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Spatial interactions between urban areas and cause-specific mortality differentials in France

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ABSTRACT

Spatial interactions constitute a challenging but promising approach for investigation of spatial mortality inequalities. Among spatial interactions measures, between-spatial unit migration differentials are a marker of socioeconomic imbalance, but also reflect discrepancies due to other factors. Specifically, this paper asks whether population exchange intensities measure differentials or similarities that are not captured by usual socioeconomic indicators. Urban areas were grouped pairwise by the intensity of connection estimated from a gravity model. The mortality differences for several causes of death were observed to be significantly smaller for strongly connected pairs than for weakly connected pairs even after adjustment on deprivation.

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1. Introduction

Although mortality has decreased dramatically in France and other industrialized countries over the last half century, the improvement has been followed by an increase in social and socio-spatial mortality inequalities (Borrell et al., 1997; Leclerc et al., 2006; Leyland, 2004; Mackenbach et al., 2003; Menvielle et al., 2007; Murphy et al., 2006; Pearce and Dorling, 2006; Preston and Elo, 1995; Salem et al., 2000; Shaw et al., 2000; Singh, 2003; Windenberger et al., 2011). In order to explain spatial inequalities, many studies have focused on the social and economic characteristics of each area, as summarized by deprivation indices (Carstairs and Morris, 1989; Pampalon and Raymond, 2000; Rey et al., 2009; Townsend, 1987). In France, in 2001, median income, percentage high school graduates and other measures relating to population composition were associated with spatial inequalities in mortality on various scales (Rey, 2007).

Preceding studies of health geography and social epidemiology that have dealt with French mortality inequalities reported large individual socioeconomic differentials (Menvielle et al., 2007) and regional (22 spatial units in France) patterns of mortality (Rican et al., 2009; Salem et al., 2000) that hold even after adjustment for deprivation on the local (commune) scale (Rey et al., 2009; Windenberger et al., 2011). This suggests that individual dimensions such as differences in lifestyle, health habits and diet, alcohol and tobacco consumption play a role as well as contextual driving factors including neighborhood features, broader living environment, health care provision and other unidentified features (Congdon et al., 1997; Scarborough et al., 2011; Stringhini et al., 2011). Among broader contextual factors operating on a larger scale that influence local health, the interactions between spatial units have yet to be investigated in France.

Places are considered “a result of endogenous and exogenous processes operating on a variety of spatial scales” (Cummins et al., 2007 p. 1832). When considering spatial interactions, places are defined as nodes in networks rather than as autonomous bounded spatial units (Cummins et al., 2007; Gatrell, 1997). The adjacency between spatial units implies likely interactions, e.g., commuting daily from home to work in a different area. The idea that adjacent units interact with each other and share similarities has also given rise to the use of statistical models that take spatial autocorrelation into account (Besag et al., 1991; Conlon and Waller, 1998). On a local scale, the relative position of a neighborhood in an urban setting, in particular relative deprivation, is associated with health independently of absolute deprivation (Aberg Yngwe et al., 2012; Zhang et al., 2011). A relational approach to spaces involves not only taking adjacency or spatial proximity into account, but also relations in terms of social and population exchanges.

Among the relationships that operate between areas, migration between two areas is a marker of socio-economic imbalance at a finer scale (Norman et al., 2005). Micro-economic approaches to migration are based on the idea that an individual compares his current situation (job, income, living environment, etc.) and the situation to which he or she can aspire through a change of residence. This human capital model not only takes into account the economic costs and benefits of migration, but also the psychological costs of leaving friends and family, or the benefits of changing climate

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(Baccaïni, 2006). A long-distance residential migration is an important decision and, in the majority of cases, is related to education or job change (Baccaïni, 2001). Individual migration is linked to individual socio-demographic characteristics as well as to features of the areas of origin and destination (Baccaïni, 2006; Champion et al., 1998).

In many countries, mortality is used to address public health issues, because of its exhaustiveness and reliability. With a view to further elucidating spatial health inequalities, several studies have emphasized the need to investigate the link between space and health from the angle of population dynamics (Boyle et al., 2004a; Cummins et al., 2007). In particular, population change and migrations play a role in the mortality rate observed at a given time and in a given place, since migration is a health selective process (Bentham, 1988; Boyle et al., 2004b; Brown and Leyland, 2010; Connolly et al., 2007; Davey Smith et al., 1998; Martikainen et al., 2008; Riva et al., 2011). A study has reported that the largest absolute flow is observed among relatively healthy migrants moving away from more deprived areas toward less deprived areas (Norman et al., 2005). However, empirical research presents contradictory findings. Migrations are not systematically associated with an increase in health inequalities (Jongeneel-Grimen et al., 2011), and can even contribute to reducing the gap between healthy and unhealthy areas (Boyle et al., 2009). The direction and strength of the association may depend on the country, spatial scale, time period, definition of deprivation and health indicator studied (Connolly et al., 2007).

All of the studies have considered the association between migration intensities and mortality. However, none of them has specifically considered migration and population exchanges as a spatial interaction marker of connectivity and inter-dependencies as well as similarities that would be associated with health. Indeed, strong migration exchanges are likely to result from a "preference" effect, which may reflect common features and complementarity between the areas. On the contrary, the absence of interaction is a sign of a "barrier" effect, which could be interpreted as a marker of difference and incompatibility.

Considering the question from a health perspective, this paper investigates whether residential migration exchanges between pairs of units may be able to measure differentials or similarities between units that are not captured by usual indicators. Could the complementarities or similarities between spatial units characterized by strong balanced exchanges be associated with more similar mortality rates? Equivalently, could weak or unbalanced exchanges be associated with larger mortality differentials?

The aim of this paper is two-fold. In the first part of the paper, residential migrations between urban areas are characterized using a spatial interaction model. The gravity model (D'Aubigny et al., 2000) enables estimation of the influxes of people in two spatial units depending on distance and population. Applying this approach allows identifying "preference" (strong influx) and "barrier" (weak influx) effects between the spatial units considered (Courgeau and Pumain, 1996). Then, the connections between pairs of spatial units are categorized by intensity. The second part of the paper focuses on the association between the intensity of connection and mortality differentials. Mortality differences are compared for several causes of death, for men and women, all-age mortality and premature mortality. Since deprived areas are less attractive for migrants than affluent areas, mortality will also be controlled for those dimensions.

2. Methods

2.1. Spatial scale

Urban areas (UA, 361 units), as defined in 1990 were used to characterize and study the intensity of migration exchanges between 1990 and 1999 in mainland France. An urban area is defined as a set of *communes* (smallest administrative unit) that are contiguous and free from enclaves constituted by an urban core and rural *communes* or urban units (peri-urban ring) and in which at least 40% of the resident working population works in the urban core or its catchment *communes* (Le Jeannic and Vidalenc, 1997). In 1990, the population of mainland France was about 57 million, with 41 million people living in the 1990 urban areas. The scale of analysis enabled both intra-regional and inter-regional exchanges to be taken into account. The urban areas had a minimum of 8200 people and a maximum of 10,656,900 people with a mean of 117,100 people.

2.2. Demographic data

The 1997–2001 mortality data were derived from the Inserm-CepiDc database for mainland France. The National Institute of Statistics and Economic Studies (INSEE) supplied the population data. The migration data were directly derived from the 1999 census, in which respondents were asked to answer the following question: "Where did you live on 1 January 1990?" Thus, the data only cover people whose 1999 unit of residence was different from that for the preceding census. The data, which were available on the *commune* scale, were aggregated to the 1990 Urban Area scale. During the 1990–1999 period, 4.6 million people changed their urban area of residence. The total number of possible migratory influxes between urban areas was $361 \times 360 = 129{,}960$, of which 50,042 were equal to 0.

Deaths were grouped in 5-year periods centered on 1999 to avoid small numbers and year-to-year fluctuations. Age and gender standardized mortality ratios (SMR) were calculated, taking national mortality over the period 1997–2001 as the reference. The categories considered were all causes of death for persons and separately for men and women, premature mortality (age less than 65 years) and cause-specific mortality (see Table S1 for ICD codes).

2.3. Spatial interactions model: the gravity model

The gravity model was specifically developed to estimate influxes between pairs of units. This model, derived from Newton's gravitation law, was inspired by the empirical observation of migratory exchange summarized by Ravenstein in the 19th century (Ravenstein, 1885):

– The population influx for two spatial units depends on their respective populations and decreases with the distance.

Each unit has its own "population send capacity" and its "carrying capacity" but the influx depends also on the distance between the two units. Following a modified version of the gravity model (D'Aubigny et al., 2000), the population influx for units i and j, F_{ij}, was expressed as

$$F_{ij} = \frac{P_i P_j}{P(D_{ij})},$$

with P_i and P_i the population of units i and j and $P(D_{ij})$ a polynomial function of the distance and with P having a log linear link with the observed influx F_{ij}. The degree of the polynomial function was limited to two because, for higher degrees, P did not monotonically increase over the range of possible distances (0–1000 km). Lastly, the quadratic effect takes into account the decreasing effect of distance on intensity of population exchange (see Appendix for explanation). The influxes F_{ij} were considered to have a Poisson distribution since the probability of migrating from unit i to unit j is relatively low compared to the size of the population. The overdispersion specifically resulting from the

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