

# Modelling the Spatial Nature of Household Residential Mobility within Municipalities in Colombia

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**Abstract** In this paper, we examine household residential mobility within Colombian municipalities and determine whether the factors that trigger residential movement vary across the country. Using Geographically Weighted Regression (GWR) and detailed data from the 2005 Census for all municipalities in Colombia, our analysis takes into account the spatial variation in the relationship between household residential mobility and the associated housing, socioeconomic and environmental factors derived from theory and previous empirical research. Our findings demonstrate that household residential mobility is strongly and positively associated with living conditions, age and income, and negatively associated with homeownership and household composition within municipalities. The comparison of global (Ordinary Least Squares regression) and local (GWR) parameter estimates reveals the presence of a non-stationary effect on household residential mobility for the predictor variables considered, and highlights the importance of local variation of the relationships. In addition to contributing to the debate on the dynamics of residential mobility in Colombia, the study results have implications for effective policy-making with regard to urban expansion and settlement of various groups.

**Keywords** Residential mobility · Households · Municipalities · Colombia · Geographically Weighted Regression

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## Introduction

Each year, approximately 5 % of the Colombian population changes its place of residence, with an average lifetime mobility of 4 to 6 changes. The advance of urbanisation has made residential mobility, whether from one city to another or within cities, increasingly predominant (CEPAL 2007), although it can vary greatly between socioeconomic groups and places. While affluent and middle-class families follow a dispersal movement from the central city to its suburbs, along with the development of services and retail shopping centres in such areas, the economically disadvantaged living in deteriorated urban areas and slums experience a great deal of residential immobility (Dureau et al. 2007; Dureau and Delaunay 2005; Dureau et al. 1994; Dureau and Gouëset 2010).

The consequences of rapid urbanisation (the country was mostly rural until the mid-20<sup>th</sup> century) are partly responsible for making everyone a migrant even if people do not move very far from their original neighbourhood. Although it is apparent residential mobility has an important role in redistributing the population and altering the demographic, social and economic composition of municipalities in Colombia, few studies have examined the factors that trigger residential movement across the country. The new urban-rural divisions in Colombian municipalities (Alfonso 2005, 2009) and elsewhere in Latin America (Borsdorf 2002; Coy 2006; Lacabana and Cariola 2003) are at the heart of a process characterised by the decentralisation of government, administrative modernisation, and improved local governance from the 1990s (Ward 2011). Within this context, the issue of population redistribution is high on national and local agendas (Alfonso 2009) due to the negative consequences of sociospatial structuring processes such as rising levels of residential and social segregation (Thibert and Osorio 2013).

In Colombia, like elsewhere, there is widespread consensus that family life-cycle, socioeconomic status and tenure are among the most important reasons for residential relocation (Boyle et al. 1998; W. A. V. Clark and Onaka 1983; Rossi 1955). Of course, many other variables also enter the equation and over time research on residential mobility has become more nuanced, taking into consideration the rationale shaping both choices and constraints. It has become widely acknowledged that only a few households are ever unconstrained in making residential choices and most observed residential mobility is restricted by individual capacities and/or characteristics; however, there has been little empirical research on the impact of contextual effects or living conditions on residential mobility, a situation that may be attributable to the mixed results (see van Ham and Feijten 2008, among others). For instance, while some studies point to the relatively low importance of living conditions in some localities in order to explain actual mobility (W.A.V. Clark and Ledwith 2006; Kearns and Parkes 2005), others find that contextual effects related to living conditions are an important predictor of residential mobility (Boehm and Ihlanfeldt 1986). Although the literature on residential mobility has shown a particular awareness of the importance of the geographical context, to the extent that some studies have even found an association between the subjective evaluation of the residential location and mobility thoughts (Lee et al. 1994), it is also important to stress that the individuals/households with the highest mobility propensities often choose to live in areas where the living conditions are 'good' (W. A. V. Clark and Dieleman 1996). It is our working premise, however, that good living

conditions within the household as well as positive externalities such as good service provision are likely to give inhabitants better opportunities for residential mobility, a relationship that some scholars have defined as ‘geography of opportunity’ (Galster and Killen 1995; Rosenbaum et al. 2002). From this perspective, two simple questions arise. First, what are the main factors that drive household residential mobility within Colombian municipalities? And second, do factors that foster or hinder residential mobility operate similarly across space or do they vary spatially? The latter question can be seen as the leitmotif of the present article, due to the significant disparities across regions in Colombia; although they are on a path toward convergence, these have become a matter of academic and political interest in Latin America (Barón et al. 2004; Branisa and Cardozo 2009).

In this paper, we aim to answer these two questions by examining how living conditions, homeownership, income, age and household size *each* help us explain household residential mobility in Colombia, including information on whether the factors that trigger residential movement vary across the country. Our work contributes to the existing literature in two specific ways. First, we extend the geographic coverage of previous analysis of residential mobility in Colombia (Dureau, et al. 2007; Dureau and Delaunay 2005; Dureau, et al. 1994; Dureau and Gouëset 2010), arguing that it is important to apply a wider framework that includes all municipalities and, therefore, the various experiences of rapid urbanisation. Second, we engage in new research that takes into account the presence of spatial non-stationary effects (Fotheringham et al. 2002) on household residential migration, using a spatial modelling technique known as Geographically Weighted Regression (GWR). By examining such effects, we gain a more complete understanding of whether the high incidence of one variable is associated with higher residential mobility in some areas, and vice versa. Previous studies of migration in which GWR has been used contribute evidence of the advantage of moving beyond the arbitrary fragmentation of a spatial context, treating space as a continuous rather than categorical variable and better approximating the macro-social conditions of an area of residence as well as the context beyond those administrative boundaries (Bitter 2008; Helbich and Leitner 2009; Jivraj et al. 2013; Nelson 2008; Partridge et al. 2008).

The next section provides a brief overview of residential mobility in Colombia, followed by a discussion of the data sources used in the paper as well as the methodology. Finally, we present the results of the analysis before concluding with some policy discussion based on the findings.

## Previous Research in Colombia

Since Edwards’ pivotal publication (1983) on residential mobility in Bucaramanga (the capital city of the department of Santander), it has been widely assumed that residential choice, preferences and constraints must be taken into account in order to fully understand residential mobility in Colombia (Dureau, et al. 2007; Dureau and Delaunay 2005; Dureau, et al. 1994; Dureau and Gouëset 2010). Edwards’ main findings suggest that residential mobility in Colombia has not necessarily followed the developmental stages proposed by (Turner 1968), whose model is based on the premise that a household’s choice is a ‘trade-off’ between three contextual priorities: (1) tenure, or

the choice between renting and ownership; (2) location, or the proximity to employment opportunities; and (3) shelter, or housing standards and space needs. According to Turner (1968), households with similar income and life-cycle characteristics make the same residential decisions about the three contextual/dwelling priorities. While recent arrivals prioritise access to central-city jobs as opposed to the need for space and ownership, and thus live in cheap rental tenements in central locations, a gradual upward socioeconomic mobility and progression along the family cycle changes the weight placed on each residential priority. Thus, the path from initial dwelling to later ones is characterised by placing a higher value on the need for more space to accommodate a growing family and on the security and independence gained from ownership, which comes at the expense of accessibility. At this stage, the household becomes a consolidator.

However, the residential decisions are not exclusively shaped by gradual income increases, as pointed out in Edwards' findings (1983). Other important factors, such as housing tenure preferences (mostly ownership) in Colombia (and elsewhere in Latin America), have an important influence, thus disrupting the links between the dimensions of residential mobility postulated in the Turner model. Both Edwards (1983) and, more recently, Dureau (2003) provide strong evidence that homeownership is the desired option for a wide range of income and age groups. In such circumstances, it is noteworthy that in the context of increased congestion in the central urban areas, homeownership for the most affluent groups has meant circumventing land-use controls and building homogeneous suburban communities with a service infrastructure in place. In contrast, the ownership of homes among the poorest groups has occurred via land invasion in the urban fringe, where the provision of services is very limited (Dureau, et al. 2007; Dureau and Delaunay 2005; Dureau, et al. 1994; Dureau and Gouëset 2010). Scholars have described this expansion of gated communities and squatter settlements as the 'secession of the rich' and the 'lock-in of the poor' (Coy 2006; Janoschka and Borsdorf 2004).

Of course, this process of population redistribution is accompanied by different living conditions not only in terms of service provision (e.g., health services, water and power supply or rubbish collection) but also with regard to housing quality (e.g. materials used for construction). While good living conditions prevail in regulated suburban developments, poor living conditions are often the norm in unregulated marginal urban areas where cheap self-help architecture has become the most effective tool to shelter the poor while raising the level of owner-occupation (Gilbert 1999). One of the consequences of such patchwork land use is that 'an impoverished middle class seeks cheap accommodation in low-income neighbourhoods, and low-income residents cling to the niches they have developed' (Roberts 1989: 675). Therefore, residential mobility in Colombia is seen 'as much a reaction to the supply of, as to the demand for, housing; less the result of individual 'trade-off' decisions' (Edwards 1983: 144). Although other scholars in Colombia have used the same lens to undertake a descriptive analysis of residential mobility in specific locations (Dureau, et al. 2007; Dureau and Delaunay 2005; Dureau, et al. 1994; Dureau and Gouëset 2010), including analyses from a qualitative perspective (Ward 2011), further understanding clearly is needed in order to assess the separate influence of specific factors such as living conditions, homeownership, income or composition, while considering all other factors to be equal.

Given the rapid process of urbanisation in Colombia and its peculiarities regarding urban expansion and settlement of different groups, we argue that new evidence about residential mobility is needed, and that this lies hidden in housing factors and the characteristics and composition of localities. Our main hypothesis for this paper is that better living conditions and gains in household socioeconomic status foster residential mobility, while increasing homeownership rates and the composition of households hinder residential mobility in the case of Colombia.

## Study Area, Sample and Variables

### Study Area and Sample

The study area is comprised of all the municipalities in Colombia in 2005, with the exception of 20 remote municipalities for which census information on residential mobility was not available. The total number of municipalities (1,119) constitutes the number of observations in our sample. Colombia's territorial extension is the fifth largest in Latin America (1,141,748 km<sup>2</sup>), and municipalities vary greatly in size (from 15 to 22,000 km<sup>2</sup>). As we show in the GWR specifications, the use of this advanced spatial analysis technique allows a continuous surface of parameter values across the total surface of Colombia so that a more flexible approach can be used at certain points to denote spatial variability (Fotheringham et al. 1996).

### Variables

The 2005 Census in Colombia allows the identification of three types of internal household movement for the period 2000–2005: a) *Local*, which have their origin and destination within a smaller administrative unit (municipalities); b) *Intradepartmental*, which imply a change of municipality within departments (larger administrative unit); and c) *Interdepartmental*, which refer to movement between departments. For our study, we used the information available on local internal movements. In practice, this means that we focus on household residential changes with origin and destination within the same municipality. As Table 1 shows, more than 77 % of households who changed residence did so within municipalities, 13 % between departments, and 10 % within departmental units.

**Table 1** Number of households that changed residence between departments, within departments, and within municipalities, 2000–2005

	All households that changed residence	Between departments	Between municipalities but within departments	Within municipalities
Number of households (2005)	2,689,526	344,175	268,705	2,076,646
Percentage	100	12.8	10	77.2

Source: DANE, 2005 census

*Residential mobility* Specific information on residential mobility is drawn from the following census questions: “Was there a change of residence during the last 5-year period?” and “What was the previous municipality of residence?” As a result, two different variables are produced and allow the recording of residential mobility for all members of the household, including room-mates and children. Our variable of residential mobility captures the proportion of households in each Colombian municipality that changed residence within the same municipality during the period 2000–2005, which can be expressed as follows:

$$m_{ij} = \frac{M_{ij}}{P_{2005}} * k \quad (1)$$

Where  $M_{ij}$  refers to all household moves from origin  $i$  to destination  $j$  within a municipality during the period 2000–2005,  $P_{2005}$  is the total households in the municipality in 2005, and  $k$  is the constant term (100). Table 2 presents a statistical summary of the households that changed residence within municipalities in Colombia as a whole (Fig. 5 in the Appendix provides the geographical distribution of this variable).

*Index of Living Conditions (ILC)* This variable is represented by an index composed of 4 dimensions: human capital, housing quality, service provision and household composition (see Table 6 in the Appendix for more detailed information). The total score ranges from 0 to 100, with higher scores showing an increase in living standards. Desirable minimums, which correspond to 67 points, are regulated in the national Constitution. Many of the almost 1,100 municipalities considered in the study had not reached the regulatory minimums in 2005. Data for this variable come from the National Planning Department (DNP), which assembles the indicator with data from the 2005 Census and the Quality of Life Survey (ECV) for the same year.

*Homeownership (HOWN)* This variable captures the percentage of homes in the municipality that are owned by residents (with or without mortgage). In 2005, 58.6 % of Colombian households were homeowners while 33.7 % lived in rented or sublet accommodation. The rest of households were classified as de facto occupants or living in rent-free accommodations.

**Table 2** Statistical summary of households that changed residence within the municipalities in Colombia, 2000–2005

	Intra-municipal household residential changes observed	Proportion of households that changed residence
Maximum	611415	47.7
Minimum	1	0.03
Mean	1890	10.7
Standard deviation	19911.0	7.34

Source: DANE, 2005 census

In addition to the abovementioned variables, other important determinants of residential migration derived from theory and empirical research have been included in our analysis, namely income, age and household size. The variable income (*INCOME*) indicates the percentage of households in each municipality that live within their means (i.e., are able to make ends meet) using their monthly disposable income. The variable age (*AGE*) captures the percentage of householders younger than 35 years of age in each municipality. Finally, the variable household size (*HSIZE*) indicates the percentage of households consisting of 4 or more people in each municipality. The use of these variables follows numerous tests in Ordinary Least Square (OLS) regression models that allowed us to select the most powerful predictors of household residential migration within Colombian municipalities (results of these tests are available from the authors).

### Model Specification

Geographically Weighted Regression (GWR) is a ‘local’ form of linear regression which is specifically designed to analyse spatially varying relationships (Fotheringham, et al. 2002). The use of GWR allows exploration of whether the relationships between the dependent variable and explanatory variables vary from place to place; this differs from a ‘global’ OLS model where only a single parameter estimate is given. A Gaussian semi-parametric GWR (SGWR) model can be described as follows:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i)x_{k,i} + \sum_l \gamma_l |z_{l,i} + \varepsilon_i \quad (2)$$

Where  $y_i$  is the dependent variable at location  $i$ ,  $\beta_0$  represents the local estimated intercept,  $x_{k,i}$  is the  $k$ th independent variable with varying coefficient,  $z_{l,i}$  is the  $l$ th independent variable with a fixed coefficient  $\gamma_l$ , and  $\varepsilon_i$  is the Gaussian error at the location  $i$ ;  $(u_i, v_i)$  is the x-y coordinate of the  $i$ th location (Nakaya et al. 2005). Thus, the model mixes geographically local and global terms. The GWR approach gives more weight to data from observations close to  $i$ , which here corresponds to the geographic coordinates of urban centres or municipal centres for each Colombian municipality. Hence, data near to point  $i$  have more influence in the estimation of each  $\beta_k(u_i, v_i)$  than data located further from  $i$ . For this purpose, different functions of spatial weighting need to be considered and calibrated. Since the weighting function is determined by the shape of the spatial kernel and the size of its bandwidth, the latter being the threshold distance beyond which the influence of one area on another is zero, it is always necessary to establish the optimal bandwidth. As a rule of thumb, spatial kernels with a small bandwidth have a steeper weighting function than spatial kernels with a large bandwidth (Fotheringham, et al. 2002). Since our data points in Colombia are not uniformly distributed across the space, the spatially varying kernel is used. Using the adaptive method, kernels are smaller in areas of the centre of Colombia (where the density of data points is high), and larger in areas of the South and East (where the density of data points is low); thus, the strategy was to adopt a bi-square kernel but in

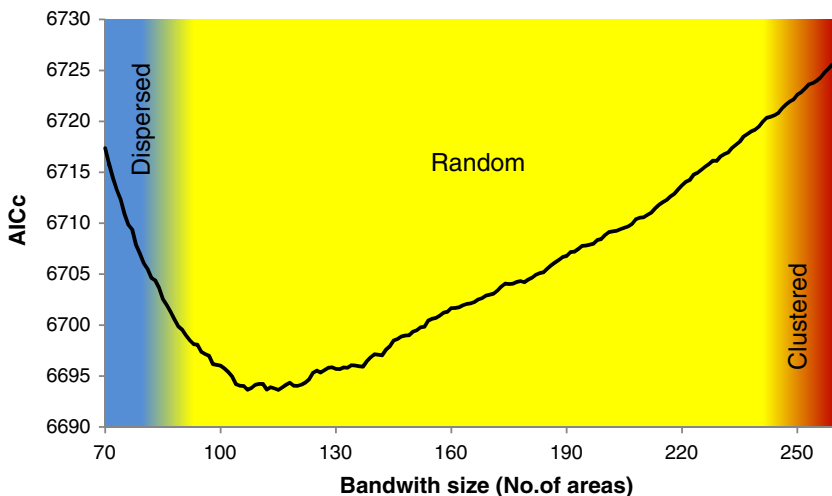


an adaptive manner so that each kernel includes the same number of areas. This can be defined as follows:

$$w_{ij} = \begin{cases} \left(1 - d_{ij}^2 / \theta^2\right)^2 & d_{ij} < \theta_{i(k)} \\ 0 & d_{ij} > \theta_{i(k)} \end{cases} \quad (3)$$

Where  $w_{ij}$  is the weight value of observation at the location  $j$  for estimating coefficient at the location  $i$ ,  $d_{ij}$  is the Euclidean distance between the regression point  $i$  and the data point  $j$ , and  $\theta_{i(k)}$  is an adaptive bandwidth size defined as  $k$ th nearest neighbour distance. The interval search criterion for the optimal bandwidth size was decided by selecting an indicator to compare models with different bandwidths.

The corrected Akaike information criterion (AICc) was selected and its values associated with kernel were compared at many different bandwidths. Bandwidth size for the model was determined by applying bandwidth sizes ranging from 70 to 260 municipalities. Within this context, we followed the general rule, which is that the lower the AICc the closer is the approximation of the model to the reality (Burnham and Anderson 2002). Finally, the spatial dependency was operationalised using Moran’s  $I$ , which was recalculated for a range of different bandwidth values. Figure 1 shows the relationship between AICc, the bandwidth size and Moran’s  $I$  of residuals. In the calibration of the adaptive spatial kernel, a bi-square weighting function based on nearest neighbours was used and the optimal number of nearest neighbours was found to be 115. The model with bandwidths less than 90 areas has dispersion problems (blue colour) and the model with bandwidths exceeding 242 areas has clustered tendencies (red colour). In the 91 to 241 bandwidth range, the residuals of SGWR model do not suffer spatial autocorrelation.



**Fig. 1** Bandwidth selection by AICc for SGWR model. Relationship between bandwidth size, AICc and spatial autocorrelation



## Comparison between OLS and SGWR

Before exploring the eventual variations in the geographic patterns of residential mobility with GWR, a global OLS regression model was carried out<sup>1</sup> using the percentage of households that changed residence (dependent variable) and the independent variables under consideration, namely the index of living conditions (*ILC*), the percentage of homeownership (*HOWN*), the percentage of households that are able to make ends meet (*INCOME*), the percentage of households under 35 years (*AGE*), and the percentage of households with 4 or more people (*HSIZE*) in each municipality. All the parameter estimates for the independent variables were standardized to have a mean of zero and standard deviation of one, allowing us to compare the values of the regression parameters and properly assess their contribution to the model. The following equation displays all the global parameters estimated:

$$y = 10.710 + 2.291ILC - 1.731HOWN + 1.369INCOME + 1.15AGE - 0.693HSIZE$$

(64.9)
(9.0)
(-8.4)
(5.9)
(6.1)
(-3.7)

(4)

The values in brackets are the *t* values, which show that all the global parameters estimated are significant at the 1 % level. The Moran's *I* test applied to residuals model determined sufficient autocorrelation. The adjusted R-squared associated with the model is 0.444 and the corrected Akaike information criterion (*AICc*) is 6861.1.

The values of the regression parameters clearly reveal that the two most explanatory variables are the index of living conditions (*ILC*), followed by the percentage of homeowners in the municipality (*HOWN*). While *ILC* is positively associated with the percentage of people who changed residence (a one-point percentage increase in the index of living conditions leads to a 2.29 percentage increase of residential mobility), *HOWN* is negatively associated (a one-point percentage increase in the percentage of homeowners reduces residential mobility by 1.73 %), suggesting that better living conditions are conducive to a growth in residential mobility but higher levels of homeownership in the municipality reduce the probability of residential mobility. The third most important variable is *INCOME*, with a positive relationship; this suggests the probability of changing residence would increase for those with higher incomes (a one-point increase in the percentage of households who are able to make ends meet is associated with a 1.37 increase of residential mobility). Two more variables with a different relationship with residential mobility are included in the model: the percentage of householders under 35 years of age (*AGE*), which displays a positive association with our dependent variable (a one-point increase in this variable results in a 1.15 increase of residential mobility), and the percentage of households with 4 or more people in each municipality (*HSIZE*), which has a negative association with our dependent variable (a one-point increase in this variable is associated with a 0.69 decrease of residential mobility).

<sup>1</sup> *GWR Software* 4.0, developed and programmed by Professor Tomoki Nakaya of the Department of Geography of Ritsumeikan University (Kyoto, Japan), was used to carry out the global OLS regression and the semi-parametric (Gaussian) GWR regression.

**Table 3** Geographical variability test of local coefficients

Variable	Diff of criterion
Intercept	29.545272
ILC	-29.891424
HOWN	-34.853584
AGE	8.837305
HSIZE	-21.568408
INCOME	7.157804

Positive value of diff-Criterion (AICc) suggests no spatial variability

Although these results already explain much of the variability, it is apparent that the OLS model does not replicate the data as well. Only 44 % of the variance in residential mobility is explained by the model, thus suggesting that the global model does not capture some factors adequately. Of course, this is because in the OLS model we assume that the relationship between the explanatory variables (ILC, HOWN, INCOME, AGE and HSIZE) and the dependent variable (the proportion of households who changed residence) is constant over space (or stationary). However, since it makes sense for an explanatory variable to be non-stationary, it is important to check whether the interquartile range of the parameter estimates from the GWR model is greater than twice the standard error from the OLS estimate. This way we can demonstrate a relatively high degree of spatial non-stationarity, which is clearly the case in our model, thus suggesting that the effect of the predictors varies across municipalities in Colombia. Additionally, we tested whether there is an intense spatial variation in the relationship between household residential mobility and each explanatory variable. This routine test, which is necessary for each geographically varying coefficient (Nakaya et al. 2009), gives the ‘Difference of Criterion’ value for each variable (Table 3). This value is the result of the test of spatial variability based on an AICc criterion and allows us to confirm spatial variability in the coefficients of ILC, HOWN and HSIZE and no spatial variability in the case of AGE and INCOME. Therefore, following these tests, we calibrated a Gaussian semi-parametric GWR (SGWR) model, in which the parameters associated with the variables ILC, HOWN and HSIZE are allowed to vary spatially while the parameters associated with the variables AGE and INCOME are held constant.

Table 4 presents Moran’s  $I$  values for the global OLS and semi-parametric GWR models. The results highlight how the high z-score of OLS model is associated with a very small p-value, indicating that the observed spatial pattern of residuals is very unlikely to be reflecting a random pattern. This would suggest that calibration of a semi-parametric GWR rather than a global model reduces the problem of spatial autocorrelation. Finally, Table 5 provides a summary of statistics for OLS and SGWR, where the model diagnostics of the fitted SGWR model, for instance AICc (6693.6), is clearly smaller than that of the global OLS model<sup>2</sup> (6861.1) and there is a substantive

<sup>2</sup> Better models are indicated by lower AICc values and a ‘serious’ difference between two models is generally regarded as one in which the difference in AICc values between the models is at least 3 (Fotheringham et al., 2002, p. 96).

**Table 4** Moran's *I* values

	Moran's <i>I</i>	z-score	p-value
Global OLS	0.0475	12.5052	0.0000
Semi-parametric GWR	-0.0061	-1.3545	0.1755

z-score are standard deviations

difference (Diff\_AICc) in the performance of the two models, suggesting that the optimal model is the semi-parametric one.

### Results of Semi-parametric Geographically Weighted Regression Model

Our set of local parameter estimates for each relationship between the explanatory and dependent variables generated from SGWR modelling are shown in Figs. 2, 3 and 4 (a).<sup>3</sup> For the colour scheme, we have used shades of blue where the parameter estimate is positive and green where the parameter estimate is negative. Municipalities with an insignificant local estimate are highlighted in the lightest shade (i.e., white). In addition, we include the geographic distribution of each independent variable under consideration at the municipal level before SGWR (b).

Figure 2a clearly displays the spatially varying association between the Index of Living Conditions (ILC) and housing residential mobility. The estimated parameters in the local model indicate that the effect of ILC varies from -2.37 to 7.49, with 50 % of the estimates between 1.33 and 3.52, thus suggesting that the effect of ILC on residential mobility is particularly strong compared to the other explanatory variables. The positive effect of ILC on household residential mobility covers a relatively large portion of the south and northwest of Colombia, although the association between the ILC and household residential mobility is particularly strong in south central Colombia, where the most populated areas of the country such as Cundinamarca (Bogotá), Tolima (Ibagué), Huila (Neiva), Quindío (Armenia), Risaralda (Pereira), Valle del Cauca (Santiago de Cali) or Chocó (Quibdó) are located. These results are somewhat intuitive and reflect the importance of Bogotá and its hinterland westwards, with the particular significance of the coffee production area in Colombia known as the Coffee-Growers Axis or Coffee Triangle. Here, the strategy of the Colombian government on service provision (energy, water and sewerage) has been greatest compared to other parts of the country, with important investments in infrastructure and more progressive social services, particularly in the realms of education and health. While the effects of government efforts in this direction in order to reduce poverty are having a considerable payoff in helping the poor, less well known is the effect on household residential mobility, which in light of these results can be seen as significant both in terms of economic and social returns. Areas where the relationship between ILC and residential mobility is significant generally are the areas with the highest living conditions in the country. Therefore, the results would support the idea that the positive relationship

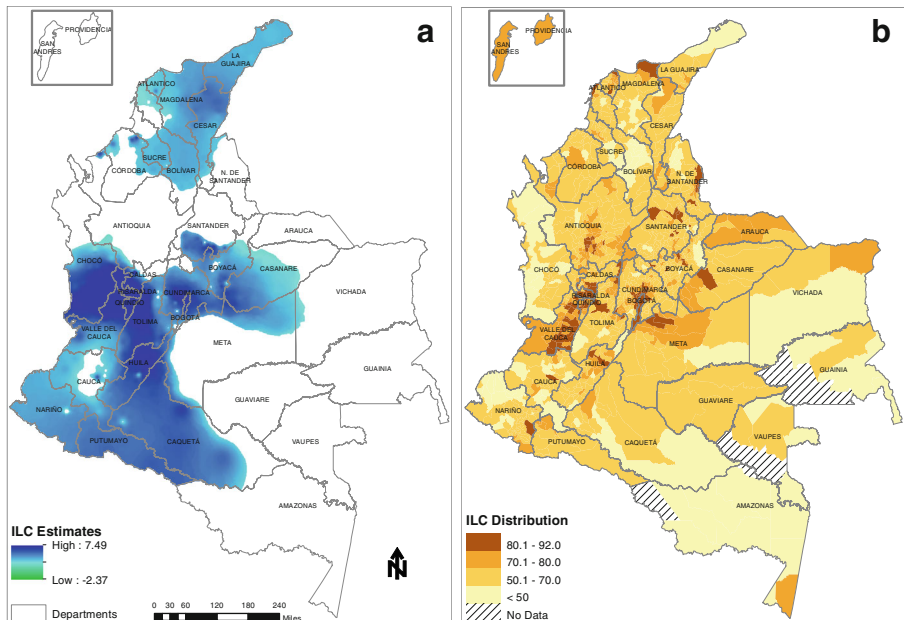
<sup>3</sup> ArcGIS 10.0 software has been used for mapping the GWR-generated parameter estimates and local *t*-values.

**Table 5** Summary statistics for OLS and SGWR

	Bandwidth	Deviance	K	AICc	Diff_AICc
Global OLS	NA	6846.9	6.0	6861.1	167.5
Semi-parametric GWR	115	6466.4	101.8	6693.6	0.0

K indicates the effective numbers of parameters. Diff\_AICc is the difference of AICc of global model from that of the best model, SGWR

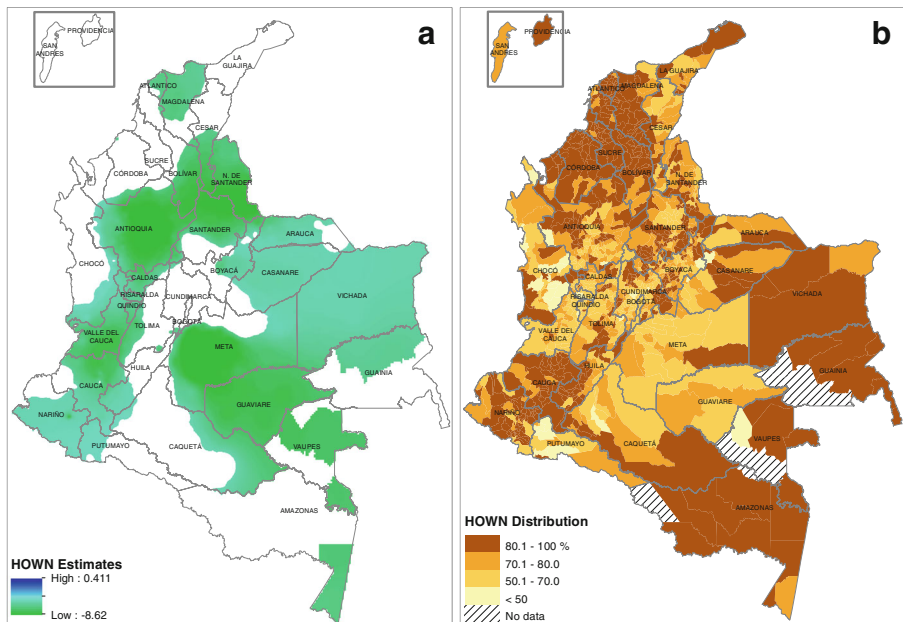
between better living conditions and household residential mobility takes place in areas with high economic activity. In the northern part of the country this relationship is also significant, albeit less strong, specifically within the departments of La Guajira (Riohacha), Atlántico (Barranquilla), Magdalena (Santa Marta), Bolívar (Cartagena) and Cesar (Valledupar). Figure 2 also demonstrates that the association between living conditions and residential mobility is not significant in most of the rural departments of eastern Colombia, such as Meta (Villavicencio), Guaviare (San José del Guaviare) or Vichada (Puerto Carreño), where rural development strategies (e.g., service provision and employment programmes) have been almost nonexistent to date. However, with the current decentralisation process in Colombia, the issue of improving living conditions in rural areas while eliminating the urban bias has gained significance in recent years, although investment in attractive rural infrastructure projects and services is still seen as a major challenge. Given the strong association between ILC and household residential mobility, one could expect that processes of rural development and



**Fig. 2** a Map of ILC estimates, significant areas at  $\pm 1.96$  level. b Map of ILC distribution

investments in social and infrastructural services would probably lead to an increase of household residential mobility, perhaps at the expense of further counterurbanisation.

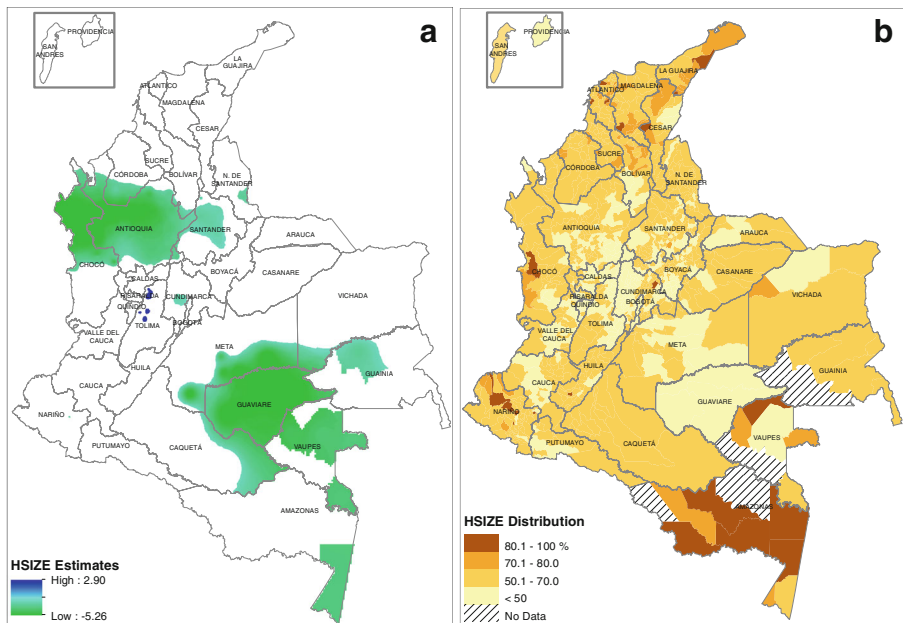
Figure 3 displays the effect of the housing tenure (HOWN) variable on the percentage of households that changed residence. The estimated parameters in the local model indicate that the effect of HOWN ranges from  $-8.62$  to  $0.411$ , with 50 % of the estimates between  $-3.77$  and  $-1.36$ , thus highlighting that the effect of HOWN on residential mobility is also strong amongst the explanatory variables that are allowed to vary spatially. In many parts of the country, this relationship is significant; however, contrary to the ILC, the association between HOWN and household residential mobility is clearly negative. This effect is clearly in line with the literature, which suggests that increasing homeownership rates, both as a result of the rapid suburbanisation in the form of gated communities and peripheral squatter settlements across municipalities in Colombia, hinder household residential mobility. Of course, this relationship is also likely to capture the differential costs involved in changing residence, with much lower costs for renters than for homeowners. Nonetheless, as noted earlier, in the case of Colombia it is worth stressing that growing homeownership rates are also the result of consolidated self-construction or unregulated housing, which is likely to further depress residential mobility as these homeowners are largely unable to sell their dwelling once they have built it, and therefore people in this situation are excluded from one of the main advantages of owner-occupation, which is having both a home and a financial asset. The results indicate that the negative effect is very strong in northwestern areas such as Antioquia (Medellín) and southwestern areas such as Valle del Cauca (Cali). The association is also very strong in the western part of the Meta department (Villavicencio), a traditional agricultural and mining area near Bogotá. Other areas that



**Fig. 3** a Map of HOWN estimates, significant areas at  $\pm 1.96$  level. b Map of HOWN distribution

display a strong negative relationship between the levels of homeownership and household residential mobility are situated in the northern departments of Santander (Bucaramanga), Norte de Santander (Cúcuta) and the southern parts of neighbouring departments, Bolivar (Cartagena de Indias) and Cesar (Valledupar). We can also observe a strong association in other parts of the country characterised by high rates of homeownership, although some of these are border areas characterized by low levels of urban development. The exception is the case of cities such as Santa Marta and Barranquilla in the departments of Magdalena and Atlántico, respectively. Finally, the case of Bogotá, although not statistically significant, deserves special attention both in terms of its share with regard to residential mobility (with more than 29 % of all intra-municipality residential changes in Colombia) and in terms of its strong residential dynamics with the neighbouring metropolitan municipalities. In assessing the non-significant relationship between homeownership and residential mobility in Bogotá, it is important to bear in mind that the lack of new housing reinforces self-help housing in the periphery and suburbanisation outside Bogotá's municipality, thus making homeownership in the capital very difficult for most people. As a result, a widespread rental market has been developed in Bogotá's municipality, representing 46.8 % of all households in 2005. From this perspective, it is understandable that in our analysis residential mobility is not very sensitive to homeownership in the capital.

Figure 4 shows the association between household size (HSIZE) and household residential mobility. The estimated parameters in the local model indicate that the effect



**Fig. 4** **a** Map of HSIZE estimates, significant areas at  $\pm 1.96$  level. **b** Map of HSIZE distribution

of the percentage of households with 4 or more members in a municipality varies from  $-5.26$  to  $2.90$ , with 50 % of the estimates between  $-1.11$  and  $0.34$ , thus suggesting that the effect of HSIZE on residential mobility is not as strong as the effect exerted by ILC and HOWN. The relevance of this association is seen as important not only from the perspective of mobility, a situation which would be reflected only in a few local 'hot spots' in the department of Tolima, but also immobility. The latter appears to be prevalent and covers two distinct areas. One is in the southern part of the country, covering the rural department of Guaviare (San José del Guaviare) as well as the most uninhabited areas of the country, such as Vaupes (Mitú), Guainia (Inírida) and Amazonas (Leticia), in which traditional primary sector activities and large household sizes go hand in hand. The other area is in the northeast, and includes almost all of the department of Antioquia (Medellín), the second most populated area and economically dynamic area in the country, and the department of Chocó (Quibdó), in which we not only find household sizes well above the national average but also the highest poverty rates in the country. In these areas whose characteristics are very different from each other, the sensitivity of residential mobility to the household size is very similar. However, it is not clear why there would be an equally strong association between a higher percentage of households with 4 or more people and lower household residential mobility within municipalities across this diverse selection of departments. This question definitely requires a localised analysis that is beyond the scope of this paper.

## Conclusions

Our main hypothesis for this paper was that better living conditions and gains in socioeconomic status contributed positively to household residential mobility, while increasing homeownership rates and the composition of households depressed it. While the findings of our research clearly match our initial hypothesis, the use of SGWR is seen as pivotal to highlight the importance of local variation in the relationship between the explanatory variables under consideration and our dependent variable (household residential mobility). Accordingly, our findings indicate that the SGWR approach outperforms the OLS approach in terms of predictive power, thus making efficient use of the information that is available for municipalities. The OLS model performed moderately well (log likelihood = 6846.9,  $AIC_c = 6861.1$ , adjusted  $R^2 = 0.447$ ), but exhibited clear signs of spatial autocorrelation (Moran's  $I = 0.0475$ ) and spatial non-stationarity. The semi-parametric GWR model provided much better results (log likelihood = 6466.4,  $AIC_c = 6693.6$ , adjusted  $R^2 = 0.554$ ), almost completely removing the effects of spatial autocorrelation (Moran's  $I = -0.0061$ ) and spatial non-stationarity.

More specifically, the examination of the relationships between the variables ILC, HOWN and HSIZE, which were allowed to vary spatially, and household residential mobility provided sound empirical evidence supporting the need for such an analysis. Our results indicate that the benefits of 'good' living conditions in some Colombian municipalities are likely to give households better



opportunities for residential change. Therefore, poor living conditions, including inadequate housing and limited access to amenities, not only impact the ability of the poorest groups to rise out of poverty but also constrain residential mobility, as demonstrated by the fact that the estimated local coefficients for ILC on residential mobility do not always have the same sign within municipalities across Colombia. Thus, the outcome of moving is affected by the different contextual conditions under which households move. It becomes apparent that improving the living conditions within municipalities in terms of education, housing, infrastructure and access to basic services not only has a positive impact on reducing poverty as defined by the United Nations millennium development goals (UN 2012), it also provides a stimulus to population movement, which is seen as important when immobility becomes part of sociospatial structuring processes with consequences such as rising levels of residential and social segregation (Thibert and Osorio, 2013). Perhaps an indication for slum improvement in some of the Colombian municipalities is the commitment made by the National Council of Economic and Social Policies to improve the living conditions of slum dwellers, to the extent that the national goal is to reduce the proportion of people living in slums from 16 to 4 % by 2020 (UN-HABITAT 2006).

With regard to housing tenure, the results indicate that the owners of homes are less likely to move house within municipalities in Colombia, although the estimated local coefficients also indicate that the effect of this explanatory variable on household residential mobility clearly varies across space. It is commonly understood that levels of homeownership are greatly influenced by government intervention and market forces that affect both the demand and the supply of housing. In the case of Colombia, the apparent lack of investment in housing policies to accommodate the growing population in urban areas has been derived, in many cases, from the growth of a self-help housing market, with implications for individual households and society at large, as the potential broadening of homeownership takes place within low-quality and informal-housing developments, and is generally associated with relatively low levels of residential mobility. As described by Edwards (1983), homeownership is the general preference of different income and age groups; however, significant social differences persist in accessing owner-occupation because the issue of providing long-term financing at the lowest market rate is not resolved. According to some authors (Clavijo et al. 2004), during the year before the 2005 Census the social housing deficit stood at 1.2 million units, whereas the private housing deficit was nearly 1.7 million units (in a country of 10.6 million households). These are crucially important aspects that, along with other factors of local housing markets, make residential changes particularly difficult for the majority of the population. From this perspective, the possibility of residential mobility as an essential ingredient for an equitable and efficient society is constrained by both poor living conditions and the very limited government intervention with regard to housing, thus prompting the expansion of gated communities and squatter settlements which are currently seen as the

‘secession of the rich’ and the ‘lock-in of the poor’ (Alfonso 2005; Coy 2006; Janoschka and Borsdorf 2004).

Thirdly, the relationship between household residential mobility and household composition, which here captures the percentage of households with 4 or more members in a municipality, is the least strong of all the explanatory variables included in the SGWR model. The importance of household composition is seen as relevant because compositional changes usually alter housing needs and thus often lead to residential mobility. While this effect appears to be occurring within some municipalities (for instance, in the department of Tolima), it is usually the exception, as demonstrated by the existence of only a few local ‘hot spots’. On the contrary, the effect of this variable is generally associated with a reduction in household residential mobility, which is interpreted differently depending on the setting. While the negative effect in rural areas, such as the department of Guaviare, is likely to occur as a result of the still predominant model of extended family households, the negative effect in the second most populated and urban department in Colombia (Antioquia) is likely explained by the consequences that follow the growth and development of self-built settlements and the increase of housing arrangements with many close kin (including adult children), and in some cases renters too, sharing the property (Gough and Kellett 2001). In these urban settings, where the self-builder owner households have gradually gained importance, households cannot react to price changes by moving residence, as any attempt to convert housing assets into cash is wildly out of line with the market rates (Englund and Ioannides 1993). As a consequence, a growing number of households with adult members are forced to share housing, a situation that leads to immobility, according to evidence from recent qualitative studies (Ward 2011).

Overall, our analysis of the effects of living conditions, homeownership, income, age and household composition on residential mobility has proved to be useful in improving our understanding of the importance of each of these factors in explaining the complex patterns of household residential mobility within Colombian municipalities. While contributing to the debate on the dynamics of residential mobility in Colombia, the findings also have implications for effective policy-making with regard to major issues high on national and local agendas, such as urban expansion, social (im)mobility and residential (de)segregation. We believe that the evidence from our analysis gives further impetus to the idea that any policies which consider household residential mobility or people’s residential aspirations must consider not only the factors that foster or hinder the process, but also their variability across space. For instance, the results have provided evidence that three of the explanatory variables (living conditions, homeownership and household composition) are clearly not equally constant in all directions. We think this is a relevant step in the analysis of household residential mobility in Colombia, as to date only a few attempts have been made to assess mobility patterns using data from the 2005 Census, and to the best of our knowledge none of them has analysed whether the reasons that explain residential mobility in one location are exactly the same as those in another. GWR is an attractive

tool, providing an effective vehicle for modelling residential mobility across diverse municipalities. However, it is also important to highlight some of its limitations. For instance, GWR results are clearly subject to the calibration of the bandwidth for the weighting function; possible problems of collinearity have also been raised (Wheeler 2007; Wheeler and Tiefelsdorf 2005). Other limitations relate to the nature of data. In this paper, we have used census aggregate figures; therefore, the analyses are subject to the ecological fallacy problem (i.e., they do not enable inference to individual migration flows). One way to partly overcome this problem would be to use individual-level data in conjunction with aggregate data with finer geographical detail. The latter is already envisaged in light of new data releases from the National Bureau of Statistics (DANE), which will allow more refined analysis and specific explorations in municipalities of interest.

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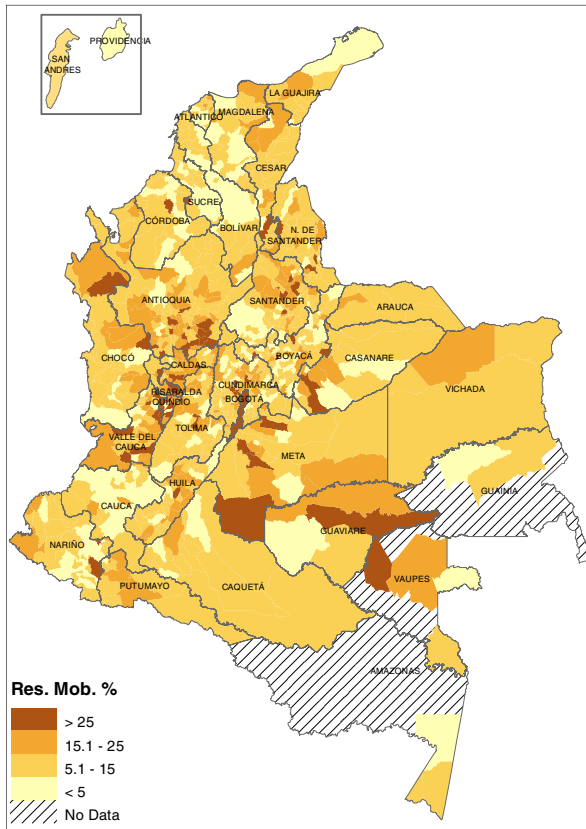
## Appendix

**Table 6** Dimensions and variables included in the Index of Living Conditions (including weighting)

Dimension	Variables	Total
Human capital	Education achieved head of household	11.52
	Average education people 12 years old and over	12.31
	Education Young people between 12 and 18 years old	5.66
	Education children from 5 to 11 years old	9.95
	SUBTOTAL	39.43
Housing quality	Material of the walls	6.11
	Material of the floors	6.79
	SUBTOTAL	12.9
Service provision	Health service	7.14
	Water supply	6.99
	With what do they cook?	6.67
	Rubbish collection	6.62
	SUBTOTAL	27.43
Household composition	Children 6 years old or younger in the household	7.45
	People per room	12.8
	SUBTOTAL	20.25
	TOTAL	100

Source: Department of National Planning

The desired and regulatory minimum in the Colombian Constitution is 67 points



**Fig. 5** Geographical distribution of household residential mobility within municipalities in Colombia, 2000–2005

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