed Effects		
	OLS	**OLS**	**OLS**	**OLS**	**ML**	**ML**
	No Spatial Effects	**Spatial Lag**	**Spatial Error**	**No Spatial Effects**	**Spatial Autoregressive Model**	**Spatial Error Model**
Log GDP t-1	-0.01741 ***	-0.01699***	-0.01714***	-0.10694***	-0.07070***	-0.09819***
	0.0046	*0.0044*	*0.0044*	*0.0041*	*0.0042*	*0.0041*
Implicit yearly speed of convergence (divergence)	1.44%	1.72%	1.42%	7.27%	5.55%	6.84%
Half life in years	39.47	31.65	40.10	6.13	9.00	6.71
rho		0.21578			0.04598	
		0.2767			*0.0554*	
rho			0.21991			0.53899***
			0.2886			*0.0480*
Cross section fixed effects				YES	YES	YES
Time Series fixed effects				YES	YES	YES
R-squared	0.390			0.640	0.703	0.656
corr-squared		0.411	0.390		0.517	0.526
AIC	-156.18	-152.73	-152.76	-2833.03	-2596.95	-2659.07
Observations	24	24	24	384	384	384
LR-test joint significance regional fixed effects					461.6***	521.7***
LM test no spatial lag	0.456			8.486***		
Robust LM test no spatial lag	0.013			1.499		
LM test no spatial error	0.468			7.649***		
Robust LM test no spatial error	0.025			0.108		

* p<0.05, ** p<0.01, *** p<0.001. Standard errors are displayed in italics.

Figure 12. Univariate kernel density estimate of relative Real Household Income, 1975 and 2000

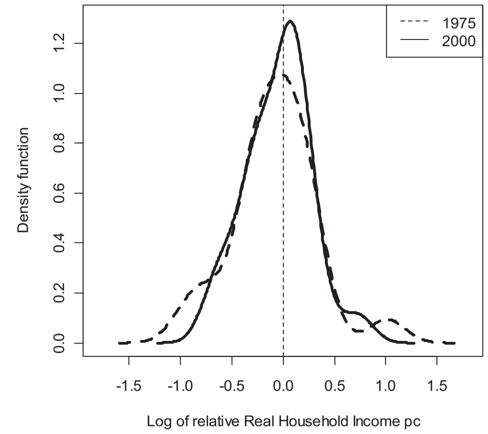


Figure 13. Kernel density estimate 3-dimensional of relative Real Household Income, 1975 and 2000

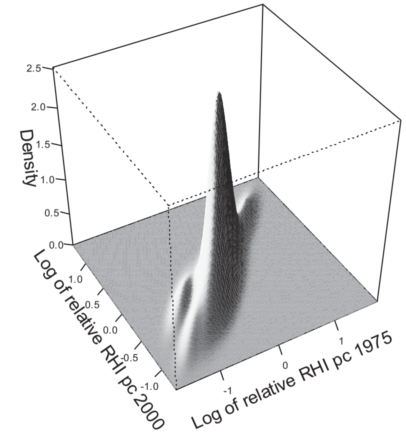


Figure 14. Contour plot of relative Real Household Income, 1975 and 2000

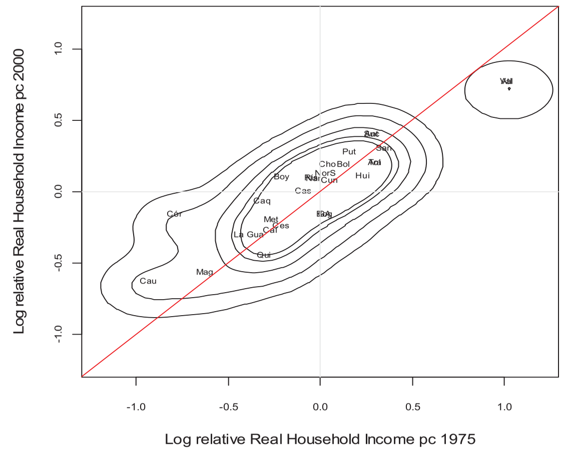


Figure 15. Cloropleth maps. Real Household Income.

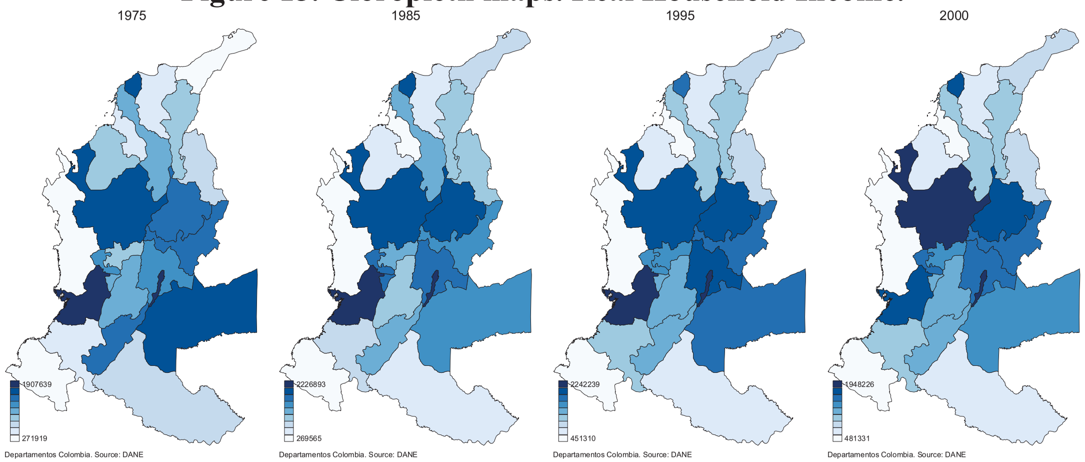
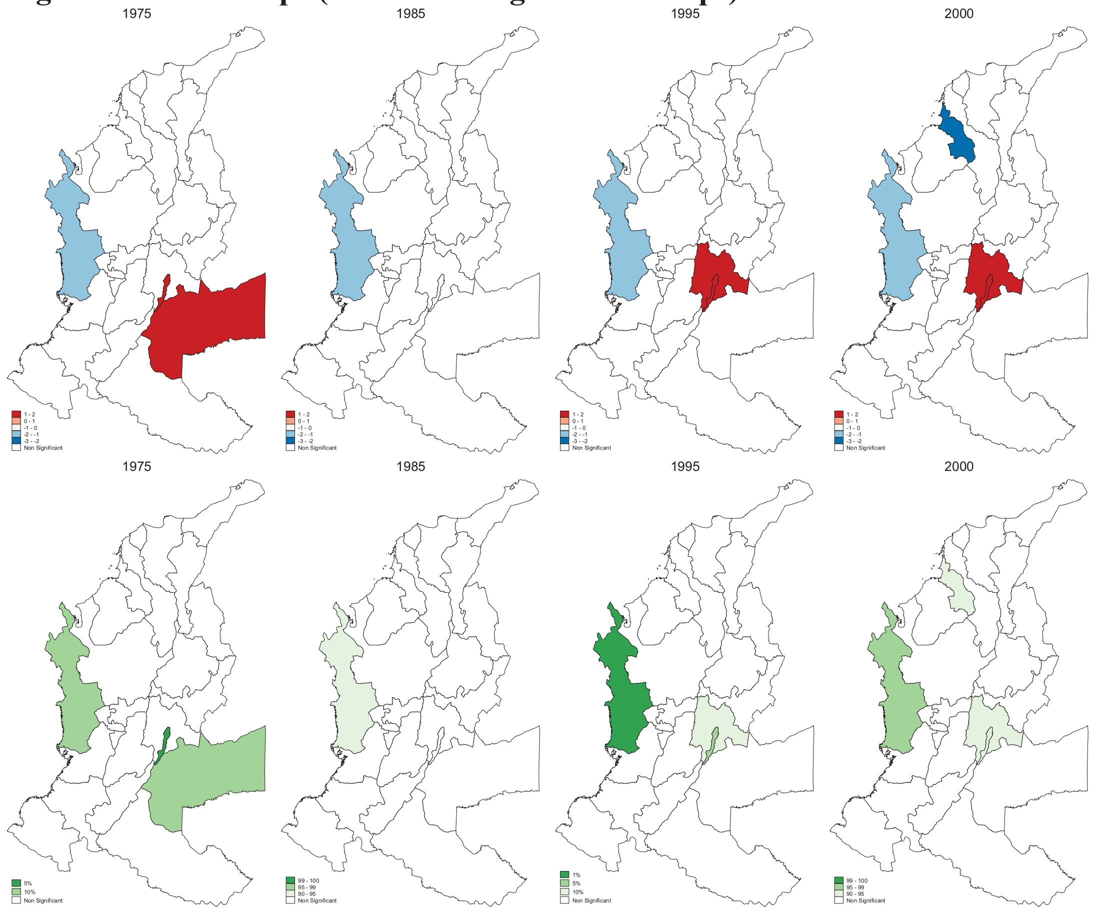


Figure 16. LISA maps (cluster and significance maps). Real Household Income.



Note: the significance level is posed at 10%.

4.2. Literacy rate

Once we have looked at the economic variables we turn to analyse the **social variables**, concerning education, health and crime.

Depending on the country, the education variable that has to be used to see if there are important inequalities in the territory can change. In our case we will use the **literacy rate** (the percentage of literate population over 15). This variable is computed from the results coming from different census and consequently is only available for four different years: 1973, 1985, 1993 and 2005. We have used the micro data available in IPUMS data bases to build our variables for the 28 departments, and we have also turn the variable rate of illiteracy rate into positive terms: the proportion of individuals who can read and write.

In general terms we see a positive evolution of this variable. The proportion of people who can read and write has been growing steadily from 78,4% in 1975 to 89,2% in 2005. The point we face now is how has been this evolution in the territory. Again, Annex 1 shows the table with all key statistics of the considered variable. In Figure 17 we see the evolution of the CV and the standardized value of the Moran's I.

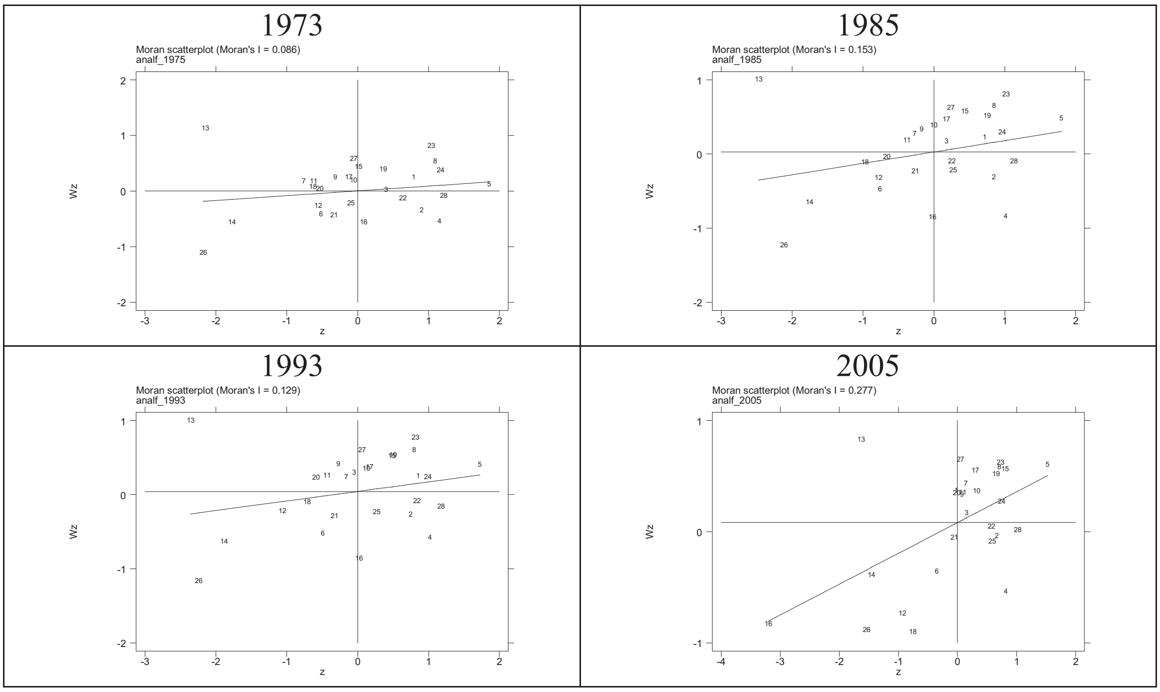
Figure 17. Literacy rate statistics

What we find is a decreasing path of sigma convergence, which stops in 1993. Figures 19 to 21 display the kernel density estimate of relative literacy rate in the years 1973 and 2005, and the three-dimensional plot of the stochastic kernel and its corresponding contour plot. Again, we see an important decrease in the dispersion of the variable: the kernel concentrates much more density close to the mean in 2005. Nevertheless several modes below the average suggest a persistence of several departments to join the rest of the country. Besides, Figure 21 shows a quite flat contour plot with few exceptions (mainly La Guajira, which worsens its position in 2005).

Parallel to this evolution we see an increasing evolution of the global spatial autocorrelation measurement, which always display a positive sign, although is only significant in 1985 and 2005. Figure 18 show the Moran's scatter plot of all four considered years, and can be clearly seen the increase in the Moran's I statistic is affected by a region, Chocó (the naturally isolated department at the Pacific coast, posed as number 13 in the considered graphs), which is away from the rest of the observations. In 2005 the Moran's I displays a value of 0.27. If Chocó had had a value equal to the average of the country, the Moran's I would have been a figure close to a significant 0.29. Instead, what we find is this Department with low values in the literacy rate and surrounded by Departments with high values. We have to remember that this situation also happened in economic variables, such as real per capita GDP and Income. The Getis and Org's G statistic of spatial concentration is significant at 10% after 1985, and highly significant in 2005 (at 1%). As happened with income, spatial concentration is observed in Bogotá and surrounding regions.

Analysing the evolution over time of dispersion and spatial autocorrelation and concentration (see Figure 17), we observe that the CV is negatively correlated both with Moran's I (the correlation between these two measurements is equal to -0.63) and with Getis and Org's G (-0.78). Consequently, in this variable, as relative differences decrease, the spatial relationship between departments increase.

Figure 18. Moran's Scatterplot. Literacy rate. 1973, 1985, 1993, 2005



Finally, figures 22 and 23 display the cloropleth and LISA maps in order to find the spatial distribution dynamics in Colombia. We have seen above that the increasing trend in the literacy rate has been accompanied by a growing degree of global spatial autocorrelation, and an increasing heterogeneity, basically due to birth of a positive high-high cluster in the departments close to Bogotá, and the strengthen of the low-low cluster of northern Departments (Cesar, La Guajira and Magdalena).

Finally we focus our attention in the beta convergence analysis (see table 4). We find strong convergence results, both because of the significant parameters in the regressions and because the high adjustment levels of the estimates: only with one explanatory variable (the initial level of the endogenous variable) we can explain more than the 60% of the variance of literacy rate growth rates. In this case, following the LM tests, the spatial error model is preferred to the OLS and the spatial error models. It means that there are non observed aspects in the growth rate following spatial patterns. In these

situations conditional models deserve particular attention. In this estimation the implicit yearly speed of convergence is up to 1.8%.
Panel data estimates show higher estimates of the speed of convergence: we find a higher speed of convergence in the conditional models displayed in panel fixed effect estimates. Now, non spatial estimates are preferred and display a short run speed of convergence of 4.72% towards every region's steady state.

Overall, literacy rate shows a strong convergence process, which is combined with an increasing importance of spatial dependence and concentration between regions.

Table 4. Beta convergence analysis. Literacy rate.

	Cross section estimates			Panel data estimates, Cross Section Fixed Effects		
	OLS	**OLS**	**OLS**	**OLS**	**ML**	**ML**
	No Spatial Effects	**Spatial Lag**	**Spatial Error**	**No Spatial Effects**	**Spatial Autoregressive Model**	**Spatial Error Model**
Log GDP t-1	-0.0227***	-0.0226***	-0.0244***	-0.0603***	-0.0443***	-0.0590***
	0.003	*0.003*	*0.003*	*0.011*	*0.007*	*0.006*
Implicit yearly speed of convergence (divergence)	1.71%	1.84%	1.80%	4.72%	4.87%	4.63%
Half life in years	30.19	27.29	28.10	11.14	10.69	11.41
rho		0.09763			0.29395***	
		0.2250			*0.1068*	
lambda			0.60715**			0.44996***
			0.2125			*0.1193*
Cross section fixed effects				YES	YES	YES
Time Series fixed effects				YES	YES	YES
R-squared	0.683			0.625	0.805	0.784
corr-squared		0.698	0.695		0.684	0.691
AIC	-275.00	-276.19	-271.19	-799.27	-731.21	-736.65
Observations	28	28	28	84	84	84
LR-test joint significance regional fixed effects				1.46	106.5***	110.0***
LM test no spatial lag	0.134			1.149		
Robust LM test no spatial lag	2.036			1.168		
LM test no spatial error	3.759*			0.475		
Robust LM test no spatial error	5.662**			0.014		

Figure 19. Univariate kernel density of relative literacy rate, 1973 and 2005

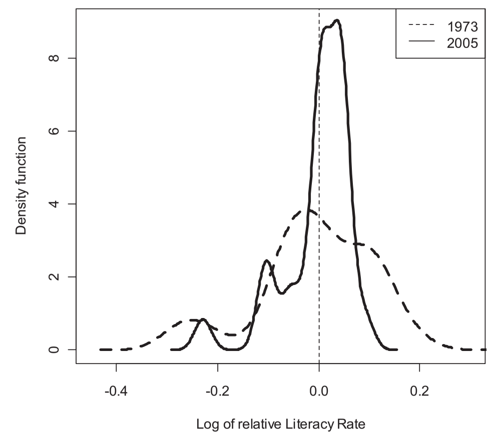


Figure 20. Kernel density estimate 3-dimensional of relative literacy rate, 1973 and 2005

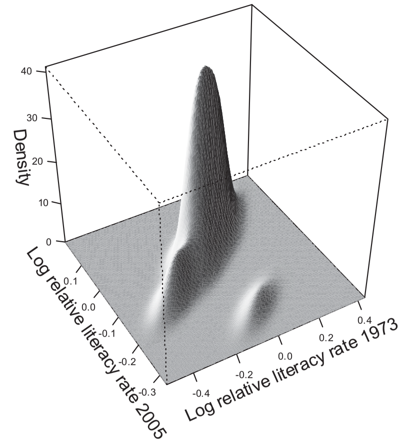


Figure 21. Contour Plot of relative literacy rate, 1973 and 2005

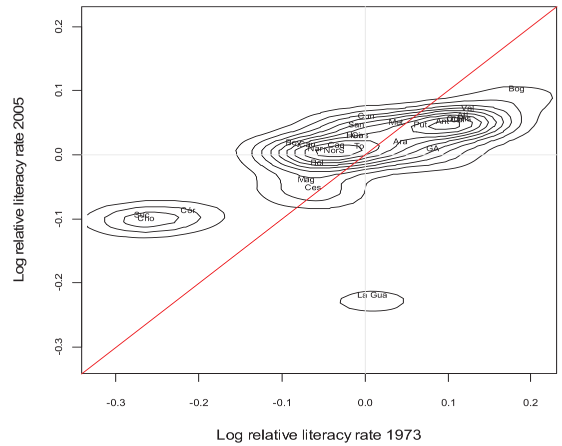


Figure 22. Cloropleth maps. Literacy rate

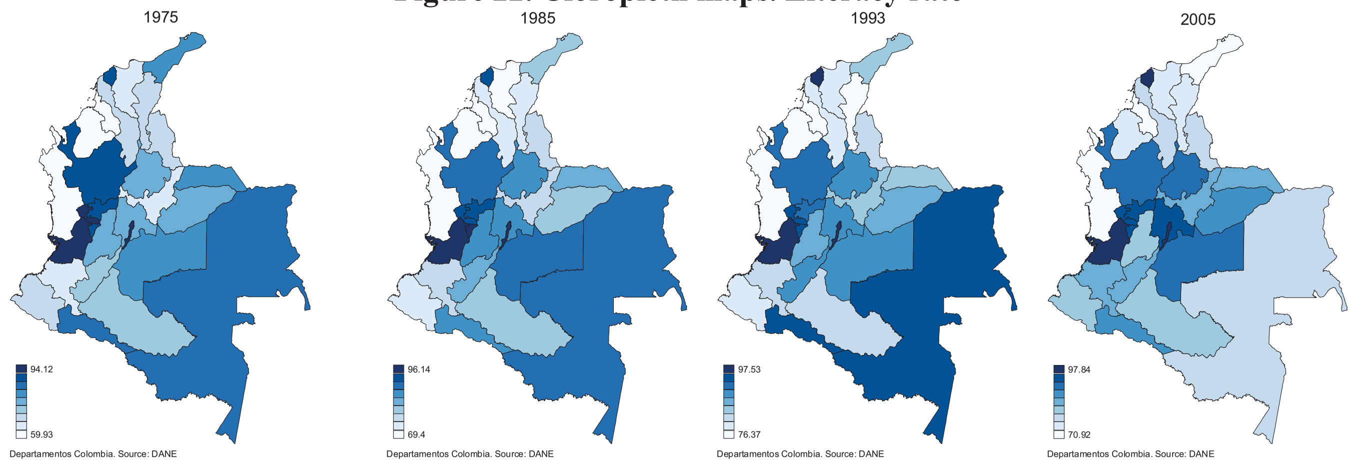
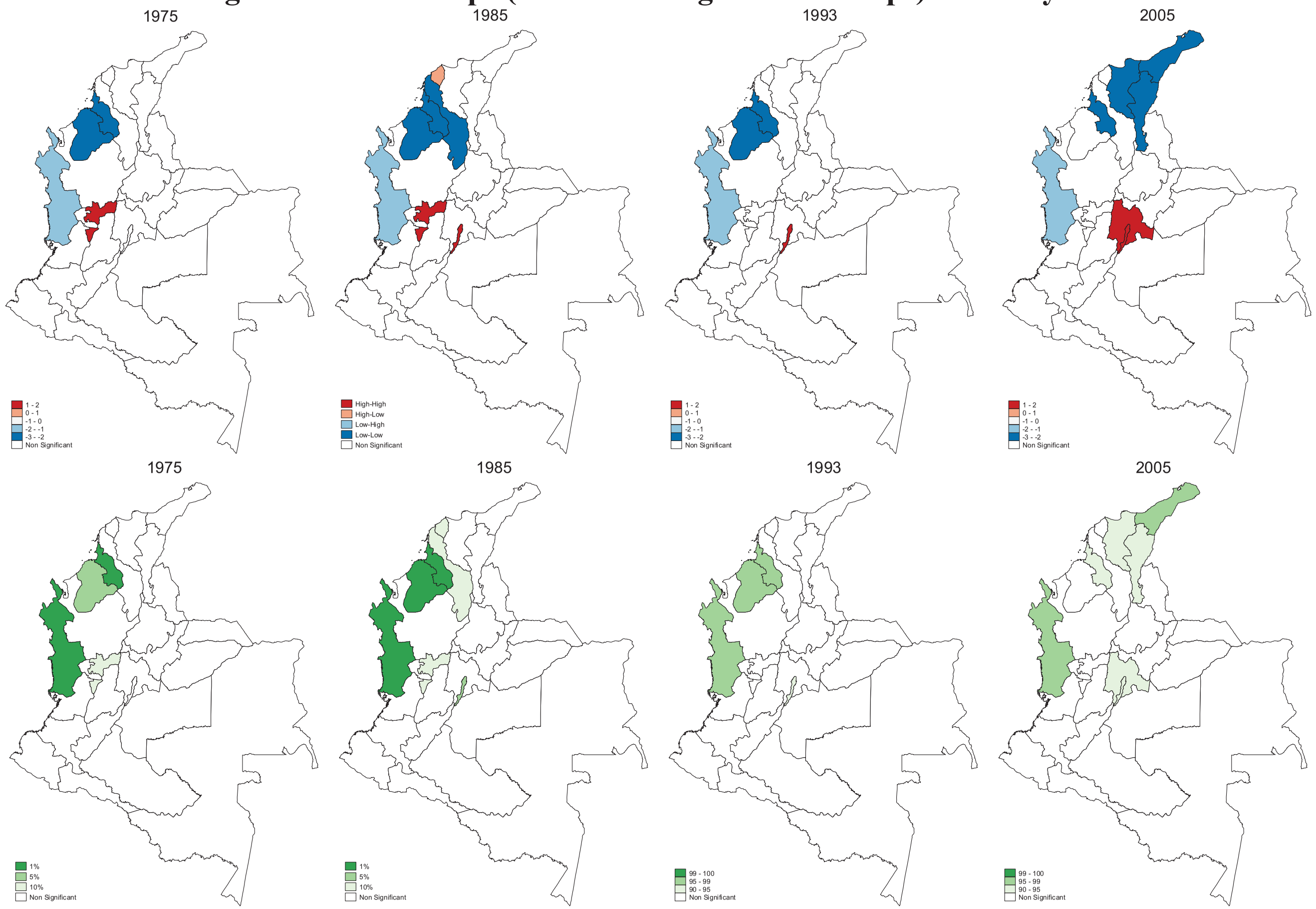


Figure 23. LISA maps (cluster and significance maps). Literacy rate



Note: the significance level is posed at 10%.

4.3. Health variables: life expectancy at birth and infant survival rate.

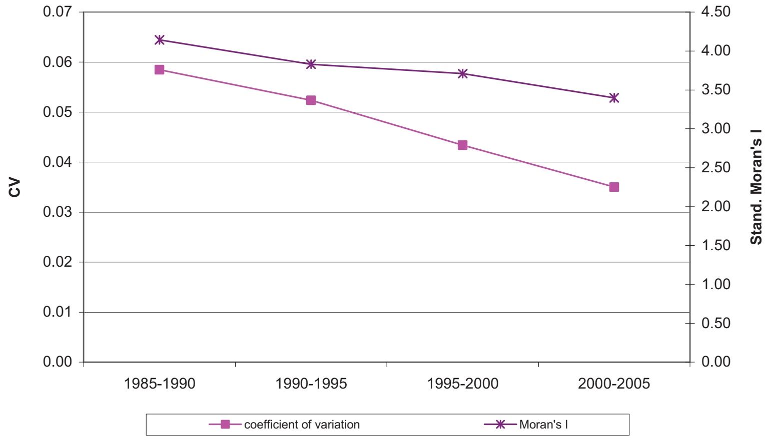
The next social variables we are facing are the ones related with health. Here we consider two of them: life expectancy at birth and infant survival rate. These variables are available for four different periods: 1985-1990, 1990-1995, 1995-2000 and 2000-2005, and are available for all 28 considered departments.

The first variable we look at is **life expectancy at birth**. We have to remark the important increase of this variable during the 30 years considered. If in 1975 the life expectancy at birth was 66.3, in 2005 it grow up to 71.1. As the standard deviation decreases, the CV experiences an important decrease: from 5.8% in 1975 to 3.5% (see Figure 24). Figures 26 to 28 show the kernel estimates. They show clearly the decrease in the dispersion of the variable (Figure 26) and a contour plot that moves away from the diagonal of the box and approaches to the horizontal line.

This evolution has been parallel to a slight decrease in the measure of spatial autocorrelation, which, in any case, is always positive and highly significant (see Figure 24). The comovement between the CV and the Moran's I can be summarized into a correlation throughout time close to 0.98. In any case, the Moran's scatter plots (see Figure 25) clearly show the strong spatial dependence in this variable and only the evolution of the department of Chocó (numbered as 13) imposes a decrease in the Moran's I. Contrary to other variables, life expectancy at birth does not display significant spatial concentration Getis & Ord's G statistic.

The spatial distribution of the variable is showing also an important degree of heterogeneity, as there are permanently two clear clusters: a positive high-high cluster formed by Atlántico, Bolívar, Córdoba and Sucre, and a negative low-low cluster, formed by Amazonía, Arauca, Caquetá, Casanare and Putumayo (see figures 29 and 30). These clusters are quite stable (see Annex 2) and demonstrate an important persistence in this variable, in our view basically due to natural conditions in every part of the country, such as deep forest in the new departments close to Amazonía. Additionally it demonstrates the difficulty of the public policies in improving health facilities and/or life expectancy.

Figure 24. Life expectancy at birth statistics



The estimates of beta convergence display significant parameters together with high levels of adjustment in all regressions (see Table 5). Despite finding strong spatial autocorrelation, non spatial estimates are preferred to spatial specifications. In all cases the speed of convergence is significant but quite low (1.39% in OLS long run estimates, and 2.53% in fixed effects panel estimates). In this case, the speed of convergence from panel and OLS estimates is relatively similar (much more than in previous situations). We interpret then that convergence process can be seen as a national phenomenon, probably based on the overall economic growth of the country.

Figure 25. Moran's Scatterplot. Life expectancy at birth. 1985-2005

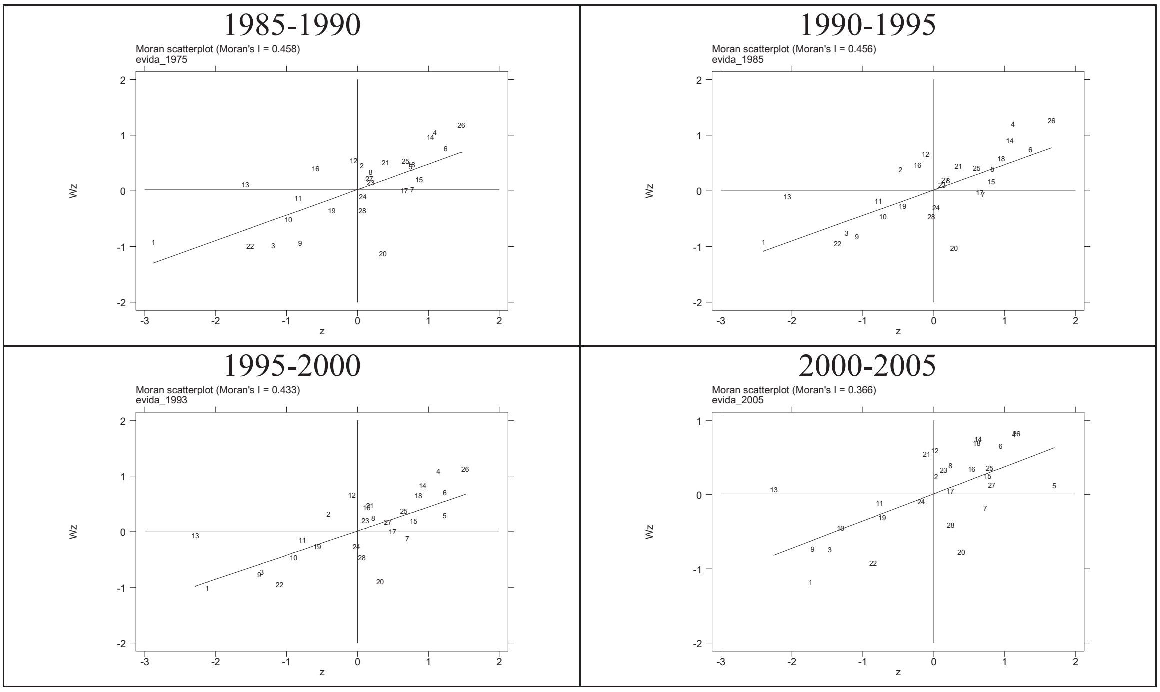


Table 5. Beta convergence estrimates. Life expectancy at birth.

	No Spatial Effects	Spatial Lag	Spatial Error	No Spatial Effects	Spatial Autoregressive Model	Spatial Error Model
Log GDP t-1	-0.0175***	-0.0196***	-0.0170***	-0.0288***	-0.0043	-0.0230***
	0.002	*0.002*	*0.001*	*0.009*	*0.004*	*0.007*
Implicit yearly speed of convergence (divergence)	1.39%	1.23%	1.36%	2.53%	1.31%	2.07%
Half life in years	39.35	45.42	40.50	23.73	48.98	29.75
rho		-0.29285			0.69298***	
		0.1815			*0.0816*	
rho			-0.55051			0.76398***
			0.3546			*0.0682*
Cross section fixed effects				YES	YES	YES
Time Series fixed effects				YES	YES	YES
R-squared	0.736			0.551	0.793	0.509
corr-squared		0.763	0.736		0.003	0.002
AIC	-330.16	-328.62	-328.37	-985.95	-911.50	-921.69
Observations	28	28	28	84	84	84
LR-test joint significance regional fixed effects				2.54**	102.1***	110.0***
LM test no spatial lag	2.202			6.297		
Robust LM test no spatial lag	1.069			0.045		
LM test no spatial error	1.142			8.271		
Robust LM test no spatial error	0.01			0.027		

* p<0.05, ** p<0.01, *** p<0.001. Standard errors are displayed in italics.

Figure 26. Univariate kernel density of relative life expectancy at birth, period 1985-1990 and 2000-2005

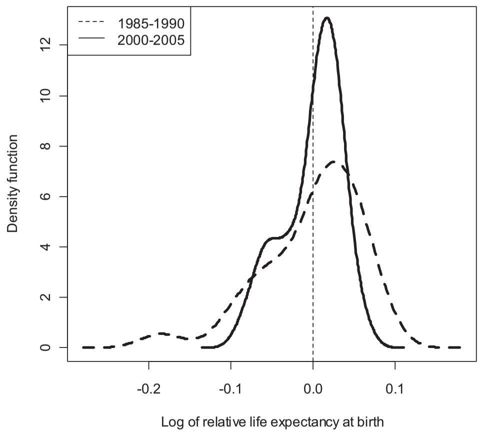


Figure 27. Kernel density estimate 3-dimensional of relative life expectancy at birth, period 1985-1990 and 2000-2005

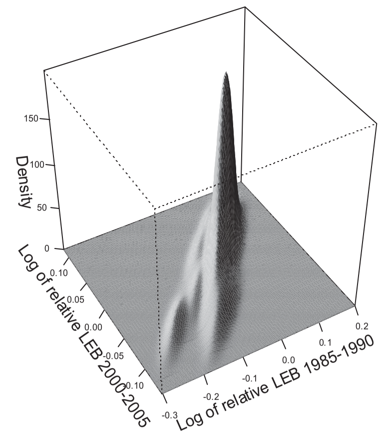


Figure 28. Contour plot of relative life expectancy at birth, period 1985-1990 and 2000-2005

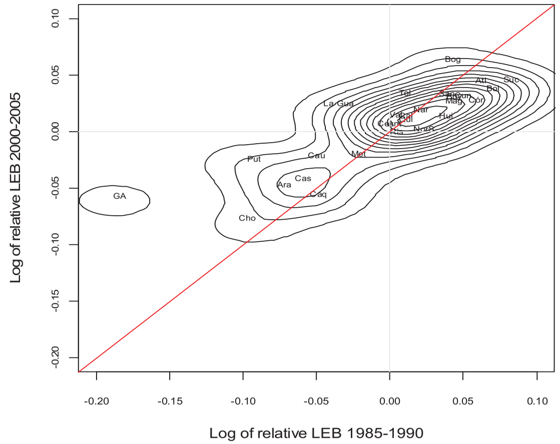


Figure 29. Cloropleth maps. Life expectancy at birth.

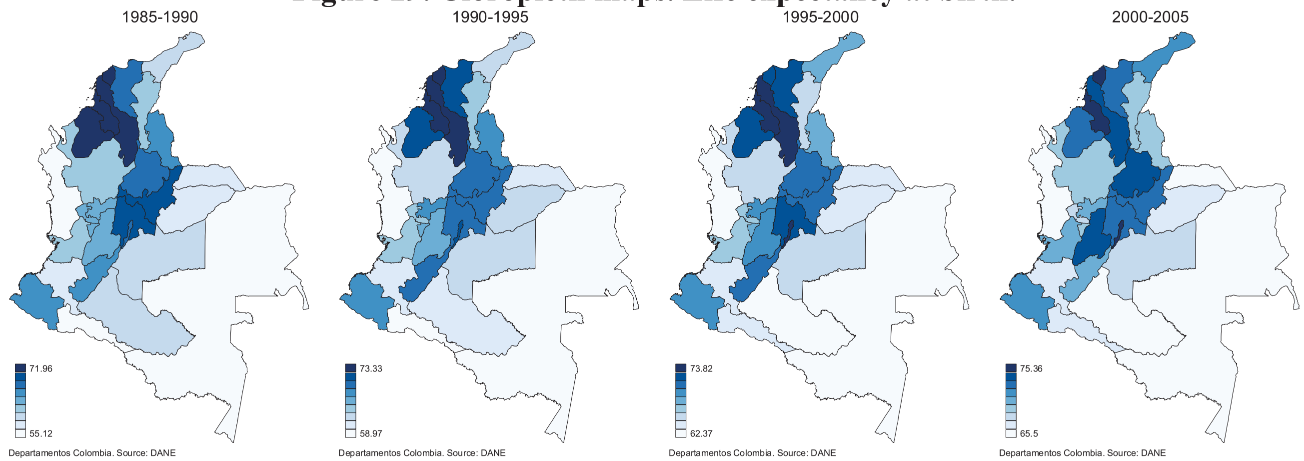
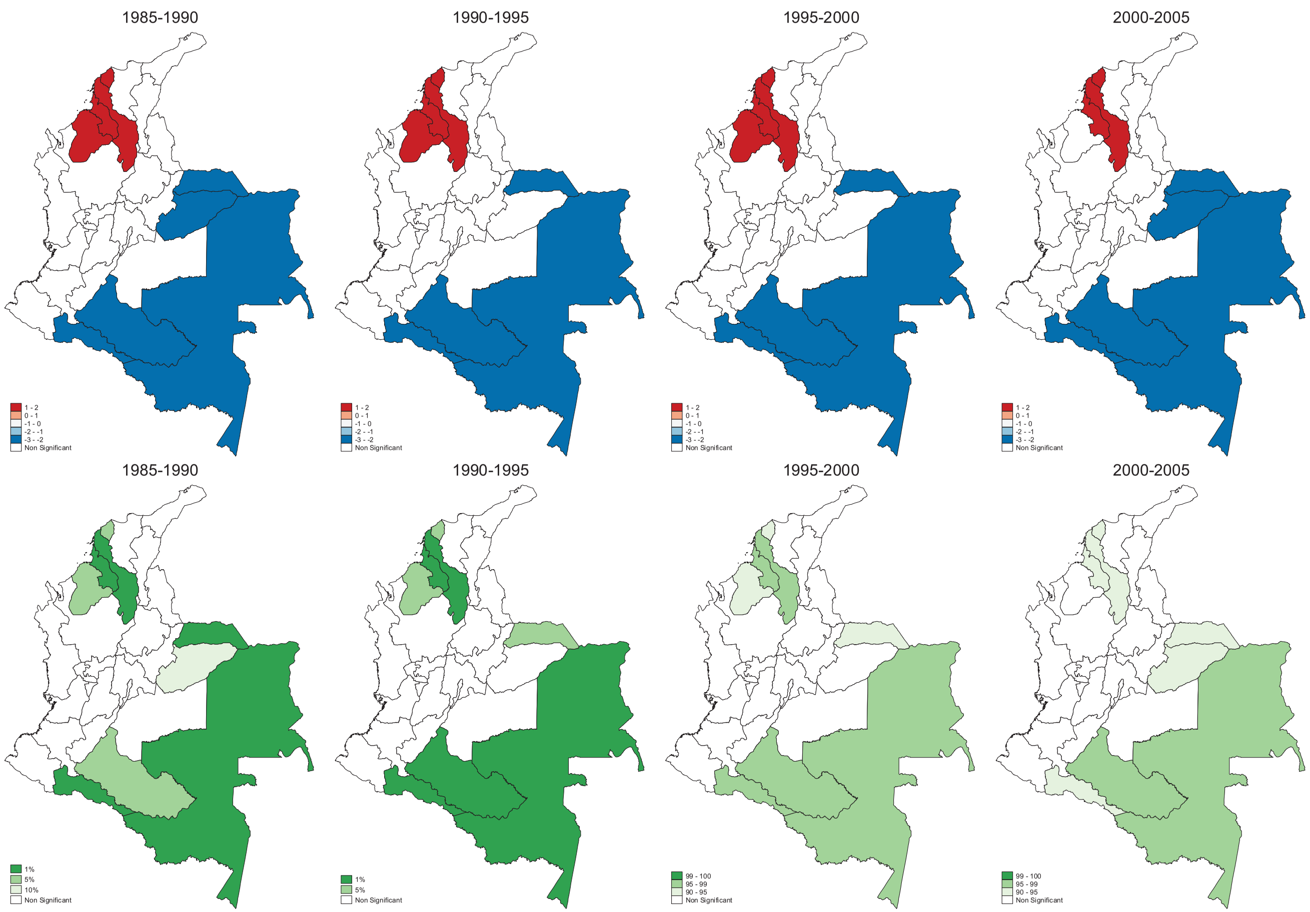


Figure 30. LISA maps (cluster and significance maps). Life expectancy at birth



Note: the significance level is posed at 10%.

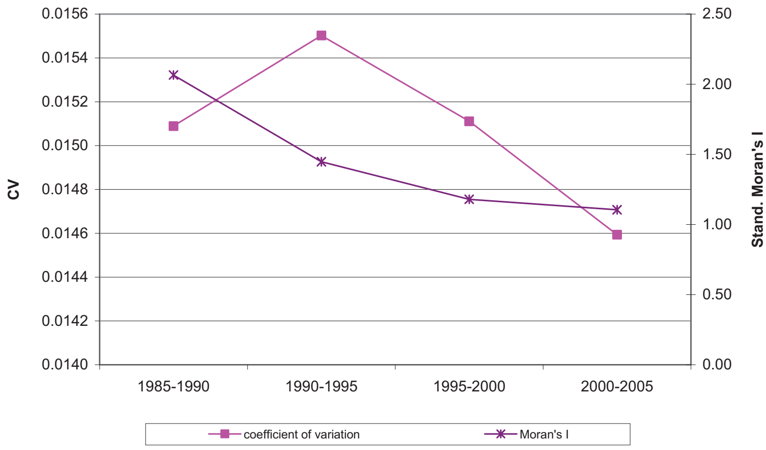
The next health variable is **infant survival rate**, which is the positive variable of the more commonly defined infant mortality rate, is usually assumed to reflect more directly the health condition of population than life expectancy at birth, due to the influence coming form the availability of health facilities.

Parallel to the increase in life expectancy at birth that we have seen above, the infant survival rate increases from 95.2% survived infants under 5 years old in the period 1985-1990 to 96.4% in 2000-2005.

As happened in other social variables, we see a small decrease in the dispersion, with a CV moving from 1.51% to 1.46% in the considered period of study (see Figure 31). Figures 33 to 35 display the kernel estimates. While the mode represented by the department of Chocó (quite away from the rest of the departments) shows a strong persistence over time, there are several changes close to the average. Some initially bad placed departments experience a positive convergence process while other departments who were over the average move towards the maximum.

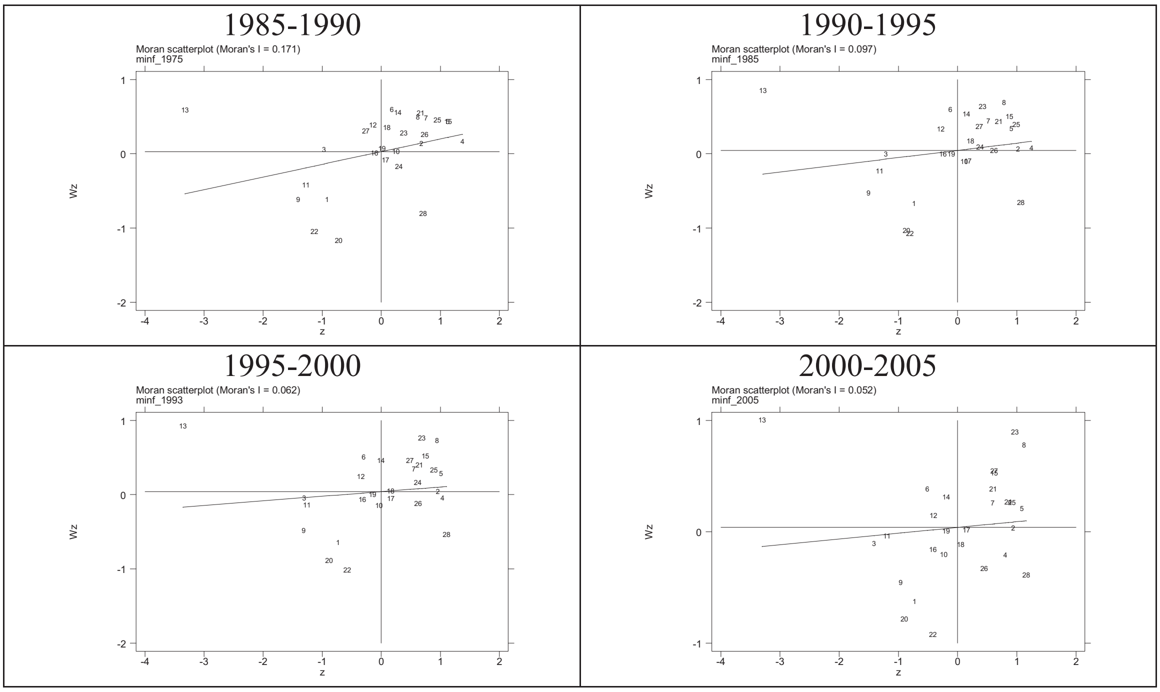
These movements in the dispersion of the variable has been observed together with a fall in the Moran's I statistic (see Figure 31), from 0.18 in 1985-1990 to 0.08 in 2000-2005 (the correlation though time is close to 0.90). The Moran's I stops being significant at 10% in the 1995-2000 period. In order to understand what is going on, the inspection of the Moran's scatterplots (Figure 32) is helpful. Firstly we see that most of the observations are close to a positive and significant spatial autocorrelation. Nevertheless, again due to Chocó, the final Moran's statistic is low, and decreasing (as the Choco's neighbours increase their performance in this indicator). If Chocó would have an infant survival rate equal to the average of the distribution, the Moran's I statistic would have been, although decreasing, always significant: 0.44 in 1985-1990 and 0.37 in 2000-2005. Regarding spatial concentration Getis & Ord's G statistic, we observe that is not significant in any considered period.

Figure 31. Infant survival rate statistics



The spatial distribution of the variable is quite close to the maps of life expectancy at birth (see figures 36 and 37). Again, there is a low-low significant cluster in the Amazonia part of the country, but now the positive high-high cluster is now close to Bogotá. In our view it reflects much more the availability of health facilities than the life expectancy at birth, probably more related with the natural environment of the regions. The urban growth experienced in Colombia during this period clearly helped to improve this indicator, as providing social services to urban residents is easier than to rural populations (Kenny, 2005). In our view it implies that there is a wide margin of improvement in this indicator if additional investments in health facilities are extended to rural areas.[8]

Figure 32. Moran's Scatterplot. Infant Survival Rate. 1985-2005



The beta convergence estimates displayed in Table 6 are insignificant for all cross section estimates. There, the spatial specifications matter, but any of them does change the non-significance of the parameter. On the contrary, the panel data models are displaying significant parameters. The LM tests signal the preference of the spatial lag model, despite it has the worst AIC statistic. In any case, it interesting to see the negative parameter of the spatial lag model, very affected by the department of Chocó that we previously analysed.

Overall, infant survival rate is a variable where we observe a modest decline in the σ -convergence statistic. The more important changes in the distribution happen close to the average. The Department of Chocó has an important influence on the global spatial statistics and even in the spatial estimates. Once we control for spatial fixed effects, and consequently for the particularities of this department, we find a modest speed of convergence (1.74% in the spatial lag panel model), what is in line with the changes in the CV.

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[8] In this line, Chay and Greenstone, (2000), claims that federal interventions during the War on Poverty in the mid-1960's in rural parts of the USA are the main responsible for convergence in infant survival rates.

Table 6. Beta convergence estrimates. Infant Survival Rate.

	Cross section estimates			**Panel data estimates, Cross Section Fixed Effects**		
	OLS	**OLS**	**OLS**	**OLS**	**ML**	**ML**
	No Spatial Effects	**Spatial Lag**	**Spatial Error**	**No Spatial Effects**	**Spatial Autoregressive Model**	**Spatial Error Model**
Log GDP t-1	-0.0038	-0.0013	-0.0006	-0.0510***	-0.0265***	-0.0804***
	0.002	*0.002*	*0.002*	*0.009*	*0.004*	*0.007*
Implicit yearly speed of convergence (divergence)	0.36%	0.32%	0.06%	4.12%	1.74%	5.90%
Half life in years	182.56	204.14	1234.77	13.24	36.02	8.27
rho		0.61831			-0.38880	
		0.1645			*0.1527*	
lambda			0.63685			0.88098 ***
			0.1634			*0.0402*
Cross section fixed effects				YES	YES	YES
Time Series fixed effects				YES	YES	YES
R-squared	0.082			0.026	0.736	0.041
corr-squared		0.432	0.082		0.372	0.262
AIC	-396.39	-401.38	-401.72	-1262.65	-1189.72	-1193.39
Observations	28	28	28	84	84	84
LR-test joint significance regional fixed effects				6.47***	98.70 ***	100.365 ***
LM test no spatial lag	10.891 ***			5.072 **		
Robust LM test no spatial lag	2.940 *			26.187 ***		
LM test no spatial error	9.095 ***			0.971		
Robust LM test no spatial error	1.144			2.766 *		

* p<0.05, ** p<0.01, *** p<0.001. Standard errors are displayed in italics.

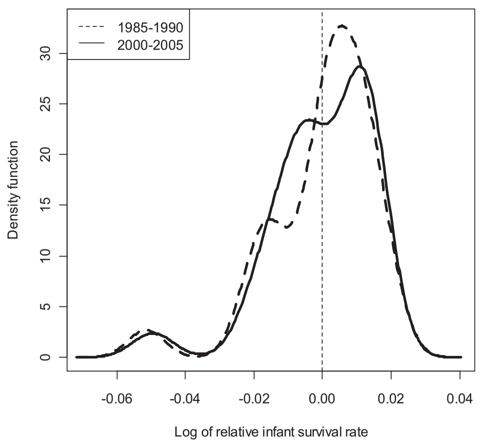
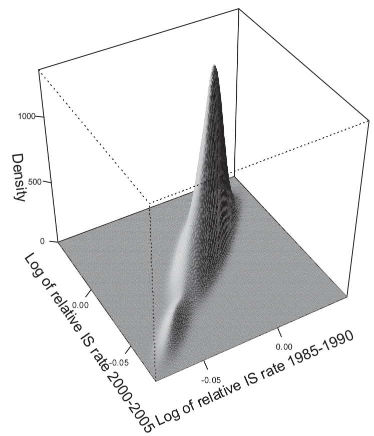
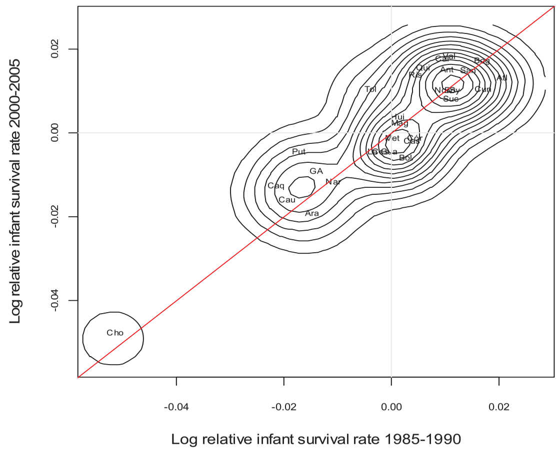
Figure 33. Univariate kernel density of relative infant survival rate, period 1985-1990 and 2000-2005	Figure 34. Kernel density estimate 3-dimensional of relative infant survival rate, period 1985-1990 and 2000-2005	Figure 35. Contour plot of relative infant survival rate, period 1985-1990 and 2000-2005
		

Figure 36. Cloropleth maps. Infant survival rate.

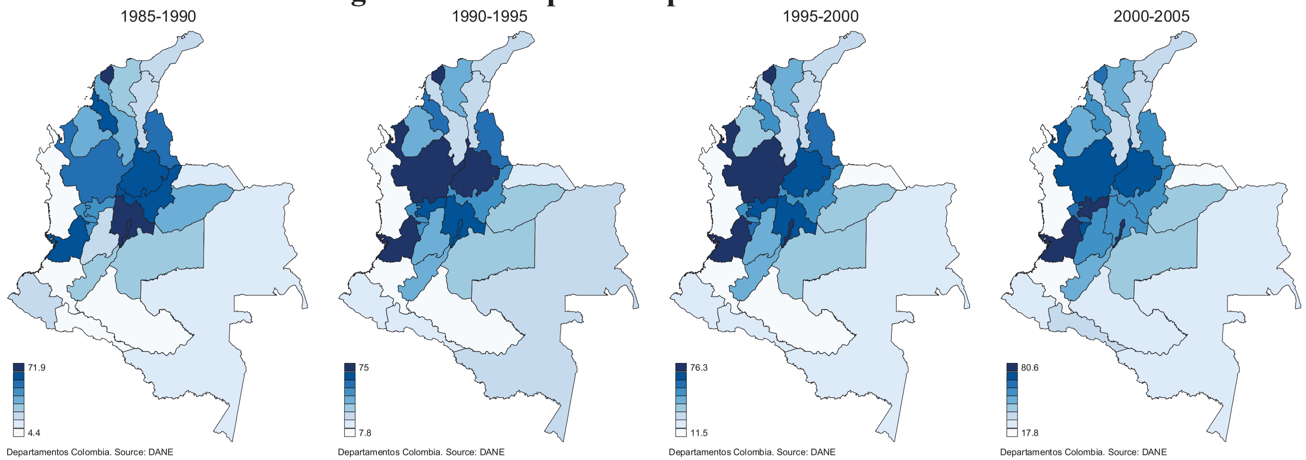
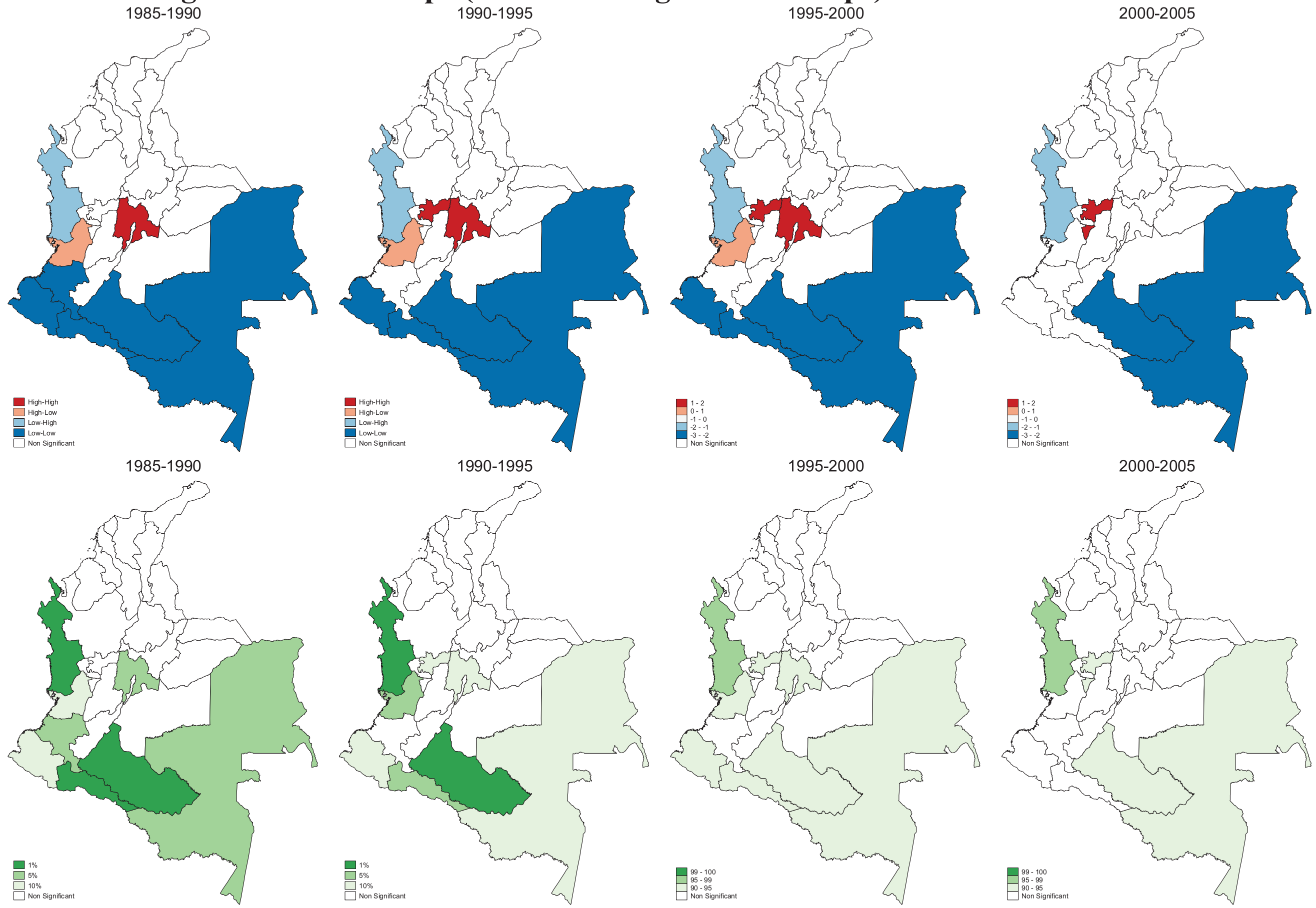


Figure 37. LISA maps (cluster and significance maps). Infant survival rate



4.4. Crime statistics

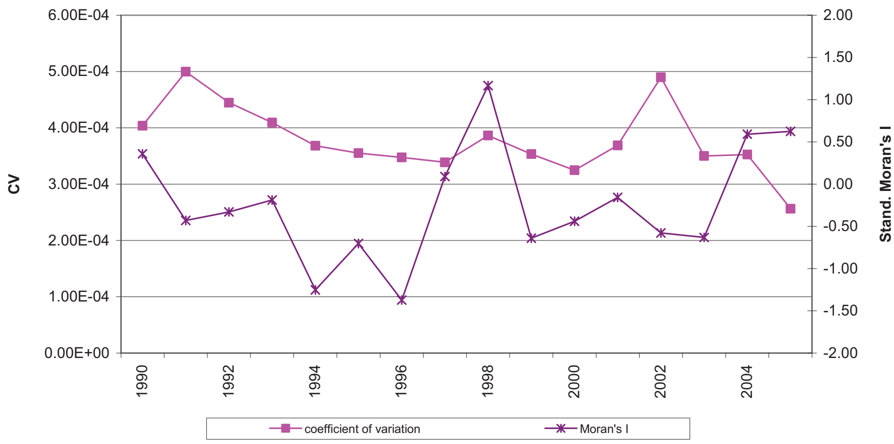
The final social variable we are using is the one related with crime. Again, we turn this variable into positive and thus we use **non-murder rate**, which considers namely the total amount of people who is not being killed over 10,000 inhabitants. This variable is observed along the period 1990-2005, and consequently this is the variable with the shortest period of study. In any case, 16 years is a wide span of years and consequently it is worth to analyse a key variable in a country as Colombia, where violence is a key issue.

The *murder rate* experienced an important increase between 1990 (5.2 murders per 10,000 inhabitants) and 2002 (7.9). Nevertheless it rebounded and in 2005 the figure was 4.6. The CV of the *non-murder rate* experienced a significant decline during the considered period: it was close to 0.05% in 1991, while in 2005 it reduced up to 0.025% (see Figure 38).

The kernel estimates (see figures 40 to 42) show a much richer picture of changes in the distribution. Firstly we see that in 1990 there was a significant mode below the average. In 2005 this mode has completely disappeared and in the contour plot we see how the department of Antioquia has experienced a dramatic change towards the average of the distribution. Contrary to this, there is a big part of the distribution below the average moving away of the convergence process (particularly Arauca and Caquetá, which move from the 9th and 10th position in the crime ranking to the 1st and 2nd respectively). In these departments, together with Putumayo and others, there is an important presence of illegal military (guerrilla and paramilitars) and the war has been a constant for decades.

The strong position from president Uribe at the beginning of the XXI century against these groups may have increased crime statistics. In a similar way Antioquia has had high presence of groups outside the law, as drug cartels and urban militia, what generated strong violence episodes in the nineties, for instance in Medellin (its capital). This situation has experienced a dramatic decline since 2000, what has reinforced the convergence path in this variable.

Figure 38. Non murder rate statistics



The spatial autocorrelation measured by the Moran's I statistic was simply non existent in any of the periods under analysis and additionally there is no trend on them. The Moran's scatterplots (Figure 39) clearly show the lack of any spatial behaviour on the variable. On the contrary, Geary's c and Getis & Ord's G statistics had significant values until 1996 and 1998, respectively. Consequently, in the XXI century no global spatial behaviour is still present. While Moran's I and Geary's c display a small correlation with the CV (the higher the spatial autocorrelation the lower CV), spatial concentration is negatively related over time with the CV (-0.49).

Spatial heterogeneity is analysed through the inspection of the LISA maps (figures 43 and 44). We see that there is a significantly high variation from the beginning of the period to the end, and also that the maps show an important number of high-low and low-high regions (particularly Antioquia and its neighbours). A significant positive high-high cluster at the north of the country is found (and is particularly strong in 2005, as violence in Antioquia decreases). On the contrary, a negative low-low cluster arises in the south, linked to the increasing relative importance of crime figures at the zone where the guerrilla is important.

Figure 39. Moran's Scatterplot. Non murder rate. 1990-2005

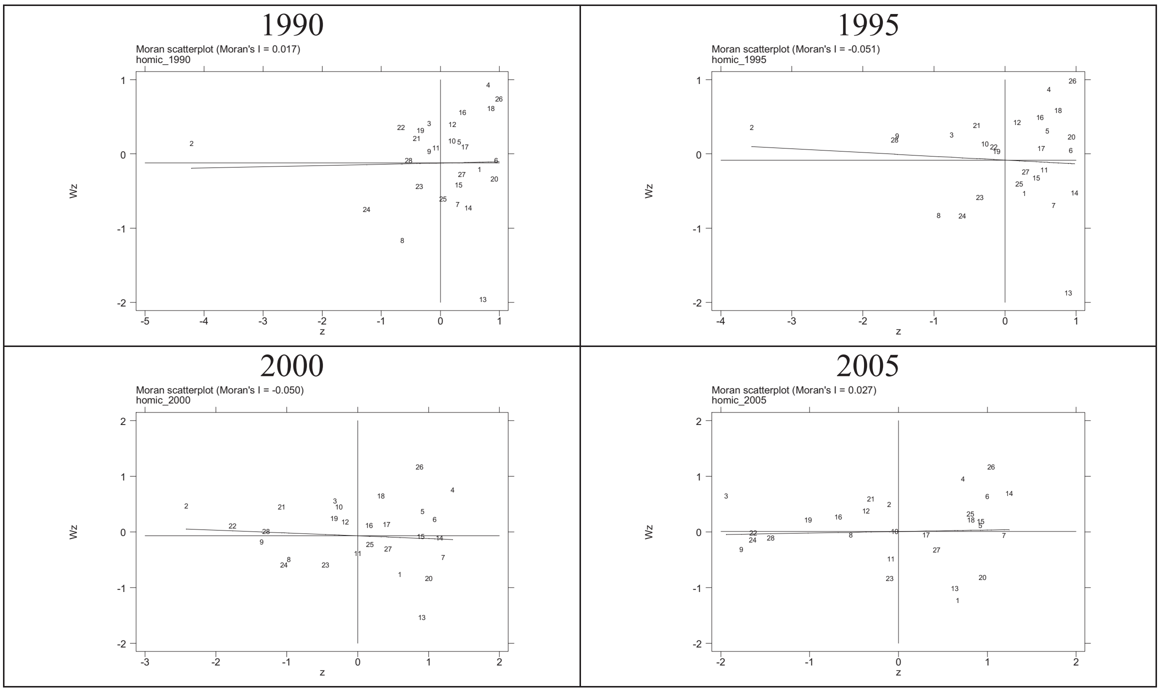


Table 7 show that Beta convergence is significant in all estimates and at high rates. As can be expected, spatial specifications are not important at the cross section models, where the speed of convergence is 3.35% (OLS with no spatial effects). Panel fixed effects estimates show, as usual, a higher speed of convergence (4.64% in the spatial lag model). As can be expected these estimates are affected by the dramatic decline of violent episodes in Antioquia. If the correlation coefficient between the growth rate and the log of initial non/murder rate is -0.78, when excluding Antioquia this statistic collapses to -0.16. Consequently, any convergence process in crime statistics is due to decrease of violent episodes in Antioquia.

Table 7. Beta convergence estimates. Non-murder rate.

	Cross section estimates			Panel data estimates, Cross Section Fixed Effects		
	OLS	OLS	OLS	OLS	ML	ML
	No Spatial Effects	Spatial Lag	Spatial Error	No Spatial Effects	Spatial Autoregressive Model	Spatial Error Model
Log GDP t-1	-0.0442***	-0.0436***	-0.0430***	-0.0672***	-0.0472***	-0.0701***
	0.007	*0.006*	*0.0003*	*0.012*	*0.011*	*0.011*
Implicit yearly speed of convergence (divergence)	3.35%	3.30%	2.70%	5.14%	4.64%	5.31%
Half life in years	15.32	11.49	15.79	9.97	11.38	9.54
rho		0.25523			0.2010 **	
		0.1721			*0.0978*	
lambda			0.23842			0.3999 ***
			0.2485			*0.0886*
Cross section fixed effects				YES	YES	YES
Time Series fixed effects				YES	YES	YES
R-squared	0.612			0.321	0.760	0.743
corr-squared		0.645	0.612		0.045	0.073
AIC	-542.55	-539.38	-540.60	-3262.16	-3166.28	-3178.44
Observations	28	28	28	84	84	84
LR-test joint significance regional fixed effects				13.2 ***	233.37 ***	243.52 ***
LM test no spatial lag	1.956			2.051		
Robust LM test no spatial lag	1.113			7.260 ***		
LM test no spatial error	0.843			0.339		
Robust LM test no spatial error	0.000			0.064		

Figure 40. Univariate kernel density of relative non-murder rate, 1990 and 2005

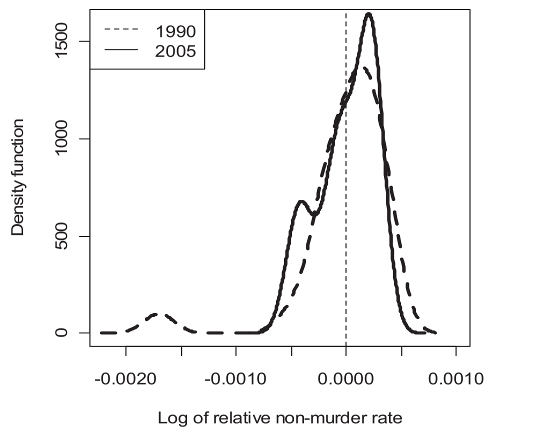


Figure 41. Kernel density estimate 3-dimensional of relative non-murder rate, 1990 and 2005

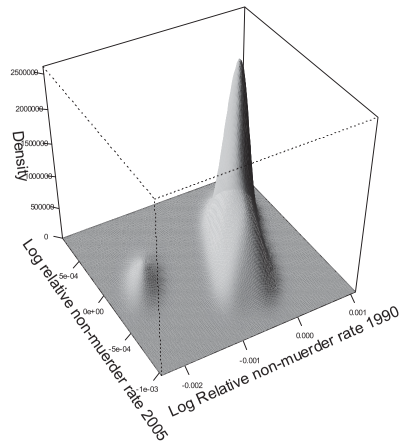


Figure 42. Contour plot of relative non-murder rate, 1990 and 2005

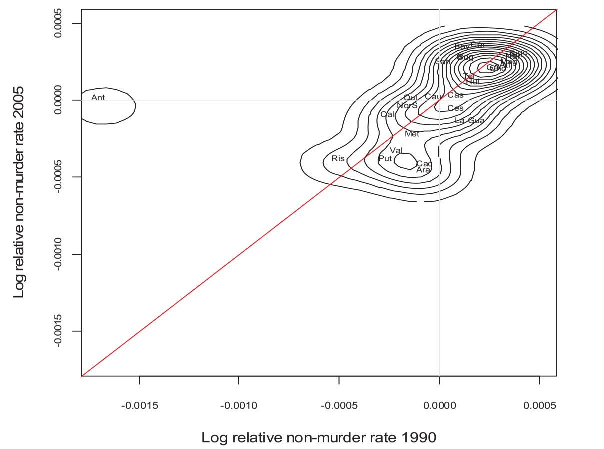


Figure 43. Cloropleth maps. Non-murder rate.

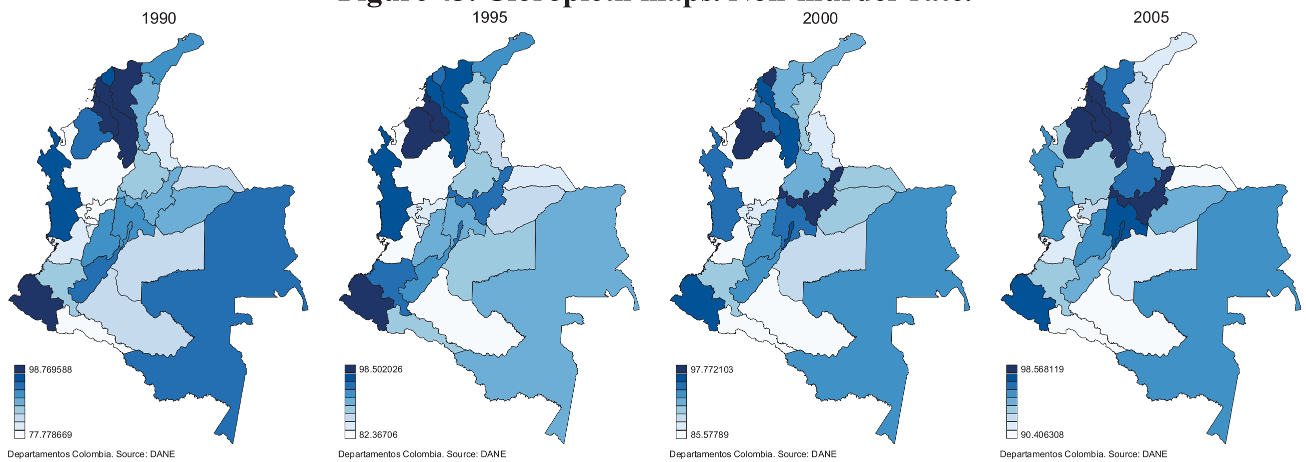
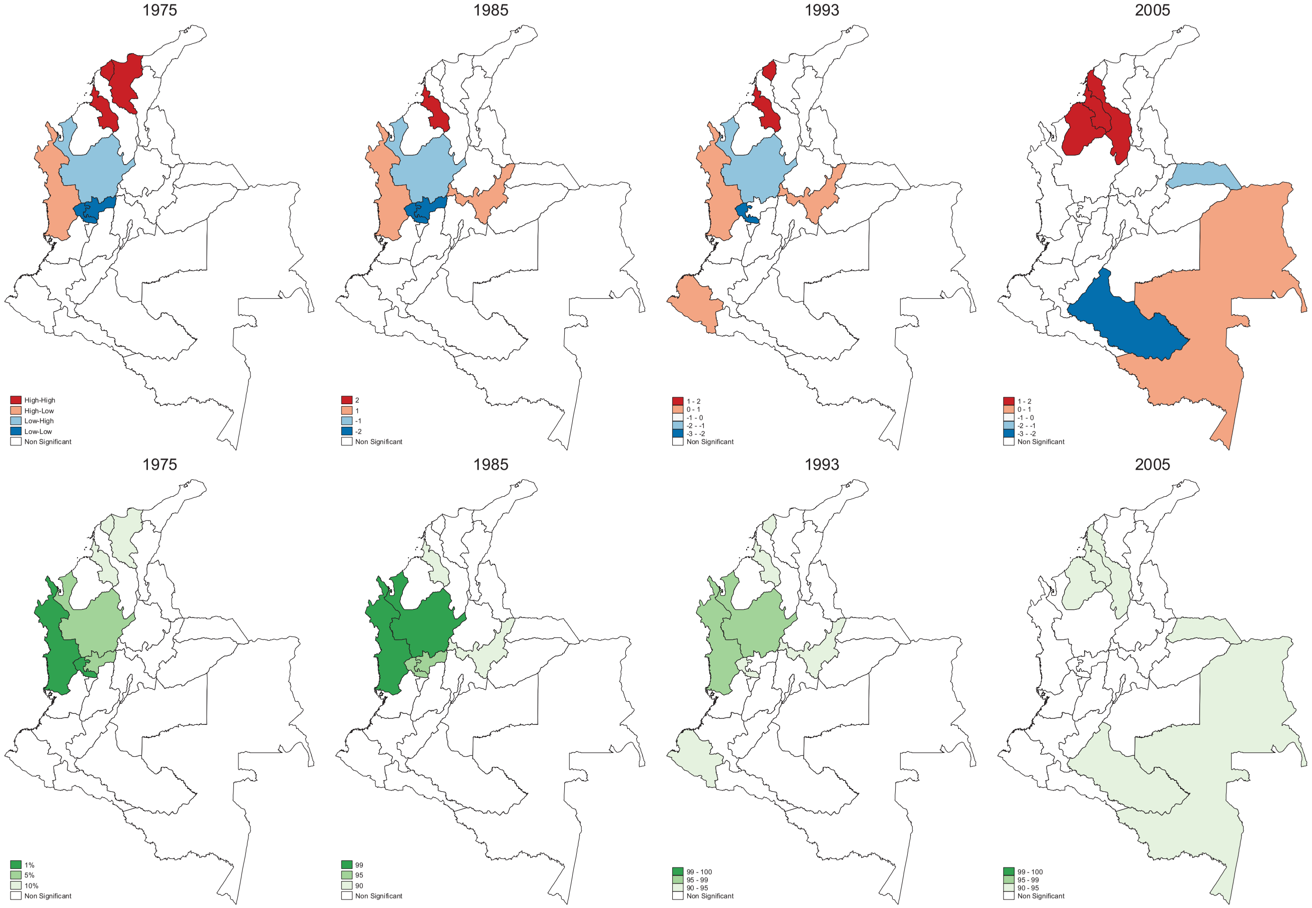


Figure 44. LISA maps (cluster and significance maps). Non-murder rate.



5. Conclusions

In this paper we have analysed social convergence in Colombia, considering not only economic variables but also social indicators of education, health and crime. We have developed our analysis by looking at sigma convergence, the distribution dynamics of the variables and beta convergence, both in the long run (using cross section specifications) and in the short run (using fixed effects panel data techniques). We have also focused on the spatial distribution of the variables, through an inspection of spatial autocorrelation statistics, and also through the use of spatial econometrics techniques for estimating beta convergence.

We have found that the economic variables display conflicting results. We find no sigma convergence between 1975 and 2005. The start of work in the Casanare oil fields in 1986 brought about significant growth rates in formerly poor departments, which in fact caused a dispersion increase. As well as this we found insignificant long-run beta convergence parameters. Despite panel estimates displaying significant convergence parameters, they are an expression of short-run convergence to every region's steady state. In our view, any convergence/divergence movement in this variable had nothing to do with the grounds of neoclassical growth theory convergence, based on labour mobility and decreasing marginal returns. It is mostly based on oil production in a subset of departments. The rest of the country maintained the same distribution over the years and consequently we understand that there was no convergence in this variable.

When inspecting real disposable household income we simultaneously find three results related to convergence: a significant decline in sigma convergence, particularly after 1986; a decrease in both tails of the kernel distribution between 1975 and 2005, in both cases towards the average; and finally, significant beta convergence estimates. A detailed analysis of the kernel estimates shows that both the richest and the poorest departments were the main factors responsible for convergence. Due to a lack of data availability, this variable is only observed in 24 out of the 28 previously considered departments. It does not consider some of the oil departments. Consequently, when refining the economic variable related to well-being, and when excluding oil field departments, it can be said that Colombia is undergoing an economic convergence process.

As regards education, we have analysed the literacy rate. This variable is a clear example of convergence: a huge decrease in sigma convergence, a dramatic change in the distribution shape (concentrating much more density close to the average at the end of the period), and significant beta estimates. We find a much higher speed of convergence panel specifications.

Both health variables, life expectancy at birth and infant survival rates, show declines in sigma convergence. However, the former also shows significant changes in the kernel estimates towards the average and significant parameters of beta convergence, while the latter does not display the same convergence evidence. Life expectancy at birth beta estimates display similar results to the cross section and panel estimations, which leads us to assume that the convergence process can be seen as a national phenomenon, probably based on the overall economic growth of the country.

However, and despite having a decreasing CV, the infant survival rate does not show any significant convergence path in long-run beta convergence terms, and the kernel estimates do not show a clear convergence pattern. These results are seriously affected by individual results observed in the department of Chocó. Once we control for spatial fixed effects we find a modest speed of convergence, which is in line with the changes in the CV. The urban growth experienced in Colombia during this period clearly helped to improve this indicator, as providing social services to urban residents is easier than providing them to rural populations (Kenny, 2005). In our view this implies that there is a wide margin for improvement in this indicator if additional investments in health facilities are extended to rural areas.[9]

Finally, the crime statistics are highly influenced by the evolution of Antioquia, the most violent department in 1990, which is finally positioned over the average in 2005. This dramatic change is counterbalanced by the negative evolution of several departments partially controlled by guerrilla and paramilitary groups, where violence increased over the years studied. Overall, one can talk about a polarization of the murder rate in a small number of departments (although covering extensive areas) close to the Amazonía. In this variable, convergence has a name: Antioquia.

Our results suggest that there is robust evidence of convergence in Colombia over the last 30 years. Convergence both in economic (income) and social variables (literacy rate, life expectancy at birth and non-murder rate) are evident and robust results. Our results are in line with Kenny (2005): convergence in quality of life indicators can be achieved even in the absence of sustained economic growth and convergence. Thus income is only one among a number of factors in determining well-being. Despite technological improvements in health and education, there is still wide scope for government intervention.

The analysis of spatial trends leads us to answer one of the questions posed in our paper - the joint analysis of the spatial distribution of the variables and the convergence processes - in an attempt to answer Rey and Janikas's question regarding the relationship between convergence and spatial autocorrelation.

We have found a huge diversity of results. There are all kinds of possible results: convergence and non-convergence with and without global spatial autocorrelation. Interestingly, we have found convergence associated with increasing spatial autocorrelation (as happened in a subsample of the GDP) or with high values of the Moran’s I (life expectancy at birth). In other words a decreasing CV has been accompanied by increases (significant or not) in the Moran’s I global measure of spatial autocorrelation. However, we also found convergence and non-significant spatial correlation (infant survival rate and non-murder rate), but these situations were mostly based on the behaviour of two departments (Chocó and Antioquia, respectively). Overall we have found some weak evidence of a link between regional convergence and spatial autocorrelation; in order to find evidence linked to the neoclassical growth theory of convergence, based on labour mobility and decreasing marginal returns linked also to capital mobility, some kind of link has to be found between regions.

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9 Along these lines Chay and Greenstone (2000) claim that federal interventions during the War on Poverty in the mid-1960s in rural parts of the USA are the main factor responsible for convergence in infant survival rates.

We recognise that more robust evidence is needed in this area, possibly by analysing a number of variables for a wider sample of countries. Nevertheless, the literature has found some additional evidence. Aroca and Bosch (2000) found opposite evolutions of the sigma convergence (decreasing) and the Moran's I (increasing) for GDP per capita in Chile. Rey and Montouri (1999) and Rey and Janikas (2005), again for GDP per capita, find huge decreases in the CV and Theil indices together with decreases in the Moran's I in the USA. In any case these convergence processes are developed in significant spatial autocorrelation scenarios, which partly supports our intuition.

An example of this situation is the department of Chocó. This is located on the Pacific coast, but there is a natural barrier of deep forest separating it from the rest of the country, making it an 18-hour drive to Medellín, the closest big capital, only 136 km away. Its isolation is a key factor for explaining the low levels in GDP, income, literacy rate and infant survival rate, despite the fact that it is surrounded by departments with high levels in all these variables. In these indicators Chocó has a significant low-high cluster.

Consequently, in our view spatial autocorrelation reinforces convergence processes through deepening market and social factor interrelations. Public action can play a key role in connecting isolated areas (such as Chocó) with the rest of the country through the development of transport infrastructures.

In our results, beta convergence panel data estimates were in many cases larger than the cross section estimates. Following Islam (1995), a higher beta convergence in panel estimates, contrary to what it may seem, calls for more policy activism. The main reason is because improvements in every individual region (every steady state) will also lead to higher transitional growth rates (higher speed of convergence).

We have found convergence processes in key social variables and no convergence in real GDP per capita. In a developing country such as Colombia it might be the case that improvements in people's well-being can be obtained at the expense of economic polarization. Strong current redistribution policies in health and education facilities together with the development of transport infrastructures may help future regional balanced growth. This recipe may be controversial and certainly deserves future research: what is the relationship in the evolution between social and economic variables at regional level in developing countries?

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Annex 1. Socio-economic variables statistics

Real GDP per capita

	Mean	Standard Deviation	coefficient of variation	Gini coefficient	Theil entropy measure	Moran's I	Geary's c	Getis & Ord's G
1975	975009	452242.1	0.4638	0.2404	0.09566	1.253	-2.137 **	0.974
1976	1025381	472602.4	0.4609	0.2429	0.09727	1.311 *	-2.106 **	1.194
1977	1073764	469806.9	0.4375	0.2367	0.09159	1.331 *	-2.278 **	1.344 *
1978	1088425	494068.5	0.4539	0.2459	0.09711	1.471 *	-2.367 ***	1.338 *
1979	1081288	493170.6	0.4561	0.2470	0.09821	1.365 *	-2.199 **	1.37 *
1980	1098860	485991	0.4423	0.2400	0.09241	1.222	-2.014 **	1.297 *
1981	1091437	488710.7	0.4478	0.2420	0.09415	1.027	-1.833 **	1.13
1982	1076574	496750.3	0.4614	0.2486	0.09907	1.29 *	-2.046 **	1.265
1983	1089185	494350.5	0.4539	0.2447	0.09670	0.993	-1.935 **	0.974
1984	1104558	511330.7	0.4629	0.2474	0.09897	0.959	-1.872 **	0.908
1985	1086293	491355.9	0.4523	0.2448	0.09779	1.152	-1.767 **	1.109
1986	1203504	571311.8	0.4747	0.2534	0.10319	1.264	-2.02 **	0.855
1987	1298071	684885.2	0.5276	0.2633	0.11839	1.511 *	-1.887 **	0.836
1988	1299847	628570	0.4836	0.2484	0.10279	1.484 *	-1.954 **	0.97
1989	1376437	705728.4	0.5127	0.2584	0.11148	1.52 *	-1.898 **	0.711
1990	1472958	855294.4	0.5807	0.2773	0.13339	1.815 **	-1.787 **	0.632
1991	1480300	848142.7	0.5730	0.2801	0.13323	1.786 **	-1.95 **	0.57
1992	1479741	812007.6	0.5487	0.2701	0.12364	1.911 **	-2 **	0.878
1993	1491499	820077.7	0.5498	0.2698	0.12420	1.936 **	-2.004 **	1.038
1994	1525503	767170	0.5029	0.2556	0.10945	1.841 **	-2.175 **	1.189
1995	1625555	851388.2	0.5238	0.2667	0.11804	1.965 **	-2.02 **	1.424 *
1996	1707068	1015229	0.5947	0.2865	0.14168	2.123 **	-1.533 *	1.352 *
1997	1746740	1011656	0.5792	0.2793	0.13550	2.284 **	-1.371 *	1.524 *
1998	1742639	1195468	0.6860	0.2961	0.16623	1.556 *	-0.482	1.225
1999	1699135	1275162	0.7505	0.2951	0.18187	1.41 *	-0.282	1.107
2000	1657417	1052566	0.6351	0.2681	0.14223	1.045	-0.27	1.142
2001	1609426	921620.3	0.5726	0.2514	0.12202	1.224	-0.373	1.454 *
2002	1571296	872044.8	0.5550	0.2522	0.11867	1.545 *	-0.54	1.69 **
2003	1588723	861914.4	0.5425	0.2569	0.11848	1.411 *	-0.606	1.64 *
2004	1612629	841759.6	0.5220	0.2560	0.11434	1.299 *	-0.7	1.625 *
2005	1659126	829611.9	0.5000	0.2506	0.10724	1.326 *	-0.819	1.608 *

Note: All measures of global spatial autocorrelation are standardized. Asterisks imply different significance levels: *** = 1%; ** = 5%; * = 10%

Real Income per capita (24 Departments)

	Mean	Standard Deviation	coefficient of variation	Gini coefficient	Theil entropy measure	Moran's I	Geary's c	Getis & Ord's G
1975	694635	320279	0.4611	0.2151	0.0860	0.718	-1.138	1.064
1976	728942	337435	0.4629	0.2171	0.0876	0.577	-1.094	1.013
1977	764764	333814	0.4365	0.2065	0.0799	0.349	-1.119	0.938
1978	785971	353600	0.4499	0.2125	0.0835	0.551	-1.100	1.021
1979	800068	360515	0.4506	0.2141	0.0837	0.657	-1.115	1.111
1980	818611	378469	0.4623	0.2184	0.0869	0.505	-1.044	1.048
1981	816316	364738	0.4468	0.2145	0.0827	0.452	-0.998	1.025
1982	804347	381307	0.4741	0.2232	0.0911	0.718	-1.077	1.130
1983	797033	372869	0.4678	0.2195	0.0890	0.648	-1.046	1.078
1984	816519	377649	0.4625	0.2192	0.0878	0.576	-1.032	1.058
1985	807775	380583	0.4711	0.2224	0.0899	0.424	-0.914	0.986
1986	859018	391044	0.4552	0.2142	0.0836	0.477	-0.897	0.960
1987	895112	405777	0.4533	0.2144	0.0836	0.536	-0.914	1.066
1988	922847	403485	0.4372	0.2092	0.0786	0.645	-0.960	1.150
1989	948558	400779	0.4225	0.2041	0.0741	0.692	-0.985	1.133
1990	928439	379470	0.4087	0.1983	0.0701	0.690	-1.047	1.119
1991	936398	380169	0.4060	0.1985	0.0700	0.756	-1.116	1.206
1992	950654	389722	0.4100	0.2014	0.0714	0.853	-1.160	1.316*
1993	967812	389339	0.4023	0.2000	0.0699	0.534	-1.028	1.331*
1994	976528	384574	0.3938	0.1956	0.0669	0.534	-1.043	1.394*
1995	980368	374231	0.3817	0.1911	0.0634	0.545	-1.047	1.515*
1996	982098	361941	0.3685	0.1840	0.0590	0.550	-1.028	1.521*
1997	968181	351332	0.3629	0.1831	0.0577	0.647	-1.089	1.638*
1998	978657	347567	0.3551	0.1789	0.0553	0.725	-1.130	1.553*
1999	949657	322991	0.3401	0.1732	0.0511	0.543	-1.049	1.584*
2000	944975	312636	0.3308	0.1703	0.0492	0.899	-1.262	1.783**

Note: All measures of global spatial autocorrelation are standardized. Asterisks imply different significance levels:
*** = 1%; ** = 5%; * = 10%

Literacy Rate

	Mean	Standard Deviation	coefficient of variation	Gini coefficient	Theil entropy measure	Moran's I	Geary's c	Getis & Ord's G
1975	78.39679	8.477802	0.108	0.0588	0.00576	0.776	-2.051**	0.787
1985	84.89214	6.265671	0.074	0.0397	0.00268	1.455*	-2.426***	1.372*
1993	88.58929	5.190908	0.059	0.0314	0.00168	1.202	-2.330***	1.373*
2005	89.17143	5.702428	0.064	0.0323	0.00204	2.381***	-2.984***	2.055**

Note: All measures of global spatial autocorrelation are standardized. Asterisks imply different significance levels:
*** = 1%; ** = 5%; * = 10%

Life Expectancy at Birth

	Mean	Standard Deviation	coefficient of variation	Gini coefficient	Theil entropy measure	Moran's I	Geary's c	Getis & Ord's G
1985-1990	66.278	3.876	0.058	0.0313	0.00168	4.143***	-2.965***	0.207
1990-1995	67.456	3.533	0.052	0.0287	0.00134	3.830***	-3.271***	-0.091
1995-2000	69.250	3.005	0.043	0.0237	0.00092	3.709***	-3.372***	-0.159
2000-2005	71.120	2.491	0.035	0.0191	0.00060	3.397***	-3.236***	-0.101

Note: All measures of global spatial autocorrelation are standardized. Asterisks imply different significance levels: *** = 1%; ** = 5%; * = 10%

Infant Survival Rate

	Mean	Standard Deviation	coefficient of variation	Gini coefficient	Theil entropy measure	Moran's I	Geary's c	Getis & Ord's G
1985-1990	95.216	1.437	0.0151	0.0078	0.00011	2.065**	-1.861**	0.596
1990-1995	95.658	1.483	0.0155	0.0080	0.00012	1.448*	-1.500*	0.866
1995-2000	96.026	1.451	0.0151	0.0078	0.00011	1.180	-1.386*	0.879
2000-2005	96.430	1.407	0.0146	0.0076	0.00010	1.105	-1.359*	0.974

Note: All measures of global spatial autocorrelation are standardized. Asterisks imply different significance levels: *** = 1%; ** = 5%; * = 10%

Non-murder rate

	Mean	Standard Deviation	coefficient of variation	Gini coefficient	Theil entropy measure	Moran's I	Geary's c	Getis & Ord's G
1990	9994.8	4.036	4.04E-04	1.80E-04	7.86E-08	0.359	1.520*	-2.100**
1991	9993.7	4.994	5.00E-04	2.36E-04	1.21E-07	-0.430	1.670**	-1.936**
1992	9993.8	4.445	4.45E-04	2.11E-04	9.54E-08	-0.329	1.634*	-2.064**
1993	9994.1	4.091	4.09E-04	2.00E-04	8.08E-08	-0.188	1.530**	-1.927**
1994	9994.5	3.681	3.68E-04	1.79E-04	6.54E-08	-1.251	1.974**	-1.575*
1995	9995.0	3.550	3.55E-04	1.75E-04	6.08E-08	-0.702	1.759**	-1.762**
1996	9994.7	3.472	3.47E-04	1.73E-04	5.82E-08	-1.372	2.222**	-1.299*
1997	9994.7	3.386	3.39E-04	1.77E-04	5.54E-08	0.090	1.205	-1.513*
1998	9993.8	3.860	3.86E-04	2.07E-04	7.20E-08	1.166	-0.502	-1.295*
1999	9994.0	3.533	3.54E-04	1.92E-04	6.03E-08	-0.640	1.023	-1.130
2000	9993.4	3.247	3.25E-04	1.79E-04	5.09E-08	-0.439	1.045	-1.207
2001	9993.0	3.685	3.69E-04	2.05E-04	6.56E-08	-0.156	0.750	-1.422*
2002	9992.1	4.894	4.90E-04	2.62E-04	1.16E-07	-0.577	0.249	-0.777
2003	9993.5	3.497	3.50E-04	1.92E-04	5.90E-08	-0.631	-0.088	-0.818
2004	9994.2	3.524	3.53E-04	1.89E-04	5.99E-08	0.592	-0.843	0.010
2005	9995.4	2.563	2.56E-04	1.41E-04	3.17E-08	0.625	-0.738	-0.158

Note: All measures of global spatial autocorrelation are standardized. Asterisks imply different significance levels: *** = 1%; ** = 5%; * = 10%

Annex 2. Local spatial autocorrelation measurements, by Department and Year

Real GDP per capita

Real departmental per capita household income

Literacy rate

Life expectancy at birth

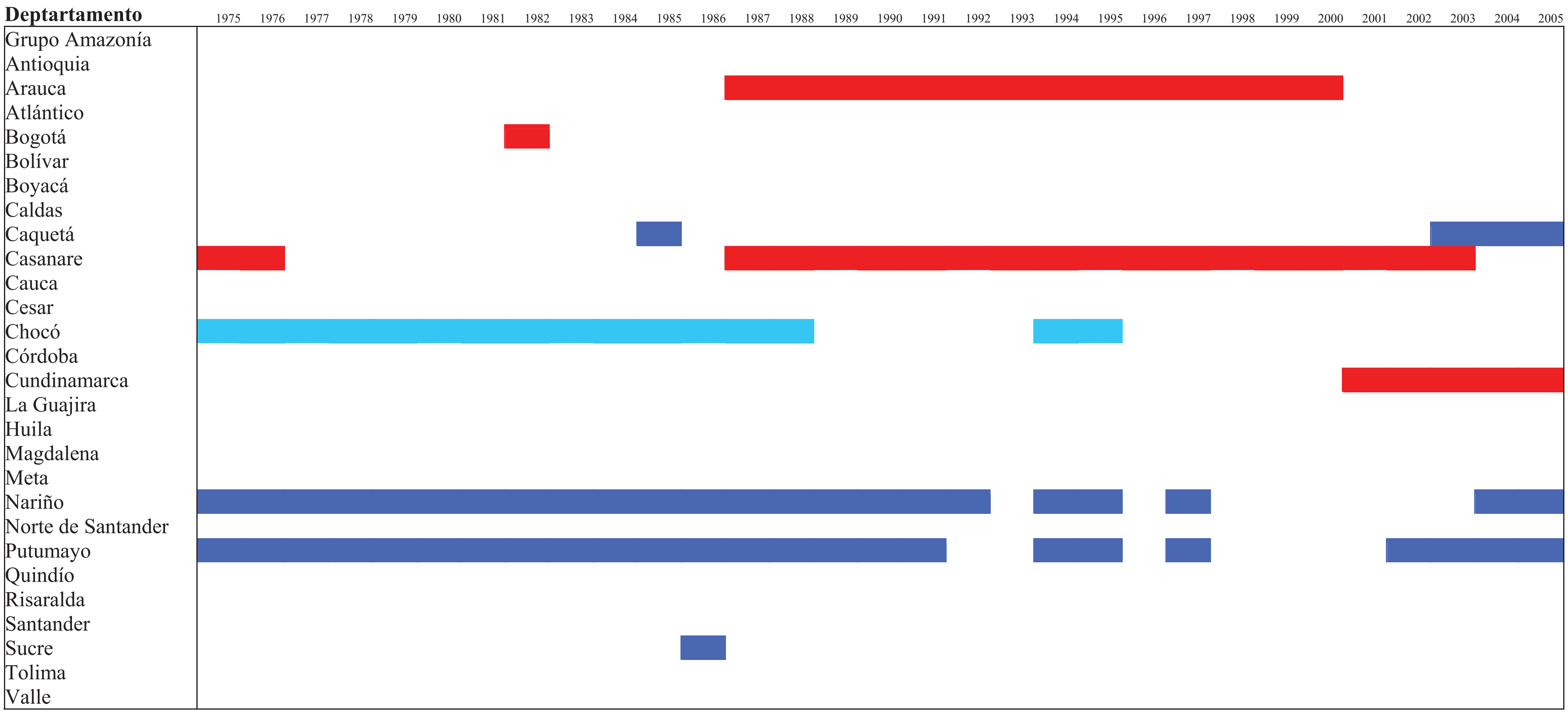
Infant survival rate

Non-murder rate

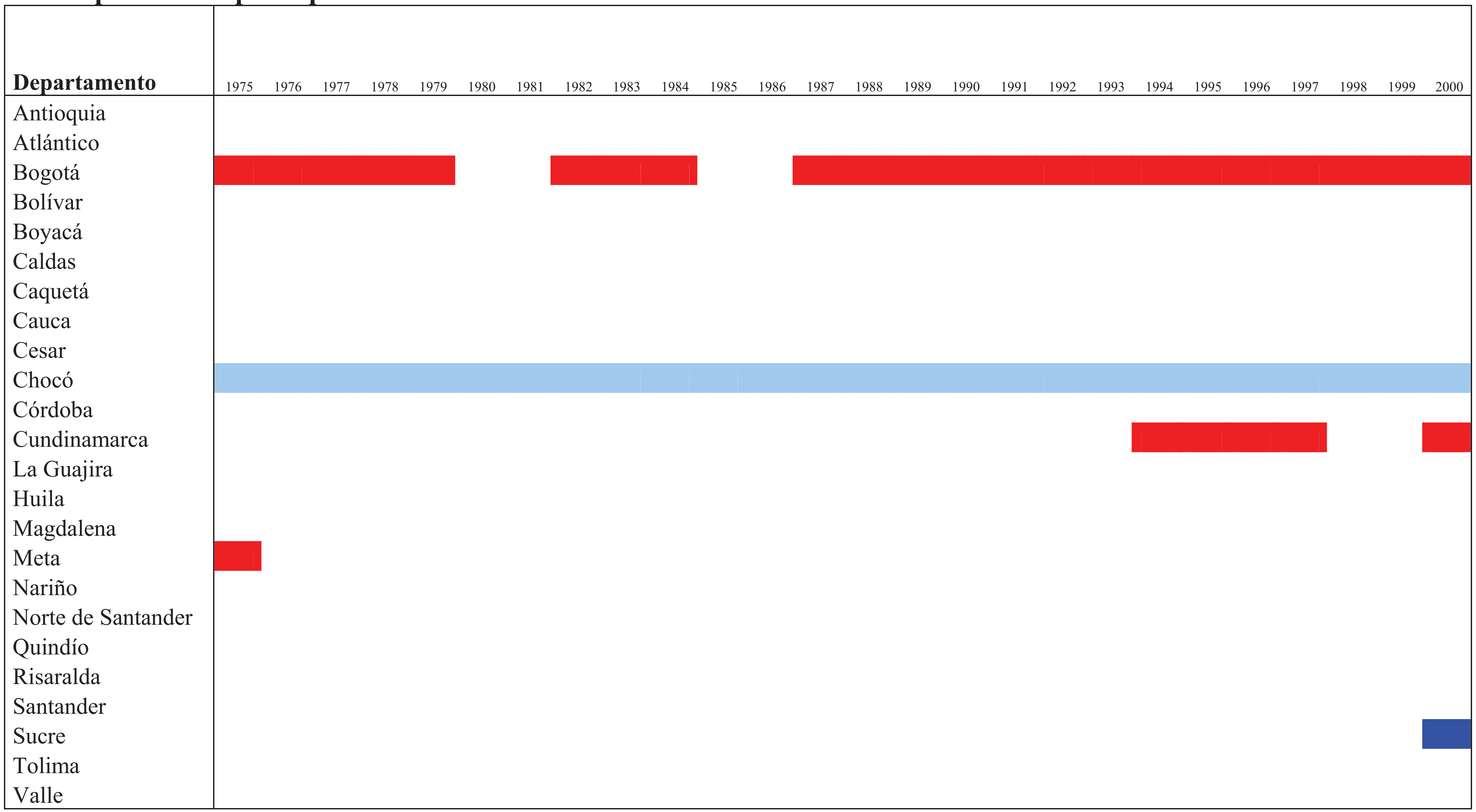
Note: In all tables the displayed colours correspond to the different significant (10%) spatial clusters:

High-High Low-Low Low-High High-Low

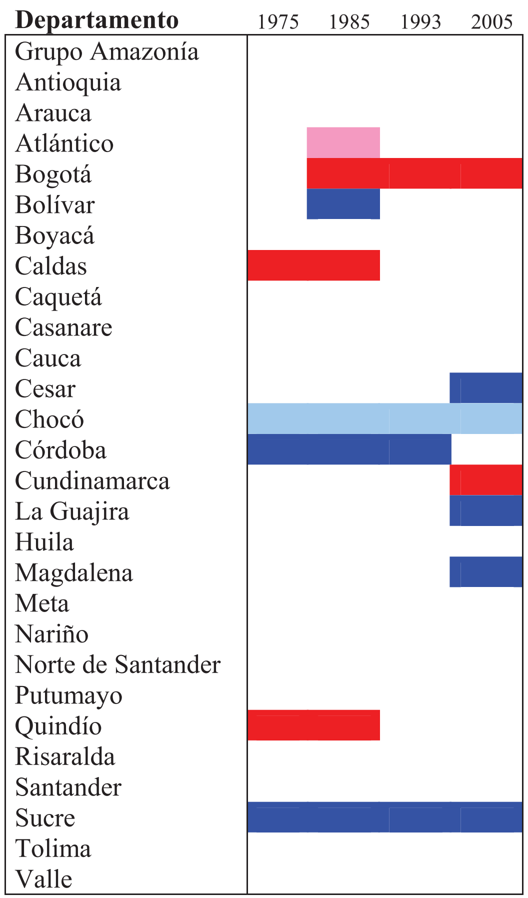
Real GDP per capita



Real departmental per capita household income

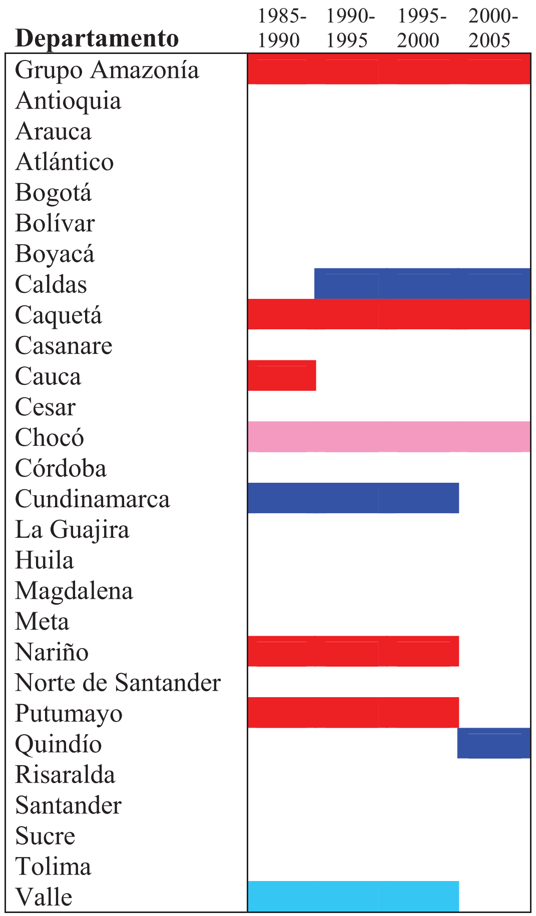


Literacy rate

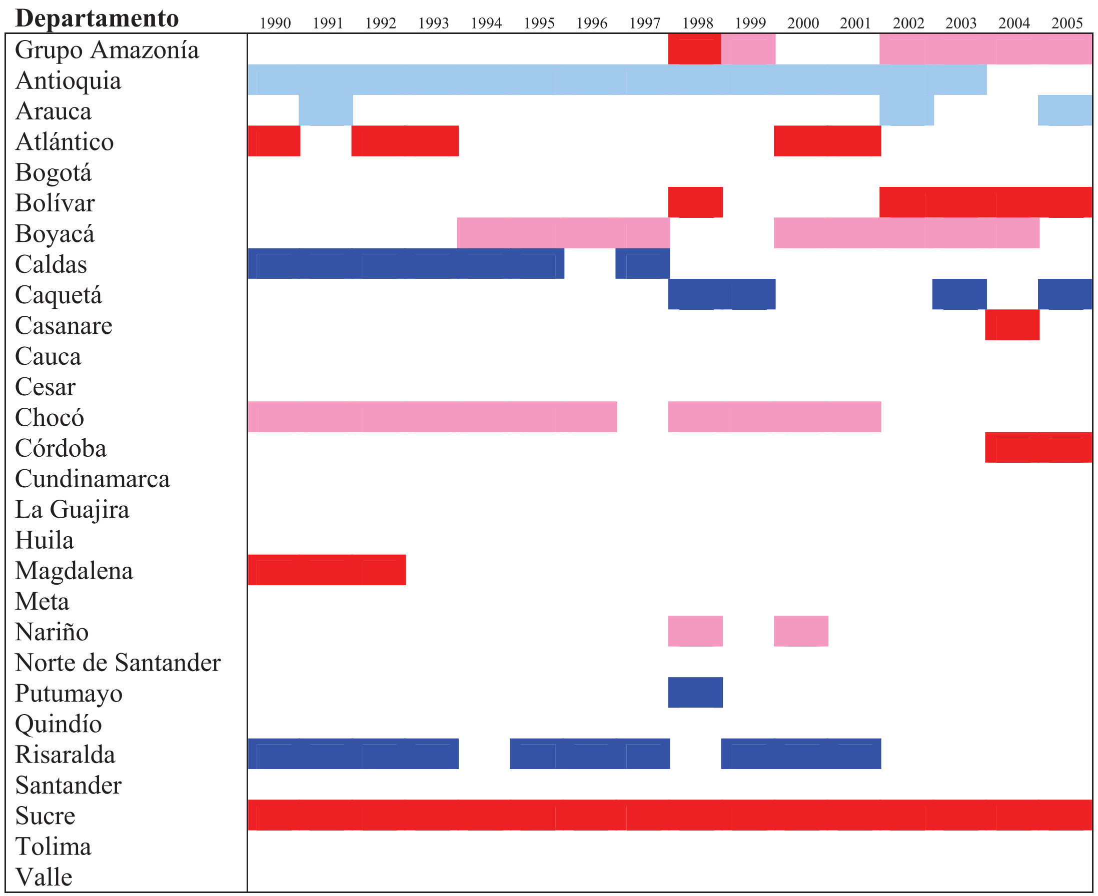


Life expectancy at birth

Infant survival rate



Non-murder rate



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