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Identifying, mapping and modelling trajectories of poverty at the neighbourhood level: The case of Montréal, 1986–2006

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A B S T R A C T

Longitudinal analysis is rarely leveraged in the field of geography to understand neighbourhood change despite many studies documenting important transformations within metropolitan areas (e.g. gentrification, impoverishment of inner suburbs, etc.). This paper aims to identify and model trajectories of neighbourhood poverty in Montreal over five consecutive census years (1986, 1991, 1996, 2001 and 2006), using Latent Class Growth Modelling. Neighbourhoods are classified in eight groups, identifying those with stable, increasing or declining trajectories of poverty. Multinomial logistic regression analysis shows that the proportion of residents with low levels of education, unemployment rate, proportion of recent immigrants and the proportion of renters measured at the beginning of the period (1986) are important predictors of poverty trajectories, as are variations throughout the study period (1986–2006) in the proportions of recent immigrants and of residents with low levels of education.

Introduction

Globalization, economic restructuring, demographic shifts, as well as changes in government policies have modified the social divisions of cities (Jargowsky, 2003; Van Kempen & Murie, 2009; Walk, 2001), notably the spatial distribution of low-income populations within metropolitan areas. As a result, the geography of poverty and social deprivation is now receiving growing attention in North America as well as in Europe (Cooke & Marchant, 2006; Heisz & McLeod, 2004; Kearns & Parkinson, 2001; Kitchen & Williams, 2009; Lupton & Power, 2004; Madden, 2003a, 2003b). To date, most of the empirical work on neighbourhood change has examined transformations between two points in time (Kitchen & Williams, 2009; Mikelbank, 2006; Reibel & Regelson, 2011; Vicino, 2008). With the exception of the recent work of Mikelbank (2011) on the Cleveland–Akron metropolitan area, few studies have analyzed trajectories with precision i.e. they have not investigated changes in the socioeconomic characteristics of neighbourhood populations over more than two points in time.

This low level of interest among geographers is surprising, given that longitudinal analysis has been developed considerably in the social sciences over the last two decades, both in North America and Europe. Indeed, many studies have investigated individual trajectories, notably professional, family and residential trajectories using, for example, event history analysis (Blossfeld, Drobnic, & Rohwer, 1998; Courgeau, 1985, 1993; Desrosiers & Lebourdais, 1991; Vandersmissen, Séguin, Thériault, & Claramunt, 2009). Transformations in the urban built environment have also received some attention, notably in relation to land use changes in cities and their suburbs (Hewitt & Escobar, 2011; Keys, Wentz, & Redman, 2007; Salvati, Munafo, Morelli, & Sabbi, 2012; Tavares, Pato, & Magalhães, 2012).

Likewise, in the 1980s–1990s, a number of researchers have analyzed gentrification processes at work in major American and Canadian metropolises (Berry, 1986; Bourne, 1993; Bunting & Filion, 1988; Clark, 1987; Ley, 1986, 1993; Rose, 1984; Smith & Williams, 1987), whereas more recently, studies have documented the impoverishment of inner ring suburbs (Cooke & Marchant, 2006; Jargowsky, 2003; Lee & Leigh, 2007; Madden, 2003b; McConville & Ong, 2003; Short, Hanlon, & Vicino, 2007; Smith, 2006). Both processes – gentrification and inner ring suburb impoverishment – result in significant changes in the urban geography of poverty. The contribution of this paper is to demonstrate the value of trajectory analysis for understanding change in neighbourhood poverty over a 20-year period in the Montreal Census Metropolitan Area (CMA).

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Latent Class Growth Model is used as a tool to identify these trajectories. These trajectories are subsequently modelled using multinomial logistic regression.

Background

Studying changes in neighbourhood poverty

Recent studies on the geography of poverty, notably in American metropolises, document changes in the distribution of poverty zones within metropolitan areas, particularly the impoverishment of inner ring suburbs (Cooke & Marchant, 2006; Lee, 2011; Lee & Leigh, 2007). Other research investigates trajectories of poor neighbourhoods, such as the study of McConville and Ong (2003) which tracked the change, or lack of change, in poor neighbourhoods, i.e. whether neighbourhoods stayed poor, worsened or improved over time. In their study, changes are explained in relation to transformations in other neighbourhood characteristics such as ethnicity, immigration, education, employment and household type.

In Canada, few studies have analyzed changes in poverty (or in deprivation) at the intra-metropolitan scale. Most studies provide descriptive analyses at the census tract level of the redistribution of poverty or deprivation within metropolitan areas. Ley and Smith (2000), jointly taking into account four deprivation indicators measured at the census tract level, observed that some deprived census tracts in Toronto, Montreal and Vancouver in 1971 were no longer deprived by 1991, while other non-deprived neighbourhoods in 1971 had become so by 1991. In a more recent study also based on census data, Heisz and McLeod (2004) reported variations in both the proportion and the spatial distribution of low-income neighbourhoods within different Canadian metropolitan areas between 1981 and 2001. They noted that in 2001, low-income neighbourhoods in Montreal and Toronto were less concentrated in the inner city and were more present in inner-suburbs than they were in 1981. Similar changes in the spatial distribution of low-income neighbourhoods were also observed in many American metropolises (Jargowsky, 2003; Madden, 2003a). Although these studies document overall changes in the distribution of the low-income population in different metropolitan areas, they do not explore trajectories of neighbourhood poverty per se.

A study by Kitchen and Williams (2009) offers a more comprehensive analysis of neighbourhood change. Looking at Saskatoon, a mid-sized Canadian metropolis, the authors characterized the socioeconomic profile of 58 neighbourhoods in 1991 (at the beginning of the period of observation), classifying them as low, middle or high socioeconomic status neighbourhoods. Then they analyzed the change in socioeconomic status in terms of decline, improvement or stability over a 10 year period up to 2001, focussing on two sub-periods 1991–1996 and 1996–2001. Considering the socioeconomic status at beginning of the study period and the type of evolution over time, they investigated the factors of change related to the socioeconomic characteristics of the population living in each neighbourhood. Although this study (Kitchen & Williams, 2009) is a fruitful contribution to the analysis of neighbourhood change, a period of ten years of observation may nevertheless be too brief to capture significant changes such as gentrification or suburban impoverishment.

Poverty trajectories and presence of populations at risk

According to classical studies of low-income populations, certain characteristics of individuals and their households are known to put them at a greater risk of poverty (Noble, Wright, Smith, & Dibben, 2006; Pampalon, Gamache, & Hamel, 2011). For example, a strong presence of lone-parent families is a factor that makes a neighbourhood particularly susceptible to poverty concentration (Apparicio, Séguin, & Leloup, 2007; Heisz & McLeod, 2004; Kitchen & Williams, 2009; Lee, 2011; McConville & Ong, 2003; Pampalon et al., 2011), as does the presence of a high proportion of immigrants, especially recent immigrants (Heisz & McLeod, 2004; Ley & Smith, 1997, 2000; Walks & Bourne, 2006). Similarly, concentrations of populations with low levels of education (Kitchen & Williams, 2009; Lee & Leigh, 2007; Lupton & Power, 2004; Pampalon et al., 2011) as well as high unemployment rates (Kitchen & Williams, 2009; Lee, 2011; Lee & Leigh, 2007; Lupton & Power, 2004; McConville & Ong, 2003; Pampalon et al., 2011; Walks & Bourne, 2006) are associated with neighbourhood poverty. The presence of a high proportion of renters is also linked to poverty (Kitchen & Williams, 2009; Lee, 2011; Lee & Leigh, 2007; Lupton & Power, 2004), although being a renter could be seen more as a consequence of poverty than as a cause. A strong presence of these characteristics in the same geographical area thus increases the probability that it will be an area of concentrated poverty.

Until now, most of the work analysing socioeconomic changes in neighbourhoods has involved two points in time, rarely going beyond a period of ten years (Kitchen & Williams, 2009; Mikelbank, 2006; Reibel & Regelson, 2011; Vicino, 2008). With the exception of the study of Mikelbank (2011) on Cleveland, and the descriptive work of McConville and Ong (2003) on Southern California, it is rare for studies to identify 'real' neighbourhood trajectories. To identify real trajectories, it is important to consider more than two points in time and look beyond a period of ten years.

Research objectives

The aim of this article is to elaborate a typology of neighbourhoods according to their trajectories of poverty from 1986 to 2006 and to test if the presence of different populations at higher risk of poverty explains these trajectories. This article therefore makes both a methodological and empirical contribution by demonstrating the relevance of trajectory analysis and applying it to the Montreal CMA.

In a first step, we identify neighbourhood poverty trajectories within the Montreal CMA by grouping neighbourhoods characterized by similar levels of poverty at the beginning of the study period as well as by a similar pattern of change in their poverty levels from 1986 to 2006 – over a 20 year period. The study is based on census data from the years 1986, 1991, 1996, 2001 and 2006, at the census tract level. At each point in time, poverty is measured as a continuous variable, so a neighbourhood can be characterized by a complex trajectory. For example, a neighbourhood can experience declining poverty level, then increasing poverty level, followed by stable level of poverty, finishing with declining poverty level. Statistically, this is achieved by applying a clustering technique for longitudinal data – Latent Class Growth Model, described later. In a second step, we examine whether these neighbourhood trajectories are explained by different socioeconomic characteristics of the neighbourhood population at the beginning of the period, and/or by the changes in these characteristics over the 20 years.

Data and methods

Identifying trajectories of relative poverty concentration

To identify trajectories of poverty at the neighbourhood level in the Montreal CMA between 1986 and 2006, two preliminary steps were necessary: selection of a measure of poverty and then harmonization of the spatial units of observation over the five

census years (1986, 1991, 1996, 2001, and 2006). Neighbourhoods are here defined using census tract boundaries; in the remaining of the paper, the terms neighbourhoods and census tracts (CTs) are used as synonyms. At each census year, poverty was measured using the "low income cut-offs" variable as defined by Statistics Canada. This variable, which is a measure of 'relative poverty', is widely used in Canadian studies of poverty or deprivation (Apparicio et al., 2007; Broadway & Jesty, 1998; Ley & Smith, 1997; Séguin, 1998; Séguin, Apparicio, & Riva, 2011). It represents the proportion of the population living in households spending 20% or more of their total income before tax on food, shelter and clothing, compared to the average Canadian equivalent household (this variable is adjusted for the number of persons in the household and the size of the community in which the household lives) (Statistics Canada, 2010, 2011). It should be noted that the proportion of low-income population is relatively high in the Montreal CMA compared to other large Canadian CMAs (Table 1): from 1986 to 2006, the lowest value was observed in 1986 (21.55%) and the highest value in 1996 (27.64%), a well-known consequence of the recession that occurred during the first half of the 1990s (Collin & Jensen, 2009; Helly, Zhu, & Trudel, 2008).

The boundaries of the CMA, the number of census tracts, as well as some of the CT boundaries within the CMA, varied throughout the study period. To address this challenge, we retained the 'initial' 1986 boundaries of the CMA and aggregated several contiguous CTs. This enabled the production of a spatial dataset with 611 CTs that are comparable across the five census years.

Finally, due to the overall variation in the proportion of low-income population in Montreal over the study period, we opted for a measure of *relative poverty concentration* – the location quotient (LQ). The LQ represents the proportion of low-income population in the CT divided by the value observed for CMA as a whole:

$$LQ_i = (x_i/t_i)/(X/T)$$

Where:

x_i = low-income population in the census tract i;
t_i = total population in the census tract i;
X = low-income population in the CMA;
T = total population in the CMA.

For each census year, the LQ allowed identifying CTs of poverty concentrations, i.e. CTs where the proportion of low-income residents is higher than that of the CMA (as indicated by LQ values greater than one) and CTs of poverty under-representation, i.e. CTs where the proportion of low-income residents is lower than that of the CMA (as indicated by LQ values lower than one).

We obtained a longitudinal dataset with 611 CTs characterized by a continuous variable (the LQ) measured at five points in time. Several clustering techniques could have been applied on this dataset to identify n groups of CTs having a similar trajectory of change throughout the period (e.g. hierarchical cluster analysis and k-means clustering or extensions of k-means, such as fuzzy-k-means, partitioning around the median) (Bezdek, 1980; Everitt, Landau, & Leese, 2001; Jain, 2007; Kaufman & Rousseeuw, 2005; McQueen, 1967). However, a 'new' type of cluster procedure for longitudinal data, Latent Class Growth Model (LCGM) (Andruff, Carraro, Thompson, Gaudreau, & Louvet, 2009; Collins & Lanza, 2009; Duncan, Duncan, & Strycker, 2009) was ultimately selected because recent works have demonstrated that LCGM slightly outperforms k-means (Magidson & Vermunt, 2002). To date, LCGM has mainly been applied in psychology (Nagin, 2005) and epidemiology. For example, it has been used to group individuals having followed similar trajectories of change in health-related behaviours (Barnett, Gauvin, Craig, & Katzmarzyk, 2008; Brookmeyer & Henrich, 2009; Cerdá, Johnson-Lawrence, & Galea, 2011; Østbye, Malhotra, & Landerman, 2011). However, only a few studies have applied this method on a spatial dataset (Riva & Curtis, 2012).

Over time, each census tract will follow a unique trajectory of changing poverty levels. This variability is summarized in LCGM by a set of polynomial functions classifying CTs into discrete groups, each corresponding to a trajectory (Andruff et al., 2009; Collins & Lanza, 2009; Duncan et al., 2009). For each trajectory, model parameters, i.e. intercept and slopes, are estimated and it is assumed that the magnitude and direction of change will vary between trajectories (Nagin, 2005). However, within a trajectory, the slope and intercept are treated as fixed (equal) between census tracts. In LCGM, the optimal number of trajectories, or groups, is informed by a sequential modelling approach whereby the modelling starts with a one-group model, and groups are subsequently added to evaluate improvement in model fit. Various model-based diagnostics, such as the lowest Bayesian Information Criterion (BIC) and posterior probabilities of group membership, are available to identify the best model, that is, to determine the optimal number of trajectories (Andruff et al., 2009).

For the current analyses, LCGM was conducted for four to 20 clusters, as we had no a priori assumption on the optimal number of trajectories. We set a minimum of four clusters to ensure some differentiation between trajectories. The optimal number of trajectories was informed by the model providing the lowest BIC value, with the additional criterion that each trajectory had to contain a minimum of about 5% of CTs (to avoid very small

Table 1
Description of poverty and other socioeconomic indicators for the Montreal CMA, between 1986 and 2006.[a]

Census year	1986	1991	1996	2001	2006
Total population	2,826,270	3,019,350	3,125,545	3,208,860	3,363,975
Low-income population	609,175	666,680	863,745	723,670	728,220
Low income %	21.55	22.08	27.64	22.55	21.65
Unemployment rate	11.32	11.69	11.22	7.52	7.01
Lone-parent families (%)	15.92	15.73	17.55	18.23	18.24
One-person households (%)	25.31	27.34	29.55	31.19	31.99
People aged $\geq$ 65 years (%)	9.26	10.26	11.09	11.97	12.70
Recent immigrants (%)	1.27	2.73	4.21	3.46	4.77
Low education (%)[b]	39.76	34.96	31.51	25.87	21.61
Renters (%)	55.54	53.65	52.19	50.45	47.51
University education (%)[c]	20.74	13.42	26.05	26.27	25.14

[a] All variables are calculated for the CMA boundaries of 1986.
[b] For 1986, 1991 and 1996 censuses: Population 15 years and over with less than grade 13 without secondary school certificate; For 2001 census: Population 20 years and over with less than grade 13 without secondary school certificate; For 2006 census, population 15 years and over without diploma.
[c] Population 15 years and over, except for the 2001 census where this information is available for population aged 20 years and over.

groupings). LCGM analysis was conducted in LatentGOLD software (Vermunt & Magidson, 2010). The trajectories of relative poverty concentration at the intra-metropolitan level over the twenty-year period can be ascending, descending or stable, and are related to the level of poverty observed at the start year (1986).

Modelling trajectories of relative poverty concentration

Having identified neighbourhood trajectories, the next step was to determine which socioeconomic factors explained and predicted each trajectory. To this end, multinomial logistic regression (Anderson & Rutkowski, 2007) was conducted, with the trajectories obtained by the LCGM treated as the categorical dependent variable. Two sets of predictors theoretically associated with poverty were modelled: 1) the socioeconomic characteristics of the CT population at the start of the period (1986); and 2) changes in the socioeconomic characteristics of the CT population between 1986 and 2006. Based on the literature reviewed above, we considered the following variables as predictors: unemployment rate, proportion of lone-parent families, proportion of recent immigrants (arrived in Canada in the five years preceding the census), proportion of residents with low levels of education, and proportion of renters. We added other predictors: the proportions of one-person households, of seniors (defined as people aged 65 years and older) and the proportion of the population with a university education. The latter was selected in line with extensive studies demonstrating gentrification in certain inner city neighbourhoods in North American metropolises (Ley, 1986, 1993; Smith & Williams, 1987), notably in Montreal (Rose, 1984). This variable was considered with the goal of determining whether gentrification explains the trajectories of diminishing poverty observed in many central-city neighbourhoods. We anticipated that a strong presence of university graduates would be associated with a descending poverty trajectory. An indicator of 'one-person household' was also considered, because poverty is associated with this variable in the province of Quebec (Canada) (Morin, 2004); however, this factor is much less frequent in the work of American geographers. Studies in the USA have shown that the generally widespread poverty among seniors has forced this group to live in poor neighbourhoods located in city centres during the 1970s and early 1980s (Fitzpatrick & Logan, 2007; Massey, 1980; Pampel & Choldin, 1978). Due to the rapid ageing of the Montreal population, considering the proportion of seniors is important (Heisz & McLeod, 2004), while keeping in mind that, in recent years, poverty has significantly declined among this group in Canada (Milligan, 2008; Osberg, 2001; Ross, Scott, & Smith, 2000).

The variable denoting the proportion of visible minorities in the CT was not retained because it is strongly associated with recent immigrants, which could introduce collinearity into the model. In all, a total of sixteen variables (eight variables as measured in 1986 and their variation 1986–2006) were tested in the model to explain the types of observed trajectories (see Table 1 for the values of these variables between 1986 and 2006).

Results

Describing trajectories of neighbourhood poverty

Location quotients of the low-income population for the five census years at the CT level are mapped in Fig. 1. As reported in previous studies (Apparicio et al., 2007; Drouilly, 1996; Lemelin & Morin, 1991; Séguin, 1998; Séguin et al., 2011), CTs displaying a concentration of poverty are mainly located in the central part of the Island of Montreal, corresponding to inner-city neighbourhoods, whereas CTs characterized by an under-representation of poverty are observed in Laval and the North and South Shores, corresponding to suburban areas. Over the 1986–2006 period, the presence of poverty in many central CTs (inner-city neighbourhoods) became less strong, while poverty gained ground outside of the central CTs on the Island of Montreal in areas urbanized during the 1950s and 1960s. Some zones of concentrated poverty located in the northern periphery of the CMA disappeared over the period of study (these are old village centres in municipalities that have witnessed the arrival of new, wealthier populations).

According to the fit statistics (not reported here) of LCGM, the 611 census tracts were optimally classified into eight trajectories. Trajectories are plotted using the mean values of the LQs for the different classes. The chart in Fig. 2 demonstrates that changes were not marked: some trajectories were stable (G and H) or somewhat stable (A), others saw a slight increase in poverty (B, C, E and F), and one group of CTs saw a decrease in poverty concentration (D), the most significant change over the period (see Fig. 2 for a map of CTs according to their type of poverty trajectory).

Trajectories A and B (titled respectively "Very high concentration" and "Increasing high concentration," respectively) capture the trajectories of the traditionally poor and old neighbourhoods of inner city areas. These trajectories also include some CTs located in areas of the central city urbanized after 1945. However, trajectories A and B are different in two ways. First, the concentration of poverty is much stronger in the CTs belonging to trajectory A, since LQs are greater than 2, regardless of the year of observation. In other words, the proportion of the low-income population in these CTs is twice as much as in the metropolitan region as a whole. Secondly, the LQ increased during the study period for trajectory B from 1.63 in 1986 to 1.82 in 2006, while trajectory A shows similar values in 1986 and 2006. This demonstrates an ongoing filtering down process for trajectory B, i.e. the replacement of residents by others with a lower socioeconomic status (Grigsby, Baratz, Galster, & Maclennan, 1987).

CTs in trajectories C and E (titled respectively "Increasing low concentration" and "Increasing very low concentration,") are characterized by an increasing poverty concentration over the period. These CTs are mainly located in the newer parts of the central city (most of these CTs were located in former suburban municipalities which were amalgamated to the city of Montreal in 2002[3]) or in the inner ring suburbs. This supports studies reporting an increase of poverty in inner ring suburbs in many North American cities (Cooke & Marchant, 2006; Jargowsky, 2003; Lee & Leigh, 2007; Short et al., 2007).

Trajectory D (titled "Concentration in decline") is very specific, as it groups CTs characterized by a decreasing concentration of poverty over the time period. These CTs are mainly located in the gentrifying areas of the inner city, supporting findings of many studies on gentrification in Canadian cities, and notably in Montreal (Bourne, 1993; Ley, 1986, 1993; Rose, 1984).

Finally, trajectories F, G and H (titled respectively "Low, Strong, and Very strong under-representation") group CTs characterized by absence of concentration of poverty or its under-representation; they are mainly located in suburban areas of the CMA.

Before describing the final results of the multinomial logistic regression, we present a brief overview of the socioeconomic profile of each trajectory. This is done by using the trajectories' mean value (standardized Z-score values, with mean = 0 and variance = 1) for each of the socioeconomic factor measured in 1986 (Table 2a) and 2006 (Table 2b), and their variation between

[3] The limits of the central city of Montreal changed drastically in 2002, after the amalgamation of many former suburban municipalities located on the Island of Montreal into the City of Montreal.

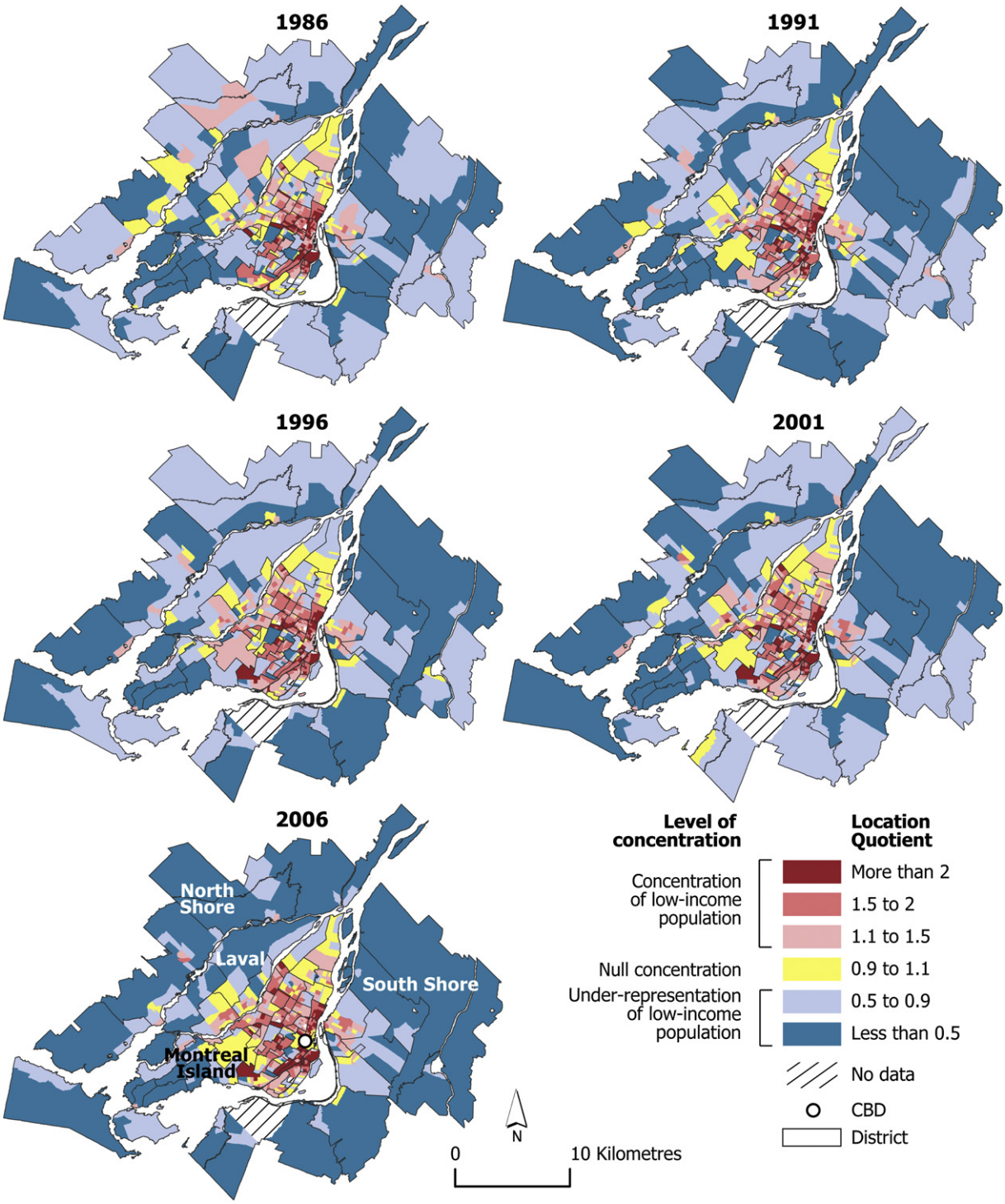

Fig. 1. Relative poverty levels in Montreal CMA between 1986 and 2006.

1986–2006 (Table 2c). A positive value indicates a stronger presence of a socioeconomic characteristic among CTs in a given trajectory compared to the mean value of this characteristic among all of the 611 census tracts; a negative value indicates a lesser presence. In 1986, populations living in CTs belonging to trajectory A ("Very high concentration") were characterized by low socioeconomic status, with the highest unemployment rates and the highest proportions of lone-parent families, of recent immigrants, of residents with low levels of education, and of renters, and the lowest proportion of residents with a university education. Trajectory B ("Increasing high concentration") shows similar but less pronounced socioeconomic characteristics. At the other end of the spectrum, the socioeconomic profiles of trajectories F to H ("Low, Strong, and Very strong under-representation") are more favourable, since almost all of the mean values of the variables associated with high risk of poverty are negative (except for the proportion of university graduate which is positive, as expected). In 1986, CTs belonging to trajectory D, the

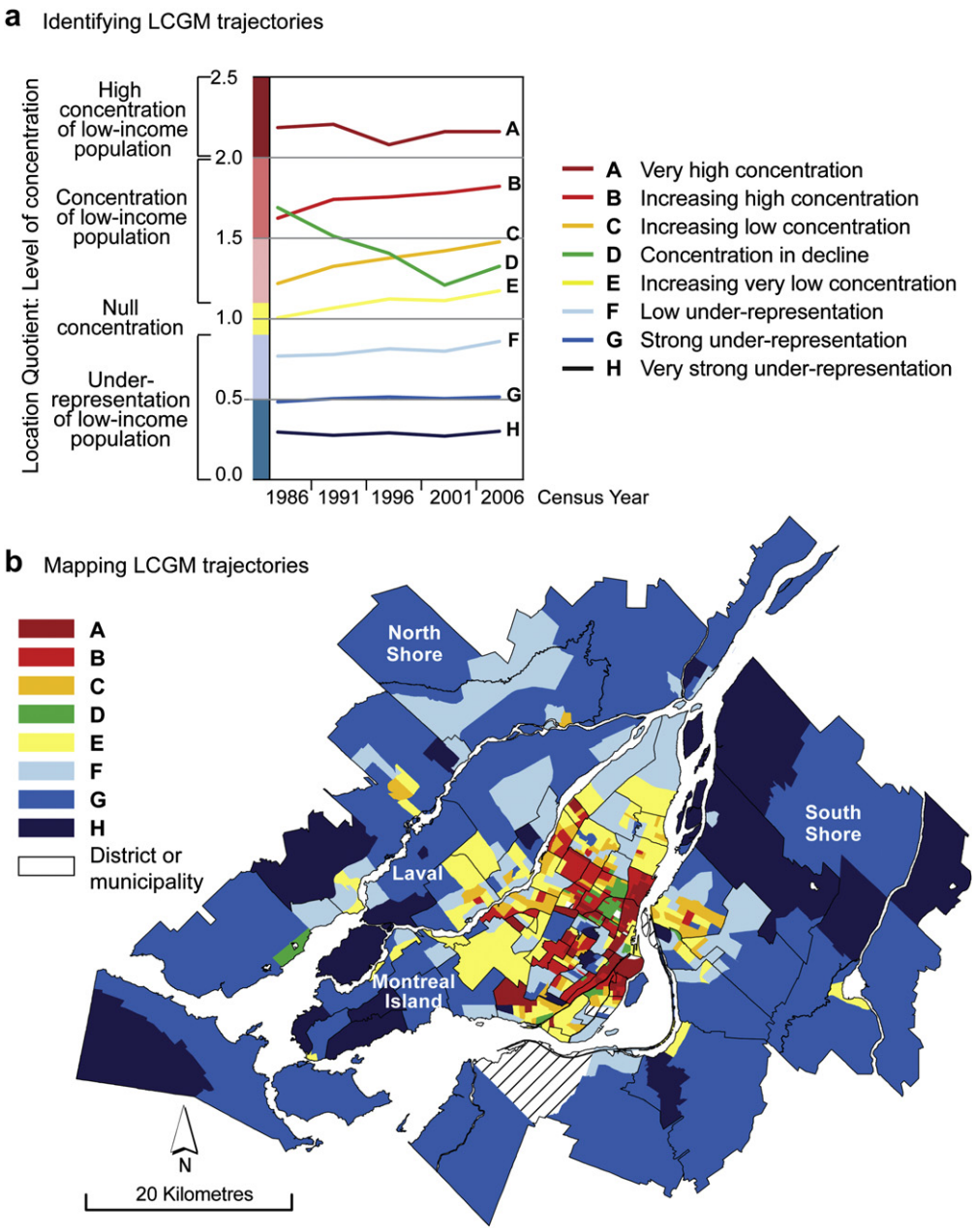

Fig. 2. Trajectories of relative poverty concentration obtained by LCGM method.

gentrification trajectory ("Concentration in decline"), displayed a low socioeconomic status: on average, the proportions of unemployed populations, lone-parent families, one-person households and renters were high. However, the proportion of the population with a university education was also important in these CTs in 1986, and this proportion increased between 1986 and 2006. This supports the seminal study of Rose (1984) who demonstrated the existence of "marginal gentrifiers" in Montreal at the beginning of the 1980s. By "marginal gentrifiers", Rose refered to highly educated households (sometimes with household members still in school) often working in precarious professional jobs, living alone (or being heads of lone-parent families), and displaying modest incomes.

The changing socioeconomic profiles of trajectories between 1986 and 2006 appear in Table 2c. For a given trajectory, a positive value indicates a higher variation in comparison with the variation observed for all CTs, and a negative value corresponds to a lower variation. For trajectories A and B, we note that poverty concentration remained stable (trajectory A) or increased slightly (trajectory B) (the average change in their LQ was −0.02 and 0.20 respectively). However most of the values of the socioeconomic indicators decreased during the period, particularly in the case of trajectory A, indicating a reduction in the concentration of populations at risk of poverty. Moreover, CTs in these trajectories are also characterized by a relative increase in the proportion of university graduates. This could be explained by the parallel increase in recent immigrants who, despite their high level of education, face problems of economic integration.

For trajectories C and E ("Increasing low concentration" and "Increasing very low concentration"), almost all of the socioeconomic indicator values increased, showing a higher presence of populations at risk of poverty in these groups of CTs. For trajectory

Table 2
Average values of location quotients and of standardized independent variables (socioeconomic factors) for each LCGM trajectory.

Trajectories	A	B	C	D	E	F	G	H
Census tracts (N)	81	72	69	45	98	100	106	40
%	13.26	11.78	11.29	7.36	16.04	16.37	17.35	6.55
a) 1986								
Location quotient[a]	2.19	1.63	1.22	1.69	1.01	0.77	0.48	0.29
Unemployment rate	1.53	0.58	0.13	0.77	−0.25	−0.54	−0.81	−1.13
Lone-parent families (%)	1.45	0.70	0.21	0.82	−0.13	−0.49	−1.00	−1.29
One-person households (%)	0.93	0.61	0.27	0.82	0.01	−0.31	−0.90	−1.24
People aged ≥ 65 years (%)	0.22	0.25	0.27	0.20	0.21	0.05	−0.54	−0.79
Recent immigrants (%)	0.90	0.51	−0.05	−0.08	−0.14	−0.28	−0.45	−0.32
Low education (%)	0.97	0.53	0.31	0.33	0.08	−0.34	−0.71	−1.27
Renters (%)	1.10	0.85	0.53	0.72	0.16	−0.35	−1.25	−1.72
University education (%)	−0.31	−0.24	−0.30	0.12	−0.19	0.12	0.28	0.86
b) 2006								
Location quotient[a]	2.16	1.82	1.48	1.33	1.17	0.86	0.51	0.30
Unemployment rate	1.17	0.84	0.40	−0.20	−0.01	−0.49	−0.78	−1.03
Lone-parent families (%)	0.89	0.75	0.48	0.14	0.13	−0.34	−0.87	−1.31
One-person households (%)	0.89	0.75	0.48	0.14	0.13	−0.34	−0.87	−1.31
People aged ≥ 65 years (%)	−0.62	−0.30	0.28	−0.77	0.49	0.59	−0.08	−0.25
Recent immigrants (%)	0.87	0.81	0.36	−0.11	−0.07	−0.36	−0.69	−0.83
Low education (%)	0.43	0.35	0.38	−0.59	0.13	−0.11	−0.27	−0.81
Renters (%)	1.08	0.90	0.63	0.58	0.19	−0.40	−1.23	−1.75
University education (%)	0.07	−0.05	−0.28	0.79	−0.27	−0.08	−0.06	0.55
c) 1986–2006 variation								
Location quotient[a]	−0.02	0.20	0.26	−0.36	0.16	0.09	0.03	0.01
Unemployment rate	−0.72	0.05	0.18	−1.03	0.27	0.19	0.25	0.40
Lone-parent families (%)	−0.77	0.02	0.32	−0.86	0.32	0.20	0.22	0.06
One-person households (%)	−0.42	−0.20	0.16	−0.05	0.31	0.23	−0.03	−0.29
People aged ≥ 65 years (%)	−0.83	−0.54	0.02	−0.95	0.28	0.53	0.43	0.51
Recent immigrants (%)	0.61	0.73	0.46	−0.10	−0.01	−0.29	−0.61	−0.85
Low education (%)	−0.99	−0.45	−0.11	−0.96	−0.00	0.38	0.77	1.09
Renters (%)	−0.34	0.00	0.24	−0.69	0.07	−0.09	0.32	0.25
University education (%)	0.66	0.30	−0.03	1.30	−0.18	−0.35	−0.58	−0.41

[a] Except for the location quotient, all mean values are computed on the z-scores variables.

C, the increase in the proportion of recent immigrants was particularly important while for trajectory E, the proportion of one-person households was influential. In both trajectories, the proportion of lone-parent families also increased noticeably. By contrast, for trajectory D ("Concentration in decline"), variation values for all socioeconomic indicators decreased, with the obvious exception of the proportion of the population with a university education which increased over the period.

Although the socioeconomic profiles of neighbourhoods (located mainly in the suburban areas) belonging in trajectories F, G and H were still favourable in 2006, the presence of populations at risk of poverty increased relatively during the time period in these groups of CTs. In particular, the proportions of seniors, residents with low levels of education and, to a lesser degree, unemployed people and renters (in that latter case except for trajectory F) have increased. These observations support the process of ageing in some suburban areas documented by Séguin, Apparicio, and Negron (2008).

Explaining trajectories of neighbourhood poverty

The final multinomial model comprises 11 predictors of neighbourhood poverty trajectories. Three variables were excluded because they were not significantly associated with the trajectories: the variation between 1986 and 2006 in the proportions of lone-parent families, of one-person households and of renters. In addition, the proportion of the population with a university education and the variation of this population were also excluded due to excessive multicollinearity. In the final model, the variance inflation factor (VIF) values, not reported here, suggest that there is no excessive multicollinearity among the remaining predictors (the maximum VIF value was 8.3, which is less than the common cut-off threshold of 10 retained by several authors, see for example Chatterjee & Hadi, 2006; Studenmund, 2010).

Results of the final model are reported in Tables 3 and 4. The Wald Khi2 values in Table 3 indicate the most important predictors of the model. They are, in decreasing order: in 1986, the proportion residents with low levels of education, the unemployment rate, the proportion of lone parents families, of recent immigrants and of renters; followed by the variation between 1986 and 2006 in the proportion of recent immigrants, of residents with low levels of education, in unemployment rate and in the proportion of seniors, although for this last variable the strength of the association is weaker. These findings are consistent with a recent study modelling low-income population distribution in Montreal (Apparicio

Table 3
The most significant predictors of the multinomial logistic regression (dependent variable: LCGM trajectories).

Predictors	Wald Khi2	Pr.
Low education, 1986	106.59	<0.0001
Unemployment, 1986	60.50	<0.0001
Lone-parent families, 1986	58.81	<0.0001
Recent immigrants, 1986	56.41	<0.0001
Renters, 1986	54.02	<0.0001
Recent immigrants, variation 1986–2006	49.65	<0.0001
Low education, variation 1986–2006	34.40	<0.0001
One-person household, 1986	33.72	<0.0001
Unemployment, variation 1986–2006	30.96	<0.0001
65 years and older, variation 1986–2006	22.45	0.002
65 years and older, 1986	21.64	0.003
AIC	840.21	
BIC	1211.08	
R2 (Cox &Snell)	0.948	
R2 (Nagelkerke)	0.965	

Table 4
Multinomial logistic regression (dependent variable: LCGM trajectories).

Traj.[a]	Coef.	OR[b]	OR (95% CL[c])		Pr.	Coef.	OR[b]	OR (95% CL[c])		Pr.
	Unemployment rate, 1986					Recent immigrants, 1986				
A	4.43	84.03	19.98	353.46	<0.0001	4.35	77.30	6.32	945.10	0.001
B	4.02	55.53	13.62	226.37	<0.0001	3.51	33.29	2.80	395.32	0.006
C	3.56	35.12	8.87	138.98	<0.0001	2.42	11.24	0.98	128.42	0.052
D	3.72	41.25	10.19	166.94	<0.0001	2.80	16.46	1.39	195.72	0.027
E	2.87	17.70	4.68	66.92	<0.0001	1.95	7.01	0.65	76.24	0.110
F	2.05	7.80	2.18	27.93	0.002	1.34	3.82	0.37	38.90	0.258
G	1.61	5.00	1.50	16.62	0.009	−0.13	0.88	0.11	6.98	0.901
	Lone-parent families, 1986					Low education, 1986				
A	1.32	3.74	2.02	6.92	<0.0001	2.21	9.12	5.59	14.90	<0.0001
B	0.94	2.56	1.42	4.63	0.002	2.01	7.50	4.66	12.07	<0.0001
C	0.57	1.77	1.00	3.11	0.048	1.75	5.74	3.63	9.10	<0.0001
D	0.86	2.36	1.32	4.23	0.004	1.79	6.00	3.75	9.61	<0.0001
E	0.38	1.46	0.86	2.50	0.164	1.48	4.40	2.82	6.88	<0.0001
F	0.13	1.13	0.68	1.89	0.632	1.08	2.95	1.95	4.49	<0.0001
G	−0.27	0.76	0.48	1.20	0.236	0.69	1.99	1.37	2.89	0.000
	One-person households, 1986					Renters, 1986				
A	0.46	1.59	1.00	2.53	0.050	0.83	2.28	1.73	3.01	<0.0001
B	0.30	1.35	0.86	2.13	0.192	0.64	1.90	1.47	2.44	<0.0001
C	0.19	1.20	0.77	1.88	0.413	0.54	1.72	1.36	2.18	<0.0001
D	0.29	1.33	0.85	2.09	0.210	0.39	1.48	1.16	1.89	0.002
E	0.12	1.13	0.73	1.75	0.588	0.43	1.53	1.22	1.92	0.000
F	−0.06	0.94	0.61	1.43	0.767	0.40	1.49	1.19	1.86	0.000
G	−0.12	0.89	0.59	1.32	0.555	0.35	1.42	1.15	1.76	0.001
	65 years and older, 1986									
A	−0.13	0.88	0.52	1.50	0.638					
B	0.05	1.05	0.64	1.73	0.836					
C	0.26	1.29	0.81	2.06	0.276					
D	−0.04	0.96	0.58	1.59	0.874					
E	0.29	1.34	0.87	2.06	0.192					
F	0.44	1.55	1.02	2.35	0.039					
G	0.34	1.40	0.96	2.05	0.084					
	Unemployment rate, variation 1986–2006					Recent immigrants, variation 1986–2006				
A	1.94	6.96	2.65	18.27	<0.0001	3.57	35.66	8.54	148.93	<0.0001
B	1.74	5.68	2.22	14.57	0.000	3.44	31.23	7.54	129.42	<0.0001
C	1.43	4.16	1.67	10.36	0.002	3.22	25.09	6.11	103.01	<0.0001
D	1.38	3.99	1.56	10.21	0.004	3.14	23.00	5.55	95.33	<0.0001
E	1.23	3.41	1.41	8.22	0.006	2.91	18.34	4.53	74.17	<0.0001
F	0.69	1.98	0.86	4.56	0.106	2.55	12.78	3.22	50.70	0.000
G	0.49	1.64	0.77	3.48	0.199	2.14	8.48	2.21	32.62	0.002
	65 years and older, variation 1986–2006					Low education, variation 1986–2006				
A	−0.23	0.80	0.54	1.17	0.246	1.19	3.29	1.87	5.81	<0.0001
B	−0.23	0.79	0.56	1.11	0.173	1.17	3.21	1.84	5.60	<0.0001
C	−0.10	0.91	0.67	1.23	0.529	1.13	3.09	1.79	5.33	<0.0001
D	−0.49	0.61	0.43	0.88	0.008	0.96	2.62	1.51	4.57	0.001
E	−0.02	0.98	0.75	1.29	0.910	0.97	2.64	1.55	4.49	0.000
F	0.13	1.14	0.89	1.46	0.304	0.72	2.06	1.23	3.45	0.006
G	0.09	1.10	0.89	1.36	0.399	0.59	1.80	1.11	2.91	0.017

[a] See the list on the Fig. 2.
[b] Odds ratio.
[c] 95% Wald confidence limits.

et al., 2007) and for the most part, consistent with the study of Heisz and McLeod (2004) on Canadian metropolises.

The final multinomial logistic model (Table 4) was built with trajectory H as the reference class. This trajectory had the lowest poverty rates over the 20-year period. This model allows identifying socioeconomic factors that are significantly predicting the likelihood of a CT to belong to a trajectory. First, in 1986, unemployment rates, the proportion of recent immigrants, of residents with low levels of education and of lone-parent families were the most important predictors explaining membership to trajectories A, B, C, or D. Secondly, the proportion of renters was particularly significant in explaining trajectories of high poverty concentration (A and B): the higher the values of this socioeconomic indicator for a CT in 1986, the more likely it belonged to trajectories A and B displaying high concentrations of poverty and to trajectories of "Increasing low concentration" (C). Finally, the proportion of seniors in 1986 contributed only marginally to the model; this variable was significant ($p = 0.039$) only for trajectory F.

Having controlled for the baseline socioeconomic predictors, we next evaluated the importance of the variation in these variables over the study period as predictors of trajectory membership. Between 1986 and 2006, increases in unemployment rates and in the proportion of recent immigrants and of residents with low levels of education were associated with trajectories of poverty concentration (A, B and C). Finally, a decrease in the proportion of seniors was associated with the gentrification trajectory (D), illustrating the likely displacement of seniors by the gentrification process (Burns, Lavoie, & Rose, 2012; Newman & Wyly, 2006).

Conclusion

Our results show that radical changes in the geography of poverty are an exception in the Montreal CMA. Poverty zones evolved according to their initial characteristics and changes were minor over time, except for CTs in the gentrification trajectory where changes in poverty levels were more marked. From 1986

onward, we observed the presence of weak and very weak concentrations of low-income populations in the older suburbs, as indicated by LQ values greater than one. This illustrates that the impoverishment process was already underway in these CTs and that it slightly increased during the period of study (these CTs were characterized by trajectories of increasing poverty). Although census tracts in trajectories F and G were characterized by low LQ values, indicating lower poverty in these neighbourhoods than across the Montreal CMA, poor populations were nonetheless present within these territories. As documented in past studies (Séguin, 1998; Séguin & Germain, 2000), this supports the phenomenon of a relative social mix in Montreal neighbourhoods, even in wealthier areas.

The identification and modelling of neighbourhood poverty trajectories over a long time period remains underused in the fields of geography and urban studies. Indeed, until now, few studies have used data from consecutive censuses to identify, describe and model neighbourhood trajectories from the perspective of poverty or other pertinent neighbourhood characteristics. The contribution of this paper is therefore both methodological and empirical. In terms of methodology, results show that LCGM is a powerful method of classification to identify neighbourhood trajectories from a single variable measured over several years. Once trajectories are identified, the use of multinomial logistic regression is a valuable strategy to understand the factors that influence neighbourhood trajectories over time.

From an empirical perspective, the observed neighbourhood poverty trajectories corroborate findings of other more descriptive and qualitative studies on the transformations of intra-metropolitan spaces in Montreal (Ades, Apparicio, & Séguin, in press; Séguin, Mongeau, & Archambault, 1999; Sénécal, Tremblay, & Teufel, 1990), especially 1) the stability or increase of poverty in certain inner city neighbourhoods over the last 20 years, 2) the gentrification of certain central neighbourhoods, and 3) the relative increase in poverty in certain areas of the inner-ring suburbs (some of them having been amalgamated to the central city in 2002).

In addition, our results indicate that some variables are particularly strong predictors of neighbourhood poverty trajectories in the Montreal CMA: the proportion of residents with low levels of education, unemployment rates, proportions of lone-parent families, of recent immigrants and of renters all measured at the beginning of the period (1986), as well as variations throughout the study period (1986–2006) in the proportions of recent immigrants and of residents with low levels of education.

For the analyses reported here, the choice of variables was limited to those describing the socioeconomic characteristics of residents in the neighbourhoods. This was done to clearly measure the importance of the presence of populations at risk of poverty in predicting neighbourhood poverty trajectories. Future studies should examine the role of other variables, such as variables related to the built residential environment (Lee, 2011; Lupton & Power, 2004) to better understand neighbourhood poverty trajectories in Canadian metropolises.

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