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Victoria Eugenia Soto*
Institute of Health and Society – Université Catholique de Louvain
victoria.sotorojas@uclouvain.be

Vincent Lorant*
Institute of Health and Society – Université Catholique de Louvain
vicent.lorant@uclouvain.be

Abstract

This paper aims *to analyse the space and time distribution of the infant mortality rate (IMR) at municipality level in Colombia before and after conferring greater responsibilities to the municipalities for the administration of the local health care systems. Using special econometrics, we find that there is a geographical concentration of IMR persisting over time and defining two groups of municipalities with mortality levels that oppose each other. Additionally, IMR distribution is found to depend on local and neighbouring factors. We conclude that after 18 years of decentralization, differences among municipalities in terms of IMR increased. Decentralization policies' designs should include the municipalities' development levels as well as the neighbouring area context in order to improve the results expected from decentralization.*

Key words: Infant mortality, decentralization, municipal socioeconomic characteristics, spatial analysis, Colombia.
JEL Classification: C21, I12, H7, N56.

Introduction

In the last decade, Colombia had shown a significant decrease in its infant mortality rate thanks to the improvements in life quality of the population and an active health care policy (Diaz 2003). Between 1970 and 2005, infant mortality rates went from 76.5 to 15.9 per 1,000 live births (1973

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Census; DANE 2005). However, in spite of this reduction at national level, there are wide geographic differences. More developed regions present lower mortality levels, and these differences are persisting over time. At the beginning of the 1990s, municipal infant mortality ranked from 100 to 5.1 deaths per 1,000 live births (DANE, 1998). By 2005, this difference in infant mortality remains in spite of the enforcement of several reforms to the health care system that seek to achieve universal access to health care and a decrease in geographical inequalities in health.

Like many other Latin American countries, Colombia reformed its health care system at the beginning of the 1990s. The main strategy was to decentralize[1] primary health care services provision for municipalities. In theory, in a decentralized model local authorities are aware of the needs of their communities and, hence, social services are provided in response to them. Thus, fiscal resources are more efficiently administered by local governments than the central government could do it (Saltman et al. 2006). Innovation and adaption to local conditions should have a positive effect on health indicators (Saltman et al. 2006). Targeting disadvantaged population groups, as well as monitoring diseases and building hospitals in marginalized areas, etc., are all tasks that could be better performed at a local level and, by the same means; inequities should be reduced within municipalities.

Given the promising results of decentralization, Colombian municipalities have then acquired a leading role when it comes to designing strategies and providing maternal and infant health care services since 1993. At national level, figures show an improvement in access to health care and health status indicators. Health insurance coverage has increased significantly, going from 29% in 1992 to 70% in 2005 (Flórez and Soto 2007). Vaccination and reproductive health care coverage has increased during these years (Profamilia 2005). On contrast, incidence of diarrheal diseases and acute respiratory infections has decreased (Flórez and Soto 2007). In this mixed picture, geographical differences regarding infant mortality persist across the country.

There are some hypotheses that could explain this result. The administrative and financial capacities of local health care systems, as well as their contextual characteristics (corruption, cultural aspects, socioeconomic level of the population, etc.) could limit the potential effect of local administrations in health indicators such as infant mortality (Rubio-Jimenez 2010). Socioeconomic and contextual context in neighbouring municipalities might also affect service provision (Gallup et al. 2003). Preventive vaccination programs are an example: if a municipality decides not to enforce them, its inhabitants can still benefit from the vaccination programs in neighbouring municipalities (Gallup et al. 2003; Janssens 2004). Nevertheless, not all neighbouring effects are beneficial for local settlements. The results of local preventive programs could be limited in a municipality if it is affected by diseases spreading from other neighbouring municipalities. Thus, neighbour municipalities' contexts, along with local context may favour differences among local or regional health care systems. Indeed Kuate-Defo and Diallo (2002) show that mortality concentrations in Africa reflect a negative neighbouring effect: unfavourable socio-economic conditions and an inequitable distribution of financial resources and infrastructure in certain

[1] Decentralization is broadly defined as a complex process. It has been characterized by the transfer within political levels (devolution), within administrative level (deconcentration), from political to relatively independent institutional level (delegation) (Saltman, 2006; Soto et al. 2012). In this paper, decentralization is synonymous of devolution because our interest is to study the municipalities' performance when acquiring responsibility in social services provision, specifically, health care provision.

geographical areas. Thus, monitoring health inequities seems to be a relevant policy tool in order to reducing the existing gaps (Flórez and Tono 2002).

In this context, this paper aims to analyse spatial distribution of infant mortality rates in Colombia before and after the municipalities took on providing primary health-care services under a decentralized framework. In addition, we seek to determine if spatial distribution of infant mortality rates only obeys to local factors, or whether neighbouring context may be contributing to it.

This paper is formed by six sections in addition to this introduction. The second section briefly describes the decentralization process in Colombia. In the third one we define our area of study and the variables to be analysed; we also identify sources of information and we present our methodological frame. The fourth section analyses the spatial concentration of the mortality rate and the spatial heterogeneity between 1993 and 2005; we then present the results of the local and proximity factors that have contributed to the concentration of infant mortality rate in each of the years analysed. In the fifth section we discuss the results in order to infer what the role of returning health-care competences to the municipalities has been. In the sixth and final section we present our general conclusion.

1. Health Care Decentralization

Colombia is considered to be one of the most decentralized countries in Latin America (Mejía and Attanasio 2008). It has three government levels: a central government, 32 departments and 1098 municipalities.

Health care decentralization in Colombia started at the end of the 1980's, when municipalities were granted the authority to build, equip and maintain local health care centres and hospitals. By the 1990's, responsibility for the functioning of first level health care facilities was placed in the hands of municipalities, while departments were made responsible for the second and third-level ones. In 1993, the health system was reformed and criteria was determined so that municipalities could receive health care resources according to their transferred powers, such as basic care plan development, environmental sanitation, service provision and population insurance (Jaramillo 2000). Years later, in 2001, there was another decentralization reform giving priority to investment in social services. That is, fiscal participations for health are distributed according to criteria of served population and population-to-be-served, equity and administrative efficiency (Mejía and Attanasio 2008). The responsibilities assumed by the municipalities during the 1990 and 2001 are detailed in Table 1.

Table 1
Municipalities' Authorities in a Context of Decentralization

Level	Health	Education	Basic Services
Central	Formulating development policies for the sector. Coordinating and assessing investment projects. Technical assistance for the municipa lities. Managing co-financing funds, credit programs.	Formulating development policies for the sector. Coordinating and financing education programs. Technical assis tance for the municipalities. Managing co-financing funds and credit.	Technical assistance for the municipalities. Managing co-financing funds and credit programs.
Department	Running the Sectional Health System. Promoting health and disease preven tion. Technical assistance for the municipa lities. Financing 2nd and 3rd level health care services provision.	Managing state educational service provi sion. Financing and co-financing infrastructure and equipment investments.	Ensuring potable water and sewage services provision. Promoting benefit programs for social housing.
Municipalities	Running the local health care system and the health projects according to national and department policies. Managing resource collection and execution for the health sector. Financing first-level services provision. Enforcing promotion and prevention actions. Financing the building and equipping of service-providing institutions. Promoting local participation mechanisms. Identifying the poor and vulnerable population for health insurance and social programs.	Financing infrastructure and provision investments. Managing state educational services. Inspecting and surveying state educational services.	Ensuring potable water and drainage services provision. Promoting benefit programs for social housing.

Source: Mejía and Attanasio 2008. Summary of responsibilities delegated to the municipalities according to law 60, 1993 and law 715, 2001.

2. Data and Methods

2.1 Area of study and geographical scale of the analysis

Colombia is a large and heterogeneous country. It is the fourth largest country in South America and it is constituted by 1098 municipalities. There are wide demographic, socioeconomic and cultural differences across municipalities (Sánchez and Núñez 2000). Over 70% of the population live in the central mountain area, in northern and western shores and in the capital Bogotá and its surrounding area. According to the population census performed in 2005, ethnic population represents over 3% of the total population, and it is mainly located in the peripheral municipalities to the north and southeast of the country. The afro-descendant population corresponds to 10% of the total Colombian population and it manly inhabits the west and the northeast areas. 64% of the population is below the poverty threshold and the relation between the richest 10% and the poorest 10% was equal to 60.4 in 2009 (PNUD 2009).

2.1.1 Information sources

This study is based on two major sources of information. Infant mortality rates at municipality level are estimated on the bases of the 1993 and 2005 population censuses and on life statistics by the Department Administrativo Nacional de Estadísticas, DANE (National Administrative Department for Statistics). The socioeconomic and demographic variables of the municipalities are estimated according to the Integrated Public Use Micro dada series (IPUMS) for Colombia, which constitutes a subsample of the national census for 1993 and 2005.

IPUMS includes only 10% of the original household and individual sample of the population census. Futhermore, IPUMS defines political-administrative units as those with 100,000 inhabitants or more. Because of this, for the Colombian case, IPUMS redefines municipalities under this last criterion and the information on 1,098 municipalities is aggregated into 529 observations in the two study years, 1993 and 2005. Colombian islands were not included in the analysis, since they do not have neighbouring municipalities. Thus, in this study we use IPUMS's definition of municipality. Three municipalities (Riosucio, San José del Guaviare and Turbaco) are excluded from this study due to the lack of information regarding infant mortality in them. This means in this study we analyse 527 municipalities.

2.1.2 Study variables

Outcome variable: Infant mortality rate is defined as the number of deaths among children under 1 year of age per every 1,000 live births in a municipality. Infant mortality is one of most used indicators of a population's health status. This indicator is also considered to be highly sensitive to health system reforms (Hutton 2000). Because of this, infant mortality rates in Latin American countries is said to reflect any wider access to and use of health care services as well as any improvements in local nutritional and sanitary conditions (ECLAC and UNICEF 2008).

Explanatory variables: In this paper, municipal infant mortality is analysed in terms of the proximate determiners that can indirectly affect mortality (Ssendaula, 2002). This study is mainly focused on three types of proximate determinants: household characteristics, demographic factors and socioeconomic indicators.

Household characteristics: these include household with piped water, toilet facility and overcrowding. Evidence shows that the households' access to basic services favours individual hygienic practices, which results in a reduced risk of infant mortality (Díaz, 2003).In the same way, it is expected that improving the household's living conditions has a positive effect on the decrease of infant mortality (Cage and Foster 2002).

Regarding *demographic factors* we have included ethnic population and Afro-descendant percentages per municipality. It has been found that in Latin American countries there is a greater risk of mortality among infants born in indigenous or Afro-descendant communities (ECLAC and UNICEF 2008). Moreover, in this group of determinants we have included the percentage of children under one year of age per woman in the municipality. This variable was defined as survival population proxy, since the more infants a woman has, the greater the number of children in risk of dying and hence, leading to a rise in the infant mortality rate.

Regarding municipal *socio-economic factors,* we include infant mortality factors such as percentage of female population with primary school education or less, and percentage of female head households. Improving the women's educational level has been widely linked to a lower number of infant deaths (De Sousa et al. 2010; Díaz 2003; ECLAC and UNICEF 2008). Thus, a lower educational level amongst women constitutes a risk factor for infant mortality. In the same way, having a female head of a household has been linked to a high mortality rate due to single mothers have to cover the living expenses of the household members, which in turn reduces the time they can dedicate to child-care activities (Kishor and Parasuraman 1998).

These factors also include *fiscal factors associated to the decentralization of the health system* in this study we include taxes per capita collected by the municipalities and aimed for primary health programs. These resources are defined as the municipalities' own health resources and they have been estimated in constant terms and lagged 3 years in order to reduce endogeneity problems (Soto et al. 2012). Recent studies have shown that within a decentralization context, a greater fiscal effort from the municipalities that is aimed to providing health services reduces infant mortality (Jimenez-Rubio 2010; Habibi et al. 2003; Soto et al. 2012). All variables used in this paper were measured in logarithms.

2.2 Methods

2.2.1 Exploratory analysis

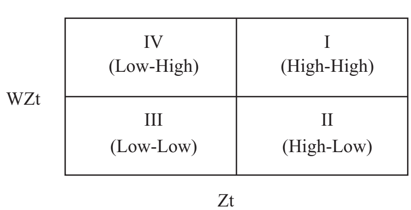
In order to analyse infant mortality concentration in specific geographical areas of Colombia and determine if the spatial distribution of this indicator is persistent over time, we use Moran's spatial correlation test I. The null hypothesis of this test is no spatial dependence. Moran's I starts from the definition of Pearson's correlation coefficient, but it also includes spatial observation localization, by means of a spatial weight matrix, Wij, that is:

$$I = \frac{N}{\sum_i \sum_j Wij} \frac{\sum_i \sum_j Wij\ ZiZj}{\sum_j Z_i^2} \qquad (1)$$

Where, $Zi = Xi - \bar{X}$ and the matrix Wij defines the "neighbour" observations. This matrix is built according to the first law of Geography, where all phenomena can be interrelated, but those which are close to each other are even more so (Tobler 1970). Hence, Wij is defined as a binary matrix containing values of one when i and j are neighbours, and zero otherwise. Municipal vicinity is defined according to spatial contiguity criteria. The term $WijZi$ is acknowledged as Z's spatial lag. Anlesin (1996) shows that Moran's I is obtained from the regression of Z against its spatial lag WZ. The spatial lag coefficient´s sign corresponds to Moran's I. If this coefficient is positive, there is a positive autocorrelation in Z's observations.

In practice this relationship is represented by a dispersion diagram that links WZ_t in its vertical axis with Z_t in its horizontal axis (see Figure 1). Four quadrants can be observed in the dispersion diagram from the position of Z's observation regarding its neighbours (Meiser and Roca 2010). Observations higher than Z's mean and higher than its neighbouring area WZ's mean are located in quadrant I or High-High quadrant. Observations higher that Z's mean and lower than its neighbour WZ's mean are located in quadrant II or High-Low quadrant. Observations lower than Z's mean and lower than its neighbour WZ's mean are located in quadrant III or Low-Low quadrant. Finally, observations lower than Z's mean and higher than its neighbour WZ's mean are located in quadrant IV or Low-High quadrant.

Figure 1
Moran's I Dispersion Diagram



In the case of infant mortality, a positive Moran's I means that municipalities with high (low) infant mortality rates are located close to municipalities with similar levels of infant mortality. In this case observations are located in quadrants I and III.

To determine if there is a spatial polarization of the infant mortality rate that persists over time, we use bivariate Moran's I dispersion diagram. This diagram links WZ_{t-1} with Z_t and allows us to simultaneously analyse space and time dimensions, comparing mortality rates in a period of time, against those observed in its neighbourhood in a different period of time (see Figure 2). Thus, municipalities located in quadrants I and III will be those that have experienced a persistent high infant mortality between 1993 and 2005.

Figure 2
Bivariate Moran's I Dispersion Diagram

WZt-1	IV (Low-High)	I (High-High)
	III (Low-Low)	II (High-Low)
	Zt	

We also examine if spatial distribution of the explicative variables contributed to geographical concentration of infant mortality rates. In order to determine this contribution, we first study if there is a geographical concentration for the distribution of each variable. After this, we re-estimate Moran's I for the infant mortality rates conditioning it to the set of explicative variables. In this way, we can determine if the spatial dependency of infant mortality rates decreases or disappears when the socio-economic and demographic conditions of the municipalities are considered (Díaz 2011).

The statistic inference of conditioned and non-conditioned Moran's I are performed with Monte Carlo simulations that randomly reassigns Z's values in the geographical space and generate a distribution for I. For each of the calculated Moran indices, 499 random distribution permutations of I are performed, so that it then is compared with the observed distribution of I and its statistical significance is determined at 5%.

In the case of spatial heterogeneity or spatial local clusters, we used Local Indicators of Spatial Association, LISA. This statistics are a derivation of the global autocorrelation performed with Moran's I. LISA statistics identify the contribution of small geographical areas to the global concentration of the study variable, infant mortality rate in this case. That is, we seek to find close values between the level of mortality rates of a given municipality and those of the municipalities in its proximity.

LISA statistics is defined I_i as follows:

(2) $$I_i = \frac{Z_i}{\sum_i Z_i^2} \sum_j W_{ij} Z_j$$

LISA statistics are presented in maps which allow to visualize the decomposition of the spatial autocorrelation in four types: high-high, low-low, high-low and low-high. The first type of spatial autocorrelation implies that a municipality with a high infant mortality rate is surrounded by other municipalities with high mortality. The opposite case corresponds to the low-low type. The two remaining autocorrelation types indicate that a municipality and its neighbouring municipalities present different mortality levels. The statistic inference of Moran statistics I_i is also performed at 5% significance using 499 Monte Carlo permutations.

2.2.2 Analysis of the explicative factors of infant mortality

Once it has been detected that infant mortality rate distribution is strongly associated to the geographical space, it is necessary to use spatial econometric techniques in order to understand the factors that can explain this phenomenon. However, there is no certainty about the type of spatial distribution followed by infant mortality rates. For this reason, we use the Spatial Durbin Model developed by Anselin (1988). This model nest different types of spatial interdependence.[2] In addition to this, Lesage and Pace (2009) point out that the spatial Durbin model produces unbiased and efficient estimators even if some relevant variables of the model have been omitted and if they are correlated with the first spatial lag of the explicative variables. This model includes a spatial lag in the dependant variable and also spatial lags in the covariates.

Thus, the model specification that associates infant mortality rate with proximate determinants is defined with the following equation:

$$IMR_i = \alpha_{oi} + \rho W_{ij}\, IMR_i + \delta_1 x_i + \delta_2 W_{ij} x_i + \mu_i \quad (3)$$

Where i is the municipality, IMR is a vector [nx1] containing the municipalities infant mortality rates n, X is a matrix [nxk] containing proximate determinants, ρ is the spatial lag parameter, δ_1 is a dimension parameters vector [kx1] and μ_i is a vector of [nx1] containing i.i.d random terms.

Given that this model's specification includes spatially lagged variables it is not possible to use the Least Squares method, since this implies a violation to one of the basic assumption (observations' independence) required to estimate them. Anselin (2010) points out that the estimation has to be developed using maximum likelihood methods, or using the Generalized Method of Moments. The first method assumes that the random term follows a normal distribution. The second method supposes independence and an identical distribution of the random term for any type of distribution. However, in the last method there is evidence showing that the consistency

[2] Anselin (1988) point out that spatial dependency among the observations is captured including a depending variable lag in the model as an explicative variable, or including the spatial dependency's structure in the error. The first model is known as a Spatial Lag Model, SAM, and the second one is known as a Spatial Error Model, SEM. The SAM and SEM models have been widely used in other studies to model infant mortality rates; however there is no consensus regarding which distribution it should follow. Spatial Durbin Model nests SAM and SEM models; so we decide to use this model, which represent the most general visualization of the phenomenon.

of the estimators is affected when the spatial Durbin model is estimated in the presence of spatially autocorrelated regressors (Pace et al. 2010 in Díaz 2011). For this reason, this paper follows the maximum likelihood method. This model has two major advantages (Díaz 2011). The first one refers to the estimation of estimators which are consistent even when relevant variables have been omitted from the model, for example: antenatal care coverage or adequate performed deliveries. The second one refers to the measurement of the effects of the explicative variables at local levels and in the neighbourhood.

Nonetheless, this model has a limitation. LeSage and Pace (2009) demonstrate that spatial Durbin model's parameters cannot be interpreted as marginal effects (e.g. $\frac{\partial IMR_i}{\partial X_k} \neq \beta_k$), as it is done in a lineal regression. This limitation derives from the spatial structure of the data, since a change in an explicative variable of a municipality i affects municipality i and, at the same time, it could have an effect on the neighbouring municipalities (Díaz 2011; Pijnenburg and Kholodilin 2011). Partial derivates are shaped into a matrix like the following:

$$\text{(4)} \qquad \frac{\partial \mathrm{IMR}}{\partial \mathrm{X}_k} = (\mathrm{I_n} - \rho \mathrm{W_{ij}})^{-1} \, (\mathrm{I_n}\, \delta_{1k} + \mathrm{W_{ij}}\, \delta_{2k}) = \mathrm{S_k}\,(\mathrm{W_{ij}})$$

Given this limitation, LeSage and Pace (2009) propose two measures to separate local and neighbouring effects: the average direct effect and the average indirect effect. The average direct effect is calculated as the average of the partial derivates associated to an explicative variable in municipality i, that is: $\sum_{i=1}^{n} \frac{\partial IMR}{\partial X_k} \Big/ n$. That is the matrix's trace $\mathrm{S}_k\,(\mathrm{W_{ij}})$. The average indirect effect is calculated as the difference of the average of all the partial derivates of the depending variable regarding $\mathrm{X_{jk}}$ for each i and j municipalities and the average direct effect. It is the average of the matrix's crossed derivates $\mathrm{S}_k\,(\mathrm{W_{ij}})$. For a detailed description of the derivation of the direct and indirect effect, see LeSage and Pace 2009.

Thus, this paper defines local effect in the same way as average direct effect of a proximate determinant; that is, the effects of this explicative variable that are produced in the municipality i. In the same way, neighbouring effect is defined as the average indirect effect of a determined proximate; that is, the effects of an explicative variable from municipality j, being $i \neq j$. These effects are estimated by using the routine developed by LeSage and Pace (2009) in Matlab.

To analyse the contribution of local and neighbouring factors of an explicative variable to the spatial concentration of infant mortality, the analysis must be focused on 3 cases (Díaz 2010). First, we conclude that the local effect of an explicative variable is dominant when the *local effect* is statistically significant, but the neighbouring effect is not. Second, we conclude that an explicative variable contributes to the *spatial concentration* of the infant mortality rate is its local effect as well as the neighbouring effect are statistically significant. Finally, we conclude that an explicative variable has an *accumulative neighbouring effect* when only the neighbouring effect is statistically significant.

3. Results

3.1 Exploratory analysis of the infant mortality rate

Between 1993 and 2005, infant mortality rates decreased significantly in Colombia dropping from 37 per every 1000 to 15.9 per 1000 live births (DANE 2005). The main reductions of this indicator happened during the 1990's, when the mortality rates went down to a 40% (Díaz 2003). However, in spite of this reduction in the infant mortality rates, there are wide differences among the departments and this tendency seems to persist over time. The departments Chocó and Cauca, located to the west of the country, present high mortality rates in both years (Figure 3). In the same way, infant

Figure 3
Department Infant Mortality Rate. Colombia 1993 -2005

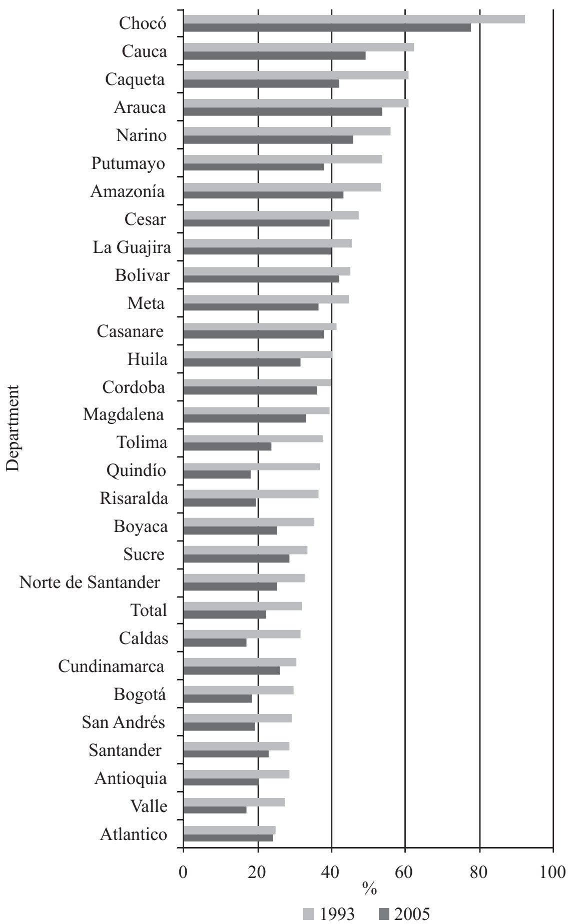


Table 2
Descriptive Statistics

Variables	Mean	Des. Est.	Mean	Des. Est.
Dependant variable				
Infant mortality rate	37.99	15.73	35.02	14.22
Explicative variables				
Household characteristics				
Proportion of households with:				
Piped water	64.06	23.12	70.71	20.16
Toilet facility	55.42	24.96	75.30	17.94
Overcrowding	13.42	7.87	8.33	5.24
Demographic factors				
Proportion of households with ethnic and Afro-Colombian population	6.07	12.50	16.69	24.66
Proportion of children <1 year per woman*	68.50	29.61	51.83	26.20
Socioeconomic factors				
Proportion of female head households	21.58	4.76	26.51	4.68
Proportion of females with primary school level of education or less	66.81	12.69	55.82	12.69
Local resources per capita destined to primary health services	1.42	2.30	3.41	4.26
Number of observations: municipalities IMPUS	527.00		527.00	

Note: *women between 15 and 49 years old at the time of the census.
Source: These results were taken from IMPUS-CP - Colombia data. King, M., Ruggles, S., Alexander, T., Flood, S., Genadek, K., Schroeder, M., Trampe, B., and Vick, R. (2010). Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. Minneapolis, MN: Minnesota Population Center.

mortality in the municipalities shows wide differences. In 1993, municipal infant mortality rates oscillated between 11.98 and 106.94. The situation is very similar in 2005, when these rates fluctuated between 9.46 and 116.69 (Table 2).

During 1993 and 2005, infant mortality decrease came along with an improvement in the households' living conditions. Access to piped water and toilet facility incremented and the percentage of overcrowded households was reduced. However, some socioeconomic factors are still challenging the municipalities. The proportion of low-educated female inhabitants was still above 50% in 2005. Local primary health resources per capita have increased, but they were widely spread among the municipalities. Results are presented in Table 2.

Figure 4 shows the results of Moran's I, which is positive and goes from 0.45 in 1993 to 0.64 in 2005. This result implies that there is spatial concentration of infant mortality rates that increases over time. Figure 4, panel B shows a greater spatial concentration in the municipalities located in the Low-Low and High-High quadrants, although there is a slightly higher number of municipalities in the latter.

Figure 4
Municipal Infant Mortality Rate: Spatial correlation Moran's I.
Colombia 1993- 2005

Panel A. Year 1993 **Panel B. Year 2005**

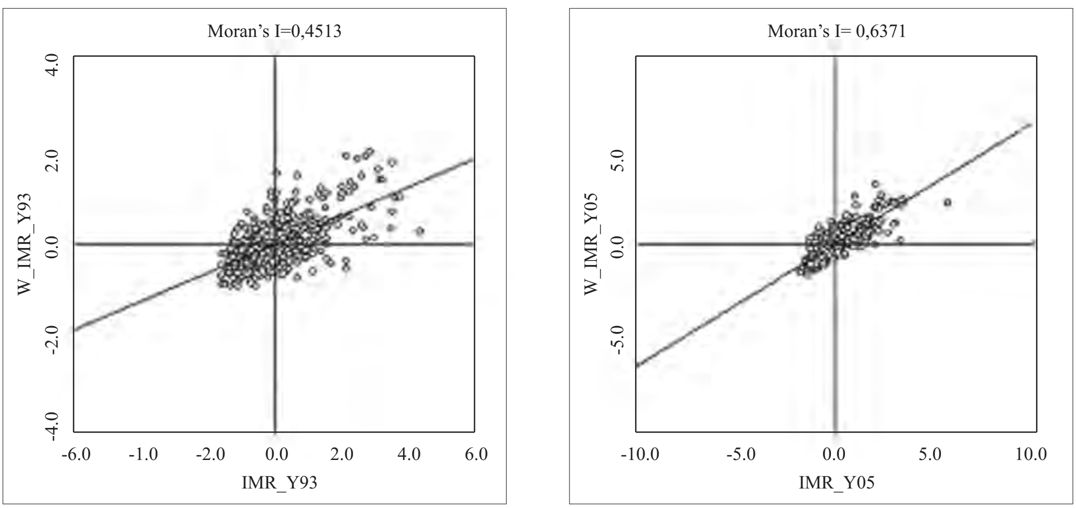
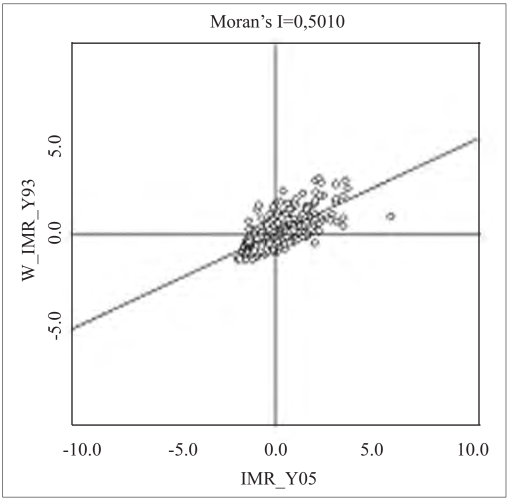


Figure 4 (continued)

Panel C. Year 2005 versus Year 1993

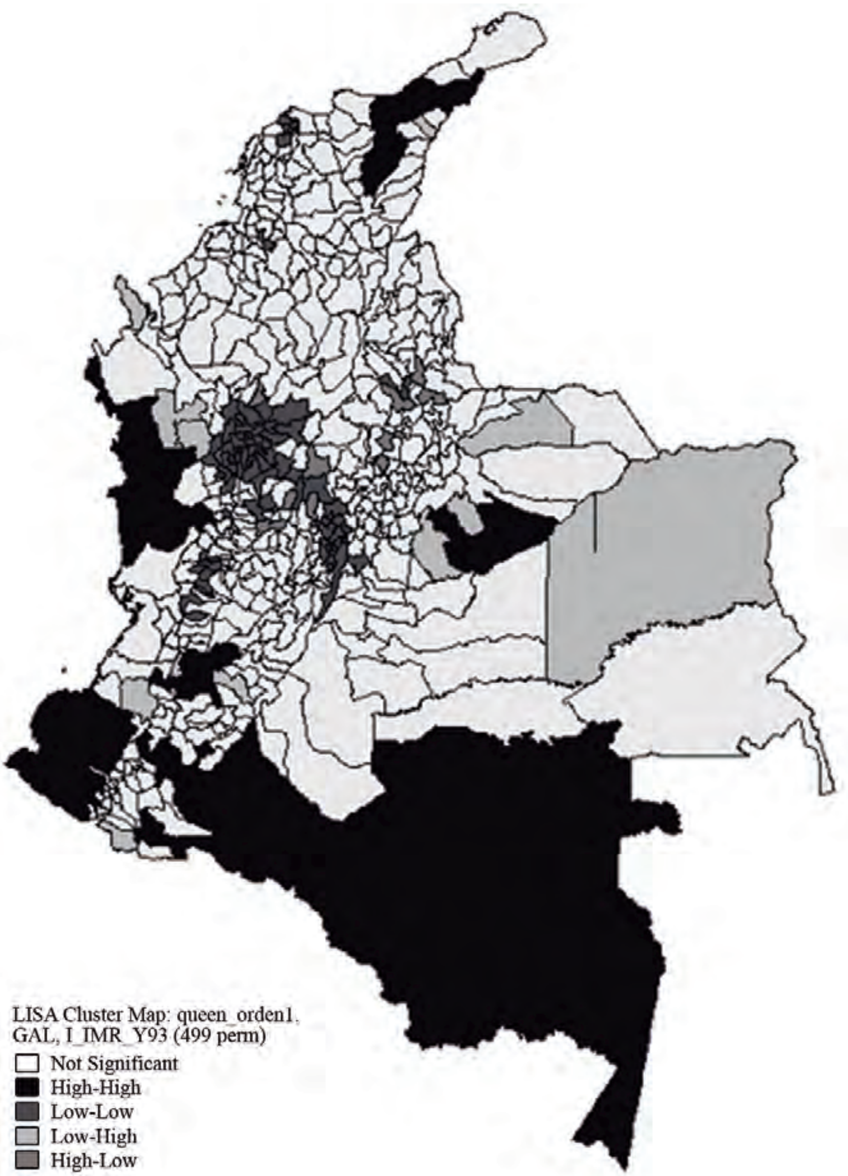


Note: Authors' calculations. Statistic inferences on the basis of 499 permutations at 5% significance.

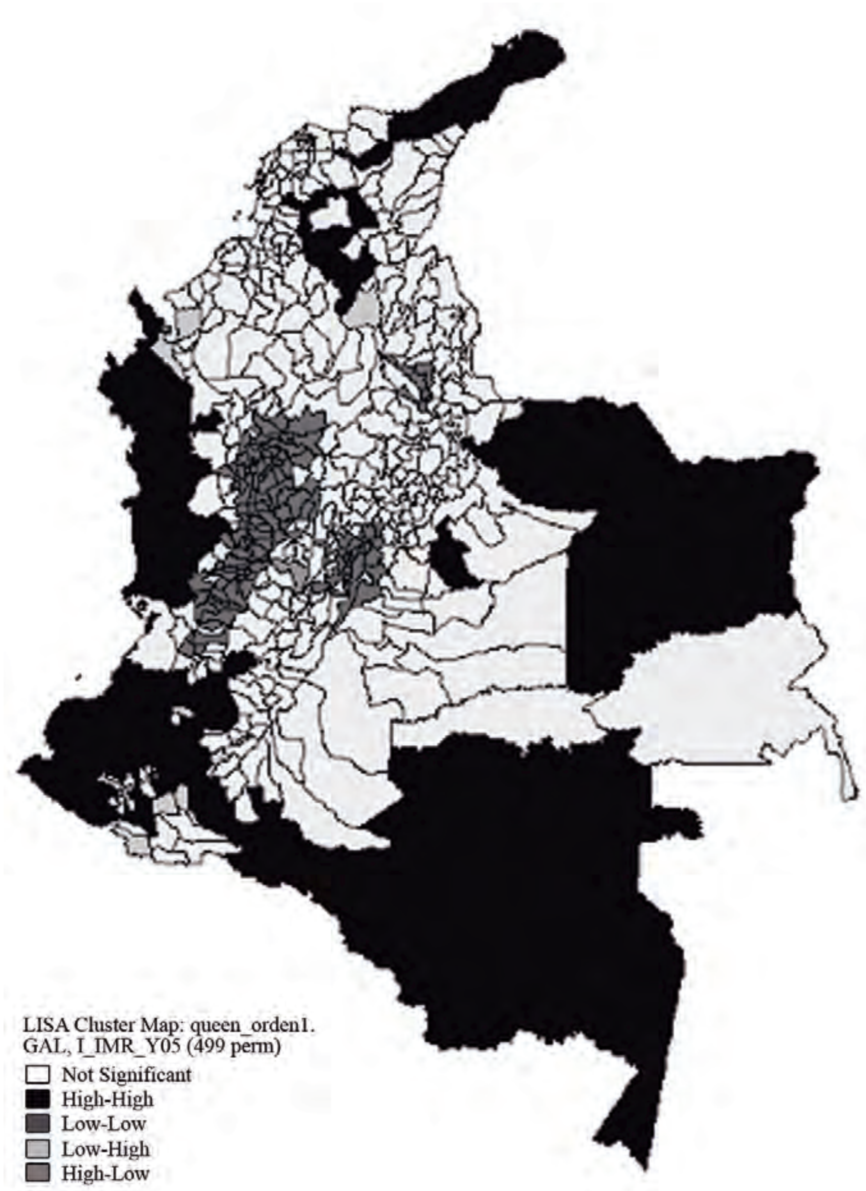
We can also observe persistence in the infant mortality rate between 1993 and 2005. Figure 4, panel C presents the results of bivariate Moran's I for infant mortality between 1993 and 2005. This dispersion diagram compares infant mortality levels in 2005 and the mortality levels observed in nearby municipalities in 1993. The results show that most municipalities are concentrated I the Low-Low and High-High quadrants. This implies that municipalities with low mortality rates in 2005 are characterized by being geographically surrounded by municipalities with low mortality rates in 1993. A similar result is that one of municipalities with high mortality levels in 2005 (High-High quadrant, Figure 4, panel C). Thus, there is spatial concentration in the levels of infant mortality between 1993 and 2005. And in particular, we find a larger number of municipalities in the High-High quadrant.

The results of the spatial heterogeneity analysis of the infant mortality rate for 1993 and 2005 and presented in maps 1 and 2. The coloured areas indicate the four types of spatial autocorrelation previously mentioned at a 5% significance level. Maps 1 and 2 show once again that there is a concentration of the infant mortality rate for both 1993 and 2005. In 1993 there is a high concentration of municipalities with high infant mortality rates, mainly in the south of the country (high-high or black areas). Concentrations of high morality are also found in the northeast and the southeast, although in less proportion. In 2005, the situation changes a little and it seems as if there have been two concentration processes with the municipalities with high and low infant mortality. The country seems to be divided in two large areas: central and peripheral. The central area is characterized by municipalities with low infant mortality rates (low-low or dark grey areas) and the peripheral area is characterized by municipalities with high infant mortality rates. There are very few municipalities with a negative spatial autocorrelation (high-low or medium grey areas and low-high or light grey areas) and their number has been reduced during the study period.

Map 1
Municipal Infant Mortality LISA Map. Colombia – 1993

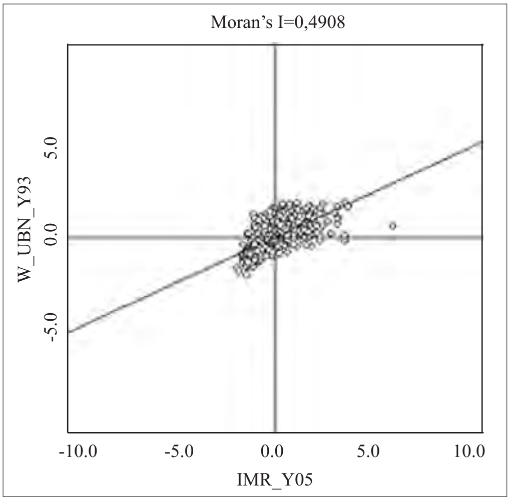


Map 2
Municipal Infant Mortality LISA Map. Colombia – 2005



This map of mortality concentration in the central and peripheral areas in 2005 is related to the poverty map of the country (Meiser and Roca, 2010). Municipalities located in the central area of the country have better indicators of wealth and access to sanitary services. On the contrary, peripheral municipalities have less favourable indicators. In order to study if the municipalities' development conditions have favoured their tendency towards a higher or lower level of infant mortality over time, we estimate the bivariate Moran's I that's related to the percentage of households with unsatisfied basic needs (UBN) in the municipalities in 1993 and the infant mortality rate in 2005. Results are shown in Figure 5.

Figure 5
Spatial Correlation Moran's I of Municipal Infant Mortality Rates in 2005 with Percentage of Households with Unsatisfied Basic Needs in 1993. Colombia



Note: Authors' calculations. Statistic inference done on the basis of 499 permutations at 5% significance.

The dispersion diagram shows the existence of a positive spatial autocorrelation between these two variables. High infant mortality rates in 2005 are associated with neighbouring municipalities in 1993 with a high proportion of households with UBN (High-High quadrant). The opposite case is that one of the municipalities with low infant mortality levels in 2005; in 1993, their neighbouring area was characterized by a low proportion of households with UBN. This result would indicate that poverty levels have long term effects on infant mortality and have favoured the differences among infant mortality levels from the geographical perspective.

Proximate determinants also showed a statistically significant spatial dependency (Table 3). In 1993, Moran's I for the proportion of overcrowded households, households with toilet facility and number of children under 1 per women were higher than 0.40. By contrast, Moran's I for the percentage of households with ethnic and Afro-Colombian populations was relatively small (0.22). In 2005, most explicative variables show a similar spatial dependency pattern. However, it should be underlined that Moran's I increases particularly for local primary health resources between 1993 and 2005.

Table 3
Spatial Concentration of Infant Mortality Rate and Municipal Socioeconomic Conditions in Colombia. 1993-2005

Variables	1993		2005	
	Non-conditioned	Conditioned	Non-conditioned	Conditioned
Dependent variables				
Infant mortality rate	0.45 ***	0.25 ***	0.64 ***	0.33 ***
Explicative variables				
Household characteristics				
Proportion of households with:				
Piped water	0.40 ***		0.41 ***	
Toilet facility	0.57 ***		0.50 ***	
Overcrowding	0.63 ***		0.55 ***	
Demographic factors				
Proportion of households with ethnic and Afro-Colombian population	0.22 ***		0.12 ***	
Proportion of children <1 year of age per woman*	0.59 ***		0.65 ***	
Socioeconomic factors				
Proportion of female head households	0.16 ***		0.13 ***	
Proportion of females with primary school level of education or less	0.37 ***		0.39 ***	
Local resources per capita destined to primary health services	0.32 ***		0.41 ***	

Note: ** p<0.01, **p<0.5, *p<0.1. ; * Women between 15 y 49 years old at the time of Census. Unconditional Moran's I is defined as I= e'We/e'e, where "e" are the error terms resulting of the regression of the infant morality rate as a constant and W represents the spatial contiguity matrix. This matrix defines a neighbour municipality as one sharing geographical limits with the municipality. Conditional Moran's I is defnined as I´ = u'Wu / u'u where "u" are the error terms of the regression of the infant mortality rate on a constant, on a group of explicative variables (yi = a + bxi + ui) and on W, that corresponds to the spatial contiguity matrix. All variables are estimated in logs. Statistic inference is based on the standardized value of z, which follows a normal distribution.
Source: These results were obatined from IMPUS-CP - Colombia data. King, M., Ruggles, S., Alexander, T., Flood, S., Genadek, K., Schroeder, M., Trampe, B., and Vick, R. (2010). Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. Minneapolis, MN: Minnesota Population Center.

Regarding Moran's I for infant mortality rates, we found that, after controlling by the proximate determiners set, spatial concentration for this health status indicator decreases in 1993 and 2005 in comparison with unconditioned Moran's I (Table 3). However, spatial concentration does not disappear; it increases over time. Moran's I increases between 1993 and 2005, going from 0.25 to 0.33. This suggests that certain non-observable local factors continue to feed spatial concentration of infant mortality rate.

3.2 Infant mortality rate determining and proximate factors: local and neighbouring effects

Table 4 shows the local and neighbouring effects of proximate determinants over infant mortality rate in 1993 and 2005. These effects are calculated from the estimation of the Spatial Durbin Model's coefficients included in Annex 1. Notice that these coefficients are slightly different from the ones reported on Table 3; this is basically because of the feedback effects of the municipalities as a group. In other words, average local and neighbouring effects represent the effects of the explicative variables on the mortality rates in municipality i and from the neighbouring municipalities j, but there is also a feedback effect of the whole system. Municipality i also affects its neighbouring municipalities and so on, so that an accumulative effect is produced throughout the municipalities. By comparing the coefficients presented in Annex 1 and the averages of the local effects shown in Table 4, they are very similar in most cases, and hence we conclude there are no feedback effects. Except for some socioeconomic determinants, these effects are important and they shall be discussed later on.

Table 4
Average Local and Neighbouring Effect of Proximate Determiners on Infant Mortality Rate

Municipal characteristics - Independent variables	Spatial Durbin Model (SDM)			
	1993		2005	
	Local Effect	Neighbouring effect	Local Effect	Neighbouring effect
Household characteristics				
Proportion of households with:				
Piped water	-0.21 [-1.21]	-1.21 [-2.49] **	-0.30 [-2.69] ***	-0.85 [-2.35] **
Toilet facility	-0.73 [-3.32] ***	0.56 [1.30]	-0.60 [-3.79] ***	-1.17 [-2.50] **
Overcrowding	0.22 [0.59]	0.02 [0.03]	0.92 [3.16] ***	1.01 [1.35]
Demographic factors				
Proportion of households with ethnic and Afro-Colombian population	0.18 [1.22]	1.91 [4.39] ***	0.03 [0.62]	0.11 [0.60]
Proportion of children <1 year per woman*	0.35 [2.71] ***	-0.31 [-1.28]	0.21 [2.29] **	-0.23 [-1.05]
Socioeconomic factors				
Proportion of female head households	1.55 [3.42] ***	-2.01 [-1.61]	0.70 [2.59] ***	-2.24 [-2.46] **
Proportion of women with primary school level of education or less	0.03 [0.09]	-1.86 [-3.06] ***	1.60 [9.71] ***	-1.96 [-4.52] ***
Local resources per capita destined to primary health services	-1.58 [-2.01] **	-5.05 [-2.41] **	-0.20 [-0.67]	-2.80 [-2.99] ***
R2	0.36		0.72	
N	527		527	
Most appropriate model specification test				
Spatial correlation in the errors model OLS				
Durbin-Watson tes (DL =1.76914, N= 550 and K=9 including the constant)	1.58		1.22	

Table 4 (continued)

Municipal characteristics - Independent variables	Spatial Durbin Model (SDM)			
	1993		2005	
	Local Effect	Neighbouring effect	Local Effect	Neighbouring effect
Best especification: Spatial Durbin Model (SDM)				
Log Likehood SDM	72.23		321.65	
Log Likehood SAR	39.79		205.87	
Maximum likehood reason SAR vs SDM		65 ***		232 ***
Log Likehood SEM	66.01		261.23	
Maximum likehood reason SEM vs SDM		12.43 ***		121 ***

Note: ** p<0.01, **p<0.5, *p<0.1. ; * Females netween 5 amd 49 years of age at the time of census.
These results are derived from the estimation of Spatial Durbin Model's (SDM) coefficients included in Annex 1. T statistics are presented in brackets. The spatial contiguity matrix used in SDM results defines a municipality's neighbourhood as a group of municipalities sharing a point or vertex in their geographical limits. It must be highlighted that the coefficients estimated in Spatial Durbin Model and present in Annex 1 are slightly different to those reported in Table 3. Basically, this difference represents the feedback effects on the municipalities as a group. In other words, there are effects on the mortality rate of municipality i and its neighbouring municipalities j, but municipality i also affects its neighbouring municipalities and so on, so that there is an effect across the municipalities as a group. However, if we compare the coefficients presented in Annex 1 and the averages of the direct or local effects presented in Table 3, it can be seen they are very similar in most cases, so we conclude that there are no feedback effects. Nonetheless, it must be stressed that, for local resources per capita for primary health in 1993 and for socioeconomic determiners in 2005, feedback effects on the average indirect effects were higher than 2.
Source: These results were obtained from IMPUS-CP - Colombia data. King, M., Ruggles, S., Alexander, T., Flood, S., Genadek, K., Schroeder, M., Trampe, B., and Vick, R. (2010). Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. Minneapolis, MN: Minnesota Population Center.

Durbin and Watson's tests determine that modelling infant mortality rates with a lineal regression produces biased and inefficient coefficients. Maximum likelihood test determines that Spatial Durbin Model is the best specification in comparison with other spatial specifications used to model infant mortality rates, such as the Spatial AutoRegressive Model (SAR) or the Spatial Error Model(SEM).

In 1993 results indicate that for most of the explicative variables, the local effect is dominant. Regarding the household characteristics, the proportion of those with toilet facility has a positive effect in the infant mortality reduction. A 1% increment in the number of households with toilet facility reduced the mortality rates by 7.3% per 1,000 live births. Regarding demographic factors, the proportion of children per female and households with a female's head constitute a risk factor for infant mortality.

By contrast, local resources per capita destined to primary health contributed noticeably to the geographic concentration of infant mortality rates. A 1% increase in local resources per capita reduces mortality rates by 15.8% per 1,000 live births. This result comes together with a positive effect on the reduction of infant mortality in the neighbouring area, as the 1% increase of resources per capita in neighbouring municipalities reduces the infant mortality rate by 50% per 1,000 live births. However, this last result must be taken with caution due to feedback effects, that is, the effect of the municipalities as a group over municipality j also representing in this case 23.7% approximately.[3]

Concerning the accumulative effect of the proximate determiners, results show that the percentage of households with piped water in neighbouring municipalities produces positive externalities and it reduces infant mortality rate at a local level. A contrary result is obtained regarding the proportion of households with ethnic and Afro-Colombian population in the neighbouring municipalities. Surprisingly, it is found that the female population with a low educational level in the neighbouring municipalities does not constitute a risk factor; on the contrary, it reduces infant mortality rates.

In 2005, results show a different situation. Most of the proximate determiners feed spatial concentration of infant mortality rate and hence they ultimately sustain the differences regarding infant mortality rates among the municipalities. Only the proportion of overcrowded households and the proportion of children under one year of age per female have a dominant local effect. These variables constitute risk elements for infant mortality at a local level.

Regarding to the households' characteristics, the proportion of households with piped water and toilet facility widely reduce mortality at a local level. Same effect has access to these basic services in the nearby municipalities. These two effects together explain the geographical concentration of infant mortality rates. The same result was obtained for proportion of households with a female head and women with a low educational level. However, for these two variables, local and neighbouring effect presents a contrary effect on the infant mortality level. At a local level, a 1% increases in the proportion of households with a female head increases the mortality rate in a

[3] The difference between the neighbouring effect coefficient (2.69) and the average indirect effect (5.05) equals 2.37.

7% per 1,000 live births. On the other side, the proportion of women with low educational level reduces the mortality rate by 16% per 1,000 live births. Thus, these two socioeconomic factors constitute risk factors for the infants' health at a local level. However, an opposed result is obtained when analysing the neighbouring area. Contrary to what is expected, a 1% increase in the proportion of households with a female head and the proportion of women with low educational level reduce morality by 22.4% and 1.96% respectively. Again, these magnitudes need to be taken with caution, since the feedback effects for these two variables are of 10% and 26%.

Unlike 1993, local resources per capita for health care do not contribute to the geographical concentration of the infant mortality rate in 2005. Only the neighbouring effect for this explicative variable turned out to be significant and lower in comparison with that one obtained in 1993. The system's feedback effects are also maintained above 20%.

4. Discussion

4.1 Main results

This study shows that between 1993 and 2005, infant mortality rate distribution is characterized by a spatial dependency across municipalities. This distribution has been accentuated in 2005, resulting in two municipalities' concentrations differentiated by mortality level. The centre of the country is distinguished by having municipalities with low infant mortality rates, whereas the municipalities with high infant mortality rates are mainly located in the peripheral area. This geographical concentration is mainly explained by the households' access to basic services and to socioeconomic factors in the municipalities, as well and in their neighbourhood.

4.2 Contribution to health decentralization analysis

The spatial concentration of the infant mortality rates points out to the importance of developing a local analysis of health indicators, especially in those contexts were decisions on how, when and where social services are provided are taken in a decentralized context. In Colombia, after 1993, the municipalities were empowered by widening their capability to make decisions on social services provision. Local governments are responsible for providing an efficient administration of, primary healthcare, education, and basic services, and it is assumed that local provision is performed according to the communities´ needs. In theory, local resources administration should reduce the differences within the municipalities. However, it is an enormous concern whether the difference between municipalities might increase. In the case of Colombia, it seems the case. Empowering the municipalities has increased differences of infant mortality over time.

As a matter of fact, it seems that this policy has been more effective to improve the performance of the more developed municipalities, rather than that one of the least developed. Meiser and Roca (2010) find that most of the peripheral municipalities are poor. This spatial distribution of poverty coincides with that one of infant mortality rates, which presents higher rates in the same municipalities. Additionally, his phenomenon is persistent over time, and that recent infant mortality rates are correlated with low development levels of the municipalities in the past. This shows that social inequities within municipalities are a limiting element to reduce health-related differences. Thus, the theoretical and promising results of decentralization could be limited and the differences between municipalities increase in the long term. In line with, Soto et al. (2012) find that fiscal decentralization has a major effect on mortality rate reduction in the municipalities with a low proportion of households with UBN, in comparison with those with high levels of households with UBN. This indicates that a favourable local context (e.g. adequate technical and administrative unities, fiscal resources, etc.) is necessary for the local governments to be able to adequately assume their delegated responsibilities and thus reach the proposed objectives regarding social development. Experiences in other countries regarding devolving responsibilities to the municipalities confirm these results. Sousa et al. (2010) find a similar situation in Brazil, where policies and interventions focused on children under five years of age and enforced in a decentralized context have had better results in rich municipalities. The authors ascribe this result to the fact that poor municipalities in Brazil have limited access to drinking water and sewage and they lack adequate local healthcare facilities and qualified staff.

In the municipalities located in the northwest and the northeast coast of Colombia, over 10% of childbirths are carried out in the households, whereas in the capital that percentage is 2% (Profamilia 2005). Flórez et al. (2007) finds that indicators of health insurance coverage and health status exhibit a low performance in the departments with greater social inequities. In a decentralized administrative system, local contexts acquire greater importance in reducing geographical inequities. However, an inadequate local context limits the capacity of the local governments to improve their communities' conditions and the differences between wealthy and poor municipalities increase.

Regarding the proportion of women with primary school education or less and the proportion of households with a female head, those factors contribute to the geographical concentration of infant mortality. However, their local and neighbouring effects are opposed. Their local effects increase infant mortality rates, whereas at their neighbouring effects they reduce them. There are many possible reasons for this result. Vulnerable population is still a challenge for local government, as it is mainly characterized by a low education level and female's head households. In 2005 this type of population amounted to 49.5%, and the probability of female heads of households being in a vulnerable situation was of 48.8% (DNP 2006). These figures might explain how adverse context local favour infant mortality in the municipalities. Nonetheless, the results of this paper would show that some social programs managed by local governments and encouraged by the central administration have attenuated some risk factors for children health.

Since the mid-1990's, Colombian government has created a great number of social programs aimed at infant population and focused mainly on the vulnerable population (Núñez and Espinosa, 2007). One of the most important ones is the Programa de Hogares Comunitarios (Communitarian Households Program), which provides care for children under 5 living in poor households. This program develops an important nutritional constituent, enhances healthy practices such as vaccination and provides health education for the parents and the general community. This program covers over 1.2 million children from poor households (Bernal 2010). Other social programs such as infant homes are mainly focused on providing care for them while their parents are away from home, and they have been implemented across the country. The evaluation of these programs indicates that the most vulnerable part of the population has benefited from them, mainly women with a low education and female's head households (Attamasio and Vera-Hernandez, 2004). Thus, these centre-managed programs could be improving infant health through neighbourhood.

This result questions the local governments' ability to overcome and reduce social inequities by comparison with the results the national government might get in handling them. Surely, it would be more advisable to reduce the differences between the municipalities in terms of access to basic services in the households and equipping the local health systems before handling responsibility for their management to the local governments. Local operational limitations should be a crucial element when designing decentralization policies, since in practice these could noticeably reduce the potential and positive effect of this policy device.

4.3 Study limitations

This study analyses the differences of the infant mortality rates in a decentralized context. However, the conclusions derived from it must consider data limitations. Firstly, variables related to maternal health care services were not included in the estimations. A study performed in Ecuador found that geographic distribution of both human resources and hospitals are a determining element of population health status between municipalities (Lopez-Cevallos and Chi, 2010). Secondly, the methodological approximation used in this study is based on a contiguity matrix of the municipalities. The estimations of the coefficients and the statistic inference depend on this matrix and some studies claim that different definitions of it can affect the coefficients' estimations (LeSage y Fischer 2008; Pijnenburg and Kholodilin, 2011). This study uses the aggregation of the municipalities made by IPUMS, thus defining the municipalities' geographical limits and hence, their neighbouring areas. Future studies should use the same methodology to analyse smaller geographical units which are closer to the political-administrative map of the country. It would also be interesting to disaggregate mortality rates by cause; this would allow us to draw and analyse in more detail a health map of children controlling by environmental and geographical factors.

5. Conclusions

This study analyses spatial and temporal distribution of infant mortality rates in Colombia before and after granting greater responsibilities to the municipalities to management their local health systems. The results indicate there is a spatial concentration of the infant mortality rate that persists over time and defines two groups of municipalities with opposed mortality levels. The municipalities in the centre of the country show low rates, whereas those in the periphery have high rates. Additionally, the infant mortality rate distribution does not only obey to local factors. The neighbourhood noticeably contributes to this indicator's spatial distribution. This, the concentration of infant mortality rate is mainly explained by the access of the households to basic services and by the socioeconomic conditions of the municipality and its neighbouring area. Thus, 18 years after administrative responsibilities of local health systems were transferred to the municipalities, the differences between them in terms of infant mortality have not decreased. An adverse local context can limit the capability of the local authorities to act. Additional efforts should be made in order to reduce socioeconomic inequities between municipalities before granting them administrative responsibilities. Health decentralization policies' design should take into account the local context, as well and the neighbouring context in order to improve the results that could be reached by enforcing this type of management strategies.

Annex 1
Infant Mortality rate (Ln) in Colombia 1993-2005. Spatial Durbin Model Results

Municipal characteristics - Independent variables	1993		2005	
	Local Effect	Neighbouring effect	Local Effect	Neighbouring effect
	β	γ	β	γ
Household characteristics				
Proportion of households with				
Piped water	-0.15 [-0.59]	-0.70 [-0.90]	-0.26 [-1.86] *	-0.30 [-1.00]
Toilet facility	-0.76 [-4.32] ***	0.65 [2.16] **	-0.53 [-4.54] ***	-0.34 [-1.62]
Overcrowding	0.22 [0.96]	-0.08 [-0.25]	0.87 [5.33] ***	0.08 [0.30]
Demographic factors				
Proportion of households with ethnic and Afro-Colombian population	0.08 [0.25]	1.19 [3.32] ***	0.02 [0.11]	0.05 [0.18]
Proportion of children <1 year per woman*	0.37 [0.96]	-0.34 [-0.62]	0.22 [0.71]	-0.23 [-0.47]
Socioeconomic factors				
Proportion of female head households	1.65 [12.65] ***	-1.96 [-11.02] ***	0.83 [8.38] ***	-1.57 [-11.70] ***
Proportion of women with primary school level of education or less	0.12 [0.26]	-1.22 [-1.54]	1.71 [6.22] ***	-1.89 [-3.94] ***
Recursos locales destinados a servicios primarios de salud	-1.36 [-9.58] ***	-2.69 [-9.67] **	-0.05 [-1.09]	-1.45 [-15.60] ***
Local resources destined to primary health services	0.39 [0.28]		0.51 [1.00]	
Constant	3.20 [72.50] ***		2.70 [98.33] ***	
R2	0.36		0.72	
N	527		527	

Note: ** p<0.01, **p<0.5, *p<0.1. ; * Females between 5 and 49 years of age at the time of census.
All variables measured in logs. T statistics are presented in brackets. The spatial contiguity matrix used in SDM results defines a municipality's neighbourhood as a group of municipalities sharing a point or vertex in their geographical limits *Source:* These results were obtained from IMPUS-CP - Colombia data. King, M., Ruggles, S., Alexander, T., Flood, S., Genadek, K., Schroeder, M., Trampe, B., and Vick, R. (2010). Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. Minneapolis, MN: Minnesota Population Center.

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