Internal migration in the United Kingdom:

The effects of scale and zonation on migration indicators

Stephane Jean Henri Chatagnier

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Abstract

This thesis examines the effects of the modifiable area unit problem on indicators of internal migration intensity, pattern and impact in the United Kingdom (UK) using directional migration flow data from the last two censuses of population. Consistent sets of 'basic spatial units' are selected that have enabled (i) an investigation of subnational internal migration between local authority districts across the UK as a whole but also (ii) an investigation of migration between wards within in a selected region (Greater London). The analyses utilise sets of migration flow data disaggregated by age, since age is a key proxy for understanding migration from a life course perspective. This research was designed to provide an understanding of the sensitivity of quantitative measures of internal migration behaviour to geographical scale and area configuration, but also to provide new insights into the characteristics of migration propensities and patterns in the two single-year pre-census periods (2000-01 and 2010-11) and the changes that have taken place over the inter-censal decade. The computation of scale and zonation effects has been undertaken using the IMAGE Studio, a software system developed previously to allow cross-national comparison of internal migration indicators. The results reported in the thesis demonstrate that certain indicators, such as intensity of migration and the distance that migrants travel when changing address, have pronounced scale effects with relatively little variation around the mean value at each scale whereas other indicators, such as migration effectiveness and the frictional effect of distance on migrants, tend to exhibit more scale independence but vary more between different zone configurations as the number of zones reduces. Using the same analytical approach with more spatially disaggregated data for a single region highlights characteristics of internal migration that differ from the national picture, but exposes certain problems for which further development of the software is required. The thesis thus provides a useful critique of the IMAGE Studio as well as underlining the necessity for geographic researchers and geodemographic analysts to remain alert to the spatial systems they use when studying demographic phenomena.

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Abbreviations

ACMI	Aggregate Crude Migration Intensity
AMEI	Aggregated Migration Effectiveness Index
ANMR	Aggregate Net Migration Rate
ARC	Australian Research Council
ASR	Aggregated Spatial Region
BFS	Breadth First Search
BSU	Basic Spatial Unit
BUA	Built-up areas
BUASD	Built-up areas sub-divisions
CAS	Census Area Statistics
CCG	Clinical Commissioning Group
CEC	Council of the European Communities
CMI	Crude Migration Intensity
CPS	Current Population Survey
EU	European Union
FHSA	Family Health Service Area
GL	Greater London
GOR	Government Offices for the Regions
HRP	Household Reference Person
IC	Index of Connectivity
ICT	Information and Communications Technology
IMAGE	Internal Migration Across the GlobE
INMI	Index of Net Migration Impact
IPF	Iterative Proportional Fitting
IPS	International Passenger Survey
IRA	Initial Random Aggregation
LA	Local Authority
LAD	Local Authority District
LAU	Local Administrative Unit
LHB	Local Health Board

LS	Longitudinal Study
LSOA	Lower Layer Super Output Area
MAD	Mean Absolute Deviation
MAUP	Modifiable Areal Unit Problem
ME	Migration Effectiveness
MEI	Migration Effectiveness Index
MIGMOD	MIGration MODeller
MMD	Mean Migration Distance
MSOA	Middle Layer Super Output Areas
NAW	National Assembly for Wales
NHS	National Health Service
NHSAT	NHS Area Team
NHSCR	National Health Service Central Register
NISRA	Northern Ireland Statistics and Research Agency
NRS	National Records of Scotland
NS-SEC	National Statistics Socio-Economic Classification
NUA	No Usual Address
NUTS	Nomenclature of Territorial Units for Statistics
OA	Output area
ODPM	Office of the Deputy Prime Minister
OLS	Ordinary Least-Squares
ONS	Office for National Statistics
PAR	Population at Risk
PCO	Primary Care Organisation
PMMD	Predicted Mean Migration Distance
PUA	Primary Urban Area
RERC	Rural Evidence Research Centre
SAR	Samples of Anonymized Records
SHA	Strategic Health Authority
SIM	Spatial Interaction Model
SMI	Standardized Migration Intensity
SMS	Special Migration Statistics

SSA	Standard Spending Assessment
ST	Standard Table
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
VML	Virtual Microdata Laboratory
WICID	Web-based Interface to Census Interaction Data
WZ	Workplace Zone

Chapter 1: Introduction

1.1 Research context

The redistribution of a country's population through internal migration is a process that has important implications for both the places of origin and destination that lose and gain migrants respectively but also for the individuals, households or families involved. The activity of voluntary migration is often perceived as being stressful for the migrants taking part but usually represents the realisation of opportunities for self-betterment or upward social mobility. Geographical areas at different spatial scales will either suffer or benefit from the consequences of losing or gaining members of their resident populations. In most places, a two-way interaction takes place, a stream and counter-stream, resulting in a positive or negative net exchange of internal migrants which may be of sufficient magnitude to influence local population change, particularly in areas where natural change and net international migration are of less importance.

Internal migration is therefore a key driver of population change in some places in terms of the volumes associated with net migration. Greater London, for example, has been losing migrants to the rest of the country in net terms over recent decades, although the resulting deficits have been offset by a large net international migration influx (Champion, 2015). However, it is not only the volumes of migrant flows that are significant; the different demographic characteristics of flows into and out of different places may also have a significant impact on the local population structure. London, for example, attracts large numbers of younger adult in-migrants seeking work, attending higher education or climbing the career ladder, but also generates large numbers of older out-migrants, many of whom are stepping off the escalator (Fielding, 1992) or retiring from work. Similar processes are at work in many other provincial cities in the United Kingdom (UK) (e.g. Findlay et al., 2008 in the South East of the UK). Moreover, as internal migration redistributes the population within a country, in doing so it creates changing variations in the demand for goods and services, with significant implications for commercial traders and public sector service providers.

Internal migration is therefore a key activity which has attracted the attention of researchers from different disciplines over many decades, particularly from geographers since migration is an interaction phenomenon that is intrinsically spatial and geographers have sought to identify volumes and spatial patterns of movement, to understand, model and explain them and also to establish the consequences or the impacts. The sociology literature on internal migration, on the other hand, tends to be dominated by studies focused on explaining the motivations for migration and the effects of migration on neighbourhoods and communities as well as on individuals and families, whereas researchers from other disciplines, such as economics, health, education, demography, transport, housing and planning are all concerned with the relationship between migration and their own specific subject areas. Economists, for example, are interested in how internal migration can be used to understand local and regional economies; the sources and magnitude of internal migration allows recognition of the type and origin of development processes (Todaro, 1980). In less developed countries, once internal migration patterns have been identified, they can be used to create suitable policies to guide the development process to ensure all social aspects have been covered. Economic and social policies have a direct impact on internal migration as they influence the real incomes for rural and urban households and will therefore control possible migration flows (Todaro, 1980).

Understanding the economic implications of internal migration also involves labour market considerations and internal migration was regarded as the important equilibrating factor in classic theories of regional development (Dawkins, 2003); migration was seen as the mechanism through which labour demand and supply in different regions found some equilibrium although Myrdal (1957) argued that economic growth frequently resulted in increasing regional disparities due to cumulative causation. However, internal migration has also had very important influence on the housing market (and hence property prices or rents) in different parts of the country (Bate et al., 2000). In terms of planning, internal migration is an essential component in the population estimation and forecasting models used by the national statistical agencies the Office for National Statistics (ONS) in England and Wales, the National Records of Scotland (NRS) and the Northern Ireland Statistics and Research Agency (NISRA), all of which collect internal migration data that are used in the process of generating mid-year estimates and projections that are used by the Government as the basis for resource allocation (Raymer et al., 2011) and which feed into household and housing projections.

Researchers of internal migration from different disciplines have used a variety of methods to analyse migration – ranging from the highly quantitative statistical approaches of econometric modelling used by economists based on secondary data (e.g., Salvatore, 1984) to the qualitative methods of participant observation or interview frequently used by sociologists or political scientists based on primary data (e.g., Zapata-Barrero and Yalaz, 2018). Almost invariably, researchers conducting spatial analyses have used data on migration at one spatial scale. In this thesis, a quantitative geographical perspective on internal migration is adopted with a particular focus on the use of a selection of statistical and model-based indicators to examine, monitor and analyse different dimensions of internal migration in the UK. It first looks at one scale but then, crucially, to identify how these indicators change through a series of more aggregate spatial scales and with different configurations of the spatial units concerned at each scale. The indicators cover domains that include migration intensity, impact, distance and connectivity. Quantitative studies of internal migration in any country are usually based on data from censuses, administrative and/or survey sources released at particular spatial scales. In the UK, for example, the ONS has released nationwide origin-destination flows from the last two censuses (2001 and 2011) at output area, ward and local authority area levels. In this thesis, the data used will be based on the 2001 and 2011 Censuses conducted by the three national census agencies in the UK and released by ONS. The following sections of this chapter identify the research questions that are addressed in the thesis (section 1.2), present and justify the aims and objectives of the thesis (section 1.3) and outline the structure of the thesis (section 1.4).

1.2 Research questions

The study of migration within the UK from a geographical perspective dates from the late nineteenth century when Ravenstein (1885) proposed a set of laws of migration based on his analysis of lifetime migration in Britain using data from the 1871 and 1881 Censuses. These propositions, formulated in answer to various basic questions about the people who migrate, the distances over which they migrate, the reasons for migration, the places between which they migrate and the frequency of their migration, have been regarded as the theoretical basis for much research that has subsequently followed (Boyle et al., 1998), including gravity and human capital models as reviewed by Stillwell and Congdon (1991). There has been a plethora of studies of an empirical nature, such as Newton and Jeffrey (1951) and Rowntree (1957), that have sought to answer one or more of the fundamental questions outlined above using different types of data for different periods of time. Moreover, an increasing number of later studies have chosen to compare migration activity (levels, characteristics and impacts) in different countries of the world (e.g., Parish, 1973; Rogers et al., 1983; Long et al., 1988, Rees and Kupiszewski, 1999; Sanchez and Andrews, 2011) although attempts to answer questions about which countries have the highest or lowest internal migration rates are usually stymied by the lack of comparable data.

One of the key ‘data comparability’ problems for migration analysts, particularly when making cross-national comparisons but apparent in all research endeavour, is a problem that has been fundamental to almost all human geographic research; this is the longstanding question of the scale at which a spatial phenomenon should be studied. Much geographical research is based on data for areas ranging from very small localities, such as output areas for which census data are collected, through to large administrative or planning regions. Researchers have to decide which one is the appropriate set of areas (or spatial scale) to undertake the analysis they wish to conduct. This issue was initially identified as the Modifiable Areal Unit Problem (MAUP) by Gehlke and Biehl (1934) but it was several decades later that Openshaw and Taylor (1979) demonstrated how the use of different numbers of spatial units might result in different bivariate correlation coefficients depending on the scale used to define the same area. Openshaw and Taylor distinguished the ‘scale problem’ of the MAUP as well as a second ‘aggregation problem’ arising when the same number of zones were involved in the analysis but when their size and shape were allowed to vary. Further work on the MAUP followed in the 1990s (e.g. Openshaw and Rao, 1995; Fotheringham and Wong, 1991; Holt et al., 1996) and 2000s (e.g. Marble, 2000; Tranmer and Steele, 2001; Manley, 2005; Flowerdew, 2011).

More recently, a major international study of internal migration in countries across the world, the IMAGE (Internal Migration Across the GlobE) project funded by the Australian Research Council (ARC), has developed software that follows a methodology that addresses the MAUP and computes a suite of indicators with which to compare aggregate migration in different countries (Stillwell et al., 2014). The IMAGE project asks the following questions: How can the migration in different countries using a range of indicators be compared? How does migration intensity vary in countries across the world? How far do internal migrants travel in different countries? What is the impact of internal migration on population redistribution in different countries? In all cases, the results of the project were based on all-age flows of internal migrants for one time period and have appeared in a series of papers including Bell et al. (2016), Stillwell et al. (2016) and Rees et al. (2017).

In this thesis, some of the underlying ideas behind the IMAGE project provide the platform for a more intensive study of internal migration in one country, the UK, and the research questions are refocused on:

1. What are the scale and aggregation effects on selected indicators of migration in the UK?
2. What differences exist in these effects when age group migration streams are analysed?
3. How have these effects changed over time (between censuses)?
4. Can the approach be used to examine scale and aggregation effects in one region of a country rather than the country as a whole?

The research question about which scale and zonation system to use for geographical analysis is as important for studying internal migration as it is for the spatial analysis of ethnicity or deprivation, for example. In the same way that the level of concentration of a minority ethnic group across a nation or region will depend on the size of the zones being used (smaller areas or city suburbs will have higher location quotients than the cities or regions in which they are located), so measures of migration intensity, distance and impact are also likely to show scale effects. Openshaw and Rao (1995) used census data on ethnicity in Liverpool to demonstrate that alternative zone configurations resulted in very different patterns of ethnic concentration and therefore different values of indicators of concentration. Likewise, zonation effects may occur when using different indicators of internal migration.

What are these effects on migration measures and how we might quantify them? How much variation is likely to exist between national crude migration rates at ward level and at regional level, for example, and what determines the scale effect if there is one? Explanations for the variations are likely to be found in the types of migration that are being measured and in the motivations that underpin migration behaviour. It has been shown by Ravenstein (1885) and in many modelling studies since then (e.g., Stillwell, 1978) that migration rates increase as distances between places get smaller. Moreover, the movements taking place between large zones in the UK (e.g. standard regions) will have a higher likelihood of being job-based and over longer distances than movements taking place between small zones (e.g. wards) which will have a higher probability of being home-based. This motivational difference may be used to distinguish the concepts of internal migration from residential mobility but very little data on motivation-specific migration flows are directly available.

However, aggregate migration streams and their intensities will vary according to the composition of the migrants involved. Reliable and comprehensive migration data may be available to decompose aggregate streams (e.g., by age and sex) from censuses or administrative sources, but data of motivation-specific migration are only available from sample surveys. Some previous researchers have attempted to model separate motivation-specific migration streams from aggregate migration data at one spatial scale (Stillwell, 1978; Gordon, 1992), while others have used different distance values to distinguish between types of mobility (Niedomysl et al., 2015) and others have attempted to create zone systems for analysis of migration between more functional regions (city regions used by Stillwell et al., 2000; 2001) or migration-type regions based on zone classification methods (e.g. Dennett and Stillwell, 2010a) again using data at one spatial scale. The IMAGE project was the first attempt to decipher the effects of scale and zonation on indicators of migration in countries across the world for which some inter-zonal data were available at one or more scales.

Whilst there are good academic reasons to investigate scale and zonation effects on internal migration and to make use of age-specific data to examine how these effects vary as migrants transition through the life course, there are also practical reasons for undertaking research on this topic. One key issue relates to the need to estimate and/or predict migration at a scale for which no data exists and for which it is necessary to use data available only at a more aggregate spatial scale. One example of this is the estimation of total migration taking place in a national system of interest; i.e., moves involving any change of address which might be estimated using the relationship between migration intensity and scale established by Courgeau (1985) and therefore track whether overall mobility (in terms of changing address) is changing and establish what the implications of this will be for development variables such as housing, services and infrastructure.

One of the measures of migration intensity selected for analysis of these effects in this thesis is the crude migration rate, a measure that is valuable for making comparisons between zones because it standardises for the size of the population at risk. Historical rates of internal migration are used for analyses of spatial variations but also for use in multi-regional population models which themselves utilise selected zone systems at different spatial scales. For example, migration rates at district level have been used in national demographic projection models such as ONS' subnational population projection model for England (ONS, Undated 1), whereas migration rates between NUTS2 regions were used in the DEMIFER (Demographic and Migratory Flows affecting European Regions and Cities) project for projecting populations across European countries (Rees et al., 2012).

In the case of DEMIFER, the aim of the project was to evaluate potential fluctuations in population growth, the ageing population, the size of the labour force and to investigate policies targeting regional competitiveness and social cohesion across Europe (De Beer et al., 2010). Within the DEMIFER project, the demographic analyses, typology and scenarios were primarily based on the NUTS2 regions, a scale chosen because of the availability of data for most countries or because it could easily be estimated (De Beer et al., 2010). Where migration data at NUTS2 level were not available for certain countries, migration rates had to be borrowed from other places or from rates computed at different scales, thereby raising questions about what scale or zonation effects might be operating and what form of adjustments should be made to allow for these effects. The DEMIFER project therefore highlights the importance of having consistent data scales or understanding the nature of scale and zonation effects. Knowledge of the scale and zonation effect would in this instance help to ensure that the crude migration intensity, or other migration indicators, were not skewed by having the scale set at an inappropriate level.

An understanding of scale and zonation effects on crude migration rates is therefore useful in the context of estimating flows for models projecting populations at scales where data may only be available at more aggregate levels. It is currently unclear what data on inter-zonal migration will be published in future by the census offices in the UK as the move to a more administrative census takes place (Teague et al., 2018), but it is possible, given the demand from local authorities for small area population estimates, that new models for estimating migration rates between smaller areas based on data for larger areas will need to be developed and scale effects will be an important consideration in this process. The practical rationale may be extended to other variables such as distance decay parameters calibrated using spatial interaction models based on observed data, another measure of migration used in this thesis. The research question in this context might be whether such a parameter calibrated using historical flows between districts in the UK might, for example, be used in a model to distribute flows at ward level and the answer would depend on the extent to which the distance decay parameter is sensitive to scale effects.

1.3 Aims and objectives

Data on internal migration behaviour are captured through censuses, surveys or administrative registers. Microdata on migration have been used for analysing migration characteristics (e.g., Norman and Boyle, 2010) but once processed and aggregated to avoid risks of disclosure, macro data are frequently released for empirical analysis at a limited number of spatial scales from large regions down to small areas. Thus, the focus of attention in most previous research has been on the patterns and processes of internal migration at selected geographical scales: frequently researchers choose to analyse migration using one set of zones as the basis for their study. This approach is open to criticism because analytical results may be scale-dependent and differ depending on the size and shape of the zones used.

The primary aim of this thesis is to consider the effects of the MAUP on indicators of internal migration intensity, pattern and impact in the UK from the last two censuses of population in 2001 and 2011 in order to understand changes that have taken place over the inter-censal decade. The analyses will rely on consistent sets of 'basic spatial units' that will allow (i) investigation of subnational characteristics of internal age-specific migration across the UK as a whole but also (ii) investigation of age-specific internal migration in a selected region (Greater London).

The disaggregation of migration rates by age has already been alluded to and is a very important dimension in this thesis, not only because of the need to quantify variations in scale and zonation effects on age-specific migration indicators, but also because of the practical need for local authorities to improve their methods for generating age-specific population projections for areas within their jurisdictions that are used to determine public services associated with particular age groups, such as education (e.g. provision of schools for primary and secondary pupils) and health care (e.g., provision of care facilities for the elderly) as well as the demand for new housing from different socio-economic and demographic household units. Understanding age-specific migration is essential in this context, since age will help identify the life course events of migrants. Migration has shown to be dependent on the individual's position in the life cycle (Clark and Hunter 1992) and factors which 'push' or 'pull' migrants between different places differ with age and stage in the life course (Boyle et al., 1998;

Champion et al., 1998). Furthermore, environmental policymakers and planners in charge of our natural resources rely on age-specific migration trends in order to conduct projections of future housing growth, to forecast development impacts on natural resources and to identify policy and planning needs (Lee et al., 2016), as well as economic opportunities (Clark and Hunter 1992). Lee et al. (2016) show how age-specific population redistribution changes the character of rural housing estates, for example.

To achieve the primary aim, six objectives are proposed:

1. Undertake a review of the definitions, theory and previous research on internal migration behaviour in order to understand the context in which the research is conducted and recognise the gap that this thesis is trying to fill.
2. Explain the underlying MAUP, the statistical and model-based indicators used to compare migration and the methodology by which the IMAGE Studio computes these indicators and their summaries at different scales and zone configurations. These explanations will provide the methodological foundations for the thesis and the basis on which to build interpretation of the results.
3. Review the data sets available for analysis of internal migration in the UK, make appropriate selections of the origin-destination data sets to be used given the constraints on computer-processing time and adjust the chosen sets so as to ensure consistent measurements for temporal comparison. The rationale for the choice of data at a scale appropriate to fulfil objectives 4-6 is based on data availability and suitability but also on practical constraints imposed by limited resources.
4. Analyse and visualise the characteristics of all-age and age-group internal migration taking place between local authority districts as the 'basic spatial units' selected for the whole of the UK in order to understand the spatial patterns which the migration indicators are quantifying and the changes that have taken place between the two census periods.
5. Use the IMAGE Studio to identify the effects that scale and zone configuration have on selected migration indicators for different age groups when progressively aggregating the basic spatial units the across the whole of the UK. The purpose of this analysis is to examine parameter stability across different scales and zone systems and identify changes between two time periods.
6. Undertake analyses of the scale and zonation effects, as well as the spatial patterns of age-specific migration for one region (Greater London) that is part of the UK in order to identify the relationships between scale and selected indicators of internal migration in this region and make comparisons with internal migration in the country as a whole.

A subsidiary aim of the thesis is to evaluate the application of the IMAGE Studio as a software platform for internal migration analysis in a single country and for a single region within a country. As part of the conclusions of the research, an assessment of the IMAGE Studio as software platform for internal migration analysis will be provided.

1.4 Thesis structure

This thesis consists of eight chapters. The first step is to put into context the thesis, to understand what research exists and what nomenclature is needed to support this research. This will be undertaken in Chapter 2: the concepts and literature review, where and where basic definitions and types of migration w introduced and the literature about internal migration and migration indicators, including relevant theoretical perspectives, methods and empirical case studies of internal migration will be discussed. The first half of the chapter will discuss the theoretical ideas relating to internal migration and will introduce migration nomenclature. This chapter will go on to discuss the relationships between life course theory and migration propensity and the difficulties and inconsistencies in measuring migration, including the temporal dimension of migration. The literature on migration propensities and patterns in the UK will be reviewed to acknowledge some of the relevant work that has been undertaken previously to understand where and why people migrate within the UK. The chapter also provides an introduction to the concepts of area, scale and time, with particular attention being paid to the hierarchies of zone systems in the UK, with examples of areas and scales used by previous researchers. Moreover, the fundamental conceptual components of the Modifiable Areal Unit Problem (MAUP) that underpin much of the research reported later in the thesis will be explained, together with a review of the IMAGE project which examined issues of zone variability when comparing internal migration in countries across the world. This will be followed by a succinct review of modelling studies of internal migration in the UK.

Once existing research has been considered and a detailed nomenclature has been put in place, the data used in the subsequent empirical analysis in the thesis needs to be identified, gathered, understood, and adjusted (where necessary) to be fit for purpose. Chapter 3 will focus on the sources of the data used for the research reported in this thesis; primary attention will be given to the 2001 and 2011 Censuses as sources of directional migration flows between origins and destinations at different spatial scales. Other sources of migration data are briefly reviewed, including the National Health Service Central Registers (NHSCR), since these administrative data have been used in a number of previous studies. . This chapter also contains an explanation of methodology used to adjust the migration data to be consistent between the two one-year periods and outlines the two systems of basic spatial units that are used for subsequent national and regional analyses.

Once potential data sources have documented, issues identified, data sets selected and adjustments made where necessary, the results of analyses will be reported in Chapters 4 through 7. The order of these chapters follows a logical progression beginning with an analysis of migration in the two census periods at local authority district (LAD) level in Chapter 4 in order to understand the spatial patterns, of internal migration as well as intensities, considering the scale and zonation effects on intensity and impact (Chapter 5) and on distance and its connectivity (Chapter 6) and ending in Chapter 7 with an analysis of MAUP effects in one a specific area of the UK (Greater London). The structure of the IMAGE Studio and its methodological framework based on four subsystems (data preparation, spatial aggregation, migration indicators computation, spatial interaction modelling) will be outlined in Chapter 3 and the selected migration indicators and spatial interaction model used to derive the distance decay parameters will be explained at the beginning of Chapters 5 and 6 respectively.

The first analytical chapter (Chapter 4) focuses on changing internal migration propensities and patterns at the LAD scale across the UK. This chapter will look at population and internal migration trends in the UK between the 2001 and 2011 Censuses and across different age groups. This analysis is carried out at district level so as to establish the extent to which internal migration is related to population change using correlation and ordinary least-squares (OLS) regression methods. Different configurations of net migration will also be explored using an alternative indicator of net migration, migration effectiveness, which provides a more direct measure of migration impact than the conventional net migration rate. Chapter 4 is important because it provides analyses of the spatial patterns of internal migration across the whole of the UK using so-called 'local indicators' for all basic spatial units that are not computed when the flow data are aggregated; only system-wide 'global indicators' of migration are available for aggregated spatial regions.

Chapter 5 investigates the scale and zonation effects on migration intensity and impact. The matrices of migration flows between LADs for two time periods will be used as the input data for the IMAGE Studio, which will aggregate these data for Basic Spatial Units (BSUs) into different configurations and will compute migration indicators for sets of Aggregated Spatial Regions (ASRs) at different spatial scales. The variation in the mean values of each indicator as the number of ASRs changes will provide a measure of the scale effect whereas the variation around the mean values of different indicators at each scale, measured by the range between the maximum and minimum, will provide a measure of the zonation effect. This analysis will use data from the 2001 and 2011 Censuses for different age groups to provide a detailed analysis; including results of measuring the scale and zonation effects on

2010-11 all-age migration between LADs using the Initial Random Aggregation (IRA) wave algorithm with different scale increments and numbers of configurations. New statistical measures of total scale and zonation effects are introduced to facilitate comparison between different age group scale schedules and zonation profiles.

Chapter 6 will then examine two further important migration indicators, migration distance and the connectivity of internal migration in the UK, in order to provide an analysis on the distances over which migrants' travel, the frictional effect of distance on the propensity to migrate, and the extent of connectivity between different parts of the country in terms of migration interaction. This chapter will explore how far migrants move, both as aggregate flows but also as flows at different stages of the life course, and how different age groups are affected by physical distance. Two measures of migration distance will be used and how these indicators are influenced by scale and zonation in the two pre-census periods, 2000-01 and 2010-11 will be reported. Doubly constrained spatial interaction models will also be calibrated using model software available in the IMAGE Studio to identify the distance decay parameters associated with all-age and age-group flows in both time periods. This chapter will also report on the scale and zonation effects on distance, distance decay and zone connectivity. The distance and connectivity indicators are mapped only at the BSU (district) level in order to provide clarification of the spatial patterns that the indicators are representing at the most detailed spatial scale.

Chapter 7, the last analytical chapter, looks into scale and zonation effects on migration indicators at a smaller geographical area: the region of Greater London. This chapter reports the application of combination of methods and indicators used in Chapters 5 and 6 but starting from a more refined scale to show a ward-based analysis of Greater London. Whilst the results reported in this thesis in Chapters 4-6 have all been based on a UK-wide set of LADs with consistent boundaries between 2001 and 2011, the aim of this chapter is to examine the effects of scale and zonation at a smaller area scale of wards in one particular region. This chapter will begin with an analysis on London's population and how it has changed between 2001 and 2011 as a context for the migration analysis. The results are reported for multiple indicators as used in previous chapters: the crude migration intensity, the migration effectiveness index and the aggregate net migration rate. As well as these indicators, this chapter will also explore distance migrated, distance decay and ward connectivity within Greater London.

Chapter 8 is the final chapter of the thesis and contains a review the results obtained followed by a discussion on how these matter, what limitations have been encountered and what further research possibilities can be contemplated.

1.5 Conclusion

This introductory chapter has established a context for the research and identified the research questions that the thesis is designed to address. The aims and objectives of the thesis have been presented together with the rationale for the subsequent analyses and the chapter structure of the thesis has been outlined. The key contribution of the research which distinguishes this work from virtually all previous work prior to the IMAGE project is on understanding how indicators of migration may change as the spatial scale or zone configuration changes. As well as providing new insights into migration intensity, distance and impact in the UK, the thesis illustrates how the IMAGE Studio can be used for intensive analysis of internal migration in one country and for subgroups of the population in that country.

Chapter 2: Concepts and Literature Review

2.1 Introduction

This chapter provides an overview of the literature relating to internal migration and migration indicators, including relevant theoretical perspectives, methods and empirical case studies of internal migration. The purpose of this chapter is to set the context of the thesis but also to define some basic terminologies and concepts and to identify some potential lines of enquiry. The first section in this chapter reviews some fundamental concepts relating to internal migration and uses a schematic framework for introducing migration nomenclature. The types and definitions of migration are considered together with a discussion of internal migration *vis à vis* residential mobility. Previous geographical studies of internal migration in the UK are reviewed in section 2.3, together with a discussion of the relationship between life course theory and migration propensity, emphasising the importance of using age disaggregated data when considering migration behaviour and motivations. Since variations in migration indicators by scale and zonation is the central focus of this thesis, section 2.4 outlines the various zone systems and scale hierarchies that exist in the UK and the systems that have been used by previous studies of internal migration. This section also explains the MAUP and its scale and zonation components as well as outlining the IMAGE project and reviewing some of its key findings. Thereafter, the temporal dimension of migration is examined before the literature on time series trends in migration propensities and patterns in the UK is reviewed to acknowledge some of the relevant work that has been undertaken previously to understand where and why people migrate within the UK. The final part of the chapter reviews some of the modelling studies of internal migration in the UK before conclusions are drawn in the final section that highlight the research gap that the thesis is attempting to fill.

2.2 Definitions and types of migration

To better understand migration behaviour, it is crucial to understand what migration is, why people move, why internal migration is important, what geographical scales are available for analysing migration, why obtaining accurate data for human geography and internal migration is essential, and what difficulties and inconsistencies are encountered when measuring migration.

2.2.1 Basic definitions and types of migration

Migration has been defined numerous times by researchers in the past, such as Peterson (1956) and Thomlinson (1961), who define it as a change in the place of residence. Most definitions show similarity, stating that a migrant is defined by the physical transition of an individual, or a group, from one society to another, or from one place to another. According to Mangalam (1968), human migration is a phenomenon where an individual or a family undergoes relocation from one place to another to seek a new life; this relocation may be a permanent move, but it might also be long-term permanent move. Mangalam's permanent move consists of moving into a new dwelling which becomes the primary place of residence for a limited amount of time, while his long-term permanent move refers to a move that will involve a duration of stay without a given timeframe or for five years or more.

There are various types of migration, as listed by the National Geographic (2005): internal migration, which consists of a move to a new place within a country; external migration, which involves a move to a new destination outside a country of origin. Emigration is the state of moving out of one country to a new place in another country whilst immigration is movement in the reverse direction. Further categories of migration can be identified including: population transfer, which is involuntary or forced migration; impelled migration, which consists of leaving a place not by force but due to unfavourable or a hostile environment caused by war, political or religious oppression; circular or repeat migration, which is the temporary and usually repetitive movement of workers between home and a destination, typically for the purpose of employment; step migration, which is the process of multiple short migration steps from the place of origin to the final destination; chain migration, which is the process of migrating with other migrants, usually but not exclusively as a family member; return migration, which consists of migrants returning to their place of origin; and seasonal migration where migrants move for specific time periods (Mangalam, 1968).

Migration, of whichever type listed above, therefore involves a permanent or semi-permanent change of residence (Lee, 1966) of sufficient duration and distance to change routine activity patterns (Brown et al., 2015). According to Kajzar (2013), the seasonal movements of individuals or groups can be considered as part of semi-permanent residence involving, for example, farm labourers or higher education students. Similarly, there are people who have jobs that require a lot of traveling and spending time at different dwellings, such as truck drivers, salesmen and short-term consultants; they will therefore spend less time where other members of their families live, which means they may be away for a total period of time of more than six months per year (United Nations Statistics Division, 2006). They have to use their family home as their usual permanent address as it is unlikely that they spend more than six months at one of the other semi-permanent addresses that they visit. Many employees need a semi-permanent residence far from home so as to perform their job duties in order to support their families financially (United Nations Statistics Division, 2006).

There are also other alternative ways to define a migrant, based on the distance over which an individual changes residence or the size of the geographical areas between which moves take place. For example, internal migration is frequently differentiated from residential mobility according to physical distance or some proxy for distance, such as whether the move involves crossing an administrative boundary. Whilst the Office for National Statistics (ONS) classifies any move between two locations in England and Wales that takes place irrespective of the distance involved, some researchers, particularly in the United States (e.g., Cooke, 2010), tend to refer shorter-distance migration within city suburbs (or local authority areas) as residential mobility and longer-distance migration between local authority areas as internal migration. The implicit question here is: how far does an individual have to move to be classified as an internal migrant?

It is important to remember that "migration is defined broadly as a permanent or semi-permanent change of residence" (Lee, 1966, p.49) and it often also includes long-distance travel and also a possible change in a person's occupational status (Champion et al., 1998). As it is possible to have multiple individuals involved in the relocation decision-making process, e.g. within a household, they may be referred to as migration 'units' as their place of origin and destination will be the same. Multiple migrants moving from origin area i to destination area j will create inter-area migration flows that can be represented algebraically as M_{ij}, and since time is and has a great influence in defining and measuring migration flows, it is crucial to set a time period constraint on the migration data. The extent of the time scale chosen is important because if the time interval is too short, the data may lead to under-representative measurements of flows and if the time interval is too long, it is possible to find undercounts where migration units move from area i to area j and then to area k (k being an alternative destination) where the move to area j might get lost; long time intervals may also cause a loss of migration information as it possible for a migration unit to move from area i to area j and then return to area i during a set period of time (Champion et al., 1998).

Figure 2.1 is a schematic diagram representing the standard migration matrix annotated with a basic nomenclature that helps to clarify the difference between different measures of migration where M_{ij} is the flow from origin zone i to destination zone j; in this matrix, the number of i zones (n) does not necessarily have to be identical to the number of j zones (m) but in many cases, symmetry will exist and therefore, the diagonal cells contain flows where zone i equals zone j. Each cell in the matrix is represented by a value of M_{ij}. The total of a row is referred to as M_{i*} or O_i and represents the total out-migration from origin zone i, the total of a column referred to as $M*_I$ or D_j represents the total in-migration into destination zone j, and the total sum is represented as M_{**} or M. The * represents summation over all zones i or j from 1 to n, where n is the number of origin or destination zones in the system of interest. The relationship between these components can be written in algebraic form such that:

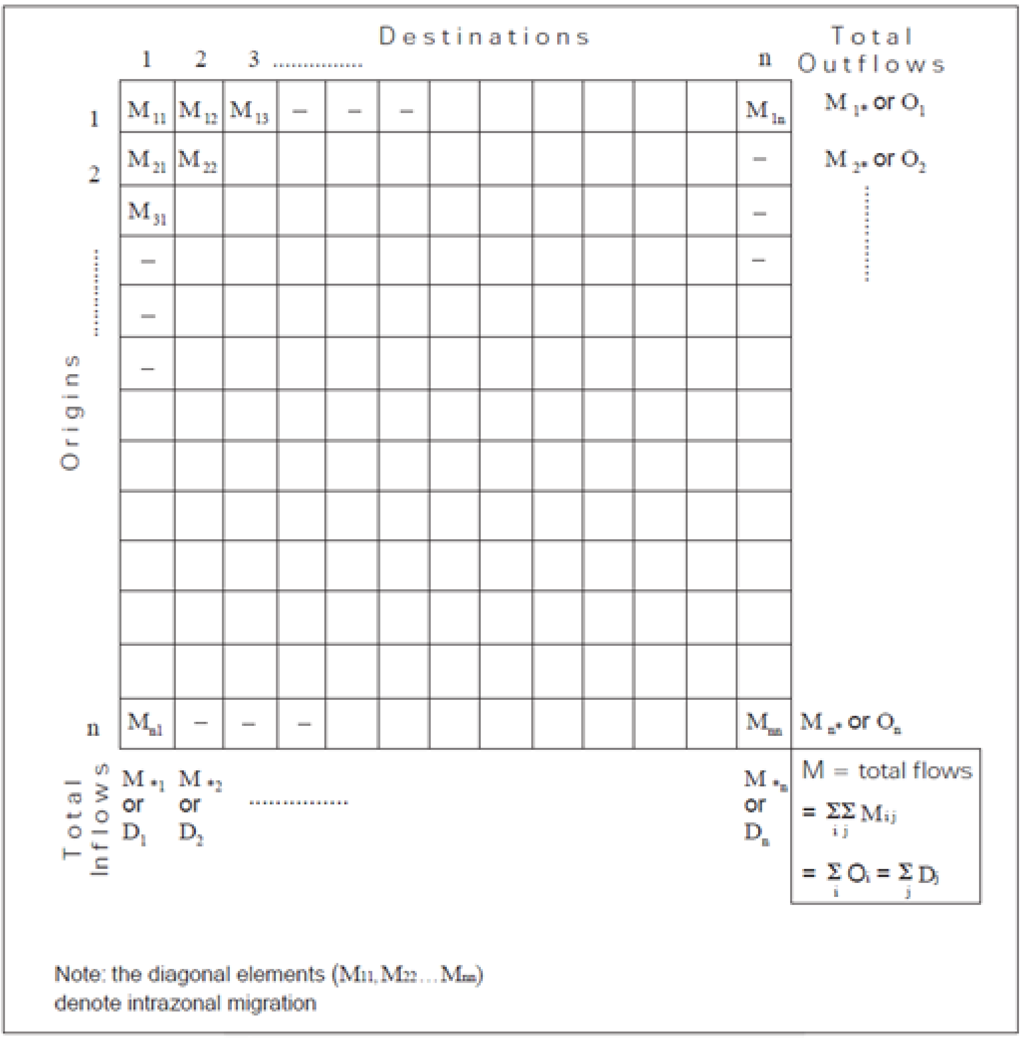
$$\sum_i M_{ij} = M_{i*} = O_i \quad \text{(total outflows from each origin)} \tag{2.1}$$

$$\sum_j M_{ij} = M_{*j} = D_j \quad \text{(total inflows to each destination)} \tag{2.2}$$

$$\sum_i \sum_j M_{ij} = M_{**} = M \quad \text{(total flow between origins and destinations)} \tag{2.3}$$

and thus:

$$\sum_i M_{i*} = \sum_j M_{*j} = \sum_i Oi = \sum_j Dj = M_{**} = M \tag{2.4}$$



Source: Champion et al. (1998)

Figure 2.1: A migration matrix and its marginal totals

Inter-zonal flows are defined as migration flows between zones, while intra-zonal flows are migration flows within the same zone and both inter-zonal and intra-zonal flows make up total or aggregate migration flows and can be included or excluded in a migration flow analysis. The migration flow from zone i to zone j is often called the gross migration flow from i to j, the migration flow from zone i to zone j plus the migration flow from zone j to zone i represents the total migration flow between zones i and j, the migration flow from zone i to zone j minus the migration flow in the opposite direction from zone j to zone i is the directional net migration flow between the two zones; these concepts can be observed in the following equations:

$M_{ij} + M_{ji}$ is the total migration flow between zones i and j (2.5)

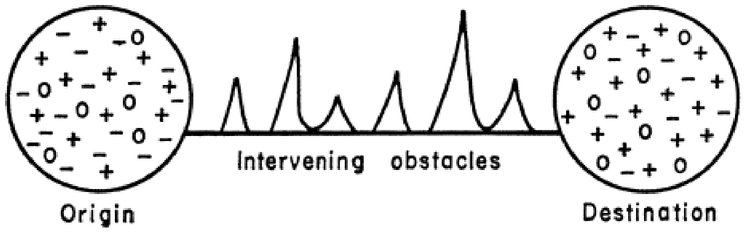
$M_{ij} - M_{ji}$ is the net migration flow between zones i and j. (2.6)

The difference between total in-migration and total out-migration for any zone i:

$\mathrm{NM_i} = \mathrm{D_i} - \mathrm{O_i}$ is the net migration flow or balance of zone i. (2.7)

Perhaps the most well-known contributions to the academic sub-discipline of migration studies are the theoretical dimensions for migration articulated by Ravenstein (1885 and 1889) and Lee (1966). The latter, in his seminal paper in 1966 based on the laws relating to migration initially proposed by Ravenstein (1885), refers to seven dimensions: migration and distance; migration by stages; stream and counterstream; urban-rural differences in the propensity to migrate; predominance of females among short-distance migrants; technology and migration; and the dominance of the economic motive.

Lee (1966) states that the majority of early research studies have been based on one or more of these dimensions of migration, but observes a noticeable lack of work focused on the volume of migration and the reasons for migration. In formulating his theory of migration, Lee attempted to identify the factors that determine the act of migration in order to cover the gap in the migration studies undertaken hitherto. These include: factors associated with the area of origin; factors associated with the area of destination; intervening obstacles; and personal factors. Figure 2.2 is Lee's depiction of how these factors work.



Source: Lee (1966, p.50)

Figure 2.2: Origin and destination factors and intervening obstacles in migration

Within the origin and the destination area, the plus and minus signs symbolize the many factors that either attract or repel people, with the zeros representing neutral factors with no influence on migrants. What makes an area appealing will differ from person to person or unit to unit and could be influenced by climate, real estate quality, neighbourliness, deprivation, labour market conditions and so forth – a wide range of characteristics. Since it is difficult to measure the causal factors for every individual migration, Lee (1966) suggests that the average reaction of a migration group will be used.

These factors will be the main determinants that attract migrants to or repel migrants from an area. Lee (1966) also states that migration decisions cannot always be measured precisely, as there may be unknown factors creating uncertainty when migrating into a new area.

Lee considers the most popular migration factors, but he also mentions the decisions involved before making a move which would involve children and the elderly members of the family and their needs since migration frequently involves the relocation of a household group. Thus, according to Lee, the volume of migration into a specific area varies depending on the multiplicity of different people involved, the difficulty in relocating to the destination, the current state of the economy in the destination, the time period to get to the destination and the likelihood of that destination will prosper in the future (Lee, 1966).

2.2.2 Internal migration or residential mobility

Distance is a key component, influencing the decision to relocate, and may be used to define the difference of a residential move against an internal migration, as mentioned previously. Since distance is an obstacle to overcome as far as a migrant is concerned, it is having a frictional effect on the propensity to migrate which may be different at different scales and for different time periods. This frictional effect causes spatial interactions to be more common at shorter distances (Tobler, 1970) and migration flows experience the familiar distance decay effect that was recognised by Ravenstein (1885) and that has been captured in many migration studies since then, a recent example being that by Stillwell and Thomas (2016) whose study suggests a way of measuring short distance migration (i.e. within an area) where no origin or destination locations are provided.

The decline of migration flows over distance is due to the fact that not only does the proximity of their current social contacts, such as family and friends, make it more difficult to move away, but also the capital invested at the point of origin (e.g. in their housing) over a period of time can increase the difficulty level. In some cases, cumulative inertia sets in, whereby the longer someone lives in one location, the greater the likelihood that they will not move elsewhere; this is the so-called duration of stay effect modelled by Thomas et al. (2016). The knowledge and information of the prospective destination locations correlate negatively with the distance decay in migration (Ritchey, 1976). The overall moving costs also play a role since short-distance moves tend to be less expensive than long-distance moves with regard to transportation costs, for example.

The distinction between internal migration and residential mobility that has been drawn above on the basis of distance moved, can also be conceptualised according to the characteristics of the migrants involved. Generally speaking, short-distance migration may involve some job-related migrants who move home, but it primarily consists of home-based migrants who change their homes but not their jobs, hence the term residential mobility is more applicable (Gordon et al., 2017). Longer-distance internal migrants, on the other hand, are much more likely to be individuals who relocate to a new geographical location but also change their jobs; in many cases, a new job is the reason for moving house. Stillwell and Thomas (2016) point out that there are no clear guidelines towards making a clear distinction between these two types of mobility on the basis of a specific distance.

Niedomysl (2011) addresses this issue by performing a large-scale survey in Sweden to better understand how migration drivers change over migration distance. Many drivers will impact on migration, including the socio-economic and demographic characteristics of the individuals themselves as well as characteristics of the places of origin and potential destination. Niedomysl (2011) criticises the fact that most previous studies have focused on specific migration trends or environment, and suggests the need for a more comprehensive study. As expected, his research has shown that short moves are primarily dominated by housing-related motives; 35% of the respondents in a survey of 10,000 migrants who moved a minimum of 20 kilometres in 2006 moved for housing reasons and this proportion dropped over long distances. Another reason for migration is education and Niedomysl's results for education-related migration demonstrated that short-distance moves are insignificant, and 34% of these migrants moved between 101 and 150 kilometres; moves beyond that decreased to 23% (Niedomysl, 2011). It is important to point out that even though these results might be repeated in other developed countries, the size and the socio-economic characteristics of the country may play an important role. For example, whilst education is a strong motive for longer-distance moves across Sweden (Niedomysl, 2011 and Niedomysl and Fransson, 2014) and in the UK (Thomas et al., 2015 and Pelikh and Kulu, 2017), in the United States, for example, students living in dorms are registered at their home or parent address; in this case this will not count towards a migration move (Schachter, 2001). In the UK, the ONS method of capturing student locations through the census has changed. At one time, members of this population subgroup were recorded at the address of their home or parental domicile but this has now changed with students in the 2011 Census being counted at their term-time address (Simpson and Brown, 2008) though the parental home is also recorded, enabling ONS to create origin-destination matrices of student flows referred to as the 2011 Special Student Statistics. Niedomysl's Swedish sample indicates that 50 to 60% of employment-related moves have a migration of distances greater than 100km.

Research by Lomax et al. (2016) using property sales data from 2014 provided by Zoopla has also helped identify home-based mobility. The data relates to the 2011 Census with the addition of new properties built on postcodes not in existence before 2011. Lomax et al. (2016) show that the highest rate of home moves, are at short distances; it is also more common for people to upgrade their homes rather than moving to a less desirable property.

Thus, in summary, how far an individual has to move to be classified as a migrant is relative to the size and socio-economic circumstances of a country. Home-based moves are often classified as residential mobility and employment or educational moves that also involve a change of home are classified as internal migration.

2.2.3 Changing mobility

Many of the studies of migration in more recent decades have sought to identify and understand the processes and patterns of internal migration in countries around the world using the dimensions that Lee (1966) considers. It is possible to make a simple distinction between those studies that use a descriptive approach to explore key sets of migration data at an aggregate (macro) or individual (micro) level and those that seek to expose regularities in migration characteristics or explain migration trends and patterns using quantitative modelling methods, although these two approaches are certainly not mutually exclusive. This dichotomy is used to structure the review of migration research in the rest of the chapter, but focus is restricted to studies published since the turn of the century.

One dimension of migration that is not addressed by Lee (1966) is whether migration intensities are increasing as humankind transitions into an increasingly mobile world. Sheller and Urry (2006) demonstrate how mobility has increased for groups such as students, tourists, refugees, backpackers, the early retired and the armed forces. The use of new technologies, such as the internet, helps people explore and imagine new travel destinations, encouraging the growth of travel as people become more mobile (Sheller and Urry, 2006). The idea behind this new mobility paradigm is to prove that all possible destinations are linked to some kind of network of connections, even small ones, that can expand world-wide, meaning there is nowhere that a person can be completely isolated; these networks consists of air and sea travel and roads (Sheller and Urry, 2006). Local, national and global media can have big effect on mobility, providing images and information that allow potential migrants to embrace as much knowledge as possible; communications is also a key factor influencing mobility, as it makes it easier to organise and construct new social lives.

According to Sheller and Urry (2006), six types of theories are used to define mobility research: the will to connect; being competent with information and communications technology (ICT); wanting to develop or change lifestyle; emotional geographies based on what is achievable and affordable; social networks and the adaptability to the economy, occupation and households. Airports historically built for military purposes have now become a tremendously effective form of mobile power and are now a mass transportation tool (Sheller and Urry, 2006), such as the Leeds Bradford Airport formally known as the RAF Yeadon from 1939 to 1947. An airport is a "space of transition", a geographical location from where people and objects are sent around the globe (Gottdiener, 2001, p.10-11), making mobility easier where the entire world can be brought into one place (Urry, 2002). The conclusion of Sheller and Urry's research is that technologies and social behaviour are changing rapidly around the world, encouraging more mobility everywhere, creating more connections; the new organisation of 'machines' working together with people enhances mobility through time and space. So the important question in the context of internal migration, is whether the trend to hyper-mobility has a positive or negative effect on migration propensities – are people becoming more or less prone to migration?

2.3 Studies of migration and reasons for moving

2.3.1 Geographical studies of internal migration in the UK

There is a long history of studies of migration in the UK which starts with Ravenstein (1885) and is exemplified by, amongst others, contributions from Newton and Jeffery (1951), Rowntree (1957), Flowerdew and Salt (1978), Ogilvy (1982), Devis (1984), Champion (1989a), Fielding (1989), Stillwell and Boden (1989), Rosenbaum and Bailey (1991), Stillwell et al. (1992, 1995), Stillwell (1994). This literature review will concentrate on more recent studies, from the last 20 years and on the data, time period and in particular, the scale(s) used for analysis since these studies provide the most relevant context for this thesis.

Champion et al. (1998) distinguish three types of migration flow: migration within England, migration between England and the rest of the UK and migration between England and countries outside the UK. The magnitude of each migration type of migration varies between different geographic scales. When considering migration flows between larger spatial units, the accuracy of the measurements of separation between the selected zones falls because separation is normally measured by distance between zone centroids and these may become less accurate as the zone size increases

A migration flow matrix with the structure shown in Figure 2.1 may be available in published form at one or more scales. ONS collects census data from the other two national statistical agencies (NSAs) in the UK – National Records of Scotland (NRS) and the Northern Ireland Statistics and Research Agency (NISRA) – and releases matrices of flows within the UK at scales from very small output areas to very large regions. Between censuses, the NSAs produce annual estimates of internal migration flows between local authority districts (LADs) within their own countries respectively based on data from administrative sources. Data accessible from these census and administrative sources will be reviewed in Chapter 3.

When changing the spatial scale from region to sub-region, the internal impact of migration becomes greater and processes such as suburbanisation, urban deconcentration and reurbanisation can be quantified using migration data. For this reason, it is important to analyse migration at various spatial scales, since different patterns and processes evident at one scale may be obscured at another. Champion et al. (1998) have demonstrated that migration plays a key role in population change at each available spatial scale in England. Natural change (births minus deaths) contributed less to population growth in 1994-95 than the total migration did at a national level, but natural change still accounted for a third of the national growth over the 10-year time period analysed from 1985 to 1995 (Champion et al., 1998). But the difference in the importance of migration *vis a vis* natural change varies spatially (Champion, 2016).

As indicated previously, the influence of internal migration on the population turns out to be gradually more significant at lower/smaller spatial scales since the majority of moves are short distance and the importance of the different characteristics of migration fluctuates between geographical scales. Moreover, "internal migration continues to play a much more important role than international migration at more disaggregated spatial scales" (Champion et al., 1998, p.105).

Using the 2001 Census data and the 2009-10 the National Health Service Central Register (NHSCR) dataset, Fielding (2012) analysed internal migration patterns using regions in the UK. Fielding provided an age analysis for these regions, allowing some insights on migration flows and how these have shaped the UK population time and also providing some observations on future trends in UK internal migration flows, based on environmental changes.

Champion (2005) has also used data from the 2001 Census and the NHSCR to analyse internal migration in the UK according to distance, age, gender, ethnicity and economic activity. Three different spatial scales were used to analyse patterns of migration across the country in this research: regions/country, districts and wards. The region/country level consists of 12 areas and analysis reveals that there are some significant regional differences in migration rates. The LAD with the highest intra-district migration (out of 425 LADs) in this instance was Oxford with a rate of 20.1% of its population with an address change whilst Omagh had the lowest migration rate of 6.8%; this shows the extent of variation in the shorter-distance mobility rate taking place in different parts of the UK. Champion (2005) states that Keele ward had the most migration activity with nearly two of every three residents changing address in the year prior to the 2001 Census. There is no analysis comparing the three different spatial scales with each other as each spatial scale has been evaluated individually demonstrating which areas have the highest and lowest migration rates.

Champion (2005) also showed how specific types of people have the tendency to move more frequently than others; this can be found in particular within the young age groups including students. Students were included in the census migration data for the first time in the 2001 Census and, together with military personnel, tend to relocate over longer distances. The population migrating above average distances according to the 2001 Census data also include married couples with no children, outright owner-occupiers, the retired, the unemployed and higher professionals. Champion (2005) concluded that more address changes were recorded in the 2001 Census than in previous 1981 and 1991 Censuses.

Lomax et al. (2013) have reviewed how data from administrative sources are available from the NSAs in the UK on a mid-year to mid-year basis at LAD level and have estimated flows that are missing from within the matrix, i.e., cross-border flows between LADs in different home countries and flows between LADs in Northern Ireland. These estimates have been used to observe the annual variations in aggregate migration intensity and the spatial patterns of migration between LADs in the UK between 2001-2002 and 2010-2011. The method used to estimate the missing sections of the matrix is Iterative Proportional Fitting (IPF) (Wong, 1992; Norman, 1999; Lomax and Norman, 2016) and is a method used to modify flows in contingency tables to ensure they are reliable based on a range of known marginal constraints.

Lomax and Stillwell (2015) have estimated that from 2001-02 to 2012-13, 5% (2.8 to 3 million people) of the UK population migrated between LADs in the UK; a drop in the average intensity can be found since 48.4 per 1,000 people migrated in the first six years, compared to 46.3 migrants per 1,000 people in the last six years of the time series. At the LAD scale from 2001-02 to 2005-06, there is evidence of a small decrease of migration intensity. The results obtained by Lomax and Stillwell (2015) show that with year-on-year rates of migration, from 2001 to 2006, the all-age migration rates remain constant, fluctuating from 47.7 to 48.9 migrants per thousand populations with a peak of 49.4 migrants per thousand in 2007 across the time series, experiencing a decrease in the migration rates onwards from 2008 to 2013 with a rate between 45 and 47 migrants per thousand. Migration rates for one age group stand out; the 20-24 age group remained on the top of all age groups of the time series, with the highest rate in 2009 at 141.5 migrants per thousand populations, and according to Champion et al. (2002), this is due to students who finished their studies at university and moved for their first graduate job.

The average percentage rate for each age group has undergone a decrease within the selected time series, where the drop for the 0-14 years olds lies between 8 and 10%, similar to the 75 and older age group with a drop of 10.5%, for the 15-44 year olds the drop was less significant ranging from 0.4 to 5%, for the 45-49 and 70-74 age groups the already decreasing migration rates continues to drop gradually and the 65-74 age group experienced the highest fall by 12.7% (Lomax and Stillwell, 2015). These results indicate that there has been a general decline of people moving between LADs and therefore a decline in the mobility in the UK regardless of the age group, as all ages were affected. Even though there is a decrease in the migration rate, the overall migration flows have experienced an increase from 2.88 million in 2001-02 to 2.99 million in 2012-13 affecting all age groups with the exception of the 5-14 and 35-44 age groups; also the total population in 2012-13 is larger than it was in 2001-02 affecting all age groups with the exception of the 10-14 and 35-44 age groups.

A migration effectiveness (ME) indicator was used by Lomax and Stillwell (2015) to measure the migration impact in the UK over the time series from 2001-02 to 2012-13 and for all age groups, following Bell et al. (2002). ME measures net migration for a zone as a percentage of the out-migration plus the in-migration for a zone. The combined measure of migration in different age groups is referred as the aggregate crude migration intensity (ACMI) but this masks the differences in the process at different spatial scales in some areas within the UK (Lomax and Stillwell, 2015). Counterurbanisation is one of the crucial components of sub-national migration in the UK at a district scale (Champion 1989b). This movement down the urban hierarchy from large cities to smaller cities, towns and rural areas has waned in the 2000s with a decrease in moves from metropolitan to non-metropolitan areas. The changes in ME values over the selected time series consist of two distinct spatial patterns, starting with the decrease in ME for the majority of LADs, possibly indicating a reduction in the counterurbanisation, and a change in the ME pattern in and around the London area as the ME values moved from negative scores in 2001-02 to positive scores in 2012-13 (Lomax and Stillwell, 2015).

Lomax and Stillwell (2015) also discuss the availability of data at different spatial scales provided by the two censuses used to analyse changing intensities at sub-LAD scale, including output areas, super output areas and wards; but limitations on spatial comparison are caused by boundary changes at smaller scales between 2001 and 2011. In order to measure changing intensities in the UK, the scale chosen is crucial due to the fact that sub-groups of the population are able to change the magnitude of the intensities at different scales; the diversity of the population and the pull or push factors that are in operation are also subject to variation based on the scale chosen.

Lomax and Stillwell (2015) determine that due to the change of mobility among the UK population, short-distance movement can be a positive factor so as to be close to work, or to relocate to a new employer as it is also becoming more popular to change jobs every few years, but the constant increase in house prices and the initial cost of moving may be motivations to migrate only if essential, limiting migration trends to longer distances. Longitudinal data from the last five censuses suggest that short-distance moves are in long-term decline (Champion and Shuttleworth, 2016a) whereas the evidence presented by Lomax and Stillwell (2015) in the 2000s and for Champion and Shuttleworth (2016a) since 1975 suggests less of a decline in longer-distance (inter-LAD or Inter-region) migration propensities, once fluctuations due to economic cycles are accounted for.

The issues covered by Lomax and Stillwell (2015) refer to how migration rates vary in relation to different spatial scales and how London compares with the rest of the UK. Their results show that at the LAD level, a decrease in London's net migration outflow to rest of the UK has occurred, possibly due to the last recession. Moreover, there is a decrease in the migration from urban LADs (including other urban areas than London) to non-urban areas, an increase in migration from non-urban to urban areas resulting in a rise in intra-urban migration in the UK between 2001-02 and 2012-13. However, Champion and Shuttleworth (2016a) suggest that short-distance migration (or residential mobility) has declined over several census periods (1991 to 2011) whereas longer-distance movements (internal migration) between the regions in England and Wales used in Champion and Shuttleworth (2016b) and between LADs in UK (Lomax and Stillwell, 2017) show no systematic decline but fluctuation that may be related to economic trends.

2.3.2 Push and pull factors

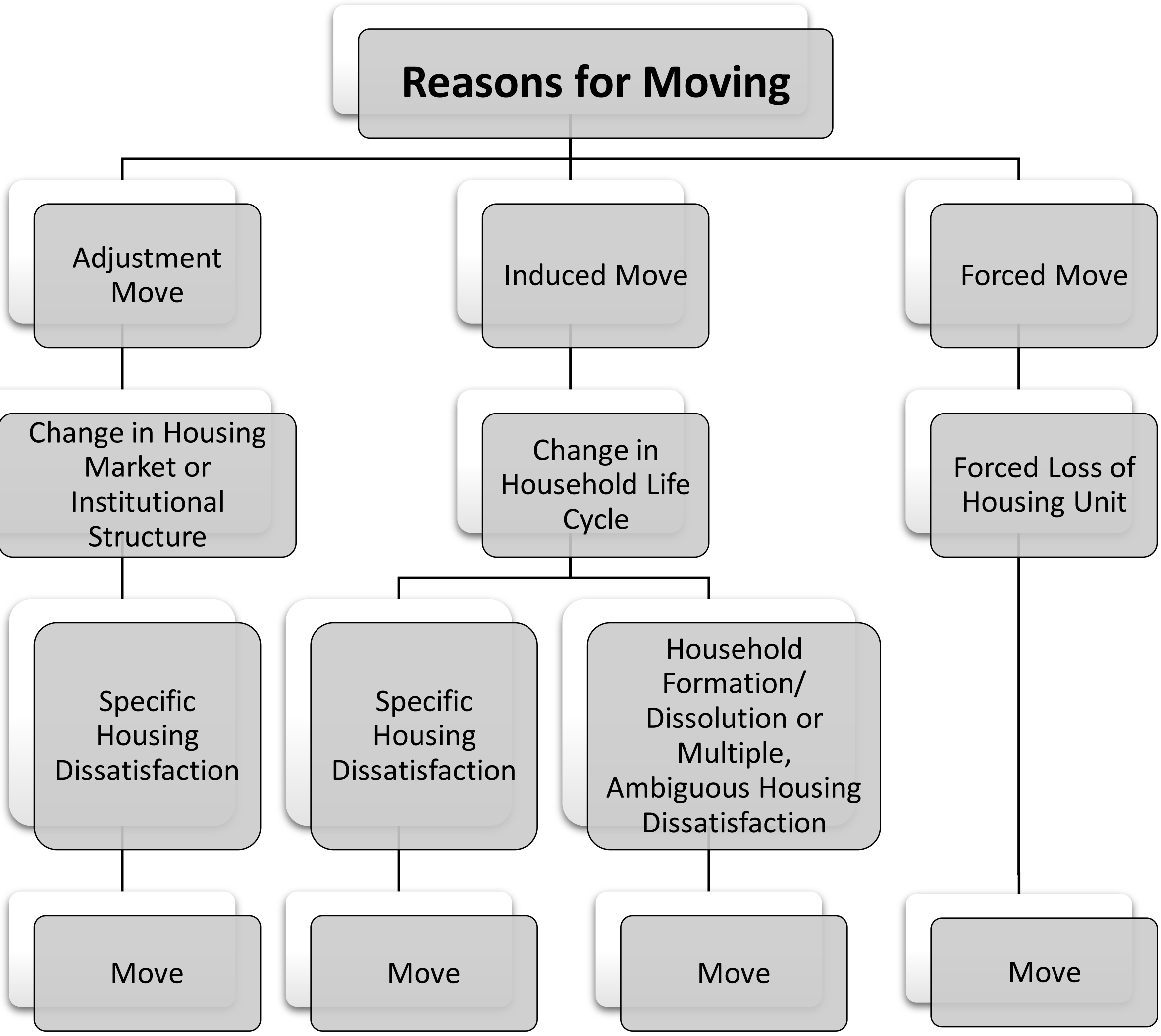
The main reason why people move is because they seek a better life for themselves, by undertaking research to compare the benefits and drawbacks of staying or moving to another place; these influences can be defined as push and pull factors in Lee's theory of migration (Lee, 1966). The different types of migration listed above are influenced by various pull and push factors that Champion et al. (1998) and IOM (2011) classified into six groups: economic factors to seek better employment; demographic and social reasons; housing factors; cultural reasons such as religious freedom and education; political reasons such as freedom of speech or war; and lastly spatial and environmental reasons such as better climate or to avoid natural disasters.

Push factors are one set of reasons why people want to leave their homes, and these factors can be caused by unemployment, lack of services, poor safety and security, high crime rates, crop failure, flooding, poverty and war, depending on where in the world these factors are relevant. On the other hand, pull factors consist of reasons why people want to move to a specific area to find some of the following: work; better services; safer area; better climate; and better quality of life with the potential for greater wealth.

Some evidence demonstrating the significance of employment on internal migration has been provided by Fielding (1992) whilst evidence demonstrating the influence of the supply of and demand for housing, which partly depends on employment status, on internal migration has been provided by Cameron et al. (2005). Income, population age composition, housing stock and interest rates are all factors that will determine house prices in the long-run, and subsequently influence migration patterns (Cameron et al., 2006).

Going to university, getting married, taking up a new job, having children and retiring from work are all examples of life course events that are more likely at certain ages. The difference within the age groups will be described in more detail later on. Rees et al. (1996) also define the life course being influenced by multiple factors, such as employment opportunities, the density of the population in specific areas and the supply and demand of housing. All these factors will affect the population differently depending on where they are in their life course.

Whilst the life course theory for understanding migration is a popular approach, the event of migration may not always be a voluntary process. Figure 2.3 follows Cark and Onaka (1983) in distinguishing between three types of residential mobility: forced moves, adjustment moves and induced moves.



Source: Adapted from Clark and Onaka (1983)

Figure 2.3: Explanations of residential mobility

Forced moves are involuntary moves, where an individual or a household is obliged to leave due to events out of their control (Clark and Onaka 1983). These events are primarily caused by institutional interventions which include housing evictions. Forced evictions can be caused by breaking a contract agreed upon before the initial move in date; this can be caused by the destruction of the property or by failing to pay essential bills. It can be difficult to distinguish voluntary and involuntary moves. Some forced moves can be based on heath conditions, forcing the occupant to relocate into a nursing home or other medical institutions based on their illness or disability (Clark and Onaka, 1983).

Adjustment moves are planned moves to improve one's quality of life and whose determinants have already been introduced. Clark and Onaka (1983) categorise the factors driving residential mobility as those caused by housing unit characteristics, neighbourhood characteristics and accessibility. Housing unit characteristics are defined by the crude space, quality and design of the property, with all factors resulting in an overall price. Adjustment moves correlate with the change of employment, as this could be the cause for moving from a rental home into home ownership. Change of neighbourhood can also improve the overall quality of life, based on the physical environment, social composition and the public services available; changing neighbourhood may also result in improved the accessibility to work, shopping, schools and/or friends and family. Just like adjustment moves, induced moves are voluntary moves and consist of moves based on changes in the life cycle, such as change a new household formation, a change in marital status or a change in the size of the household (Clark and Onaka 1983). The changes in employment or retirement are also aspects of the adjustment moves. Temporary moves are also included in this category as they support future adjustment moves.

2.3.3 Life course approach and age-related motivations

When analysing migration propensities and patterns and investigating migration trends over time, many researchers have used migration data broken down into different age groups. Age is used as proxy for life-course stages and is therefore a major component in why people move at certain stages within their life courses. Age itself is not the key determinant of migratory decisions, but those in particular age groups are influenced by certain social, cultural and economic drivers associated with being at specific stage within the life course and these will influence whether a person will migrate (Stillwell, 2008). Migrants in different age groups will have very different goals and ambitions in the desired location they want to live in. Stillwell et al. (1996, p.307) describe this as “having different patterns of destination selection at the various life course stages” where the population has to be divided into a minimum of five age groups to cover the most significant patterns: 0-15 and 30-59 year olds represent the migration of families whose parents are in the labour force; 16-19 year olds represent the migration of those leaving their homes for the first time for work or education; 20-29 year olds represent the migration of individuals seeking or starting a new career; 60-74 year olds represent retirement migration; and those aged 75 and over belong to the elderly movers. The migration of the 16-19 year olds tend to be the most significant migration flows in the UK as the population within this age group leaves home to join higher education. Stillwell et al. (1996) also state that there has been a dramatic increase over the past decades within this age group, where they choose to pursue education rather than going straight into the labour force.

Although it is clear that age is not a determinant of migration in itself, like a new job or the desire for a bigger house, age is a selective force on migration since, as mentioned previously, key motivations to move are age related. A classic example is those in the student age groups who choose to leave home to extend their education. Duke-Williams (2009) describes this as a key life-course event, encouraging long-distance migration. Dorling (2010) and Duke-Williams (2009) have shown that students in England and Wales are not likely to attend a university close to their parents' home address. Stillwell and Thomas (2016) state that the frictional effect of distance is dependent on the reasons for moving and this means that the different demographic, economic and social characteristics of individual migrants or their households will affect the overall process. Students going to university are likely to be less influenced by distance, for example, than families with children, although changes in the financing of higher education in the UK mean that the effect of distance on student migration is likely to be increasing, with fewer students choosing to travel very long distances.

As Dennett (2010) indicates, there are a multitude of factors influencing migrant behaviour but the difference in age allows identification of the major changes of location made during the life course. There are also a large number of published studies describing the role of age in relation to migration behaviour, including Rogers and Castro (1981), Bates and Bracken (1982), Rogers et al. (2002) and Raymer et al. (2006, 2007)), for example. A key study analysing migration based on age is that of Rogers and Castro (1981), in which the authors identified similarities in migration rate age patterns across various countries and cities. De Jong and Graefe (2008) and Geist and McManus (2008) have also emphasised the relationship between age and migration intensity and demonstrated the connection between life course and migration behaviour. Geist and McManus (2008) have also shown that family status can also be an influence, besides the age factor, when it comes to moving, whilst Bailey (2009) also demonstrates links between migration and certain stages in the life course. These links consist of employment status, family status including the number of children, housing preference and retirement, all of which can be related to age, as there are patterns where specific age groups are more likely to be influenced by the same factors.

For the 0-15 year olds, the pre-school migration rates are high and infants move with their parents (Dennett, 2010), but age-specific migration rates fall as children enter and transition through the compulsory education system. The 16-19 year olds age bracket will contain most of the students going to higher education, but not exclusively. To better understand migration patterns for the 16-19 year olds, Duke-Williams (2009), describes this age group to be primarily populated by students moving across the country, in order to further their education. These moves also tend to have similar patterns and similar destinations. However, non-students who fall within the same age bracket may also migrate out of their parental domicile in order to find employment. Plane et al. (2005) discuss the non-student migrants within the student age group in the USA, and how they are influenced by factors relating to that stage in their life course. Plane et al. (2005) demonstrate that large urban centres in student towns and cities will appeal to young economic migrants. Once their education has been completed, the only option left would be to face the employment market.

Faggian et al. (2006; 2007) have demonstrated that graduate student migration is based on the availability of employment across the UK. They also show that a significant migration stream of 20-24 year olds originates from student towns and cities seeking employment elsewhere. Whether regions with high unemployment rates attract or repel migrants has not yet been clearly established; Antolin and Bover (1997), for example, argue that unemployment rates motivate people to migrate, whilst Boheim and Taylor (2002) argue that unemployment rates reduce migration flows. Dennett (2010) defines the key factor for the migration flows of this age group which is the availability of employment. Further studies have also shown that migrants with more education have the tendency to move further distances (Sjaastad, 1962).

Previous studies have been conducted on the 25-29 year olds, including Plane and Jurjevich (2009), Grundy and Fox (1985), Mulder and Wagner (1993) and Bramley et al. (2006). Plane and Jurjevich (2009) define this age group as a phase where individuals settle down in a career and have a family. In the United States, this phase is often associated with moving into a suburban area (Plane and Jurjevich, 2009). The 25-29 years olds are the last age group with high migration flows; despite the fact that the 20-24 age group has a higher mobility rate, the 25-29 age group remains significant. According to Courgeau (1985), high property prices force more people to live in rented housing, allowing them to be more mobile than home owners. But since this age group is at the beginning of peoples' potential career paths and family building, this will result in a better and more reliable source of income with time, and the choices of their residential location will grow with tendencies to move away from the city and relocation will be imminent.

The next age group, the 30-44 year olds, are characterised by lower migration rates, as research provided by Dennett (2010) based on the 2001 Census data for the UK demonstrates. This decline occurs because building a career and creating a family will reduce mobility. Bures (1997) describes that from age 45 to 59 a constant increase of migration towards rural areas can be observed. This occurrence relates to the pre-retirement migrants who finds themselves in a retirement transition and whose children will have 'fled the nest' (Bures, 1997). The 60-74 age group reveals the lowest in-migration and out-migration rates of all (Dennett, 2010) as they pass retirement age. Bures (1997) states that with retirement, the residential location is no longer required to be in proximity to work, and with children in their adulthood and no need to care for them, there is the opportunity for pre-elderly groups to move to a new property that suits their new lifestyle.

Lastly, for those in the 75+ age group, priorities will change yet again and more importance may be attached to the desire to relocate nearer to family or to the supply of appropriate care facilities (Bures, 1997). Pettersson and Malmberg (2009) associate the migration increase in old age with family and social contacts rather than driven by care requirements. As with the other age groups categorised here, there will be variations in migration rates within this age category with an overall tendency for intensities to increase into very old age.

2.3.4 Personal characteristics and other reasons for moving

Besides the motivations influencing individuals in the age groups defined above, there are many other variables influencing migration intensities and patterns. In the 1990s, residential mobility in northern Europe was low (Hughes and McCormick 1987), including in the UK (Greenwood, 1997). Within the UK, this phenomenon could have been caused by the sticky prices within the housing market (Lomax and Stillwell, 2017). Whilst the economic prosperity of London appears to have been of key importance within the UK for its economic growth (Lomax and Stillwell, 2017).

Boheim and Taylor (2002) have researched migration behaviours to better understand the relationships between labour market dynamics, housing tenure and residential mobility in the UK in the 1990s. Their research has demonstrated that the manual labour force has relatively low migration rates compared to the non-manual labour force, who experience a higher regional mobility rate and also a higher net migration rate to regions with growing employment opportunities (Evans and McCormick, 1994).

A strong connection between employment status and residential mobility exists, and changing the employment status and moving home between local authorities are positively correlated (Boheim and Taylor, 2002). Brookes et al. (1994) demonstrate that since the Financial Services Act (1985) and the Building Societies Act (1986) were implemented, there has been a competitive mortgage market allowing the public to borrow more in relation to their income; therefore, the debts in the household sector have increased to 75% of annual disposable income in the early 1990s. As a result of this, the UK's housing market in the 1990s suffered from low mobility rates and high numbers of low income house owners with negative equity. Boheim and Taylor (2002) also showed that migration of home owners could include rather high transaction costs, and a move must therefore have large benefits if it is to be undertaken.

Boheim and Taylor (2002) have also shown that even though those unemployed have only a 10% mobility rate, they are still more likely to relocate than employed individuals. Moving between regions is consequently caused by the motivation for new employment where mortgage holders or housing tenures in a low skilled labour market tend to remain mobile (Boheim and Taylor, 2002). Long-term unemployment is more affected by immobility; the longer a person is unemployed, the less the likelihood that they will migrate. The UK therefore has polices to support the long-term unemployed in order to get them back in the labour market, which could have a substantial influence on the UK's mobility rate (Boheim and Taylor, 2002). It has been demonstrated that the inter-regional mobility is primarily influenced by employment opportunities, where manual workers and dual earner households are less likely to move even though they represent a variety of different demographic and local labour market characteristics (Boheim and Taylor, 2002).

Home owners with a mortgage do not have high levels of labour market or residential mobility when compared to other tenures and this can be observed in the local and intra-regional moves; it is also visible to a small level in regional migration (Boheim and Taylor, 2002). Home owners are also more likely to make long-term decisions with regard to relocation. Moves from renting to ownership are less common in contrast to owner occupation to owner occupation moves, which is crucial for labour market flexibility (Boheim and Taylor, 2002). As of the early 2000s, Boheim and Taylor (2002) state that home ownership is the leading housing tenure in the UK, and that policies are needed in order to encourage mobility in the labour force. But renting has become much more popular in the last decade, as debts have increased, house prices have risen and people cannot afford to buy houses, particularly in certain parts of the country, such as Greater London Area.

Housing market variables can be an indication on migration trends. For instance, the economic stability of an area and bordering areas can be reflected through high property prices and low vacancy rates (Stillwell, 2005). Housing tenure affects migratory patterns, including the size and quality of the availability of properties, as high property prices can be a push factor and high vacancy a pull factor (Rees et al., 2003). For council tenants, it is more difficult to relocate for a job than it is for owner-occupiers (Hughes and McCormick, 1991).

Previous studies within the UK have shown that the low mobility rate of local authority tenants correlates with occupational status, such as manual workers (Hughes and McCormick, 1981; 1985; 1987). Wadsworth (1998) also confirms that council house tenants are more exposed to unemployment while Coleman and Salt (1992) state that they are predictably less likely to relocate for an employment opportunity or if they decide to do so, will move only within a short distance. Forrest (1987), Oswald (1996; 1998) and Nickell (1998) argue that home owners are hindering mobility, resulting in higher rates of unemployment.

Gender is another demographic variable that may result in different migration patterns. The gender composition of those moving or at risk of moving has changed over the past decades. For example, early labour migration stages within Europe were primarily male dominated (Phizacklea, 1982) with female migrants seen as family creators instead of labourers in contrast to male migrants who were recognised as the main labour migratory trend (Raghuram 2004). Over time, this has changed and Anderson (2000), for example, has shown that feminisation of migration has mostly improved how women move to better their future, e.g. better employment.

Existing literature on the topic of the effects of family migration and dual-career households in the 1990s has been carried out by Boyle et al. (1999), Bruegel (1996), Cooke and Bailey (1999) and Smits (1999); where womens' roles in the labour market and their mobility have improved. Female migration rates depend on occupation, and in the 1990s the caring professions were dominated by females (Seccombe et al., 1993; Bowlby et al., 1997; Espiritu 2002). Cooke (2001) and Clark and Withers (2002) have shown in their studies that seeking new employment will have consequences on migration within a dual-career household, such as occupation and income for each partner, the current distance travelled to work and the number of children.

Economic variables, for instance, are likely to influence migrants based on the regional economic prosperity of the destination *vis à vis* the origin, especially when changing jobs associated with long-distance moves (Stillwell, 2005). The economic growth within an area will attract more migrants based on employment opportunities. This prosperity can be measured by GDP per capita, or the volume of new businesses registering over time.

Environment variables can play an important role, but are difficult to measure. The environment is defined by all the physical, economic, social and political characteristics that influence the quality of life from the type of property available, population density, crime, climate, availability of social activities, education, et cetera. One example to measure the influence of these (and other) variables is a model created for the Office of the Deputy Prime Minister (ODPM) in the UK; where a policy sensitive model of internal migration is calibrated and a convenient planning support system is developed, known as MIGMOD (MIGration MODeller). Work on the MIGMOD model has been reported by Champion et al. (2002).

Policy variables regarding migration can have a direct impact on internal migration, and also an indirect impact from government grants, local taxes, the development of higher education and the approval to build homes based on location. Policies influence not only the number of new jobs and the location and availability of homes, but also private companies and their recruitment process influencing the mobility of its staff (Rees et al., 2004).

2.4 Concepts of geographical area, scale and time

The first sub-section introduces the various scales used for administration, planning and data collection in the UK. Thereafter, the MAUP is explained and the IMAGE project is reviewed. This project involved a major study that attempted to compare internal migration behaviour in countries across the world and address the issue of how to make genuine comparisons between countries with entirely different zonal systems. Lastly the relevant time periods will be discussed. Understanding the concepts of area, scale and time are crucial for this thesis as they define key elements.

2.4.1 Scale hierarchies

Explicit in the definition of migration and implicit in the foregoing discussion about the definitions of, types of and motivations for migration is that migration involves movement across space between origins and destinations. Although there are some data sets that provide detailed information on the exact locations of each migrants' origin and destination, e.g., addresses or postcodes, most migration data comes in the form of aggregate flows that involve either counts of people leaving certain geographical areas or arriving into certain geographical areas or counts of people moving between two geographical areas. It is important to understand what geographical areas or regions are before the concept of geographical scale is considered.

Herbertson (1905) was the first to apply major natural regions to the planet, based on distinct individuality and climatic characteristics. Since then, the definition and use of regions has evolved and changed. Boehm and Peterson (1994), for example, distinguish uniform regions, functional regions and cultural diversities; these are usually based on the following criteria: crops, types of agriculture, vegetation, soils, landforms, climate, languages, cultures, religions, political boundaries and economic characteristics. These regions vary in size and can be used as a tool to better understand and organize spatial characteristics of these specific areas (Boehm and Peterson, 1994). Uniform regions can be classified by cultural or physical characteristics; functional regions or metropolitan statistical areas, can be classified by a specific point within an area, such as a major city, as a focal point and are based on concepts of internal autonomy and cohesion (in commuting flows, for example); and lastly cultural diversity can be defined by human diversity by understanding the cultural characteristics and the way of life within a region (Boehm and Peterson, 1994). More recently, Dunford (2010) describes regions as classifying the land surface into uniform, functional and administrative areas. Functional areas are the most used with regard to economic development as they are places defined by a strong degree of interdependence and strong relationships. Methods for defining functional regions in the UK, such as labour market areas, are documented in Coombes (2010), for example. Different types of administrative and functional region have been used for internal migration analysis in the UK.

Regions can be used to better organise areas, by understanding and defining their unique characteristics. Geographical areas, whether regional or local, are the basic units for geographical analysis (Rutledge et al., 2011). But there is a significant difference between regional versus local regions. As defined by the Rutledge et al. (2011), 'regional regions' can be classified by natural or artificial features, language, government, religion, forests, wildlife or climate, whereas 'local regions' will consist of more specific characteristics or are defined by the government to better classify its territory into administrative regions, for school planning or housing allocation, for example.

Having introduced the concepts of geographical areas and regions, this section will introduce and exemplify the different scales of geographical area that are associated with data available in Europe initially, but then in the UK in greater detail. Within the European Union (EU), a uniform scale system was implemented known as the Nomenclature of Territorial Units for Statistics (NUTS) in order to perform cross-country analysis. The NUTS classification was created as statisticians recognized the need for homogeneity when comparing data across the EU, thus recognising the importance of collecting, compiling and distributing comparable statistics for geographical regions across the EU (Council of the European Communities, 2003).

The NUTS classification consists of different scale levels for which regional statistics are prepared. The Council of the European Communities (CEC) (2003) has identified three different hierarchical scale levels (NUTS 1, NUTS 2 and NUTS 3), but two further NUTS levels known as Local Administrative Units (LAU) are available depending on the need for each individual member of the EU. Researchers working with regional statistics require consistent data for areas in the NUTS classification over time. The NUTS classification therefore has a rule not to update its classification too often, so as to help provide stability for comparisons over time (CEC, 2003). This rule consists of a regulation prohibiting an update of the NUTS classification to be done for at least three years, to provide regional uniformity, targeted in particular for time series (Eurostat 2013). Besides constructing comparison over time, comparing regions with each other is also an important factor for regional statistics; the issue here is that the different size of each individual region makes it difficult for accurate results. The CEC (2003) has therefore constructed regions of similar size based on the population, by ensuring that regions within a certain population will be classified in the appropriate NUTS level.

In order to facilitate comparative analysis, the CEC (2003) has classified the average size of the region of each administrative unit in each Member State into one of the three NUTS levels mentioned above: for NUTS 1, the population must be within a minimum of 3 million and a maximum of 7 million people;

for NUTS 2, the population must fall between 800,000 and 3 million people; and lastly for NUTS 3, the population must fall between 150,000 and 800,000 people. These regions will be determined based on the population having their usual place of residence in the region. The NUTS 3 level was also created in order to implement non-administrative boundaries (European Communities, 2002). If a region does not fit any of the NUTS levels described above, it must be aggregated with other regions to fit the appropriate NUTS level, taking into consideration criteria such as: geographical, socio-economic, historical, cultural or environmental circumstances (CEC, 2003).

The NUTS classification is therefore a hierarchical system used to categorize territory within the EU (Eurostat, 2010). The main benefits of using the NUTS classification are related to socio-economic analyses of the regions, where NUTS 1 involves a focus on the major socio-economic regions, NUTS 2 involves basic regions for the application of regional policies, and NUTS 3 involves small regions for more specific analyses (Eurostat, 2010). For analysis at a more local level, two LAU level have been defined. The first one is the upper LAU level, also known as the NUTS 4 level and the second on is the lower LAU level, also known as the NUTS 5 level, and consists of municipalities or equivalent units within the 28 EU Member States (Eurostat, 2013). Due to frequent changes of the LAU levels, Eurostat updates these on a yearly basis. The UK experienced on average more changes in the NUTS classification compared to other EU members; this was caused due to multiple amendments to the NUTS 3 level, in order to create the NUTS 2 level in 1989 (European Communities, 2002). The next amendment within the UK was in 1999 when all NUTS levels were updated, and the NUTS level 4 and 5 have also been created (European Communities, 2002). In 2003, the NUTS level 4 and 5 where reintroduced as the LAU levels (ONS, 2011a).

Stillwell et al. (1996) used the NUTS 2 level regions to characterize internal patterns in the UK from 1983 to 1992, and described internal migration as a key contribution in shaping the geographical distribution of the population. In particular, they highlight the net internal migration losses sustained by Greater London which are offset by net immigration, consequently resulting in a population which continues to increase. The South East region of the UK, according to Stillwell et al. (1996), shares the same characteristics as the Greater London area, by losing migration streams to more rural regions further out. This phenomenon, known as counterurbanization, has been occurring in the UK since the 1970s (Champion 1989c) and has continued to the present day. Internal migration flows between NUTS 2 regions were used in the DEMIFER project to assist in the projection regional populations across Europe (Rees, et al., 2010).

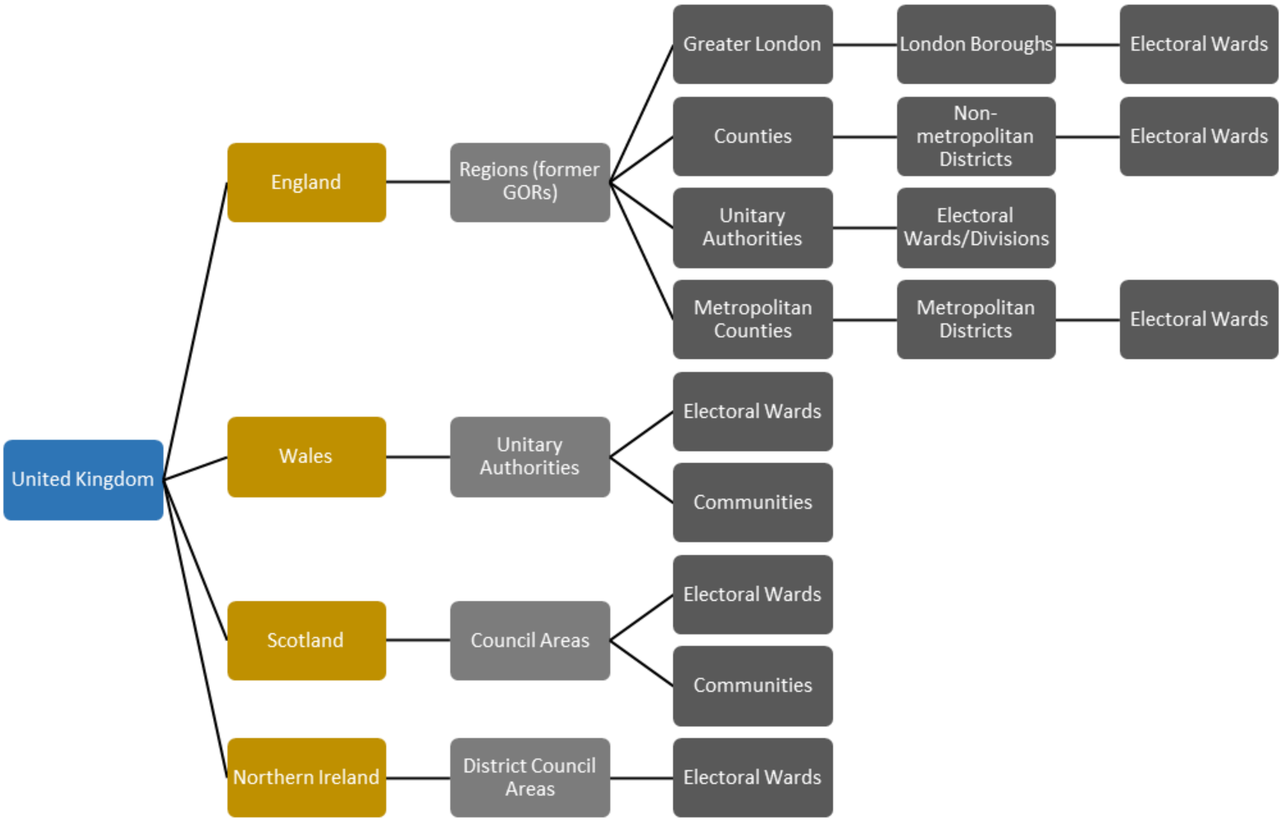
While the NUTS classification exemplifies a range of scales and is useful for cross-national comparisons between EU countries, the UK has its own hierarchy of administrative or statistical regions which differs according to each of the four home nations. The relationship between the UK's statistical geographies with the different levels of NUTS classification can be seen in Table 2.1.

Table 2.1: NUTS classification in the UK

	NUTS Level 1	NUTS Level 2	NUTS Level 3
England	Government office regions	Counties/groups of counties	Counties/groups of unitary authorities
Scotland	Scotland	Combinations of council areas, local enterprise companies and parts thereof	Combinations of council areas, LECs and parts thereof
Wales	Wales	Groups of unitary authorities	Groups of unitary authorities
Northern Ireland	Northern Ireland	Northern Ireland	Groups of district council areas

Source: ONS (2010)

To better understand the structure of the hierarchy, Figure 2.4 illustrates the administrative geography breakdown within the UK; starting with the electoral wards or communities as the lowest output level, moving up to regions or districts, all the way up to the four countries which comprise the UK.



Source: ONS (2010)

Figure 2.4: Administrative geography of the UK in 2011

Figure 2.4 demonstrates the complex multi-layered hierarchy within the UK with a different structure within each individual country relating to national and local governance. Furthermore, periodic or sporadic changes have been made to some of the boundaries within this hierarchy (ONS, 2010). The UK administrative geography has been developed with electoral wards or divisions as the basic spatial units, used to elect local government council members in: metropolitan and non-metropolitan districts, unitary authorities and the London boroughs in England; unitary authorities in Wales; council areas in Scotland; and district council areas in Northern Ireland (ONS, 2010). Government Offices for the Regions (GOR) were founded in 1994 throughout England, with the purpose of working alongside local people and organisations, with the intention of improving the quality of life and wealth (ONS 2010). Scotland, Wales and Northern Ireland are not involved in the GOR division, and are therefore listed as regions instead of maintaining a uniform structure to benefit a UK-wide research (ONS, 2010). The abolition of the GOR was announced in the Coalition Government's spending review in 2010 so there is currently no regional administrative structure in England.

Whilst the geographies shown above relate to the administrative functions of government, there are a plethora of other geographies that are used for different functions. These include various census geographies and each has its own unique set of component zones that vary in number and configuration. Each geography may be considered as representing a different level of scale. The following list of geographies, produced by ONS (2013), illustrates the majority of different types of scale levels available within the UK, excluding those that are part of local government or the NUTS/LAU classification:

- Output areas (OA)
- Lower layer super output areas (LSOA)
- Middle layer super output areas (MSOA)
- Workplace zones (WZ)
- National parks
- Census wards
- Parishes/communities
- Counties
- Former counties
- Regions
- Westminster parliamentary constituencies
- Primary care organisations (PCO)
- Local health boards (LHB)
- Strategic health authorities (SHA)
- National Assembly for Wales (NAW) constituencies
- Clinical commissioning groups (CCG)
- NHS area teams (NHSAT)
- Family Health Service Areas (FHSA)
- NHS commissioning regions (NHSCR)
- Built-up areas sub-divisions (BUASD)
- Built-up areas (BUA)

Some of these scale levels have been used for internal migration analysis in the UK. For example, Ravenstein's (1885) work was based on counties, a scale that has been used subsequently by Osborne (1956) and Taylor and Bradley (1994), amongst others. More recently, Fielding (2012) has used regions, whilst Champion (1989a) has used regions and inner and outer boroughs of London. Sander et al. (2018) has used NUTS 1 and 2 regions whereas Stillwell et al. (1996) have used NUTS 2 regions. Local authority districts have been used by Dennett and Stillwell (2010b), Stillwell et al. (2018) and Kitsos and Bishop (2018). At the small area scale, Simon (2010), Stillwell (2010) and Stillwell and McNulty (2012) have used wards.

In addition to these spatial systems, the use of more functional regions is exemplified by Scott and Kilbey (1999) who used family Health Service Areas (FHSAs and NHSCR areas), Flowerdew and Salt (1978) who used labour market areas (SMLAs) and Stillwell (1994; 2000; 2001) and Champion and

Coombes (2010), all of whom used city regions. Some researchers have developed their own systems of interest in an attempt to create alternative functional regionalizations (Stillwell et al., 2000; 2001) and in some cases, researchers have used area classifications rather than individual area systems. Champion (2000) used an area classification of 13 types of metropolitan and non-metropolitan district whereas Stillwell and Dennett (2012) used their own bespoke LAD classification; Raymer and Giuletti (2009) used 10 area groups whilst Simpson and Finney (2009) used LAD types.

In terms of modelling migration in the UK, a similar diversity of geographical systems of interest have been employed. Dennett and Wilson (2011) used NUTS 2 regions, for example, whilst Raymer et al. (2007) used 12 groups of areas. Stillwell (1978) and Gordon (1981) used counties; Fotheringham et al. (2004) used FHSAs; and Catney and Simpson (2010) and Stillwell et al. (2014; 2018) used a LAD classification.

These selected examples represent an extensive list of researchers who worked on internal migration at different spatial scales. It is apparent that many researchers have not used nationwide administrative systems of interest for their analysis, but have attempted to construct their own systems based of concepts of functionality. Having introduced the different scale levels, a crucial question must be asked: which scale level is the most suitable for internal migration analysis? Given the previous discussion about different types of migration occurring over different distances, choosing the right scale level can play an important role when examining specific types of internal migration. However, it is usually the data that dictates what scale level is appropriate.

In summary, this review indicates very clearly that many researchers since Ravenstein in the 19th century have selected the single most appropriate system that can be used for statistical or model-based analyses of internal migration. Whilst some have looked at propensities or patterns at more than one scale, the only comprehensive study of how migration indicators change across a wide range of scales is that undertaken by the IMAGE project, a synopsis of which is presented in sub-section 2.4.3, fatre the MAUP has been explained.

2.4.2 Modifiable Areal Unit Problem

As indicated earlier, the Modifiable Areal Unit Problem (MAUP) was first identified by Gehlke and Biehl in 1934 and several researchers, such as Openshaw (1984), Fotheringham and Wong (1991) and Tranmer and Steel (2001), have subsequently examined how scale affects the measurement of area-based indicators and of the relationships between variables. It was Openshaw (1983) who identified the two components of the MAUP as scale and zonation effects. These are illustrated in Figure 2.5

which shows how basic spatial units can be aggregated in different ways and therefore show different results. The data aggregated here can take many forms e.g. grid squares, postcode sectors, store catchment areas, and local government units. The two components of the MAUP can be observed in Figure 2.5, where the scale effect (on the vertical axis) shows significant differences in its analysis, depending on what size of units are being used, and the zonation effect (on the horizontal axis) shows significant differences depending on how the area is divided, even when the same scale is being used. Figure 2.5 visually represents how an area with 16 BSUs can be aggregated into 8 and 4 zones using 4 different configurations. These configurations demonstrate how the BSUs can be aggregated into different sets of aggregated spatial regions (ASRs), which can show different results. This means the ASRs can be equally shaped or have some areas larger than others. This example demonstrates how different zonal systems provide different results using the same data without major variations in zone sizes or elongated shape. Different attribute values (e.g., populations) may be associated with each of the 16 BSUs, giving areas varying population size when configured in different ways.

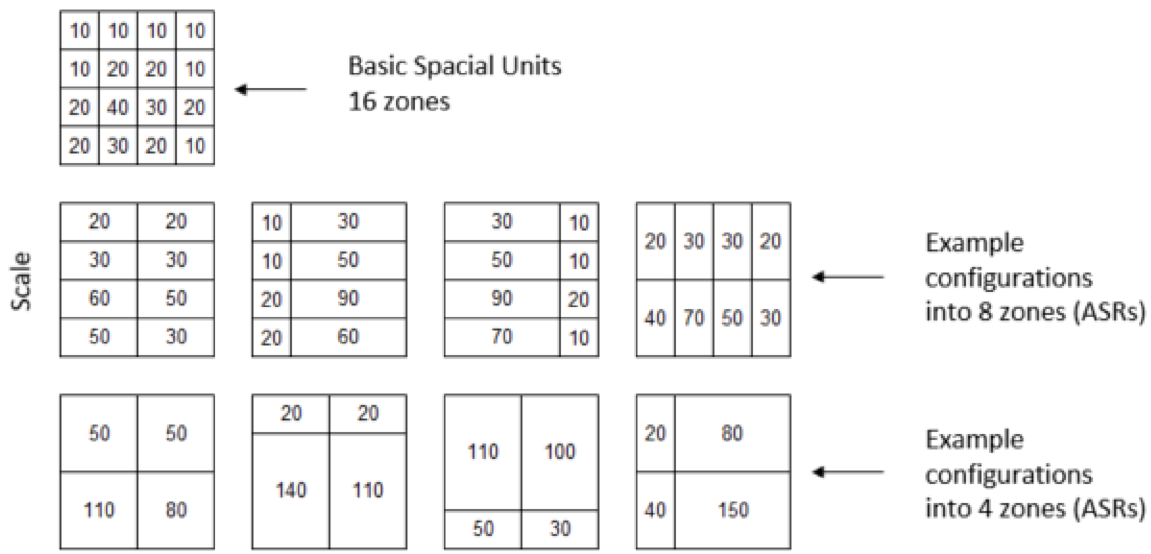


Figure 2.5: Components of the Modifiable Areal Unit Problem (adapted from Openshaw, 1983)

2.4.3 Scale and zonation effects – the IMAGE project

The aim of IMAGE (Internal Migration Around the GlobE) project was to develop a robust set of measures to be used to improve the analysis of how internal migration varies between nations. The first step was to undertake an Inventory of internal migration data produced by each of the 193 United Nation (UN) member states. Bell et al. (2015b) report the results gained from constructing the IMAGE Inventory and show national differences in: the type of data collected on internal migration, the sources used to derive migration data, the ways they measure migration, the time intervals adopted, the periodicity of the collection processes, the scope of the questions, and the spatial frameworks they employ (Bell et al., 2015b). There is recognition that internal migration is progressively becoming a key element of demographic change, and getting reliable information is essential for infrastructure and services planning; but due to the high cost of acquiring and processing migration data, countries worldwide, including the UK, are looking for more efficient methods to collect and/or estimate this information (ONS, 2012).

The IMAGE project built on earlier work (Bell et al., 2002) identifying the lack of research comparing various dimensions of migration in different countries using a basket of indicators. Consequently, an IMAGE repository was constructed containing internal migration data from different countries around the world, together with associated data on populations and risk and zone boundaries. It was deemed too much to collect data disaggregated by age or any other variable or to collect explanatory variables that might be used to examine potential determinants.

Once the various data sets had been collected, the challenge was to compare internal migration in the countries for which data were available in the database. Although the same type of data (e.g. census or administrative) were available in certain countries, the difference in the number of spatial units in which countries are classified into makes it difficult to make direct comparisons of migration intensity or impact, since the number of spatial units (or zones) of a county, defines the number of migrants or migrations captured (Bell et al., 2015a).

A methodology was therefore required to facilitate comparison and the IMAGE Studio was therefore developed (Daras, 2014; Stillwell et al., 2014) to aggregate data on migration flows, populations and boundaries to different scales and zonations as specified by the user, and to compute migration indicators for systems of aggregated spatial regions. Details of the structure and operation of the IMAGE Studio software are presented in Chapter 5. The relationship between aggregate crude migration intensities (ACMIs) and zone scale was used to estimate ACMIs for total mobility in different countries (following the equation for Courgeau's k) and to produce league tables based on migration rates (Bell et al., 2015a), demonstrating significant variations between countries with high rates of migration such as New Zealand, the United States, Australia, and Canada, and countries at the bottom of the league table such as India, North Korea, Egypt and Venezuela and identifying a relationship between migration and the level of development.

The impact of internal migration in different countries was examined using the aggregate net migration rate and its components, crude migration intensity and migration effectiveness. In this case, the IMAGE Studio was used to quantify the relative stability of these indicators over time and to explore how the aggregate net migration rates in different countries result from very different combinations of migration intensity and effectiveness (Rees et al., 2016). Unlike the crude migration rate, migration effectiveness, explained in more detail in Chapter 5, is shown to be relatively scale independent and Rees et al. (2016) suggest how the impact index offers insights into a country's level of demographic development.

Whilst Rees et al. (2016) have used the IMAGE Studio to configure geographic zones and implement new measures to compare migration data across large samples of different countries, by examining the relative contributions of migration intensity and effectiveness to cross-national variations, Stillwell et al. (2014; 2016) have used the IMAGE studio in order to compare different aspects of internal migration across different countries at a national scale.

In terms of analysing migration distance, Stillwell et al. (2016) discuss the lack of data availability on exact origins and destinations of individual moves, making it difficult to provide accurate measurement of migration distance. Since most countries with internal migration data show only flows between areas that have been created for administrative or statistical purposes, the MAUP can be observed based on inconsistencies in the size and shape of these area; from a scale component highlighting different numbers of regions to a zonation component showing how zone boundaries are defined (Stillwell et al., 2016). The IMAGE Studio was used to investigate these scale and zonation issues by comparing migration distances and a spatial interaction model was used to show how distance decay parameters vary at different scales for all countries with a matrix of aggregate flows where 99 or more zones is available (Stillwell et al., 2016). Some of the results for example have shown that larger countries, such as Canada and Australia have a much more significant scale effects on the mean migration distance, compared to smaller countries such as El Salvador and Switzerland, where the distance moved does not change much as the as the number of zones reduces. This implies that larger countries are particularly more vulnerable to the MAUP.

In terms of age groups, Bernard et al. (2017) have used techniques in association with the IMAGE Studio, to investigate internal migration intensity, age profile and spatial impact and how they vary between countries around the world. Although migration age profiles are similar from one country to another, the ages and level at which migration peaks varies. For example, Bernard et al. (2017) research has shown that migration peaks after the age of 27 in Argentina and Costa Rica but before the age of 21 in Honduras and Peru.

In summary, while the IMAGE Studio has been used for the comparative analysis of scale and zonation effects on aggregate migration indicators in different countries of the world, it has not been used to investigate these effects in detail in any one specific country or in any single region using age-specific migration data. Neither has it been applied to a set of data that is consistent between two periods to offer insights into indicator stability over time. The IMAGE Studio software has been be used extensively for the research reported in this thesis and the later chapters will explain the methodology in more detail and report the results of its application.

2.4.4 Time periods and time series

Another important dimension for internal migration analysis is the time period over which the flow of migrants is measured. Unlike population size, which can be measured by a census at one point in time, migration, like births and deaths, has to be counted over a period of time. Bell et al. (2015b) have reported the different intervals that are used to measure migration in countries around the world and, typically though not exclusively, the three major time periods for census data are one year, five years and the period since birth. The latter interval was used by Ravenstein (1885) to identify flows of 'natives' between counties of the UK by birthplace and usual residence recorded in the 1881 Census, but more recent studies using data from the one or more of the last four censuses in the UK have used migration counted in the 12 month period before each census. Internal data at regional level derived from administrative records such as the NHSCR have been published on a quarterly basis for the previous 12 months enabling time series of annual migration to be constructed. Similar time series data are available in other countries such as the USA and Sweden.

A key study of time series migration data is Cooke's (2013) analysis of migration in the USA which suggests that the internal migration rate is dropping significantly for three main reasons; first of all, there is an increase of households with two incomes, due to the fact that women are gradually joining the labour market; this factor reduces migration because it is more difficult to perform spatial jobs searches for both jobs seekers at the same time. Second, households are borrowing more money than ever before which increases debt and restricts movement; and finally, information and communication technologies (ICTs) have brought about a reduced rate of internal migration because people can communicate without the need to relocate (Cooke, 2013). Alternatively, ICTs could increase internal migration as they make it easier to keep in contact with family and friends at the origin post-migration. But Cooke is making the case for the difficulties of leaving due to debt and job opportunities for dual earning households, rather than the easiness of arriving at the new destination and maintaining the same employment via ICTs. Cooke argues that because of these factors, the Great Recession in the late 2000s did not diminish internal migration as much as expected and that the decline in internal migration in the USA is more related to extensive macroeconomic changes.

Based on data from the US Census Bureau's Current Population Survey (CPS), Cooke has demonstrated how US migration, at country level, decreased in the mid-1980s and the data from 2000 also shows that migration rates had dropped. These economic difficulties started as a consequence of the Great Recession, which caused a decrease of the US migration rate (e.g., Frey, 2009). However, Fischer (2002) stated a variety of population composition reasons for the reduction of migration rates such as change in age structure, education and ethnicity. A similar approach was taken by Wolf and Longino (2005), whose focus was primarily on age-group migration. Furthermore, Molloy et al. (2011) examined groups which have higher migration rates and showed how the population has changed regarding the different factors of sex, employment status, ethnicity, etc., summarising the situation with the following statement: "The decrease in migration does not seem to be driven by demographic or socioeconomic trends, because migration rates have fallen for nearly every subpopulation and the composition of the population has not shifted in a way that would affect aggregate migration appreciably" (Molloy et al., 2011, p.14).

The decline in migration propensities identified in Cooke's research based on US data sparked interest in whether similar trends were occurring in other countries in the more developed world. Champion and Shuttleworth (2016b) have subsequently used time series migration data for England and Wales to study, where they have not found any substantial long-term decline in the overall intensity of between-area migration in England and Wales since the 1970s and Champion et al. (2017) contains a number of case studies of migration trends in different countries, showing a diversity of experience across the more developed world.

Whilst this section exemplifies researcher's interests in migration trends over time at different spatial scales both in the UK and elsewhere in the world as they strive to ask questions about whether propensities have changed (is humankind becoming more or less mobile?) and whether patterns have changed (are migrants moving between the same origins and destinations?), this thesis focuses on census data to examine propensities and patterns for two relatively recent one-year periods of time.

2.5 Modelling studies of migration in the UK

The application of migration modelling in the UK also has a longstanding tradition as illustrated by a range of studies in the literature including, for example, Weeden (1973), Stillwell (1978), Fotheringham et al. (2004), Clark and Ballard (1980), Gordon (1982), Molho (1984) and Flowerdew and Lovett (1989). These examples suggest there exists a large number of migration models and a four-fold framework was identified by Champion et al. (1998): aggregate (macro) cross-sectional models, disaggregate (micro) cross-sectional models, aggregate (macro) time-series models and disaggregate (micro) time-series models. Aggregate (macro) cross-sectional models are based on migration data for areas to analyse all migrants or to compare selected groups of migrants based on specific variables over a single time period. Disaggregate (micro) cross-sectional models are also based on a single time period but the data are individual migrants rather than migration groups. Aggregate (macro) time-series models focus on predicting migrations based on different time series whilst disaggregate (micro) time-series models look into the diverse economic and social conditions applied to migrants to observe individual behaviour (Champion et al., 1998).

One of the main issues here is to define which spatial scale will provide the best analysis of migration flows as there may well be a set of different conclusions based on analysis at each spatial scale for the same data. The problem of spatial analysis is that it is possible to have a conclusion associated with a set of migration flows between specific regions and to obtain a different conclusion with regions at an alternative scale (Openshaw, 1984; Fotheringham and Wong, 1991). This problem also occurs in flow modelling (Amrhein and Flowerdew, 1989). These issues indicate how variations in migration intensities and patterns that are evident at one scale may be less obvious or hidden altogether when examined at a more aggregate scale.

Migration flow modelling is described by Champion et al. (1998, p.105) as "the quantitative prediction of the size of the flows using a mathematical procedure which is thought to represent how migration is determined". A typical model usually consists of two different types of factors, the first is having reliable and accurate conditions of the predictive equations and the second is the usage of independent variables which will allow having a successful predictive outcome (Champion et al., 1998).

The state-of-the-art of macro and micro approaches to modelling migration have been reviewed in detail in Stillwell and Congdon (1991) and more recently by Champion et al. (1998) and Stillwell (2008). In this chapter, the review is restricted to a single recent study that illustrates the particular development and application of one model, MIGMOD, a deterministic macro migration model designed for the Office of the Deputy Prime Minister (ODPM) (2002) in England which used seven categories of local factors as possible causes for migration: demographic; cultural and social; labour market; housing; environment; public policy; and impedance. MIGMOD is a two-stage model, looking at migration within England and Wales over a 15-year time period between 1984-85 and 1997-98; with the first stage focusing on the determinants causing migrants to leave a set of different origin areas. The labour market is an influential variable for migrants, encouraging out-migration for the working population in regions with low employment rates and discouraging out-migration in areas with high employment rates. Out-migration is also high in regions where the average person is works in a more skilled occupation (ODPM, 2002). After the labour market, housing is also a leading cause of migration; if the average cost of a home is low, out-migration will be more likely than if the average cost of housing is high, because a higher cost of the average home will cause a higher mortgage interest rate resulting in a longer commitment and keeps out-migration low. Social housing can also influence the population as a push factor, if there is a large amount of social rented housing in or around the area, but having a deprived household motivates people to remain in their residence. Weather can also be a motivation for migration, with a high number of rainy days tending to encourage more out-migration).

The second stage of the ODPM study focuses on the allocation of migrants from origins to destinations and therefore on the characteristic attributes of the destinations. Distance from the origin, however, is crucial and a very important element in the migration process, due to the fact that a migrant is more likely to move shorter distances rather than long distances. The population size of a targeted destination area will have a positive relationship with the absolute number of migration flows from a specific area of origin, because of the positive influence on the job and housing market created by a large population. Similar to the out-migration, in-migration is also strongly influenced by the labour market, as migrants are either seeking employment, a career change or a promotion. A strong rate of employment growth or high GDP per capita at the destination will encourage people to move there. Once again, housing can also play an important role for the destination area attracting all age groups except young adults, as the cost of owning a home may be too high. These two statements demonstrate that a high rate of in-migration will result in a high GDP per capita and a consistent high price of housing. An improvement in the quality of the environment can also be a pull factor; the standard preference for migrants regarding the 'ideal' environment for the destination area would be a less urbanised region with low crime rates in terms of an improved social environment.

This second stage performed in the OPDM (2002) study incorporated three spatial processes, starting with a network-weighted distance variable, a contiguity variable and a destination accessibility variable. The network-weighted distance variable is defined by OPDM (2002) as a variable which is established on distances between the population centroids of pairs of zones and the distance is not calculated by using a straight line, but by using the shortest surface route acknowledging the effect of estuaries. The contiguity variable takes the value of 1 for areas touching boundaries with one another and 0 for other paired areas (OPDM, 2002). Lastly, the destination accessibility variable allows the measurement of how much spatial competition can be encountered by a destination from other possible neighbouring destinations. The distance variable has been proven to be a valuable variable in establishing or understanding migration patterns and also to be always negative; migrants are more likely to move shorter distances rather than further distances due to the fact that migrants move to improve their quality of life but not wish to lose any social connections or jobs, migrants also need a sufficient amount of information of the destination area, spatial if it is further away, otherwise the likelihood of moving will decrease. The third and last stage of the OPDM study involved predicting migration based on seven policy-related scenarios. The first scenario providing promising results, demonstrates how migration patterns will react if a 5% increase in jobs in northern England's urban areas is introduced, where a fall of 28% is predicted in the net out-migration from the affected areas; this result means that an increase of 18% (about 0.6 million) would lead to having a net out-migration equal to null (OPDM, 2002). The second scenario looked at the house quality in northern England's urban areas and the results suggested that an increase in the house quality would cause a net out-migration reduction by one third; the house quality in this scenario involved: "a 5 percentage point increase in share of detached houses, a 3 percentage point decrease in terraced housing, a 5 percentage point reduction in the share of social housing and a 10% reduction in the incidence of six other housing-related variables" (OPDM, 2002, p.19). A further scenario observed the reaction to migrants in the northern urban areas when local government spending per head is raised by 5% relative to the Standard Spending Assessment (SSA) and taxes are reduced by 10%, showing an 11% decline in the net out-migration (ODPM, 2002). These scenarios conducted by OPDM served as a tool to better understand migration patterns and possibly influence migration policies.

Table 2.2 is a summary of the results obtained from the OPDM (2002) study, where on the left hand side, the causes producing higher rates of out-migration in targeted areas are demonstrated and on the right hand side, the causes producing higher rates of in-migration in specific areas are listed. Both sides represent how people who are migrating are looking to improve their quality of life, whether it is based on housing, employment or climate.

Table 2.2: Results from the Office of the Deputy Prime Minister study

Higher rates of out-migration are found in areas with:	Higher rates of in-migration are associated with areas with:
Poor air quality	Low rates of age-specific unemployment (especially for younger males and older age groups)
Wetter, colder climates	Warmer and drier climates
Relatively high proportions of people who commute long distances	Large population centres nearby (sensitivity to distance increases with age)

Low levels of deprivation (as measured by crime rates, housing attributes etc.) – possibly related to demographics and ability to move	Low crime rates (sensitivity increases with age)
High employment growth (turnover effect)	Low council tax rates
Large proportion of urban population	Locations away from the main London–Birmingham–Manchester population axis
High numbers of students	Higher household incomes
High household incomes	High house prices
Low house prices (moving is more affordable; reluctance to move out of areas with high house prices – fear of not getting back in or losing out on house price inflation; people at end of housing chain)	High concentrations of listed buildings (migrants like places with 'character')
Relatively low house prices nearby	Little urban renewal (probably a deprivation indicator)
Elderly in London (young people in London have low out-migration rates);	Large populations (sensitivity varies by age with younger migrants, indicating greatest preference for large urban areas)
Periods of low mortgage interest rates	Universities (for younger migrants)
High proportions of non-white residents or relatively high proportions of non-white residents nearby	Low proportions of vacant and derelict land.
Low levels of new housing developments on former urban land	
High levels of relets in the social sector (unsettled population?)	
Relatively high percentages of new builds compared with existing housing, particularly in the social sector (turnover effect; urban regeneration?)	
Low percentages of vacant dwellings (limited opportunities for internal migration)	
Periods of economic boom	
Less deprived areas surrounding them	
High proportions of single people	
Large urban areas nearby	
Periods of high unemployment rates (opposite for families with young children)	
Greater numbers of university places (16–19 year olds going; 20–24, 25–29 leaving)	

Source: ODPM (2002)

While MIGMOD represents one of the most comprehensive attempts at explanatory modelling of internal migration in one country, cross-national research on migration modelling is much less abundant than studies of internal migration in one country. The difficulties in making comparative measurements that enable cross-national comparisons of migration activity, migration distance and its decay effect are largely due to the irregularity of areas in terms of size and shape in different countries being compared. Stillwell et al. (2015) raise the concerns about the scale and zonation variation restricting cross-national comparison by comparing migration distance and its decay effect, to obtain different zonal configurations. In order to compute cross-national comparisons, the IMAGE Studio software is used to calculate the migration indicators and model parameters based on the migration data input (Stillwell et al., 2013). Measuring the distance migrated can be achieved by getting data (moves across boundaries of administrative zones) from migrants via the ONS or by estimating the origins and destinations. Stillwell et al. (2015) provided an analysis on how internal migration distance and its frictional effect vary between countries, by using a spatial interaction model (SIM) to study the variation of indicators based on to scale and zone configuration. The results obtained indicate a positive power relationship between mean migration distance and mean area size and a constant frictional effect of distance with mean population size with the exception countries with lots of small areas where there the migration matrices are sparsely populated and there is low connectivity. Spatial interaction modelling will be explained in more detail in Chapter 6 prior to the reporting of the results of model application at different spatial scales in the UK.

2.6 Conclusion

This review has covered a wide range of literature documenting different aspects of previous work on internal migration, including some selected perspectives, some methods and some case studies of internal migration. The extensive volume of literature makes a comprehensive review impossible and therefore a basic overview of key theoretical ideas has been provided and a schematic framework for introducing migration nomenclature has been outlined, allowing some of vital elements of this research to be defined. Migration definitions have been considered and the implications of distance plus the plethora of variables that influence a population to move and how far they are willing to go have been reviewed. Age has been identified as a key factor in determining migration propensities and patterns and age-specific migration data will therefore has been chosen in the analysis that follows in this thesis. This review of determinants has demonstrated the extent of research on internal migration in the UK that has been devoted to understanding causal factors. There have been a lot of studies in this area, many of which have involved fitting regression models to determine the significance of different causal factors, MIGMOD being perhaps the most sophisticated modelling analysis in recent times.

The review of recent studies of migration propensities and patterns in the UK presented in this chapter indicates that the majority of studies have concentrated on analysing data at one particular spatial scale and indicates a significant lack of migration studies that compare different indicators of migration at different geographical scales. The influence of internal migration on the population becomes gradually more significant at lower spatial scales as the majority of moves are short distance and the importance of the different characteristics of migration fluctuates between geographical scales. Thus, whilst there is a lot of research available on migration, only those papers emerging from the IMAGE project, such as Stillwell et al. (2014) and Bell et al. (2015a), have acknowledged that depending on what geographical scale is used, the results may vary. When changing the spatial scale from region to sub-region for example, the internal impact of migration becomes greater and processes such as suburbanisation, urban deconcentration and reurbanisation can be quantified using migration data. For this reason, it is important to analyse migration at various spatial scales, since different intenmsities, patterns, processes and imnpacts evident at one scale may be obscured at another.

This chapter has raised a number of data-related issues that limit migration analysis, so the following chapter will cover the availability of data and the methods used to allow a comparison of migration based on data from the 2001 and 2011 Censuses and at different spatial scales to be undertaken.

Chapter 3: Internal Migration Data and Basic Spatial Units

3.1 Introduction

Data availability and accuracy are both crucial for every research project, as they present the opportunity to generate results using analytical methods in the first place and then establish the authenticity and reliability of the results obtained from undertaking the analysis. "*In any society, knowledge and understanding of migration patterns is largely determined by the quality and detail of the data available and, only after that, by the precision of the analytical approach and the insight of the theoretical concepts employed*" (Woods, 1979, p.196). The accuracy of the data will depend partly on the collection method and partly on the way in which the data are processed (which may involve some sort of adjustment). Depending on the scale and type of data required, it can be challenging to retrieve reliable data for cross-sectional analysis, let alone for time-series comparison.

This chapter focuses on the sources of data used for the research reported in this thesis. Primary attention is paid to the 2001 and 2011 Censuses as sources of directional migration flows between origins and destinations at different spatial scales since these have been selected for the analyses reported in Chapters 4-7. Census transition data were preferred to movement data from the National Health Service Central Registers (NHSCRs) because of their reliability, accuracy, coverage (across the UK) and availability at small area level. Consideration was given to using internal migration data from the 1981 and 1991 Census returns but problems of geographical and definitional consistency arise. Changing geographical boundaries have always been a major problem when it comes to time series analysis of census data (Martin et al., 2002), as exemplified by the change from enumeration districts in 1991 to a new output area geography in 2001. One important definitional change between 1991 and 2001 is the way in which students have been counted and reported in the two censuses: students (those living away from home in higher or further education and at boarding schools) were identified at their place of study in 1991 and not included in the Special Migration Statistics (SMS) whereas the census question changed in 2001 to ask about the place of usual residence in addition to place where present at the time of census. For many migrants, the usual residence of respondents and their place of residence on census day will be the same but this is clearly not the case for students living away from the parental domicile.

The requirement to maintain geographical and definitional consistency was deemed important in order to compare migration intensities and patterns across the UK in the two census periods, 2000-01 and 2010-11. Whilst several comparative analyses based on data from the 1981 and 1991 Censuses have been reported (Champion, 1994; Bracken and Martin, 1995; Boyle and Shen, 1997; Boyle and

Feng, 2002), the systematic comparison of internal migration presented in Chapter 4 at district level is the first based on census data for the 2000s.

The 2001 and 2011 Census data have also been used to portray the MAUP and examine the scale and zonation effects associated with internal migration in Chapters 5-7. Whilst there is an argument to suggest that the purpose of the IMAGE Studio is to make comparisons between indicators at various scales based on different sets of Basic Spatial Units, running the IMAGE Studio is relatively time-consuming (depending on the chosen stepwise aggregation and number of iterations at each scale – see section 5.3 in Chapter 5) and it is therefore necessary to select input data that are appropriate for the limited amount of time and resources that are available. Choosing matrices of 404*404 for 11 age groups for two time periods equates to 404*404*11*2 = over 3.5 million cells, a substantial amount of data.

This chapter begins with a discussion of the distinction between data on migration stocks and flows available from different sources before presenting a comprehensive review of what origin-destination flow data are available from population censuses. In addition, sources of aggregate data on migration inflows and outflows are considered because these data will provide further insights into migration behaviour; theses data sources are shown to provide a good understanding of what data are available but will not be used in the analysis of this thesis. The chapter introduces the geographies that have been selected as the 'basic spatial units' for the national and regional analysis of scale and zone effects and also provides an explanation of methodology used to adjust the migration data for 2001 to account for those migrants with unknown origins in the first census period. The chapter finishes with some conclusions that summarise how the data selected will serve to fulfil the research objectives stated in Chapter 1.

3.2 Stocks, Flows and Sources

One important distinction when considering the analysis of migration data is that between migrant stocks and migration flows, a crucial step when working with migration statistics at any spatial scale (United Nations Economic Commission for Europe, UNECE, 2011). Stocks of migrants may refer to the number of migrants living within a country, and are fairly simple to obtain by counting the number of people within a country at a given point in time that have either moved into that country from elsewhere in the world (immigrant stock) or that have moved within the country (internal migrants). Migration flows, on the other hand; refer to the counts of migrants entering the country, leaving the country or moving within the country over a given period of time. Abel and Sander (2014) suggest that when undertaking international migration research, data on flows, particularly between specified locations, are more challenging to assemble that data on migration stocks. UN researchers and policy makers have been struggling to gather and assemble accurate counts of where people are moving to and from. Stockton (2014) states that there are many difficulties when obtaining data for some countries especially, though by no means entirely, for those countries outside the European Union. Counts of migration flows are available in various countries, for different time periods, estimated using different methodologies, but for cross-national or time period studies, a consistent and uniform methodology for migration estimation is required (Stockton, 2014).

There are multiple sources of migration data, which can be broadly classified as population censuses, sample surveys, administrative records and other sources. The UNECE (2013) and recent cross-national survey work by Bell et al. (2015a) report that population censuses are the main sources of more reliable data on migration patterns. Censuses are not only useful for providing data to analyse international migration trends, but also to perform internal migration analysis, as the census records the location of an individual, usually one or five years before a census enumeration. Population censuses allow researchers to obtain demographic data usually of good quality, with a coverage of the migrant population and with relatively uniform types of questions, as this is crucial for data comparability between multiple censuses (UNECE, 2013) when international comparisons are attempted. The uniformity of census data occurs because censuses collect information about the demographic and socioeconomic characteristics of the population, such as age and occupation and disaggregation based on these characteristics is often applied to migrant populations.

Sample surveys, such as household surveys and passenger surveys performed at the border, also provide data on migration. Household sample surveys (e.g. British Household Panel Survey and International Passenger Survey) tend to cover a wide range of characteristics of individuals living within a household, whereas passenger surveys are used for international migration; for both types of survey, the larger the population sample, the more confidence can be placed in the data and the results that are derived through analysis (UNECE, 2013). The drawback of surveys is mainly the high cost, and the difficulty in reaching enough people to make the sample size sufficient to generate reliable results. In the UK, a well-used survey for capturing international migration is the International Passenger Survey (IPS), used by ONS for preparing the mid-year population estimates. However, the IPS has many documented weaknesses, tying into the wider argument about a lack of reliable data available uniformly and the IPS has therefore been described as ‘not fit for purpose’.

Migration data can also be extracted from administrative records. According to UNECE (2013), these records can be divided into three categories administrative registers, border collection data and other administrative sources. Administrative registers consist of population registers, registers of foreigners and different types of registers for particular groups of people, such as asylum seekers. Administrative registers can therefore only be useful to identify international migrants based on the change of country within those records. Border collection data relates to data collection at various locations, such as airports and any other cross country ports, where the records collect the information when someone enters or leave the country and is therefore only usable for international migration research (UNECE, 2013).

One of the most well-known administrative sources of data for internal migration in the UK are National Health Service Central Registers (NHSCRs). Patient re-registration data have been available for some time (see, for example, Ogilvy, 1980; Devis and Mills, 1986). A detailed account that explains what NHSCR data are and compares NHSCR data with census data is contained in Boden et al. (1992) and various studies reporting the results of analysis of NHSCR data in the 1980s and 1990s are given in Rees and Boden (1992), whilst other studies include Stillwell (1994) and Stillwell et al. (1992; 1995). More recent papers making use of NHSCR data for time series analysis include Lomax et al. (2013), Champion and Shuttleworth (2016a; 2016b) and Lomax and Stillwell (2017), and their use in modelling research is exemplified by Fotheringham et al. (2004).

A key conceptual difference between NHSCR data and census data is that the former are counts of moves or migrations whilst the latter are counts of migrants. Consequently, NHSCR data will include multiple and return moves whereas census migrants have to be in existence throughout the 12 months prior to the census. The data as released by ONS NHSCR are one-year transition data so fundamentally are similar to the Census data: they record a migration where the address one year ago is different (even if there have been multiple moves in the year). The data are constructed from annual and quarterly NHS data (PRDS and NHSCR) but the released data are transitions. Potentially, the NHSCR data provide an alternative data set for analysing scale and zonation effects in this thesis but census data are preferred for a complete UK analysis because of the issues and extensive work involved in estimating flows between districts within Northern Ireland and Scotland and between the districts in these countries and districts in the rest of the UK (see Lomax et al., 2013). NHS patient register-based internal migration estimates at the local authority district level are produced by the ONS and are disaggregated by age and sex and cover all years from 2011 to 2018 (Available at https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/migrationwithintheuk/datasets/internalmigrationbyoriginanddestinationlocalauthoritiessexandsingleyearofagedetailedestimatesdataset). However, these data sets are disregarded because the use of census data provides ample data for comparing the two time points across the UK, and they provide consistency for undertaking small area analysis below LAD scale.

There are other reasons for not choosing to use NHSCR patient re-registration data. One reason relates to the objective of investigating internal migration in one region that requires a more spatially disaggregated data set. No intra-district movement data is available from NHSCR/Patient Registration System, whereas reliable ward to ward flows are available from both 2001 and 2011 Censuses with some age breakdown, as indicated in the next section. Furthermore, on a practical level, the volume of data for annual time series analysis based on NHSCR records would have been too extensive for running with the IMAGE Studio when time and resources were limited.

There are various other sources of internal migration data ranging from the records kept by national companies on housing transactions (e.g., Nationwide Building Society or Zoopla); Zoopla, for instance, have attached Royal Mail Forwarding Address data to some transactions (Lomax, 2016a; 2016b). These usually refer only to movers who are classified as owner occupiers, and to data created digitally through the use of global positioning systems built into mobile phones, although the tendency has been for them to be used to provide a better understanding of shorter-term (daily) commuting mobility rather than changes of usual residence (Van Acker et al., 2010).

Once the data have been collected from whichever of the sources identified above, they must be put into a usable format. During this process the data cleaning/cleansing will be performed in order to identify and remove errors and inconsistencies from the data to enhance the overall data quality (Rahm and Do, 2000). Errors and inconsistencies within raw files or large databases are caused by null and void data, missing information or misspellings during the data entry process. When multiple sources are used, or when a data collection becomes larger, the need for a data cleaning process increases considerably (Rahm and Do, 2000). This is due to redundancy within the data sources. In order to obtain accurate and reliable data, consolidating with different data sources and removing duplicate information becomes essential (Rahm and Do, 2000). Data cleaning requires multiple stages, from verification to transformation and backflow of cleaned data, also known as data analysis. Data analysis is essential to detect and solve errors and inconsistencies; but a manual inspection of the data or taking a sample of the data, or using an analysis programs, is crucial to obtain metadata about data properties and to detect data quality issues (Rahm and Do, 2000). The stages involved in processing of raw data collected in the 2011 Census and assuring quality in the outputs are summarised in Compton et al. (2018) and Martin and Compton (2018) respectively.

3.3 Origin-destination migration flow data

Whilst data on migration stocks and on migration inflows to and outflows from the zones in a system are useful in helping us to understand migration, the most valuable information comes when both the origin and destination of the migration flows are recorded, the so-called origin-destination migration data. It is data of this type that are used in this thesis and the principal sources of data used come from the 2001 and 2011 UK Censuses of Population.

Before data selection can take place, it is important to review what attribute data are available from both censuses at different spatial scales. The migration flow data from the 2001 Census are summarised in Table 3.1 which shows the scales at which origin-destination flow matrices are released by the (ONS), the particulars of each data set (or table) and their respective territorial coverage. These data are available online from the UK Data Service via the Web-based Interface to Census Interaction Data (WICID). For example, at district scale (SMS Level 1), there are 11 data sets (10 tables) of migration data available from the 2001 Census, relating to the period of 12 months prior to census date. These data can be referred to as flows for the 2000-01 period.

Table 3.1: 2001 Census internal migration flow data

<table>
<tr><th>Origin destination scale</th><th colspan="3">2001 tables</th><th>Territorial coverage</th></tr>
<tr><td rowspan="4">District level (SMS Level 1)</td><td>Table 1</td><td>Age by sex</td><td>24 age groups by 2 sex groups. Age groups: single group for age 0 and 15, 2 year increment from age 1 to 19, 4 year increment between 20 and 89 followed by 90+</td><td rowspan="2">UK</td></tr>
<tr><td>Table 2</td><td>Family status of migrant</td><td>17 family status categories by 2 sex groups</td></tr>
<tr><td>Table 3</td><td>Ethnic group by sex (GB destinations)</td><td>7 ethnic groups by 2 sex groups</td><td>GB destinations UK origins</td></tr>
<tr><td>Table 3N</td><td>Ethnic group by sex (Northern Ireland destinations)</td><td>2 ethnic groups by 2 sex groups</td><td>Northern Ireland destinations UK origins</td></tr>
</table>

Origin destination scale	2001 tables			Territorial coverage
District level (SMS Level 1)	Table 4	Whether suffering limiting long term illness by whether in household by sex by age	Yes or No by household or communal establishment and by 2 sex groups and by age: below pensionable age, pensionable age to 74 and 75+	UK
	Table 5	Economic activity by sex	Total only by 2 sex groups	
	Table 6	Moving groups	Wholly moving households and other moving groups by 1, 2 or 3 or more people, by groups and migrants.	
	Table 7	Moving groups by tenure	3 Tenure groups by wholly moving households and other moving groups by 1, 2 or 3 or more people.	
	Table 8	Moving groups by economic activity by sex	2 sex groups by wholly moving households and other moving groups by 1, 2 or 3 or more people.	
	Table 9	Moving groups by NS-SEC of group reference person	11 NS-SEC groups by 2 sex groups by Wholly moving households and Other moving groups by 1, 2 or 3 or more people.	
	Table 10	Migrants in Scotland/Wales/Northern Ireland with some knowledge of Gaelic/Welsh/Irish	11 age groups starting from age 3 in increments of 2 years till age 14 and then increments of 4 years at age 16 till 65+	
	C0711A	Ethnic group by age	7 age groups by 7 ethnic groups	Scotland, Wales and Northern Ireland
	C0711C	Ethnic group	7 ethnic groups	England and Wales destinations and origins
	C0648	Migrants by religion	9 religious groups	

Origin destination scale	2001 tables			Territorial coverage
Ward level (SMS Level 2)	Table 1	Age by sex	16 age groups by 2 sex groups. Age Groups: single group for age 0 and 15, 2 year increment from age 1 to 19, 4 year increment between 20 and 74 followed by 75+	UK
	Table 2	Moving groups	Wholly moving households and other moving groups by groups and migrants	
	Table 3	Ethnic group by sex	2 ethnic groups by 2 sex groups	
	Table 4	Moving groups by NS-SEC of group reference person	Wholly moving households and other moving groups by 11 NS-SEC groups	
	Table 5	Moving groups by tenure	Wholly moving households and other moving groups by 3 tenure groups	
Output area level (SMS Level 3)	Table 1	Age by sex	3 age groups by 2 sex groups	UK
Postal sector level (SMS Level 2 (Scotland: postal sectors))	Table 1	Age by sex	16 age groups by 2 sex groups. Age groups: single group for age 0 and 15, 2 year increment from age 1 to 19, 4 year increment between 20 and 74 followed by 75+	Scotland
	Table 2	Moving groups	Wholly moving households and other moving groups by groups and migrants	
	Table 3	Ethnic group by sex	2 ethnic groups by 2 sex groups	
	Table 4	Moving groups by NS-SEC of group reference person	Wholly moving households and other moving groups by 11 NS-SEC groups	
	Table 5	Moving groups by tenure	Wholly moving households and other moving groups by 3 tenure groups	

Origin destination scale	2001 tables			Territorial coverage
Flows from regions to wards (C0723A)	Table 1	Ethnic group by age	7 age groups by 7 ethnic groups	UK
	Table 2	Same address one year ago	7 ethnic groups	
	Table 3	No usual address one year ago	7 ethnic groups	
	Table 4	Migrant from outside the UK	7 ethnic groups	
Flows from wards to regions (C0723B)	Table 1	Ethnic group by age	7 age groups by 7 ethnic groups	UK
	Table 2	Same address one year ago	7 ethnic groups	
	Table 3	No usual address one year ago	7 ethnic groups	
	Table 4	Migrant from outside the UK	7 ethnic groups	
Migration by religion and whether born in UK	C0946	Religion by whether born in the UK	9 ethnic groups born in or outside the UK	Wards in Greater London (with the exception of the City of London, which is included as a single area) 70 selected districts and Unitary Authorities in the South East of England The remainder of England

The migration flow data from the 2001 Special Migration Statistics (SMS) at level 1 include flows between and within districts in the UK that comprise: City of London and London boroughs, metropolitan districts, local and unitary authorities in England Wales, council areas in Scotland, and parliamentary constituencies in Northern Ireland (ONS, 2001a). The 2001 SMS level 2 data include migration flows between and within wards in the UK; wards used in SMS 2 include the Census Area

Statistics (CAS) wards in England and Wales and the Standard Table (ST) wards in Scotland and Northern Ireland (ONS, 2001b). Some smaller CAS wards were merged with larger neighbouring wards to fit within the output thresholds; besides that, CAS and ST wards are alike in every way (ONS, 2001b). The 2001 SMS level 3 data include migration flows between and within output areas (OAs) in the UK; only one data set is available disaggregated by the main demographic variables of age and sex (ONS, 2001c). Finally, data are available at postal sector level from the 2001 Census for Scotland (ONS, 2001d).

In addition to the tables released by ONS, commissioned tables of flow data meeting statistical disclosure control thresholds can also be supplied on demand to users, but obtaining custom table can be a difficult task and users need to demonstrate how this will be used and in some cases also provided a payment. The migration flow data to districts in England and Wales by religion (2001 C0648 Migrants by religion) is a custom-built data set drawn from the 2001 Census, where the migration flows are dis-aggregated into groups such as the type of religion, 'no religion' or 'prefer not to say' (ONS, 2001e). These migration tables are available for districts for England and Wales as origins and destinations (ONS, 2001e). There are two further commissioned tables of internal migration data available from WICID at district level:

- C0711A: Migrants by ethnic group and age; and
- C0711C: Migrants with no usual address and same address at the beginning of the period (2000-01) by ethnic group.

The C0711A table contains migrant flows disaggregated by ethnic group and age for the UK, with flows from LADs in the UK to LADs in England and Wales, and from LADs in Great Britain to LADs in Scotland (ONS, 2001f). Two origin destination tables can be drawn from this, one with origin in the UK with destination in England and Wales and the second table has origins from Great Britain with destinations in Scotland.

But even though there are available data of migration flows with origins in Northern Ireland and destinations in England and Wales, no destination flows are found in Scotland and no flows with destinations in Northern Ireland from the rest of the UK (ONS, 2001f). Table C0711C contains migration flows to districts in England and Wales by ethnic group, by migrants with no usual address one year before the 2001 Census took place (ONS, 2001g). This table also includes data for the number of people who were holding the same address for over a year prior to the census, classifying them as non-migrants according to the census definition (ONS, 2001g).

The data for England and Wales by age and ethnicity are available in two tables: C0723A contains region to ward migration flows; C0723B contains flows in the reverse direction (ward to region) (ONS, 2001h). These tables were commissioned to provide some information about migrants disaggregated by age and ethnic group at ward level (Stillwell, 2010). Lastly, the data for migration by religion and whether born in UK (C0946: Migration by religion and whether born in UK) are available for flows to locations in England based on their stated religion, containing 'no religion' and whether the migrant was born in the UK or not (ONS, 2001i). The available scales for this data set are based on wards in the Greater London area, except the City of London, as it is included as a single area, and on 70 specific districts and unitary authorities in the South East of England (ONS, 2001i). These sets of areas are used for both origin and destinations.

Migration origin-destination flow data from the 2011 Census are available via WICID for the single year prior to the census, the period referred to in the thesis as 2010-11. There are 56 data sets (tables), five of which are 'open' for any user to access and download and the remaining 51 are 'safeguarded', requiring ONS user registration and authentication. There are a further 127 'secure' data sets available from the ONS Virtual Microdata Laboratory (VML). Many of these tables include international flows of migrants into the UK from outside and are therefore not directly relevant to this research. Table 3.2 shows there are 23 tables with different migration characteristics across the different scale levels, 19 data sets are at district level, 3 at ward level and 1 at OA level.

Table 3.2: 2011 Census internal migration flow data

Origin Destination Scale	2011 Tables			Territorial Coverage
District level	MM01CUK (Open)	Migrants by age (broad grouped) by sex	5 age groups by 2 sex groups	UK
	MU01BUK (Open)	Migrants by age (grouped)	22 age groups no age 0, 4 year increment between 20 and 89 followed by 90+	UK
	MU01AUK (Safeguarded)	Migrants by age (single year)	115 age groups , no age 0	UK
	MM01AUK (Safeguarded)	Migrants by age (grouped) by sex	20 age groups (no age 0), 4 year increment between 20 and 84 followed by 85+, by 2 sex groups	UK

	MM01BUK (Safeguarded)	Migrants by age (grouped - mid) by sex (including those aged under 1)	23 age groups, 4 year increment between 20 and 89 followed by 90+, by 2 sex groups	UK
	MU02UK (Safeguarded)	Migrants by family status	9 family status categories	UK
	MU06UK (Safeguarded)	Migrants by tenure	6 tenure groups	UK
	MU04UK (Safeguarded)	Migrants by economic activity	9 economic activity groups	UK
	MU05AUK (Safeguarded)	Migrants by NS-SEC (detailed)	47 NS-SEC groups	UK
	MU05BUK (Safeguarded)	Migrants by NS-SEC (grouped)	15 NS-SEC groups	UK
	MU08UK (Safeguarded)	Migrants by industry	21 industry groups	UK
	MU03UK (Safeguarded)	Migrants by long-term health problem or disability	3 long-term health problem or disability groups	UK
	MU07UK (Safeguarded)	Migrants by general health	5 general health groups	UK
	MU02EW (Safeguarded)	Migrants by whether in a wholly moving household	3 moving household groups	UK
	MU06AEW (Safeguarded)	Migrants by passport held (detailed)	10 passport held groups	UK
	MU01AEW (Safeguarded)	Migrants by ethnic group (detailed)	18 ethnic groups	UK

	MU01BEW (Safeguarded)	Migrants by ethnic group (grouped)	7 ethnic groups	UK
	MU05EW (Safeguarded)	Migrants by religion	9 religion groups	UK
	MU03W (Safeguarded)	Migrants by Welsh language skills	7 Welsh language skill groups	UK
Ward level	MM01CUK (Safeguarded)	Migrants by age (broad grouped) by sex	5 age groups by 2 sex groups	UK
	MU01BUK (Safeguarded)	Migrants by age (grouped - mid) by sex (including those aged under 1)	23 age groups, 4 year increment between 20 and 89 followed by 90+, by 2 sex groups	UK
	MM01AUK (Safeguarded)	Migrants by age (grouped) by sex	20 age groups (no age 0), 4 year increment between 20 and 84 followed by 85+, by 2 sex groups	UK
OA/SA	MF01UK (Safeguarded)	Migrants	Number of persons	UK

Now that the availability of census migration data has been summarised, consistent data that are comparable between both censuses must be identified for extraction. As Table 3.3 demonstrates, there are eight data sets at district level that can be used to make comparisons between 2001 and 2011 but there is only one data set that is available from each census at the ward and OA levels.

Table 3.3: Compatibility between 2001 and 2011 Census internal migration flow data

Origin-destination Scale	2001 Tables			2011 Tables			Territorial coverage
District level (SMS Level 1)	Table 1	Age by sex	24 age groups by 2 sex groups. Age groups: single group for age 0 and 15, 2 year increment from age 1 to 19, 4 year increment between 20 and 89 followed by 90+	MM01BUK (Safeguarded)	Migrants by age (grouped - mid) by sex (including those aged under 1)	23 age groups, 4 year increment between 20 and 89 followed by 90+, by 2 sex groups	UK
	Table 2	Family status of migrant	17 Family status categories by 2 sex groups	MU02UK (Safeguarded)	Migrants by family status	9 family status categories	UK
	Table 3	Ethnic group by sex (GB destinations)	7 ethnic groups by 2 sex groups	MU01BEW (Safeguarded)	Migrants by ethnic group (grouped)	7 ethnic groups	UK
	Table 3N	Ethnic group by sex (Northern Ireland destinations)	2 ethnic groups by 2 sex groups	MU01AEW (Safeguarded)	Migrants by ethnic group (detailed)	18 ethnic groups	UK
	Table 4	Whether suffering limiting long term illness by whether in household by sex by age	Yes or No by household or communal establishment and by 2 sex groups and by age: Below pensionable age, Pensionable age to 74 and 75+	MU03UK (Safeguarded)	Migrants by long-term health problem or disability	3 long-term health problem or disability groups	UK
	Table 5	Economic activity by sex	Total only by 2 sex groups	MU04UK (Safeguarded)	Migrants by economic activity	9 economic activity groups	UK

	Table 7	Moving groups by tenure	3 Tenure groups by wholly moving households and Other moving groups by 1, 2 or 3 or more people.	MU06UK (Safeguarded)	Migrants by tenure	6 tenure groups	UK
	Table 9	Moving groups by NS-SEC of group reference person	11 NS-SEC groups by 2 sex groups by wholly moving households and Other moving groups by 1, 2 or 3 or more people.	MU05BUK (Safeguarded)	Migrants by NS-SEC (grouped)	15 NS-SEC groups	UK
Ward Level (SMS Level 2)	Table 1	Age by sex	16 Age Groups by 2 sex groups. Age Groups: Single group for age 0 and 15, 2 year increment from age 1 to 19, 4 year increment between 20 and 74 followed by 75+	MU01BUK (Safeguarded)	Migrants by age (grouped - mid) by sex (including those aged under 1)	23 Age groups, 4 year increment between 20 and 89 followed by 90+, by 2 sex groups	UK
Output Area Level (SMS Level 3)	Table 1	Age by sex	3 age groups by 2 sex groups	MF01UK (Safeguarded)	Migrants	Number of persons	UK

Table 3.3 is a crucial component for this research, as it demonstrates what variables have the potential to be used for comparison at each respective scale level between the two censuses. In summary, data sets associated with eight variables are available at district Level and with UK coverage:

- Sex
- Age
- Family status
- Ethnic group
- Limiting long-term illness
- Economic activity
- Tenure
- NS-SEC

For the purpose of this research only the age groups data set will be used, because age is a key indicator. Age analysis allows the interpretation of what type of activity a person might carry out at a given life stage. The 21 most-disaggregated age groups are as follows:

- 1 - 4
- 5 - 9
- 10 - 14
- 15
- 16 - 17
- 18 - 19
- 20 - 24
- 25 - 29
- 30 - 34
- 35 - 39
- 40 - 44
- 45 - 49
- 50 - 54
- 55 - 59
- 60 - 64
- 65 - 69
- 70 - 74
- 75 - 79
- 80 - 84
- 85 - 89
- 90 +

At ward level, only one data set is available, covering the age (in the 21 disaggregated age groups listed above) and sex variables. Lastly at the OA level, only one data set can be used to compare just the migration flows between both censuses.

As identified from the tables above, census data on internal migration are only available at specific scale levels. The lowest level demographic data available from the 2001 Census are data for OAs for the entire UK. OAs were used first in the 2001 Census. Enumeration districts (EDs) were used in previous censuses just to collect data whereas OAs were created to publish outputs and for data distribution as well as for collection (Vickers and Rees, 2006). The UK consists of 223,060 OAs as of the 2001 Census, 175,434 of which are in England and Wales, having an average population of between 297 and 124 households. Scotland had 42,604 OAs in 2001 with an average population of between 119 and 52 households, and Northern Ireland had 5,022 OAs with an average population of between 336 and 125 households (Vickers and Rees, 2006).

Super output areas (SOAs) were implemented in order to advance reporting capabilities of small area statistics based on clustered OAs (ONS, 2012a). Two different kinds of SOAs were made available, lower level SOAs (LSOAs) and middle level SOAs (MSOAs) for England and Wales. Scotland's equivalent for LSOAs are data zones (DZs), and the MSOA equivalents are intermediate geographies (IGs); Northern Ireland has data only for LSOAs (ONS, 2012a). LSOAs have a minimum population of 1,000 up to a maximum of 3,000, with a minimum number of households of 400 up to a maximum of 1,200; MSOAs must have a minimum population of 5,000 up to a maximum of 15,000, with a minimum number of households of 2,000 up to a maximum of 6,000 (ONS, 2012a). In 2001, there were 32,482 LSOAs in England, 1,896 LSOAs in Wales, 6,505 DZs in Scotland, and 890 SOAs in Northern Ireland (Payne and Abel, 2012). These aggregate into 6,781 MSOAs in England, 1,896 MSOAs in Wales and

1,235 IGs in Scotland (ONS 2012a). These numbers changed slightly in 2011, due to the population change, where 375 LSOAs where added to England and Wales, resulting in 32,844 LSOAs in England and 1,909 LSOAs in Wales. Also seven MSOAs where added in 2011, resulting in 6,791 MSOAs in England and 410 MSOAs in Wales (ONS, 2012a). The numbers of Census areas in 2001 and 2011 are also shown in Table 3.4.

Table 3.4: Census areas, 2001 and 2011

	Census Areas	2001	2011
England and Wales	Output Areas	175,434	181,408
	Lower level Super Output Areas	34,378	34,753
	Middle level Super Output Areas	7,194	7,201
	Local Authority District	351	346
Scotland	Output Areas	42,604	46,351
	Lower level Super Output Areas (Data Zones)	6,505	6,976
	Middle level Super Output Areas (Intermediate Geographies)	1,235	1,279
	Local Authority District	32	32
Northern Ireland	Output Areas	5,022	4,537
	Super output areas	890	890
	Local Authority District	26	26

Data source: ONS (2012a)

LADs in the UK are used to define areas for local government (Bibby and Shepherd, 2001) and include: non-metropolitan districts, metropolitan districts, unitary authorities and London boroughs in England; unitary authorities in Wales; council areas in Scotland; and district council areas in Northern Ireland. Furthermore, the geography of LADs in the UK consists of a mix of rural and urban areas, where urban areas are those LADs inhabited by a population of 100,000 or more (Bibby and Shepherd, 2001).

In 2001, England alone consisted of 354 LADs and, according to the Rural Evidence Research Centre (RERC, 2005), the structure of LADs was divided into a sixfold grouping where: 76 LADs are identified as major urban areas; 45 LADs as large urban areas; 55 LADs as other urban areas; 53 LADs as significant rural areas; 52 LADs as rural-50; and lastly 73 LADs were classified as rural-80. RERC (2005) advice is to use this six-fold classification of LADs for data presentation and analyses. RERC (2005) also aggregated the LADs into three categories: predominantly urban, which consists of major, large and other urban areas; significant rural: and predominantly consisting of rural-50 and rural-80. This classification is based on the geographical pattern and location of LADs and the characteristics of natural settlement within them (Champion and Shepherd, 2006).

Wales consists of 37 districts, which were replaced in 1996 by 22 unitary authorities (UAs) with the accountability for all the services of local government (ONS, 2015b). Scotland consisted of 32 council areas in 1996, which originated from nine regions and 53 districts whose councils were unitary administrations with accountability for all local government services (ONS, 2015c). Northern Ireland consists of 26 district council areas (DCAs) based on the six historical counties: Antrim, Armagh, Down, Fermanagh, Londonderry and Tyrone (ONS, 2015a).

The following table will help summarize the available scales within the UK. Some of the above described LAD levels for the UK will match the NUTS 4 level mentioned in the previous chapter, but they do not add up in Scotland. The NUTS 4 level includes LADs in England, individual unitary authorities in Wales; individual unitary authorities or groups in Scotland; and individual district council areas in Northern Ireland (Mort, 2003). It is important to note that these levels represent the UK in 2001. When the 2011 Census results were released, some of the scale levels were updated.

Table 3.5: United Kingdom NUTS levels 1 to 5 in 2001

	England	Wales	Scotland	Northern Ireland	Total
Level 1	Government Office Regions	Country	Country	Country	
	9	1	1	1	12
Level 2	Individual counties or groups of counties/ London boroughs/ metropolitan counties/ counties/unitary authorities	Groups of unitary authorities	Groups of whole/part unitary authorities (councils) and/or local enterprise companies	Country	
	30	2	4	1	37
Level 3	Individual counties/ unitary authorities or groups of counties/ London boroughs/ metropolitan counties/ unitary authorities/ local authority districts	Groups of unitary authorities	Groups of whole/part unitary authorities (councils) and/or local enterprise companies	Groups of district council areas	
	93	12	23	5	133
Level 4	Individual London boroughs/metropolitan districts/ unitary authorities/ local authority districts	Individual unitary authorities	Individual or groups of whole/part unitary authorities (councils) and/or local enterprise companies	Individual district council areas	
	354	22	41	26	443
Level 5	Wards	Wards	Wards	Wards	
	8,442	865	1,247	582	11,136

Data source: ONS (2005)

3.3 Migration data from the aggregate statistics

Whilst migration flows between origin and destination areas are available from the 2001 and 2011 Censuses in tables that comprise the Special Migration Statistics (SMS), migration data are also released as part of the aggregate statistics tables with the following components:

- Lived at same address one year ago
- Lived elsewhere one year ago; within same area
- Inflow: Total

- Inflow: Lived elsewhere one year ago outside the area but within 'associated area'
- Inflow: Lived elsewhere one year ago outside the 'associated area' but within the UK
- Inflow: Lived elsewhere one year ago outside the UK
- Outflow: Total
- Outflow: Moved out of the area but within 'associated area'
- Outflow: Moved out of the 'associated area' but within the UK
- Net migration within the UK

These tables therefore provide data on inflows and outflows at different spatial scales rather than data on inter-area flows as described above. The 2001 Census data do not provide the same migration data set found in the 2011 Census. The Key Statistics data sets must therefore be used in 2001 to have some comparative data. Table 3.6 shows the compatibility of the 2001 and 2011 census of aggregated data.

Table 3.6: Compatibility 2001 and 2011 Census of aggregated data

Origin-destination Scale	2001 Tables	2011 Tables	Territorial coverage
Districts, Merged Wards and OA	KS002 - Age structure	UKMIG001 - Migration by sex by age	UK
	KS004 - Marital Status	UKMIG002 - Migration by family status	
	KS006 - Ethnic group	UKMIG003 - Migration by ethnic group by age	
		UKMIG004 - Migration by ethnic group by NS-SEC	
	KS021 - Households with LLTI and dependent children	UKMIG005 - Migration by long-term health problem or disability	
	KS009 - Economic activity	UKMIG006 - Migration by economic activity	
	KS014 - NS-SEC	UKMIG007 - Migration by NS-SEC	
	KS024 - Migration	UKMIG008 - Migration	
	KS020 - Household composition	UKMIG009 - Household migration by household composition	
	KS018 - Tenure	UKMIG011 - Household migration by tenure	

3.4 Other Census data

Besides aggregate migration data or origin-destination data, the 2001 Census also entails a plethora of tables, grouped into different categories. The Key Statistics category for example, consists of 33 tables and holds summary figures for a range of topics such as economic activity, industry of employment and household composition. These data can be obtained at different geographical scales, from national level down to very small census output areas.

In the Univariate Tables category, 64 tables can be found, providing insights about single census topics. These tables provide very detailed information from the census about a specific topic, for instance: qualifications, time since last worked, distance travelled to work, approximated social grade and number of people living in households. These figures can be also obtained at different geographical scales, from national level down to very small census output areas.

Within the Census Area Statistics category, 80 tables crosstabulate two or more topics. Age by sex and resident type, economic activity by sex and limiting long-term illness, sex and occupation by employment status and hours worked and also sex and age by distance travelled to work are amongst other topics. The data held in this series of tables contain a minimum population threshold of 100 persons and 40 households, in order to produce geographic scales at output areas and higher.

The ST category holds 115 tables, which also cross tabulates two or more topics, but have data available from wards level and higher. Having 115 tables to choose from allows having more detailed data at lower scale levels. Some of these topics include: age of household reference person (HRP) by sex and marital status (headship), schoolchildren and students in full-time education living away from home in term-time by age, general health and limiting long-term illness and occupancy rating by age and also shared/unshared dwelling and central heating and occupancy rating by religion of household reference person.

The CAS Theme Tables category is the smallest one with only 9 tables. This category holds information regarding multiple topics about a particular theme combined into single tables for output areas and above. Examples include: theme table on all dependent children in households, theme table on people aged 50 and over and theme table on religion.

The last category in the 2001 census is the Standard Theme Tables. With 19 tables, this category shows a variety of subjects about a particular theme joined in single tables for facilitating referencing. Amongst others are: Theme table on dependent children, Theme table on resident, workplace and daytime population and Theme table on religion of all dependent children in households (Nomis, 2014a).

The 2011 census data also entails a multitude of categories. Starting with the key statistics having 27 tables, such as; National identity, Household composition and Hours worked.

These data are available from national level down to the very small census output areas. Similarly to the univariate tables category in 2001, the Quick Statistics category with 75 tables contains information about single census topics, household life stage, households by deprivation dimensions and long-term health problem or disability to name a few. These tables provide the most detailed information available from the 2011 census and is available from output areas to the national level.

Exactly 203 tables can be found in the Local Characteristics category, which crosstabulates two or more topics, with a minimum population threshold of 100 persons and 40 households. Some of these topics are: living arrangements by age, age of youngest dependent child by family type, religion by accommodation type and country of birth by ethnic group. These tables can be obtained at output areas and higher geographies, and provide the most comprehensive data sets for output areas.

The Detailed Characteristics category is the largest one in 2011 with 228 tables crosstabulating two or more topics. Due to the combination of different topics, this category provides the most detailed reports without breaching the confidentiality of personal information, and are available from local authority to the national level. Some key topics include: marital and civil partnership status by sex by age, household composition by ethnic group of household reference person, residence type by economic activity by age and proficiency in English by general health by sex by age (Nomis, 2014b).

The Longitudinal Study (LS) and the Samples of Anonymized Records (SAR) are the two microdata sets available that are based on census data. The LS is based on linked census and life events data since the 1971 census, for a 1% sample of the population of England and Wales (Rees et al., 2002). The SAR is available for the 1991 and 2001 Censuses and is a parallel resource to the 2011 SARs (Wathan et al., 2017). The census microdata are made available to help improve data analysis while protecting the confidentiality of the people; furthermore, these microdata have immense research potential due to the flexibility, source and size (Wathan et al., 2017). The census microdata are un-aggregated outputs made from individual records samples, containing a multitude of characteristics for each person (Wathan et al., 2017).

3.5 Population at risk

A region's population at risk (PAR) is the population used as the denominator when computing migration rates in this thesis. Since the population is not the same at the beginning and at the end of the one-year period, due to migration, births or deaths, it is important to specify which point in time the PAR refers to. The problem is that whilst the end-of-period population is easily available from the published census results, it does not necessarily represent the actual population at risk of migration during the pre-census period. There is an argument to suggest that the start-of-period population is more appropriate since it includes all those individuals who changed address during the period as well as those who died during the period, though it does not include those who immigrated or who were born during the period. Rees et al. (2000) suggest that, in theory, a mid-period population is the best option, estimated for each region as:

$$\mathrm{PAR} = \frac{1}{2}\left(\mathrm{P(t)} + \mathrm{P(t+1)}\right) \tag{3.1}$$

where P(t) is the population at the start-of-period time period and P(t+n) is the population at the end of the time interval of 1 year.

Measuring migration intensities with this method, has the benefit of maintaining consistency between the numerator and denominator, especially if migrants and non-migrants are identified in the same data set (Rees at al., 2000). The problem with using this approach for UK data is that start-of-period populations are not available and have to be estimated before the mid-period population estimates can be derived. As a consequence, this research adopts the end-of-period populations as the PARs for the zones in the selected systems on the assumption that these populations are the most reliable estimates and that the use of mid-period estimates would be likely to make very little difference to the relative intensities. The respective population counts have been downloaded from the relevant tables of the 2001 and 2011 Censuses.

3.6 Basic Spatial Units

Basic Spatial Units or BSUs are the sets of geographical units that are used throughout this thesis as inputs to the IMAGE Studio to local indicators (as used in Chapters 4 and 7) and to compute scale and zonation effects (as reported in Chapters 5-7). The selection of BSUs is dependent on the data that are available, on the one hand, but also on the constraints imposed by the software, on the other. As indicated in Chapter 5, the IMAGE Studio generates new data sets through aggregation of BSUs and this process can take a lot of computer time if the spatial scale is too fine or the number of scale steps are too large (see Chapter 5 section 5.3). For these reasons, the two sets of BSUs that have been selected for analysis of propensities and patterns and then, subsequently, scale and zonation effects are as follows:

- migration between local authority districts (LADs) within the UK in 2000-01 and 2010-11; and
- migration between wards within Greater London in 2000-01 and 2010-11.

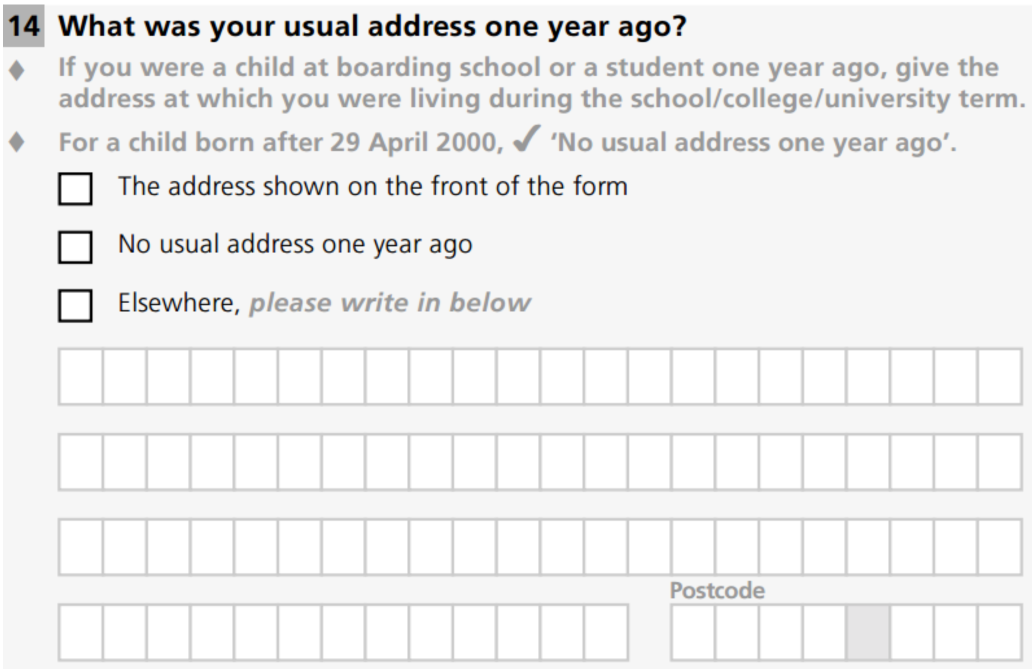
Use of the same BSUs for both periods allows for consistent geographical comparison but it is also necessary to address the problem of inconsistent definition of the migration counts obtained from the two censuses. The problem of inconsistency in the migration counts at the LAD level is considered in the next section before the selection of BSUs used for the analyses of data across the UK and for Greater London are outlined.

3.7 Achieving consistency between 2001 and 2011

3.7.1 Migrants with 'no usual address' one year before the 2001 Census and their allocation

The availability of accurate and timely data is essential for monitoring internal migration, the process which redistributes the population within a country. As mentioned previously, the most comprehensive understanding of the population's migration behaviour in the UK is attained once every ten years through the census of population, which asks respondents where they lived one year prior to the census date. By comparing respondent locations, the migration flow information can be extracted and used to build a picture of change over time, both in terms of migration intensities (Champion and Shuttleworth, 2016a) and spatial patterns of residential relocation (Lomax et al., 2014). Problems arise, however, when migration counts are not comparable between censuses. From one census to the next, there are often alterations to census questions and coverage, to the adjustment procedures or to the way in which outputs are provided; for example, there may be changes in age bands for which the data are produced, the way the data are treated to avoid disclosure, and boundary changes which make spatial comparison tricky. This section of the chapter deals with a very specific issue that makes the published 2001 Census migration data incompatible with the migration data released from the 2011 Census and necessitates some form of adjustment if the two data sets are to be compared. The problem relates to the way in which some respondents reported their place of residence one year ago in the two censuses.

In the 2001 Census, a migration was recorded using the response given by the household reference person to a question asking: 'What was your usual address one year ago?' One possible response was 'no usual address', intended to identify only 'a child born after 29 April 2000', who would not have been in existence on that date (ONS, 2014). However, this question caused substantial confusion amongst respondents to the 2001 Census, with many household reference persons ticking the 'no usual address' response for themselves or for other members of their household who were not aged under one at the time of the census. Figure 3.1 shows how the question was presented in the 2001 Census, with a bold header but fairly indistinct grey instructions before the tick box options.



14 What was your usual address one year ago?

- If you were a child at boarding school or a student one year ago, give the address at which you were living during the school/college/university term.
- For a child born after 29 April 2000, ✓ 'No usual address one year ago'.

☐ The address shown on the front of the form

☐ No usual address one year ago

☐ Elsewhere, *please write in below*

Postcode

Source: SASPAC (2001)

Figure 3.1: Question 14 from the 2001 Census questionnaire

As a result of this confusion, 467,036 individuals were identified as having 'no usual address one year ago' in the 2001 Census return (ONS, 2001j). Of these, an estimated 463,605 (99.27%) were aged one year or over at the time of the 2001 Census, so should have been included with some origin stated, either within or outside the UK. This confusion and the resulting over-count of people meant that the 'no usual address' (NUA) response was removed for the 2011 Census (ONS, 2012b). The NUA problem with the 2001 Census has been recognised and discussed previously by Champion (2005), Stillwell et al. (2007) and Lomax (2013), but to date no definitive solution has been offered for allocating the NUA migrants to origin areas to provide an adjusted set of intra- and inter-district flows for 2000-01.

The methodology outlined here estimates the origins of those people who should not have been identified as having NUA in the 2001 Census returns so as to compile complete sets of migration flows for the UK for 11 age groups which are comparable to equivalent data for 2010-11. The data used are outlined first of all, followed by an explanation of the estimation methodology.

3.7.1.1 The data on NUA migrants

There are a number of data tables in the 2001 Census where an origin of 'no usual address' was reported, all of which are part of the Special Migration Statistics (ONS, 2001b) available to download from the UK Data Service-Census Support Flow Data portal. The NUA problem is one that permeates through the hierarchical geography of the UK census, from region down to Output Area. Table 3.7 outlines the key tables affected.

Table 3.7: Tables from the 2001 Census where a migrant origin of 'no usual address' was reported

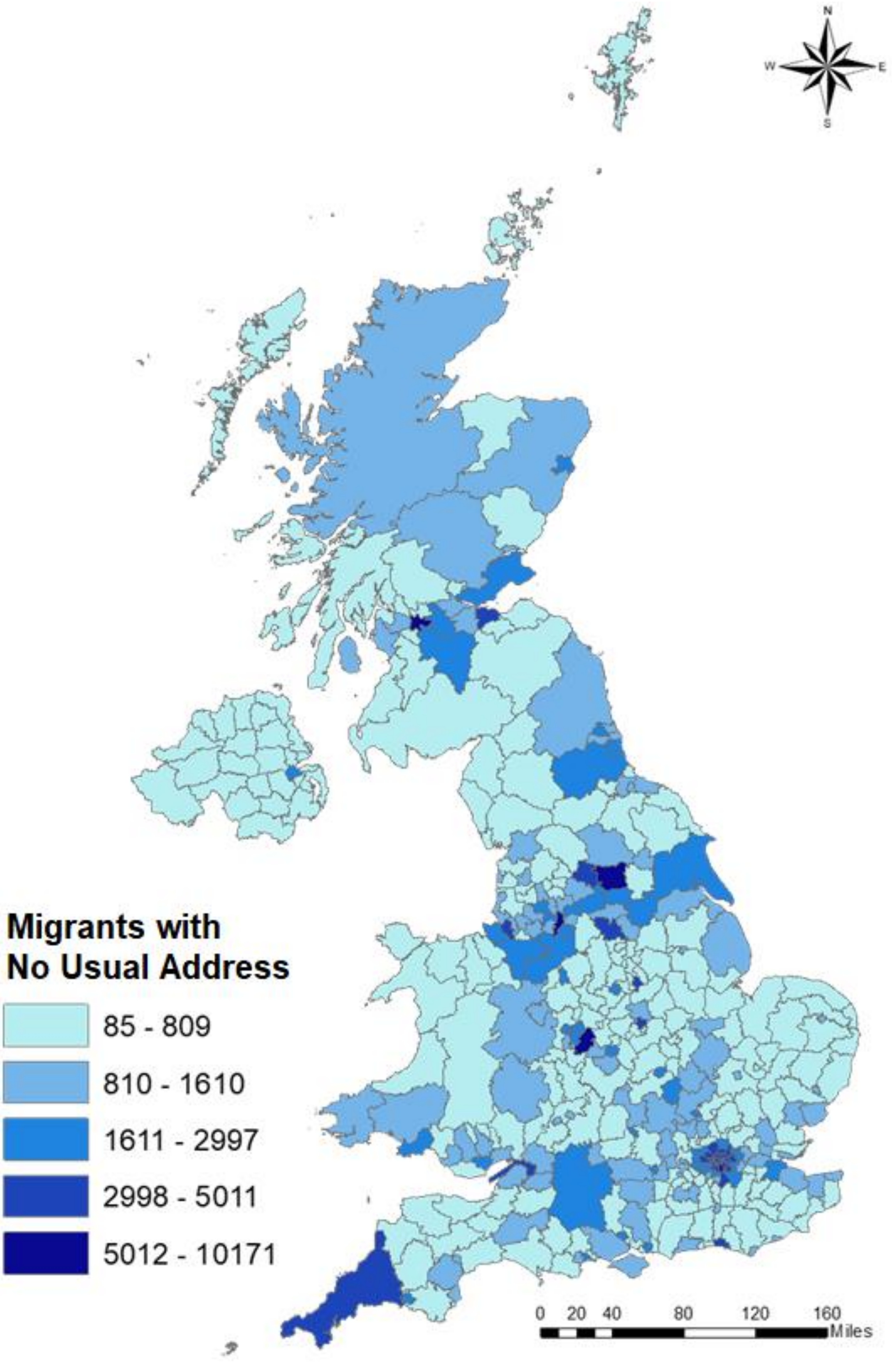
Table code	Table name	Variables available in table
MG101	District Level Migration	Table 1 Age by sex Table 2 Family status of migrant Table 3 Ethnic group by sex (GB destinations) Table 3N Ethnic group by sex (Northern Ireland destinations) Table 4 Whether suffering limiting long term illness Table 5 Economic activity by sex Table 6 Moving groups Table 7 Moving groups by tenure Table 8 Moving groups by economic activity by sex Table 9 Moving groups by NS-SEC Table 10 Migrants in Scotland/Wales/Northern Ireland with some knowledge of Gaelic/Welsh/Irish
MG201	Ward Level Migration	Table 1 Age by sex Table 2 Moving groups Table 3 Ethnic group by sex Table 4 Moving groups by NS-SEC Table 5 Moving groups by tenure
MG301	Output Area Level Migration	Table 1 Age by sex

Source: UK Data Service

To exemplify the allocation methodology, Table 1 of MG101 will be used, providing the LAD of origin for migrants, with an additional count for those who stated 'no usual address' twelve months previously. There is a complete record of the LAD destinations of migrants reported in MG101. The migration flow data are available disaggregated by age and sex, but for the purposes of the estimation, only age disaggregation has been used. The age groups reported in MG101 have been aggregated to

11 age groups to facilitate reporting and comparison with 2011 data. While the approach presented here is specific to the age bands used, it can be used to estimate migrants with NUA for other tables from the Special Migration Statistics.

To exemplify the spatial distribution of the NUA migrant problem, Figure 3.2 shows the total number of migrants reported in the 2001 Census who stated that they had NUA one year ago across all 404 LADs in the UK. The highest number of NUA migrants can be seen in Birmingham, where 10,171 migrants did not disclose an origin. The big city districts of Glasgow, Manchester and Leeds all have between 6,281 and 6,830 migrants with NUA stated. The LADs with the lowest number of NUA migrants are the most rural areas such as Moyle, the Orkney Islands and the Shetland Islands, all areas of low in-migration.



Source: Estimates based on data from 2001 Census

Figure 3.2: The distribution of No Usual Address migrants in the UK by LAD, 2000-01

3.7.1.2 Estimation method

This section outlines the method used to estimate the origins of NUA migrants in the 2001 Census. Figure 3.3 is a conceptual diagram indicating the origin-destination migration matrix with n = m districts. All district destinations (j) are columns of the matrix while origin districts (i) are rows. The sum of a column of cell values (Dj) is the total migration into district j, while the sum of a row of cell values (Oi) is the total migration out of district i. All cells on the diagonal of the matrix are intra-LAD migration flows (i.e. moves which occur within the district) whilst all off-diagonal cells contain inter-district flows.

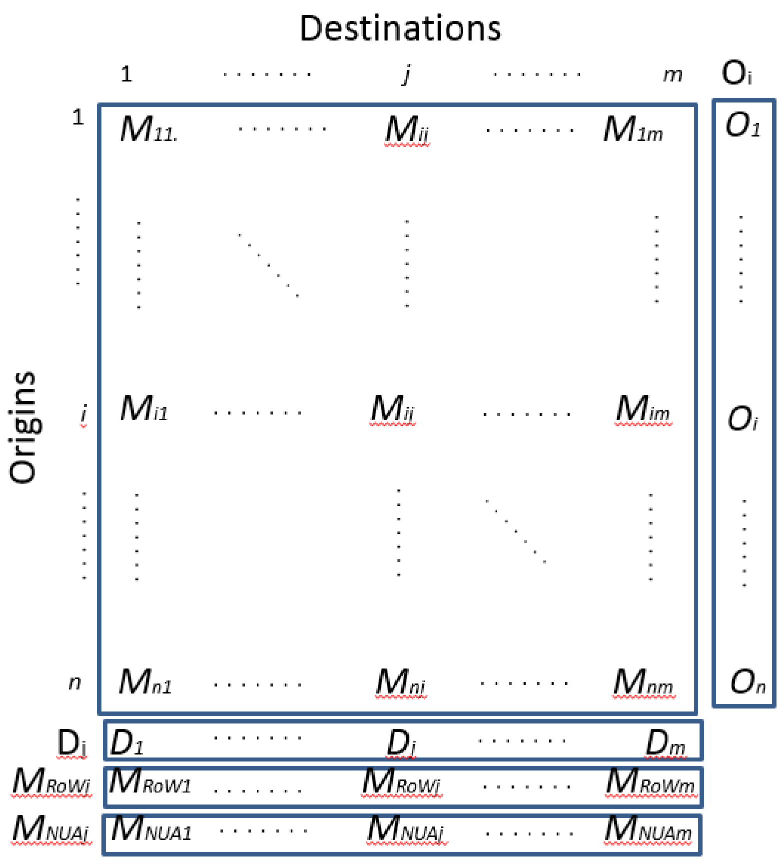


Figure 3.3: The conceptual migration flow matrix and its marginal totals

The matrix contains all migrants who reported an origin and a destination in the 2001 Census. Two kinds of migrant (M) are indicated within the matrix in Figure 3.3:

(i) migrants with an origin and destination in the same district (intra-district flows): $M_{ij,}\ i = j$; and

(ii) migrants with an origin in a different district of the UK than the destination (inter-area flows): M_{ij}, $i \neq j$.

In addition to the flows in the origin-destination matrix, two additional types of migrant can be identified:

(iii) migrants with an origin outside of the UK and a destination district j in the UK (immigrant flows): M_{RoWj}; and

(iv) migrants with NUA year ago and a destination district j in the UK (NUA flows): M_{NUAj}.

The data for all four migrant types are needed in order to adjust the cell values of the initial matrix. Of the four migrant origins, it is only M_{NUAj} which are unknown, as these migrants could have originated from within the same LAD, from another LAD in the UK, or from overseas. The NUA migrants therefore need to be apportioned between the other three migrant types in order to accurately estimate the internal migration. The first stage of the estimation process is to apportion M_{NUAj} between the intra-LAD, inter-LAD and international origins for each LAD. Table 3.8 demonstrates the proportion of total migration which can be attributed to intra-zonal flows, inter-zonal flows and flows with origin outside the UK by age group.

Other socio-demographic-economic variables are available but were not used here since age is a key proxy for important transitions through the life course as shown by Rogers et al (1978) in the USA and more recently by Dennett and Stillwell (2010b) in the UK; this was also described in more detail in Chapter 1. Furthermore not all variables are available at ward level as required for analysis in Chapter 7. The argument to exclude male-female split is based on the evidence that suggest rates and patterns of migration are not hugely different between the sexes. The problem of matrix sparsity occurs with variables when certain categories have relatively small proportions of total flows.

Table 3.8: Percentages of migrants that are intra-district, inter-district and from outside the UK, by age group, 2000-01

Age group	Percentage of intra-zonal flows	Percentage of flows inter-zonal flows	Percentage of flows with origin outside the UK
0-4	66.11	29.39	4.49
5-9	67.04	27.99	4.97
10-14	66.40	28.40	5.20
15-19	49.68	44.55	5.77
20-24	51.66	40.67	7.67
25-34	51.78	40.53	7.68
35-44	57.66	36.34	5.99
45-59	56.70	38.15	5.15
60-64	57.15	39.00	3.85
65-74	60.14	37.11	2.74
75+	65.53	33.19	1.27
All	56.30	37.55	6.15

Immigrants therefore represent 6.15% of all flows within and into the UK, so applying this proportion to the NUA migrant total suggests that 31,476 of the NUA migrants came from overseas and the remainder (435,560) came from somewhere within the UK. The original flows in the matrix can then be adjusted upwards using the following adjustment factor:

$$\text{New } \mathrm{M_{ij}} = \mathrm{M_{ij}}\left(\mathrm{D_j} + \frac{\mathrm{M_{NUAj}}}{\mathrm{D_j}}\right) \tag{3.2}$$

where New $\mathrm{M_{ij}}$ represents the adjusted cell value in the origin-destination matrix.

Table 3.9 summarizes the results obtained after using the NUA allocation method for all age groups, where all 435,560 migrants were successfully added to the internal migration figures, excluding the 31,476 migrants who are estimated to have moved from outside the UK. The biggest impact of this NUA allocation method can be seen in the youngest age group, the 0-4 year olds, with 50,639 internal migrants were added to the known internal migration total.

Table 3.9: Summary of results of adjustment method

Age group	Original Internal migration total	Immigrants	Internal + immigration total	NUA total	NUA Internal total	Adjusted internal migration total
0-4	522,317	24,564	546,881	53,150	50,639	572,956
5-9	362,311	18,959	381,270	16,897	15,984	378,295
10-14	299,535	16,416	315,951	14,688	13,858	313,393
15-19	493,936	30,236	524,172	25,879	24,231	518,167
20-24	1,084,546	90,031	1,174,577	74,884	68,638	1,153,184
25-34	1,595,507	132,676	1,728,183	133,238	121,933	1,717,440
35-44	816,981	52,063	869,044	65,586	61,486	878,467
45-59	554,343	30,103	584,446	46,149	43,613	597,956
60-64	110,757	4,437	115,194	8,971	8,567	119,324
65-74	159,471	4,495	163,966	13,412	12,975	172,446
75+	203,295	2,624	205,919	14,182	13,969	217,264
All	6,202,999	406,604	6,609,603	467,036	435,560	6,638,559

This adjustment results in the transformation of many of the cell values from integer to real numbers and prompts the question as to whether the data should be rounded and thus represent whole persons rather than fractions of individuals. As Table 3.10 indicates, rounding to the nearest integer results in the loss of a substantial number of migrants – precisely 8,383 individuals from the all-age group matrix, for example, and higher proportions from some the matrices for older age migrants. In the case of those migrants aged 60-64, 1.29% of migrants would be lost. The other problem caused by rounding is that the sum of the migrants across all the age groups will not be the same as the total migrants in the all-age group. In fact, there is a difference of over 31,000 migrants between these totals as the rounding of adjusted flows will have a greater effect on the numbers in the age groups. Since the process of rounding the adjusted data alters the flow counts significantly, it would appear preferable to use unrounded figures.

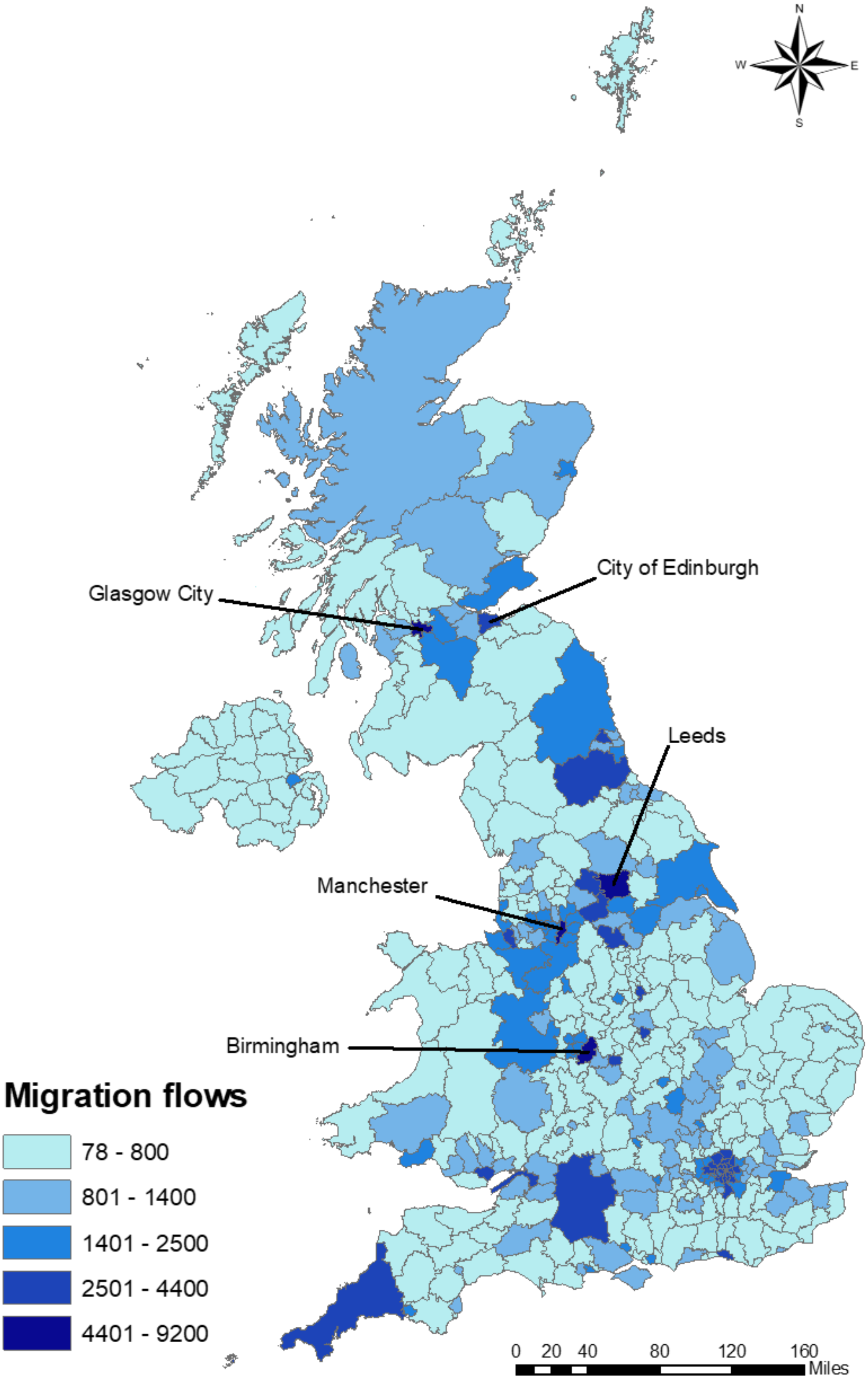
Table 3.10: Summary of effect of rounding on the adjusted values

Age group	Original Internal migration total	NUA Internal total	Adjusted internal migration total	Adjusted with rounding total	Rounding difference	Percentage difference
All	6,202,999	435,560	6,638,559	6,630,176	-8,383	-0.13
0-4	522,317	50,639	572,956	569,391	-3,565	-0.62
5-9	362,311	15,984	378,295	376,233	-2,062	-0.55
10-14	299,535	13,858	313,393	311,700	-1,693	-0.54
15-19	493,936	24,231	518,167	513,943	-4,224	-0.82
20-24	1,084,546	68,638	1,153,184	1,146,616	-6,568	-0.57
25-34	1,595,507	121,933	1,717,440	1,710,338	-7,102	-0.41
35-44	816,981	61,486	878,467	872,769	-5,698	-0.65
45-59	554,343	43,613	597,956	593,612	-4,344	-0.73
60-64	110,757	8,567	119,324	117,782	-1,542	-1.29
65-74	159,471	12,975	172,446	170,501	-1,945	-1.13
75+	203,295	13,969	217,264	215,445	-1,819	-0.84

The difference between the original and adjusted migrant numbers in within each LAD can be seen in Figure 3.4, having the biggest changes in Birmingham, Leeds, Glasgow City, Manchester and the City of Edinburgh.

Birmingham has 78,731 migrants within its boundary compared to 73,008 before applying the NUA method, Leeds has 69,067 compared to 65,533, and Glasgow City has 51,741 compared to 47,898 migrants. The smallest impact of adjustment is within LADs; in Moyle, Orkney Islands and Shetland Islands, 48 to 64 migrants where added after the NUA method was applied. The highest total in-migration flows to LADs from the rest of the UK (excluding the intra-LAD moves) after adjustment are: Birmingham, Wandsworth and Leeds. The biggest impact of the NUA method for migration to LADs can be found in Birmingham with an increase of 3,713, Glasgow City with an increase of 2,506 and Manchester with an increase of 2,330 migration flows. The smallest impact lies within Moyle, Orkney Islands and Shetland Islands with an increase varying between 31 and 42 migrants.

Figure 3.4 illustrates the different migration flow changes before and after the NUA method was applied. Figure 3.4 indicates that the biggest impact of flows within LADs after applying the NUA migrants can be found in Islington with an increase of 21%, Lambeth with 20% and Haringey with 18%. The Orkney Islands is the only LAD that was impacted the least causing an increase of 3% by adding an extra 54 migrants. The highest migration flows within LADs can be found in Birmingham, Leeds and Glasgow City, with a migration flow of 78 to 51 thousand including the 5 to 7% increase, whereas the lowest flows with LADs are Moyle, Ballymoney and Eilean Siar with less than 1,300 migration flows and a change of 6 to 7%.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 3.4: Local Authority District Migration flows change after No Usual Address estimation applied

3.7.2 Data Preparation: UK

In order to make spatial comparisons of internal migration propensities and patterns between 2000-01 and 2010-11, it is essential to have spatial units that have consistent geographical boundaries. Due to significant population changes between 2001 and 2011, the boundaries of certain LADs have changed. The data preparation for the UK at district level will therefore start by merging a small number of the 409 local authority districts (LADs) used to record the 2000-01 migration data to create a set 404 LADs used for the 2011 data. The LADs that need merging are as follows: in 2001, the City of London and Westminster formed two LADs and in 2011, they were merged into a single LAD called City of London, Westminster. In addition: North Cornwall and the Isles of Scilly merged into Cornwall, Isles of Scilly; Mid Bedfordshire and South Bedfordshire merged into Central Bedfordshire; and North Shropshire and South Shropshire merged into Shropshire. The set of 404 consistent LADs are the Basic Spatial Units (BSUs) for the nationwide analysis reported in Chapters 4-6.

The origin-destination migration flow matrices for LADs for 2000-01 and 2010-11 were extracted from WICID. The 2000-01 flows were adjusted to the 2010-11 LADs and merged to fit the following consistent set of age groups: all age, 0-4, 5-9, 10-14, 10-14, 15-19, 20-24, 25-34, 35-44, 45-59, 60-64, 65-74, 75 and over. The same adjustments have to be made to the population at risk data to ensure uniform age groups between and across all flow matrices and population counts. The geographical boundary data, the migration flow data and the populations at risk have been prepared to be entered in IMAGE Studio 1.4.2, where they will subsequently be aggregated and processed to obtain global migration indicators for aggregate spatial regions (ASRs) at different spatial scales as well local migration indicators at the BSU scale.

3.7.3 Data Preparation: Greater London

Greater London (GL) has been chosen as a case study region, to investigate the scale and zonation effects at a different scale level, using the UKs larges migration hub. Census wards have been selected as the most suitable ‘small areas’ for use as BSUs in the analysis.

Alternative definitions of the zone system were considered. Some of the results of GL from Chapter 7 will be compared with the national results in Chapter 5 and 6. With this in mind, should the national system include or exclude GL if a separate analysis with GL will take place? It was decided that an analysis of all the inter-district flows in the system would provide a comprehensive understanding of characteristics, scale and zonation effects, whilst recognising the implications for interpretation when comparing the 'national' results (that included flows between GL districts) with results relating to migration within GL.

As with the LADs across the UK, it is necessary to use a consistent set of wards across London for the two periods. In fact, one advantage of using GL is that the number of wards in GL reduced by only five from 633 in 2001 to 628 in 2011. The 2001 wards that changed their boundaries, all of which were in central London, were as follows: Portsoken, Tower, Bishopsgate, Queenhithe, Walbrook, Farringdon Without, Farringdon Within, Aldersgate and Cripplegate. These nine wards were merged into the following four wards in 2011: Aldersgate Cheap, Aldgate Billingsgate, Bassishaw Coleman Street Cripplegate and Bread Street Castle. Figure 3.5 shows an overlay map of central London which compares the boundaries of the 633 CAS wards in 2001 with the 628 CAS wards in 2011 in order to highlight the differences. The 628 wards for GL were the BSUs for the analyses reported in Chapter 7.

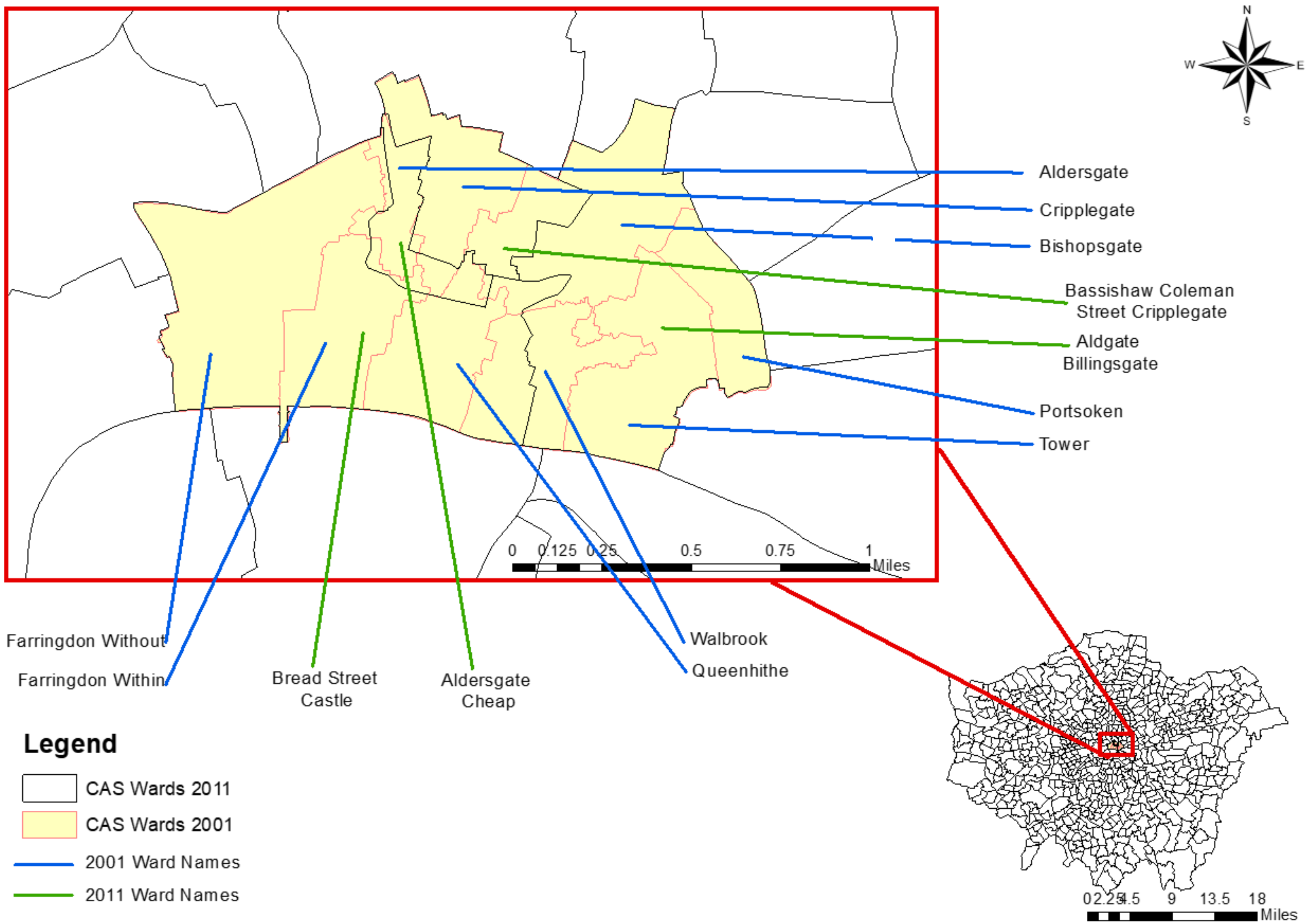


Figure 3.5: Greater London CAS wards that changed between 2001 and 2011

The following map in Figure 3.6 indicates the wards which fall into each of the 32 boroughs (LADs) of GL. Although wards are BSUs for which results are reported in Chapter 7, reference will sometimes be made to the LADs in which the wards are located.

Figure 3.6: Greater London CAS wards used as Basic spatial Units and boroughs

Greater London has been divided into two for administrative and statistical reasons: Inner and Outer London. The statutory Inner London boundary is defined by the London Government Act 1963, where local education authorities were used whereas the statistical Inner London boundary is defined by the ONS and follows the NUTS classification. For the purpose of this thesis, the boundary of the statistical Inner London will be referred to in Chapter 7. According to the ONS, Inner London is defined by the following NUTS 3 areas: Haringey and Islington; Hackney and Newham; Lambeth; Lewisham and Southwark; Tower Hamlets; Camden and City of London; Kensington and Chelsea and Hammersmith and Fulham; Wandsworth; and Westminster. Figure 3.7 shows how the Inner and Outer London areas are defined, and how the statutory and statistical boundaries differ.

Although it would be preferable to use a wider London city region because the boundaries of Greater London do not reflect London's full 'internal migration story', the wards of Greater London are chosen for practical reasons. Greater London is a familiar administrative region, making interpretation more planning-orientated and this removes the need to identify a set of other wards elsewhere in the South East that would increase the size the system of BSUs considerably and therefore extend the time taken for processing the data and increase the proportion of cells in the migration matrix with zero values.

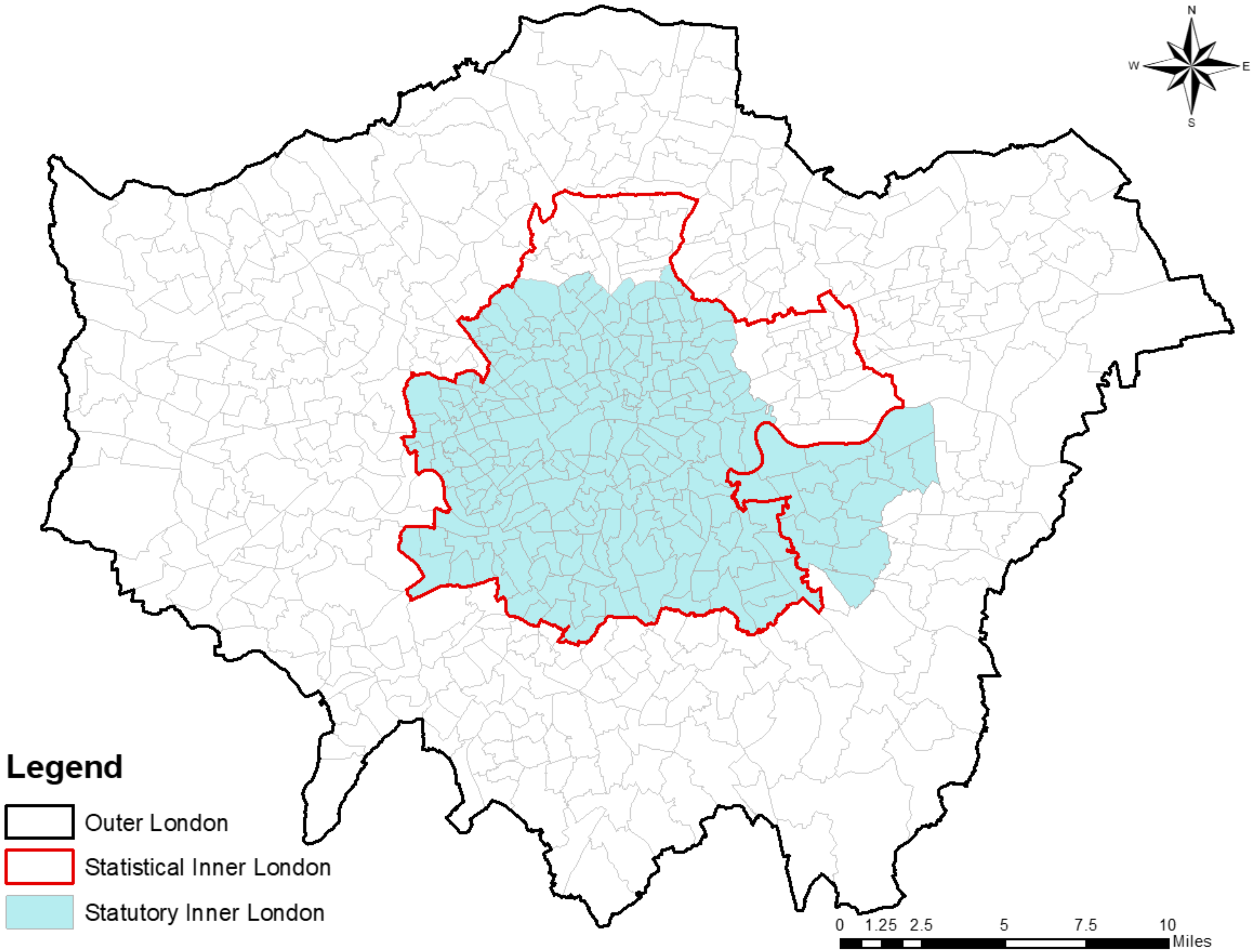


Figure 3.7: The two definitions of Inner and Outer London

Origin-destination migration flow matrices for GL wards for 2000-01 and 2010-111 were extracted from WICID and merged to fit the consistent set of 12 age groups (all age, 0-4, 5-9, 10-14, 10-14, 15-19, 20-24, 25-34, 35-44, 45-59, 60-64, 65-74, 75 and over). The same adjustments have to be made to the population at risk data to ensure uniform age groups between and across all flow matrices and population counts. However, the 2001 Census data have not been adjusted for NUA because the counts at ward level are much smaller than for LADs at the national level.

Once this is completed, the data are assembled for loading into the IMAGE Studio where local migration indicators for BSUs are computed initially and then the data are aggregated and processed to obtain 'global' (system-wide) migration indicators for aggregate spatial regions (ASRs) at different spatial scales, following a process explained in Chapter 5.

One consideration in selecting and preparing data is whether to close the system by including a 'dummy' region or regions representing the origin(s) and destination(s) of flows from and two the zones defined as constituting the system of interest. In terms of the national analysis, this might involve creating a 'rest of the world' zone and including the international flows across the UK borders. In the case of Greater London, 'dummy' regions might be defined as the 'remainder of the UK' if only migration internal to the UK was included or the 'rest of the world' if international flows were included as well. The decision was taken not to close either of the systems in this way for two reasons. The first reason is that only international immigration flows are captured by the census and there is no reporting of emigration flows to countries outside the UK. Estimates of emigration are available based on data sources that include the International Passenger Survey (IPS) but these are for mid-year time periods and help ONS estimate the mid-year populations of local authority districts. The second reason is that the IMAGE Studio software does not have the facility to identify a dummy zone or set of zones that might fulfil the function of closing the system. This is primarily because the software is designed for quantifying the scale and zonation effects on internal migration, not international migration. Neither has the software been designed for the analysis of internal migration with a single region that is part of a larger nation. Consequently, it lacks the facilities either to identify one region for aggregation whilst holding the other regions constant or to have a single 'other' region representing the 'remainder of the UK'. These issues became clear through the process of this research and suggestions for improving the software are offered in a later IMAGE Studio evaluation section. The implications of excluding flows between Greater London and the rest of the UK are indicated in the results presented in Chapter 7.

3.8 Conclusion

This chapter has reviewed the sources of the data used for the research reported in this thesis. The review has focused on the Census of Population as the key data source and has considered the different types of migration data that are available. Particular attention has been paid to the census data that are available on origin-destination flows of migrants in 2000-01 and 2010-11 since these interaction data sets are required for input to the IMAGE Studio in order to evaluate the effects of changing scale and zonation. Although there are sets of census data available disaggregated by a range of different variables, total migration flows and flows disaggregated by age group will form the main data sets in the analyses to follow, due partly to time constraints and partly to the issue of matrix sparsity with many of the matrices of flows disaggregated by other variables such as tenure or ethnicity. A method of apportioning migrants classified with no known address or origin 12 months prior to the 2001 Census has been devised and used to provide inter-LAD migration data sets that are consistent in both periods.

The selection of matrices of flows between 404 local authority districts (with consistent boundaries) across the whole of the UK for 2000-01 and 2010-11 allows the identification through analysis and visualisation (mapping) of the characteristics of all-age and age-specific migration taking place within the four home countries as well as the changes taking place between the two time periods. This analysis provides a practical means of understanding what the chosen migration indicators are actually measuring and what spatial patterns characterise the system, thus enabling the fourth objective to be achieved. This analysis also provides evidence that may prove useful when it comes to subsequent interpretation of the scale and zonation effects, and realisation of objectives five and six. Likewise, the matrices of flows between 628 wards in Greater London for the same two census-based time periods enables a clear understanding of the spatial characteristics of migration within London based on the selected indicators to be undertaken. One further reason for this selection of zones in the national and regional systems is that both geographies represent the lowest level in the census zone hierarchy for which data are published that are appropriate for input to the IMAGE Studio and for use in modelling. National ward-to-ward matrices by age group are available but these would contain very large proportions of empty cells; similarly all-age OA-to-OA matrices are available for individual region analysis but these would also be very sparsely populated, wasting a lot of time when using the aggregation facilities in the IMAGE Studio and causing difficulties when attempting to calibrate spatial interaction models.

The chapter has indicated what data sets are available from the 2001 and 2011 Censuses and has demonstrated that when it comes to making comparisons of census migration between two different time periods, 2000-01 and 2010-11, it is essential to take into account the changes that have been made to the way in which the migration data are counted and the geographical boundaries of the zones within and between which people migrate. A methodology for adjusting the 2000-01 migration data for the NUA problem has been implemented and consistent sets of boundaries of LADs across the UK and wards in GL have been determined.

Now that the data have been introduced, the adjustments have been explained and the systems of interest have been determined, the following chapters will report the analyses that have been carried out to achieve the objectives of the thesis, starting with a detailed investigation of the propensities and patterns of internal migration in the UK in 2000-01 and 2010-11 and the changes that have occurred between these two periods.

Chapter 4: Changing Internal Migration Propensities and Patterns

4.1 Introduction

The focus of this chapter is on understanding the propensities and patterns that characterised internal migration in the two 12 month periods preceding the 2001 and 2011 Censuses and to identify what changes are evident from the estimated data sets introduced in Chapter 3. Whilst undertaking the review of research carried out on internal migration in the United Kingdom (UK) in the 21st century in Chapter 2, it became clear that no empirical analysis comparing aggregate or age-specific data from the Special Migration Statistics (SMS) on internal migration between local authority districts (LADs) in 2000-01 and 2010-11 has been undertaken hitherto. The chapter therefore aims to fill this gap but also to introduce certain migration indicators used subsequently in Chapters 5 and 7. Furthermore, it identifies some of the characteristics of the spatial patterns of internal migration relating to basic spatial units (BSUs) in the two periods, since subsequent analysis of scale and zonation effects reported in Chapter 5 are based on system-wide or ‘global’ migration indicators and do not expose spatial patterns for any aggregated spatial regions (ASRs).

The chapter begins by assessing both migration intensities at national level and change between the two periods for aggregate migration and for migration by five-year age group. In doing so, it illustrates how crude migration rates are used to measure national internal migration intensity. It then goes on in Section 4.3 to illustrate the spatial variations in population and net migration change at district level by mapping patterns for four broad age groups and adopting a six-fold classification of net migration change. Migration effectiveness, a more direct measure of migration impact than the conventional net migration rate, is introduced in Section 4.4, where aggregate net migration rates for the UK are distinguished from aggregate migration effectiveness, and where changes in migration effectiveness for LADs between 2000-01 and 2010-11 are summarised using graphs.

Local authority district net migration and migration effectiveness are both measures of migration balance but, as Rogers (1990) has pointed out, there is no such thing as a net migrant. Consequently, the chapter continues in Section 4.5 with an examination of gross in-migration and out-migration components that combine to produce net migration and an analysis of the relationships between in-migration and out-migration rates for aggregate and broad age groups to confirm the extent to which migration became more or less influential on population redistribution over the 2000s. Sections 4.6 and 4.7 are aimed at understanding the volumes and rates of internal migration taking place between and within districts respectively. Maps are used to show where the largest inter-district age-specific migration exchanges are taking place in both periods and to establish the patterns of change in all-age intra-district migration. A final section contains some conclusions.

4.2 Population and migration change at national level

In order to identify what the selected data tell us about internal migration at BSU/LAD level in the UK in the two time periods, this section indicates exactly how many people are involved and how rates of migration per 100 population varied between the home nations and between age groups.

On census night 2011, the population of the UK was estimated to be 63.2 million. It had increased by 7% between the 2001 and 2011 Census dates (ONS, 2012), partly due to the changing level of fertility but largely due to the increase in the number of immigrants from abroad that reached unprecedented levels during the 2000s (Bijak et al., 2016). Total internal migration in the UK also increased from 6.64 to 6.9 million between the two census one-year periods but the aggregate crude migration intensity (ACMI) decreased by nearly 0.35%, from 11.3% in 2000-01 to 10.9% in 2010-11. The all-age statistics shown in Table 4.1 suggest that around six out of 10 internal migrants relocated to usual residences within LADs in both periods whilst the other four moved between LADs and therefore tended to migrate over longer distances. It is apparent that the intra-LAD migration rate has declined between the two one year-periods, a finding that is in line with the longer-term fall in shorter-distance migration identified by Champion and Shuttleworth (2016b) using data from the ONS Longitudinal Study for England and Wales. The rate of inter-LAD migration, referred to by Bell et al. (2015a) as the crude migration intensity (CMI) and involving movement over longer distances, has also experienced a marginal fall. According to Champion and Shuttleworth (2016a), this migration rate has tended to fluctuate up and down over the last 50 years, influenced rather more that intra-migration by changes in the state of the national economy.

Table 4.1: All-age migration in the UK, 2000-01 and 2010-11

	2000-01			2010-11		
Migration type	Flow	Share (%)	Rate (%)	Flow	Share (%)	Rate (%)
Inter-LAD	2,660,240	40.07	4.51	2,794,882	40.50	4.42
Intra-LAD	3,978,318	59.93	6.75	4,106,665	59.50	6.50
All migration	6,638,559	100.00	11.27	6,901,547	100.00	10.92

Source: Estimates based on data from 2001 and 2011 Censuses

The ACMI represents a 'genuine' measure of total residential mobility in the UK whereas the inter-LAD CMI (used in Chapter 5) is scale specific, i.e. will vary according to the particular system of BSUs being used. The extent of variation in migration volumes, ACMIs and CMIs across the four home nations and changes between 2000-01 and 2010-11 are indicated in Table 4.2. Total migration flows decreased in England by 0.05%, in Wales by 0.25%, in Scotland by 0.60% and in Northern Ireland falls by 1.07%. Within the UK, England's internal migration flows in 2000-01 involved over 5.5 million individuals compared to just over half a million in Scotland, around a quarter of a million in Wales and 140 thousand in Northern Ireland. Mobility levels are higher in England than in any or the other home nations. Crude rates of inter-LAD and intra-LAD migration declined across the board apart from migration intensities between LADs in Wales where an increase of 0.22 per 100 persons occurred, only partially offsetting the decline in the migration rate within LADs of 0.47%. The largest decline in migration intensity (1.01%) was experienced by intra-LAD migrants in Northern Ireland.

Table 4.2: All-age migration within each of the four nations, 2000-01 and 2010-11

	2000-01		2010-11		Change	
	Flow	Rate (%)	Flow	Rate (%)	Flow	Rate (%)
England						
Inter-LAD	2,238,128	4.54	2,382,473	4.49	144,345	- 0.05
Intra-LAD	3,280,841	6.66	3,430,119	6.47	149,278	- 0.19
Total	5,518,969	11.20	5,812,592	10.96	293,623	- 0.24
Wales						
Inter-LAD	43,512	1.50	52,553	1.72	9,041	0.22
Intra-AD	216,307	7.44	213,398	6.97	- 2,909	- 0.47
Total	259,819	8.94	265,951	8.68	6,132	- 0.25
Scotland						
Inter-LAD	121,349	2.39	119,127	2.25	- 2,222	- 0.14
Intra-LAD	383,976	7.58	377,200	7.12	- 6,776	- 0.45
Total	505,326	9.97	496,327	9.37	- 8,999	- 0.60
Northern Ireland						
Inter-LAD	40,001	2.37	41,709	2.30	1,708	- 0.07
Intra-LAD	97,193	5.75	85,948	4.75	- 11,245	- 1.01
Total	137,194	8.12	127,657	7.05	- 9,537	- 1.07

Source: Estimates based on data from 2001 and 2011 Censuses

The picture is not entirely complete without the flows between the four nations, for which the volumes and rates of movement are indicated in Table 4.3. The largest flows were between England and Wales and England and Scotland, whilst the highest rate was that from Wales to England at 1.56% in 2000-01 and 1.43% in 2010-11. Although the Wales to England rate decreased by 0.13 percentage points over the 10 year period, the migration rate from Scotland to England fell by 0.16 percentage points to a rate of 0.74% in 2011. The flows between Wales and Northern Ireland were low but remained constant between 2000-01 and 2010-11, and the rate between Northern Ireland and England experienced a slight increase of 0.02 percentage points. Thus, in most cases of inter-nation exchange, the flows of migrants decreased as well as the rates. The extent of the scale effect is revealed when the inter-district CMI (4.5% in 2000-01) is compared with the inter-nation CMI (0.4% in 2000-01).

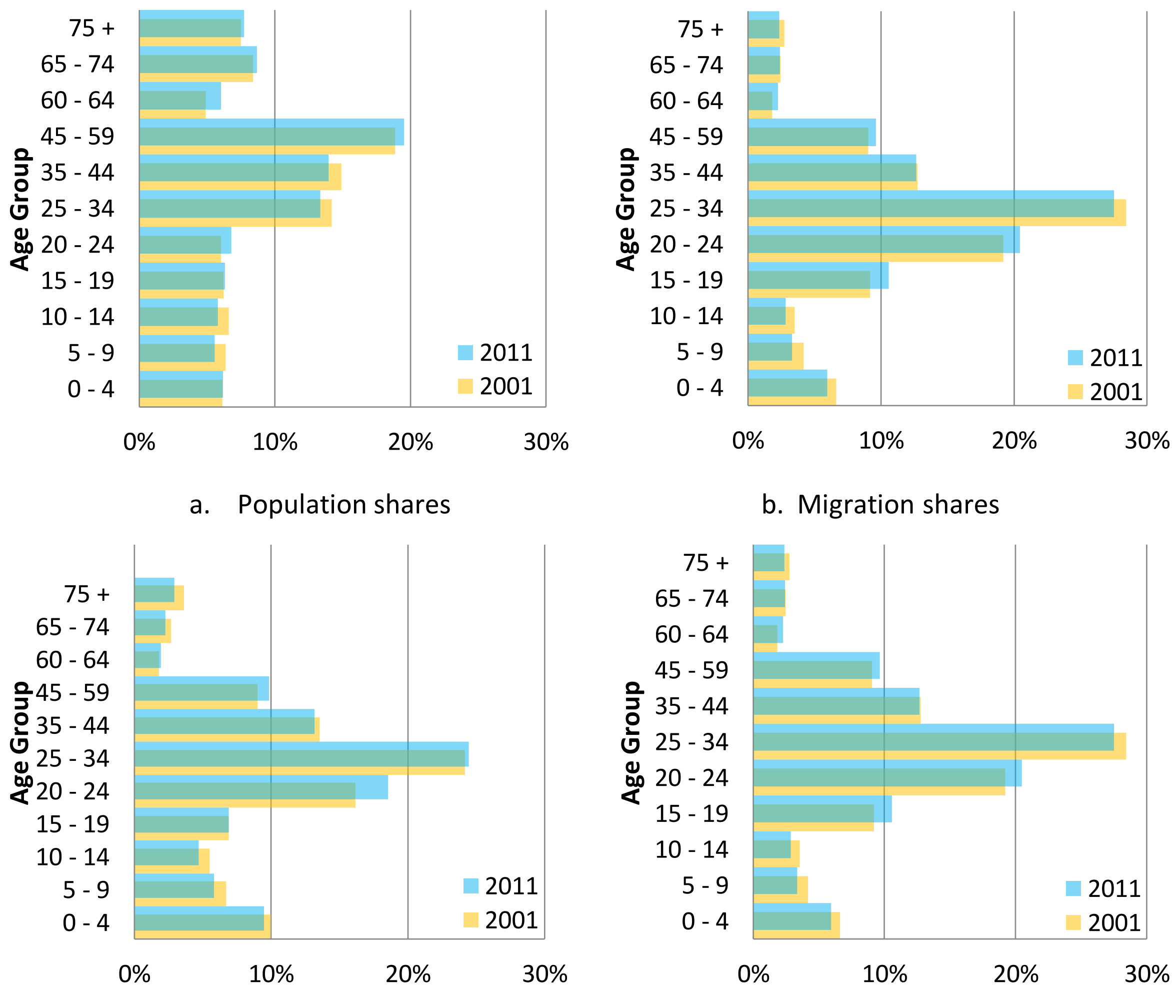
Table 4.3: All-age migration between the four nations, 2000-01 and 2010-11

Origin-Destination Flow	2000-01		2010-11		Change	
	Flow	Rate (%)	Flow	Rate (%)	Flow	Rate (%)
England - Wales	51,257	0.10	50,552	0.10	-705	-0.01
England - Scotland	46,470	0.09	37,391	0.07	-9,079	-0.02
England - Northern Ireland	8,742	0.02	8,815	0.02	73	-0.00
Wales - England	45,497	1.56	43,926	1.43	-1,571	-0.13
Wales - Scotland	1,644	0.06	1,438	0.05	-206	-0.01
Wales – Northern Ireland	304	0.01	344	0.01	40	0.00
Scotland - England	45,797	0.90	39,298	0.74	-6,499	-0.16
Scotland - Wales	1,484	0.03	1,393	0.03	-91	-0.00
Scotland - Northern Ireland	3,079	0.06	2,124	0.04	-955	-0.02
Northern Ireland - England	9,766	0.58	10,840	0.60	1,074	0.02
Northern Ireland - Wales	429	0.03	403	0.02	-26	-0.00
Northern Ireland - Scotland	2,781	0.16	2,496	0.14	-285	-0.03

Source: Estimates based on data from 2001 and 2011 Censuses

In addition to variations in migration propensities within and between nations, internal migration propensities also differ significantly between age groups, as revealed in the literature review in Chapter 2. The overall national population growth rate of 7% conceals the fact that population growth rates varied by age group; Figure 4.1a shows the age group shares of total population and how they have changed over the decade. The 45-59 year olds represent almost 19% of the UK population in 2001, increasing to 19.5% in 2011. The increasing shares of people in this age group and those aged 60 and over contrast with decline in all the other age groups apart from those aged 20-24 whose share dropped by 0.8 percentage points. The increasing elderly population due to increased life expectancy is a well-known phenomenon (ONS, Undated 2).

Figure 4.1b highlights that over a quarter of all internal migration flows in the UK are undertaken by 25-34 year olds, with a small decrease of 0.19% between the two periods. The most significant change between the 2001 and 2011 Census periods involves a nearly 2% increase in migration by 20-24 year olds, resulting in a share of over 19% in 2010-11. It can also be observed that whilst the share of migrants in the youngest and oldest age groups (0-14 and 65+ years) both experienced a decrease, the shares of migration involving 15-24 and 45-59 year olds increased. In terms of inter-LAD migration shares, Figure 4.1c shows similar patterns for all age groups observed above, including the 25-34 age groups where the migration share was 28.4% in 2001 and reduced to 27.6% in 2011. The intra-LAD migration shares (Figure 4.1d) on the other hand, show that the 25-34 age group experienced an increase from 24.2% in 2000-01 to 24.4% in 2010-11.



a. Population shares

b. Migration shares

c. Inter-LAD migration shares

d. Intra-LAD migration shares

Source: Estimates based on data from 2001 and 2011 Censuses

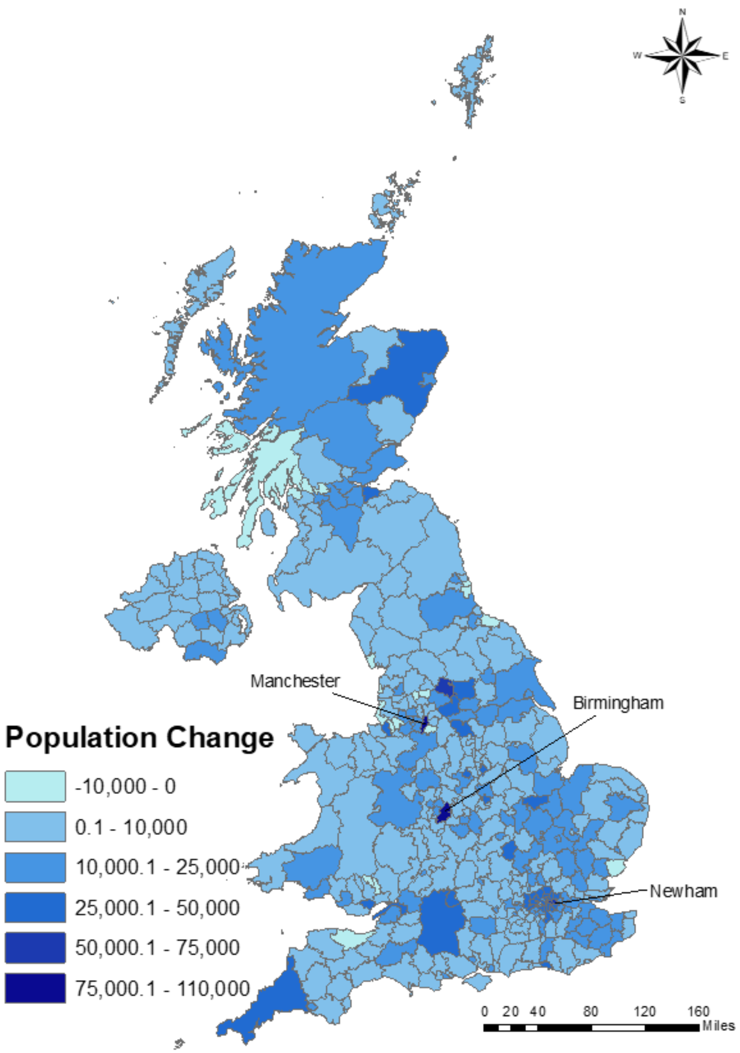
Figure 4.1: UK population and migration, by age group, 2001 and 2011

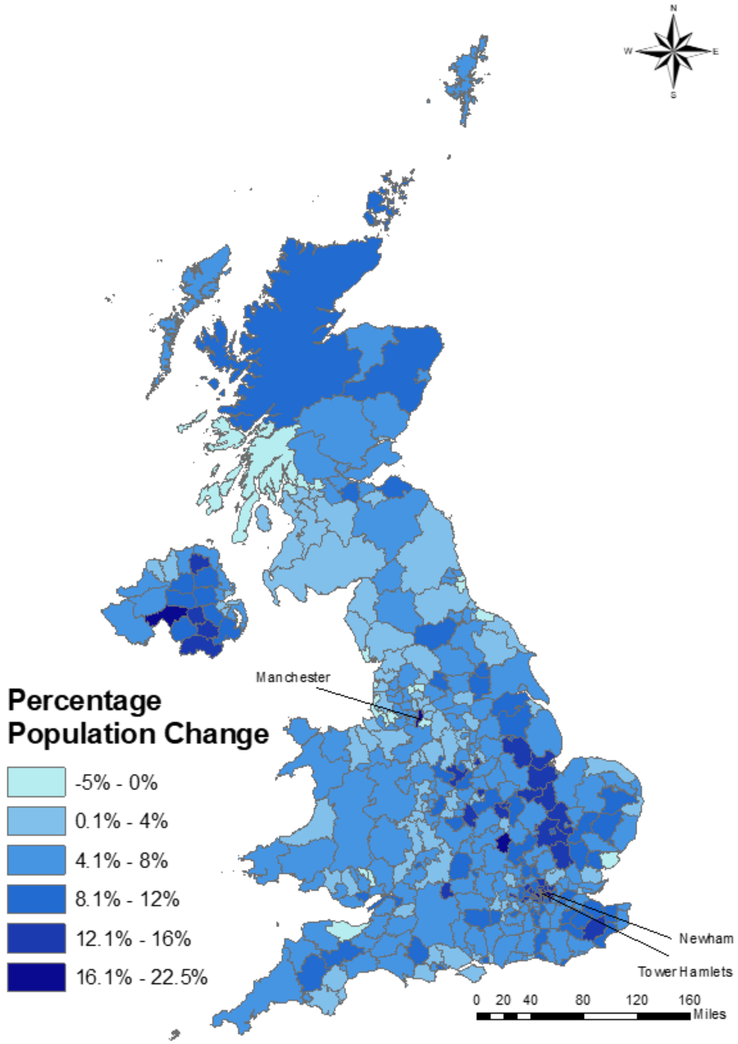
4.3 Spatial variations in population and net migration change

Having established the variations in national migration propensities by age group and the changes that are apparent between the two time periods, this section of the chapter is concerned with gaining an understanding of the spatial patterns of migration at the district level. In this context, net migration is chosen as a suitable summary indicator to explore geographical variations in migration activity and it is helpful to understand changes taking place in the light of changes in the distribution of the population.

The UK population is distributed unequally across the country at district level, with major concentrations in the big cities and large expanses of territory where population densities are very low. Outside London, the local authority districts (LADs) with the highest populations in 2001 were Birmingham (with 980,128 usual residents), Leeds (with 717,469) and Glasgow City (with 578,877). These three LADs remained the league leaders in 2011 with their usual residents increasing to 1,073,045, 751,485 and 593,245 respectively. The biggest absolute changes in population between the two censuses occurred in the two main provincial capitals, Manchester and Birmingham, and in the borough of Newham in London with increases of at least 63,000 people in each case (Figure 4.2a). The largest absolute population declines were also found in the provincial conurbation LADs of Sefton, Sunderland and South Tyneside, each with a decrease of between 5,000 and 10,000 (decreases of around 2-3%).

The biggest relative changes between 2000-01 and 2010-11, observed in Figure 4.2b, were in two of the three districts with highest absolute growth, 21% in Manchester and 20% in Newham, although both were eclipsed by the 22% increase in the population of Tower Hamlets in London. In general terms, though not exclusively, it was large towns and cities that experienced the highest relative growth, whereas Barrow-in-Furness, Argyll and Bute and Sefton were amongst the small minority of districts experiencing population declines (of 3-4% in each case). On a regional scale, it was the east and south east of England and the Midlands that experienced large percentage population increases, as did the south of Northern Ireland. In contrast, the south west of Scotland and parts of northern England saw relatively low population growth.





a. Population change b. % population change

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.2: Change in population in the UK, by LAD, 2001-2011

In order to illustrate and summarise the variation in spatial patterns of population and migration change by age group, the 11 age groups have been aggregated into four broad groups, as seen in Table 4.4, each of which represents a broad stage in the life course, as reviewed in Chapter 2. The aggregation is not ideal because of the different motivations influencing migration in each broad age group but a similar classification for aggregating the family age group was used in the MIGMOD project (Fotheringham, 2004). Couple formation and starting a family tends to begin from age 25 to 29 and raising a family from age 30 to 44. For the purpose of this thesis, the preschool/school age group of 0 to 14 year olds is included with the 'starting a family' age group as they can be classified as dependents. Similar to the MIGMOD classification, older or mature working age is classified as including those between 45 and 59 years and a 60+ year category contains those approaching and beyond retirement age (Fotheringham, 2004). The students and young workers age group are an aggregation of the 15-19 age group, an age group that includes adolescents leaving home for higher education or for first jobs, and the 20-24 year olds, which includes students leaving higher education or those moving for their working and partnership careers (Stillwell, 2005). Although a single group consisting of the 15-19 and 20-24 year olds is not be entirely appropriate, this aggregation is both convenient for summarizing the patterns but also necessary to ensure matrix paucity is avoided when modelling migration flows, as reported in Chapter 6. The aggregated groups are therefore deemed suitable for use in the UK context and for this thesis, not least because they have distinctive patterns of net migration, as shown in what follows.

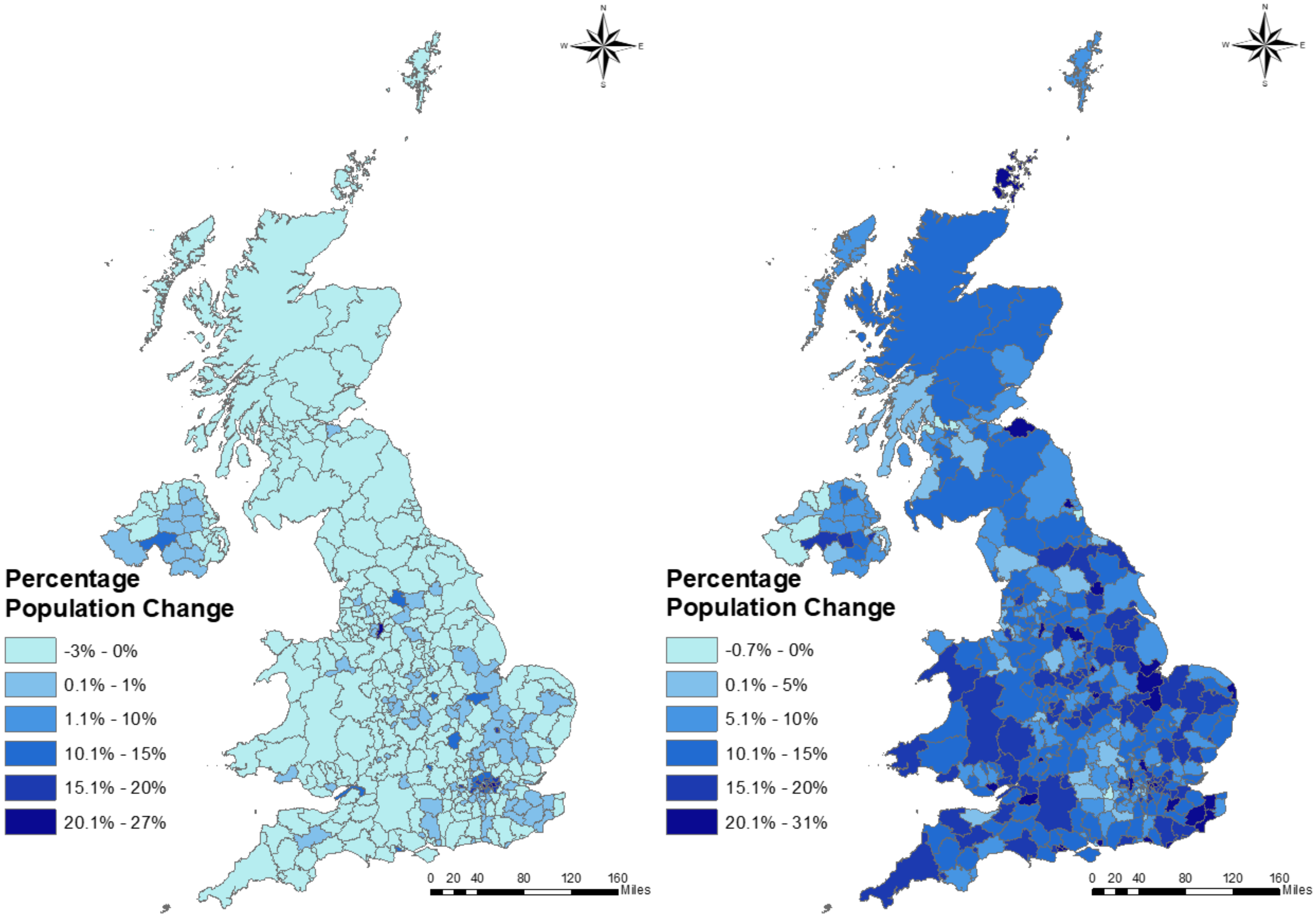
Table 4.4: Migrants in broad life course age categories

Definition	Age group	Migration in 2000-01		Migration in 2010-11	
		Flow	Share (%)	Flow	Share (%)
Family	0-14 & 25-44	3,860,885	58.15	3,826,550	55.44
Students and young workers	15-24	1,671,352	25.18	1,912,738	27.71
Mature workers	45-59	597,956	9.01	673,548	9.76
Retired	60+	509,034	7.67	488,711	7.08
Total	All age	6,638,559	100.00	6,901,547	100.00

Source: Estimates based on data from 2001 and 2011 Censuses

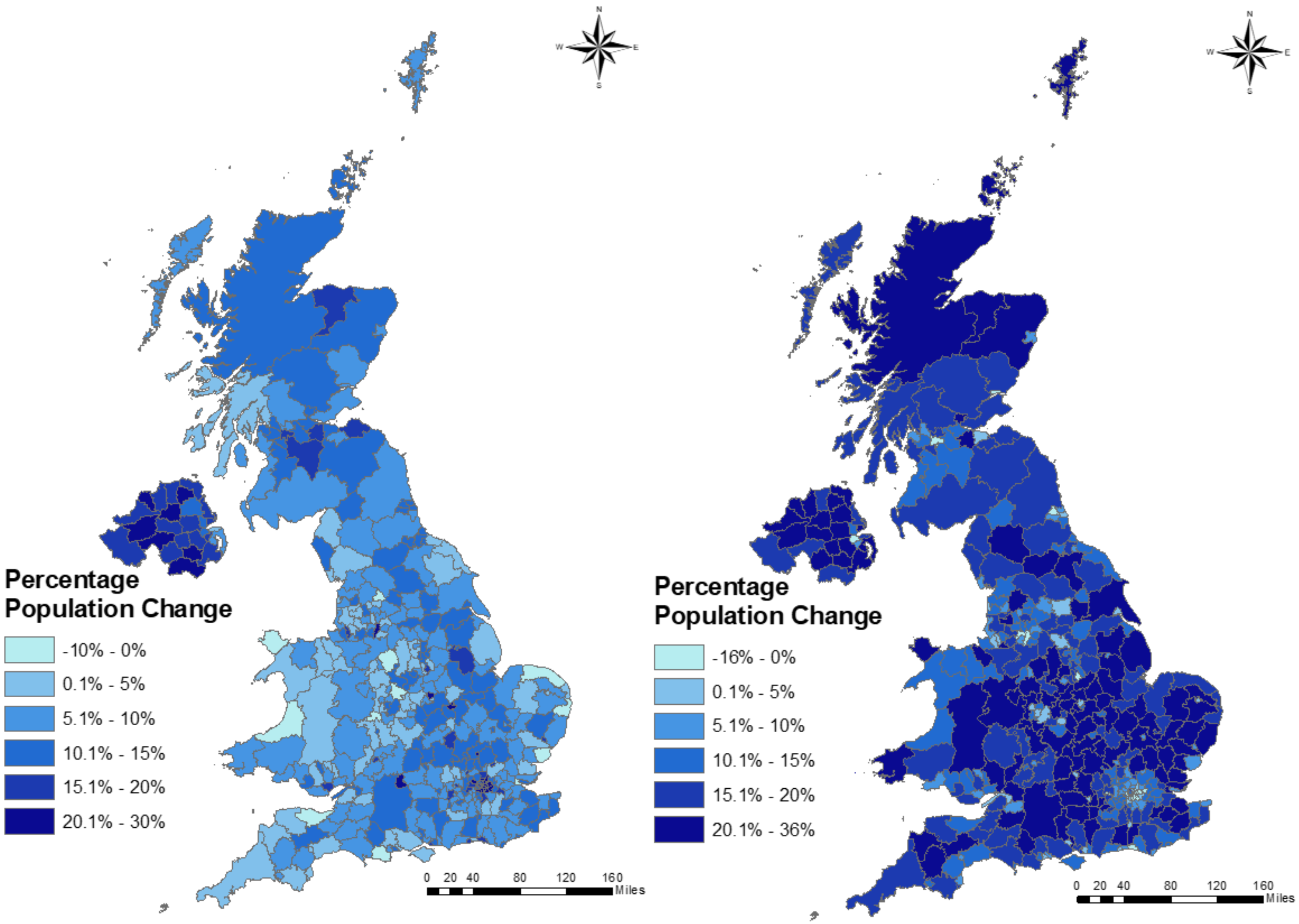
Figure 4.3 shows the percentage changes in population by LAD from 2001 to 2011 for these four groups and highlights the variation in patterns, starting with the family group mapped in Figure 4.3a, where the biggest relative population changes between 2001 and 2011 can be observed in

Manchester (+24%) and in the London boroughs of Tower Hamlets (+27%) and Newham (+22%). The majority of LADs, or 295 out of 404 to be exact, experienced a population decrease or no change within this decade. The negative values shown here in light blue can be found for LADs across Wales, Scotland, Northern Ireland and most of the north and south-west of England. There are a number of LADs with negative values on the east (coast-side) of England as well. Figure 4.3b highlights the population changes for the student and young workers group, where Welwyn Hatfield has increased by 31%, and both Manchester and Lincoln by 29%. The population changes by LAD for this group are predominantly positive, but no clear patterns can be drawn from the map when it comes to differentiate between small versus large population changes. Figure 4.3c highlights the population changes for the mature workers group, where the London borough of Southwark increased by 30%, of Lambeth by 29% and of Newham by 26%. This group mostly experienced moderate population increase in Great Britain, with slightly stronger growth in northern Scotland, but population increases for this group are most significant in Northern Ireland. Lastly, Figure 4.3d highlights the population changes for the retired group, where Daventry has the highest increase (+31%), followed by Maldon and Milton Keynes (both +29%). The retired/elderly population has increased the most compared to the other groups, with 106 LADs experiencing increases over 21%. Northern Scotland, most of Northern Ireland, east Wales and most of central England have experienced the majority of the large percentage population increases. These maps suggest that whilst the overall UK population might be growing in most LADs, it is the retired population which increased the quickest whilst the family age population actually declined across much of provincial UK between 2001 and 2011.



a. Family

b. Students and young workers



c. Mature workers d. Retired

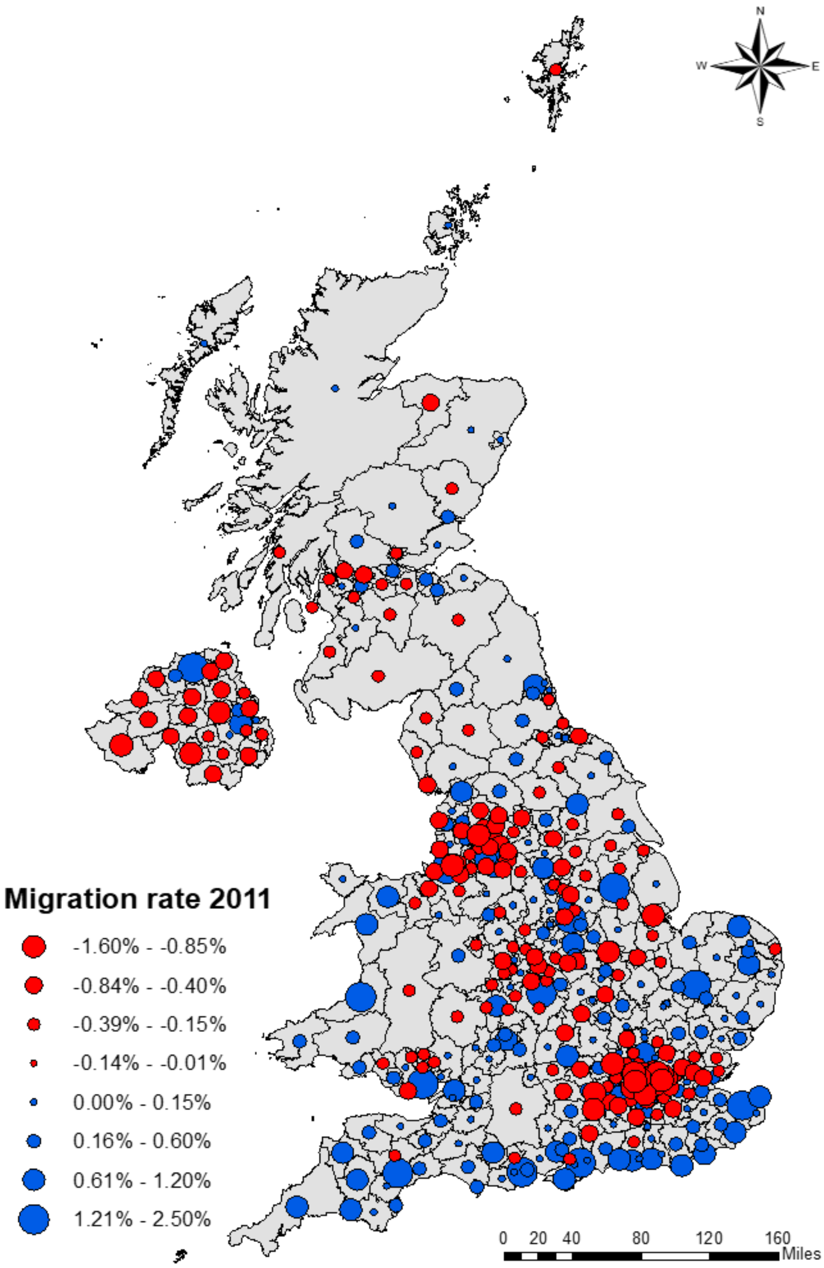
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.3: Percentage change in population in the UK, by LAD, 2001-2011

We now turn to consider how net internal migration across the UK and what changes have taken place between the two periods. Net migration rates for 2010-11 are computed as:

$$\mathrm{nmr_i} = 100\,\frac{(\mathrm{D_i} - \mathrm{O_i})}{\mathrm{P_i}} \tag{4.1}$$

where D_i represents the inflows to LAD i and O_i refers to the outflows from LAD i and this difference is expressed as a percentage of the 2011 population of LAD i. The net rates for 2010-11 are mapped in Figure 4.4 to exemplify some of the distinctive features of the spatial pattern of migration exchanges.

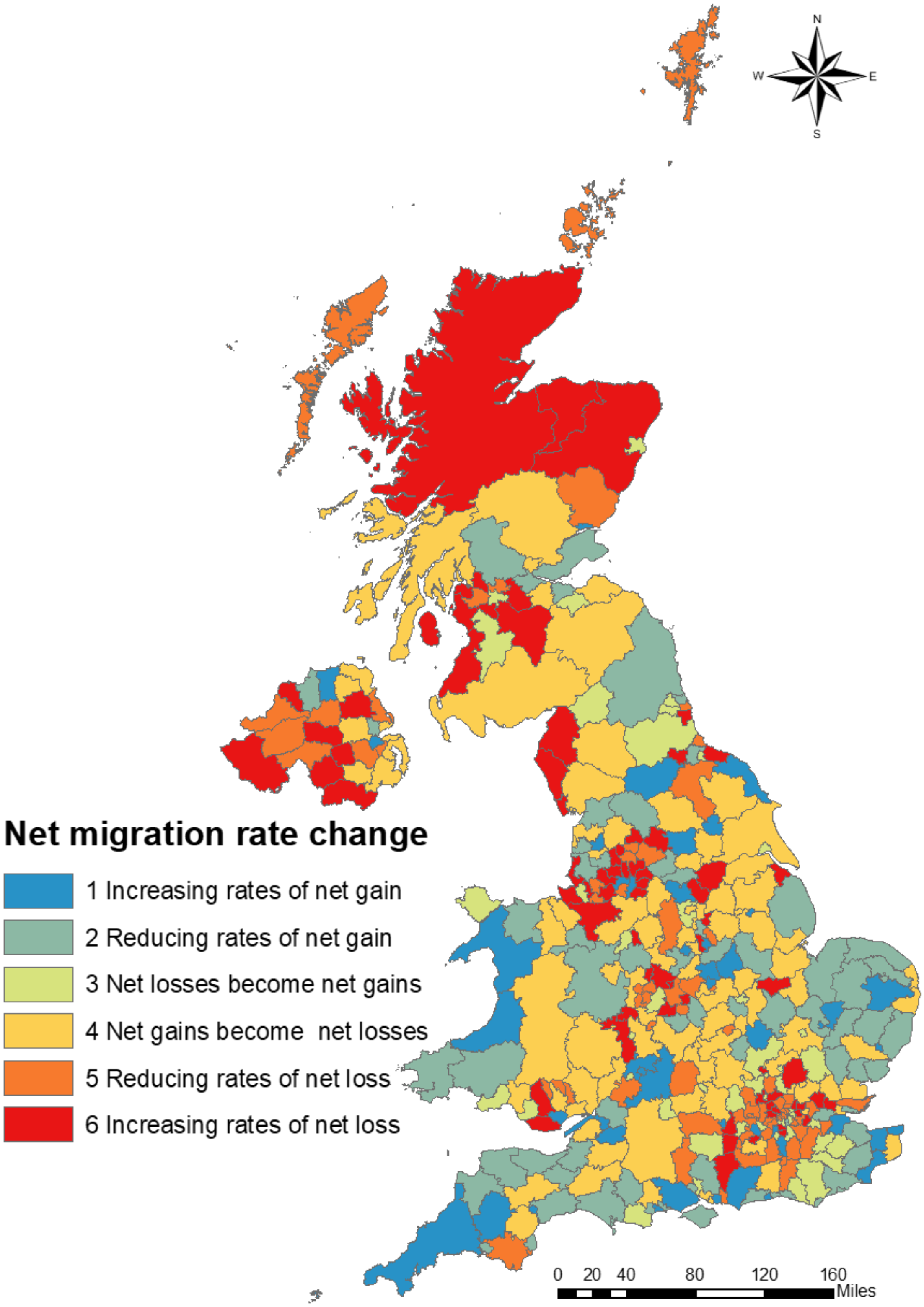


Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.4: Net migration rates in the UK by local authority district, 2010-11

Graduated symbols (with rates of net gain in blue and of net loss in red) are preferred in Figure 4.4 to choropleth shading since they offer a clearer representation of variations in net migration rates and illustrate the tendency for urban/metropolitan/conurbation districts to have experienced net migration losses in 2010-11 whereas the more rural districts have gained population through net migration. This pattern reflects the process of counterurbanisation reported widely in the literature (e.g. Champion, 2005; Lomax and Stillwell, 2017). Consequently, the highest rates of net migration gain are in rural areas such as Ceredigion, Bournemouth and Lincoln with an average rate of 2.2%, compared to urban areas where Newham, Ealing and Harrow have the highest rates of loss, averaging 1.5%. LADs with high rates of net migration gain are also found along the coast of southern England in western Wales and in East Anglia. In Northern Ireland, the spatial pattern is rather different with most rural LADs showing migration losses

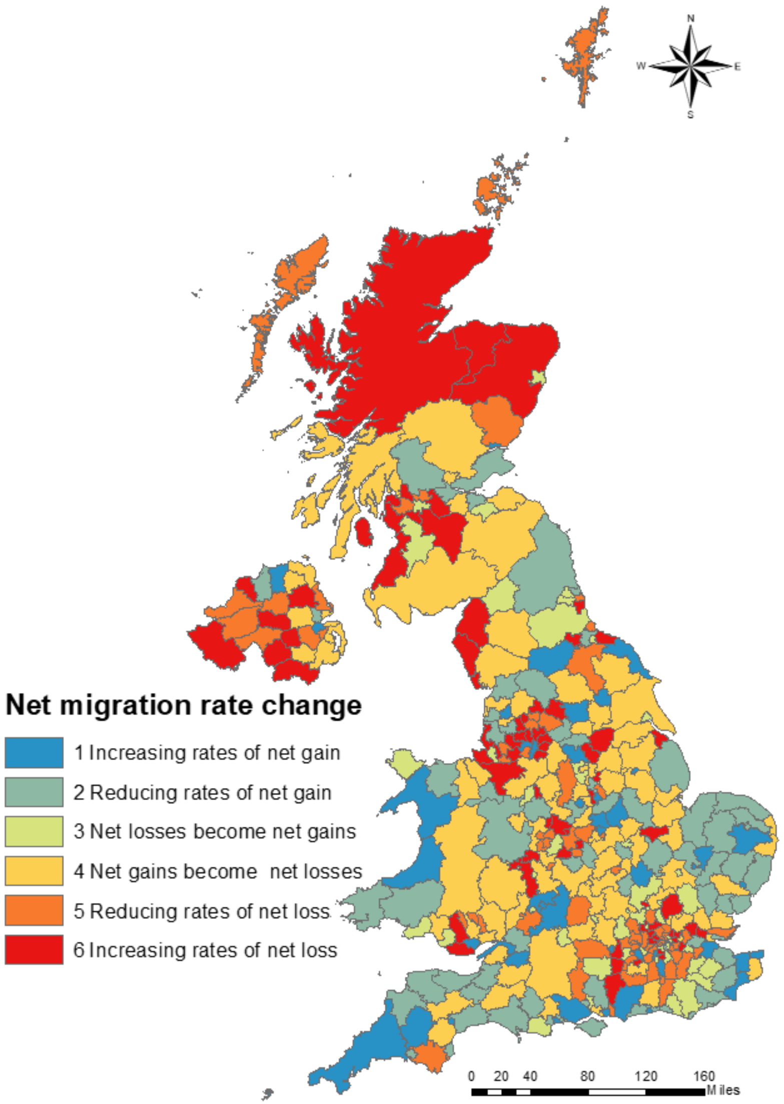
Changes in net migration rates between 2000-01 and 2010-11 are shown in Figure 4.5 using the following district categorisation: increasing net gains, reducing net gains, net losses become net gains, net gains become net losses, reducing net losses and increasing net losses. This classification shows the basic distinction between areas gaining and losing but also gives an indication of the path of change from one period to the next. The pattern of change is quite complicated. In the south, it is the coastal areas of England and Wales that gained population through internal migration at an increasing rates in contrast to much of the South East, especially the Greater London area, which has experienced net migration losses but at a reduced rate in many cases (as indicated by Lomax and Stillwell (2017). Increasing rates of net gain were also apparent in certain LADs in the Midlands e.g. Melton, Charnwood and Derby. Some more peripheral areas experienced increasing net losses especially in northern Scotland, in Northern Ireland and in the North West of England (Wigan, Warrington and Bolton). However, large migration gain rate changes are also found in the Shetland Islands (up by 1.48%) and Ceredigion (up by 1.38%). Generally, LADs on the Welsh and English coast have experienced



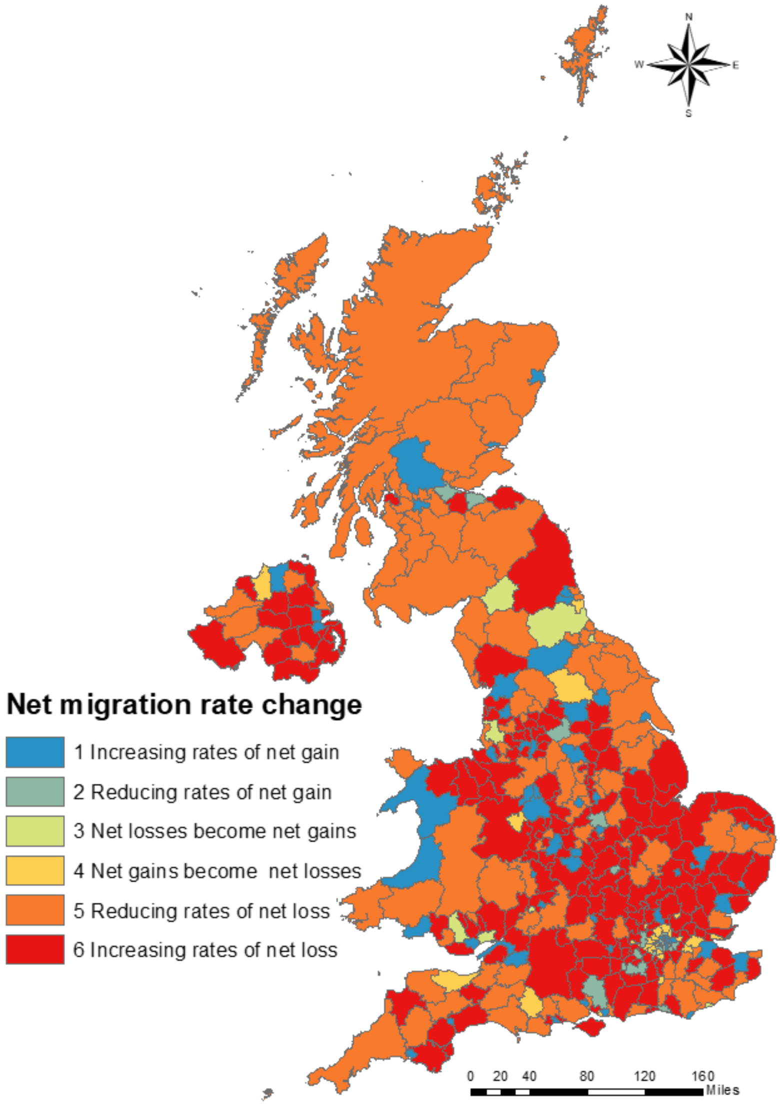
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.5: Net migration rate changes by local authority district, 2000-01 to 2010-11

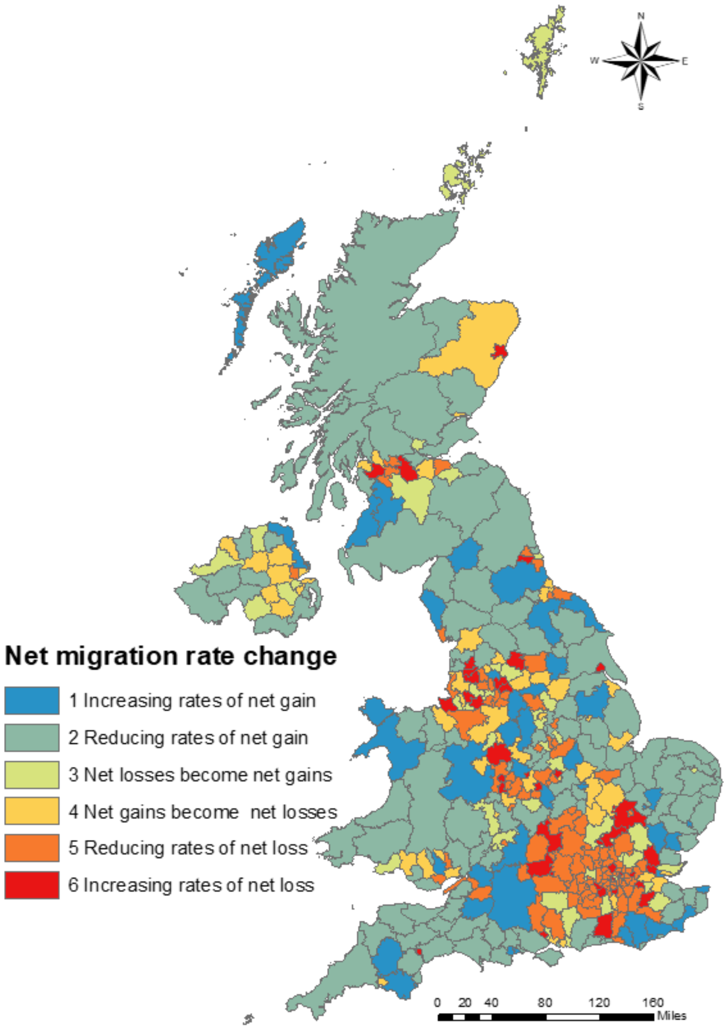
When looking at the different age groups (Figure 4.6), the primary observation is that changes taking place in net migration patterns across LADs for students and young workers are very different from the patterns for the other broad age groups. Students and young workers depart from LADs across the UK and travel to destinations with higher education institutions or large cities with employment opportunities. So, amidst the sea of increased migration losses, there are islands of increased migration gains, including Leeds, Nottingham, Sheffield and Manchester whose combined net migration balances in 2010-11 had increased by 7,200 to 9,800 from those in 2000-01. The pattern of change for the family age group (Figure 4.6a) is, to a large extent, the reverse of that of students and young workers. Net gains increased by 13% in Watford, 10% in Surrey Heath and by 9.8% in Bracknell Forest; with a recorded migration rate decrease of 14.6% primarily lead by East Northamptonshire, Rutland and Boston. The student age group has also shown significant changes (Figure 4.6b); gains have increased mostly in Ceredigion (18.4%), Lincoln (13.3%) and in Canterbury (12%). Increasing migration rate losses for this age group were highest in Harrogate, Wokingham and Hart with an average loss of 15.7%. The mature working age group has experienced change, particularly in Wandsworth, South Bucks and Rushmoor with an average increase of 1.6%. Lastly, net migration rates in the retirement age group showed positive changes of 5.1% in Wandsworth, 4.5% in the City of London and 4.2% in Runnymede, compared to Ballymoney, North Kesteven and Fenland where an average increasing loss of 4.4% was recorded.



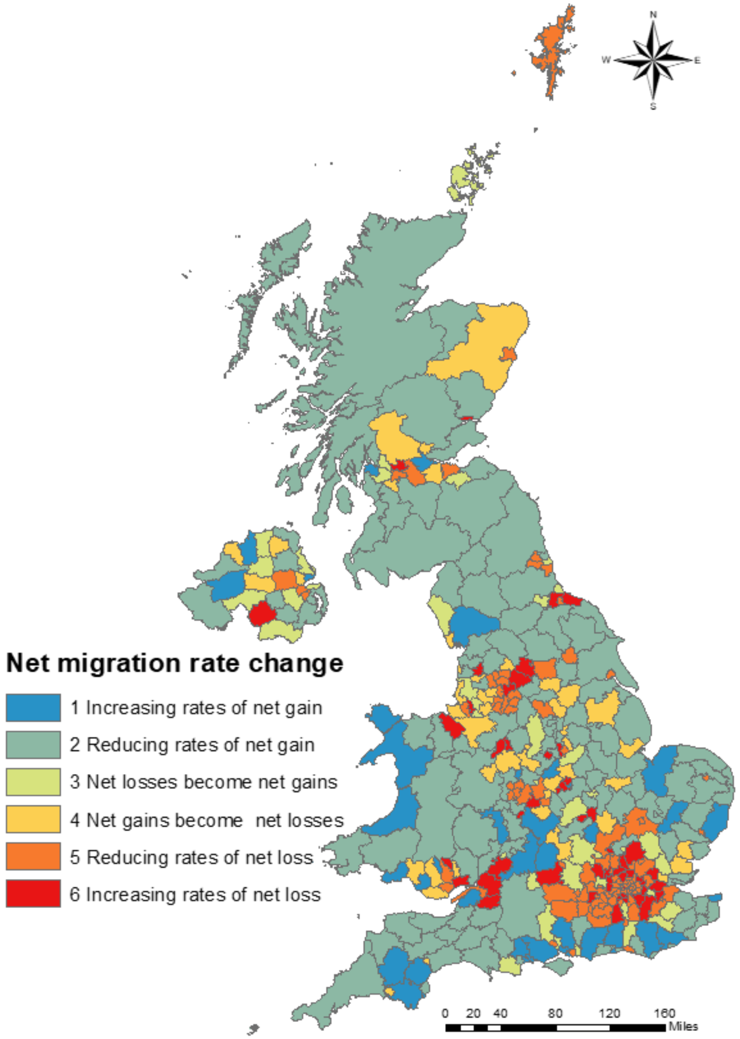
a. Family



b. Students and young workers



c. Mature workers



d. Retired

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.6: Net migration rate change, 2000-01 to 2010-11 for all age groups

Table 4.5 contains a summary the number of LADs in each category of change for each broad age group and for all age net migration. Overall, the predominant category is the 92 LADs where all-age net migration balances had switched from gains in 2000-01 to losses in 2010-11. Thus by 2010-11, almost 60% of LADs in 2010-11 were experiencing net migration losses. In the case of the family, mature worker and retired migrants, the category with the largest number of LADs was that of migration gains but at a reduced number. In each case the majority of LADs were gaining population through net migration in 2010-11. In stark contrast, 53% of LADs experienced increasing net migration losses in the student and young workers category and nearly 80% of LADs were net migration losers in 2010-11.

Table 4.5: Number of local authority districts in each category of net migration rate change, 2000-01 to 2010-11

	Change	Family	Students	M-worker	Retired	All age
Gain	Increasing net gains	96	60	43	40	45
	Reducing net gains	119	19	117	133	72
	Net losses become net gains	46	8	44	40	47
Loss	Net gains become net losses	54	24	52	45	92
	Reducing net losses	57	115	109	96	74
	Increasing net losses	32	178	39	50	74
	Total LADs	404	404	404	404	404

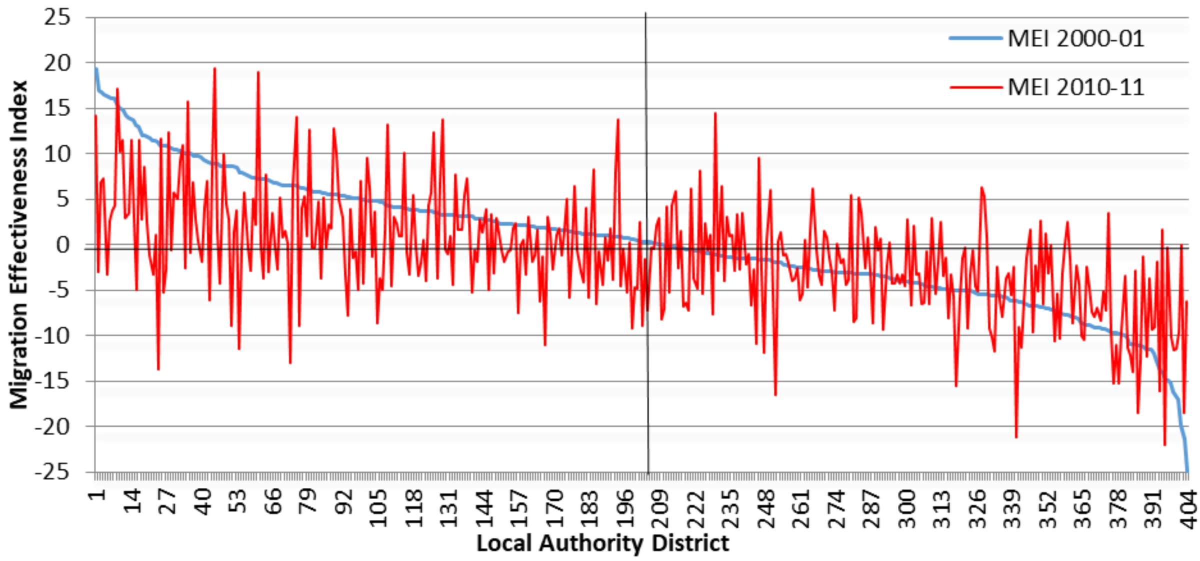
Source: Estimates based on data from 2001 and 2011 Censuses

4.4 Migration effectiveness

The Migration Effectiveness Index (MEI) is an alternative indicator of net migration which has recently been used to measure the impact of migration by Rees et al. (2016). Since the MEI as well as the aggregate net migration rate will be used to investigate scale and zonation effects in the later chapters, it is therefore a good opportunity to provide some of its key characteristics and spatial variations between BSUs as well as demonstrating the difference between the two measures at the aggregate or global level.

Net migration rate for a zone is defined in equation 4.1 whereas migration effectiveness is defined as: (In-migration-Outmigration)/(In-migration-Outmigration). The important difference is in the denominator; the former computes a rate based on a population at risk whilst the latter is based on the volume of migration taking place in both directions. The latter therefore gives a measure of net migration for a zone relative to the amount of migration taking place into and out of that zone, i.e. it shows the proportion of 'in-migration' (if ME is positive) or 'out-migration' (if ME is negative) that is not cancelled out by movement in the opposite direction. "Migration effectiveness is the indicator commonly used to measure net migration as a proportion of gross migration turnover for any territorial unit" (Stillwell et al., 2000, p.17). According to Plane (1984), the MEI has a number of properties which make it superior to the conventional net migration rate when used for the systematic analysis of migration patterns across space and time. Since it is calculated using the population of the area of interest as the denominator, the net migration rate is affected by the cumulative population history of that area. In contrast, the effectiveness measure is solely a function of movements to and from an area that occur in a defined period and is therefore more sensitive to temporal shifts and spatial variations in the pattern of migration flows. Thus, it is apparent that migration effectiveness does not measure the same thing as the net migration rate, although the two measures are often closely correlated (Plane, 1984; Rogers and Raymer, 1998). When used as a system-wide measure, the latter summarizes the extent to which migration is acting to transform the pattern of human habitation, whilst the former indicates the degree of imbalance or symmetry in the network of migration flows (Plane 1994). Both measures reflect the human response to spatial variations in opportunities and constraints, but migration effectiveness captures the extent of equilibrium or disequilibrium in the flows between geographical areas that constitute the migration system.

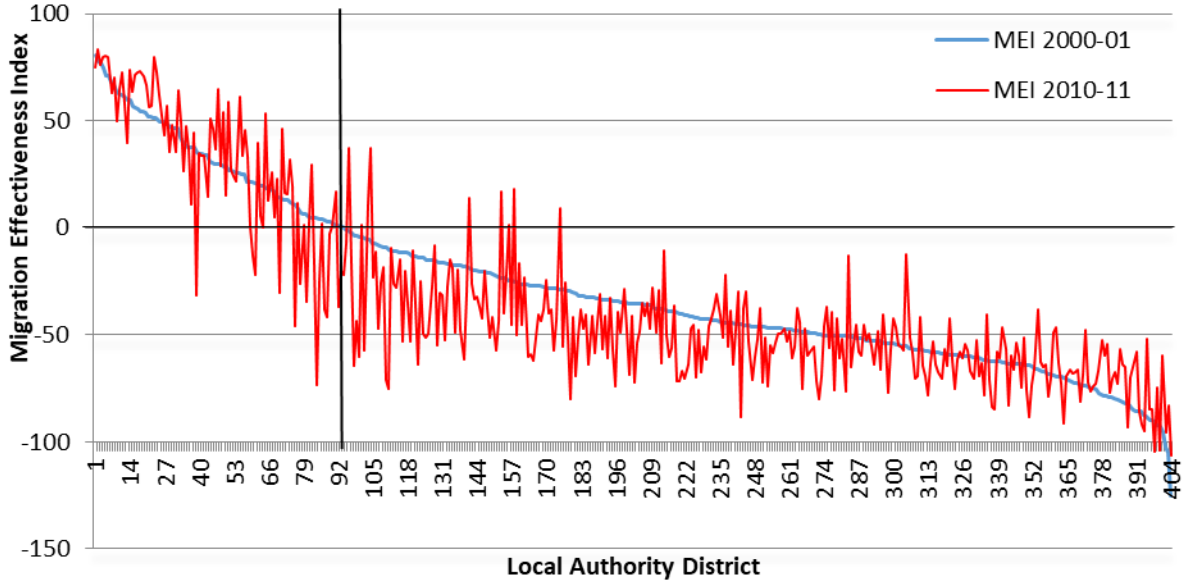
The following section introduces the MEI for LADs that will be used in the next chapter, but rather than repeating the presentation of maps like those used to depict net migration rates, graphs of ranked MEIs for LADs will be used to provide a graphic visualisation of the nature of change between the two time periods. Figure 4.7 illustrates the local MEI for each LAD ranked according to their values in 2000-01 (solid blue line) with the 2010-11 values superimposed (solid red line). Out of 404 LADs, just over half (209) recorded positive MEI scores in 2001 and the top ranking LADs were Isle of Wight, East Northamptonshire and Limavady with MEI values of 19.2, 16.9 and 16.8 respectively in 2000-01. Orkney Islands, Strabane and Shetland Islands sit at the other end of the ranking with scores of -20, -21 and -25 in 2000-01 respectively. Most LADs with migration gains in 2000-01 (the left-hand end of the graph) have lower positive MEI in 2010-11 than in 2000-01, whilst most LADs with migration losses in 2000-01 (right-hand end of the graph) have lower negative MEI in 2010-11 than 2000-01. There are, of course, some exceptions to this general pattern.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.7: UK Local Authority Districts ranked by their Migration Effectiveness Index for all-age groups in 2000-01

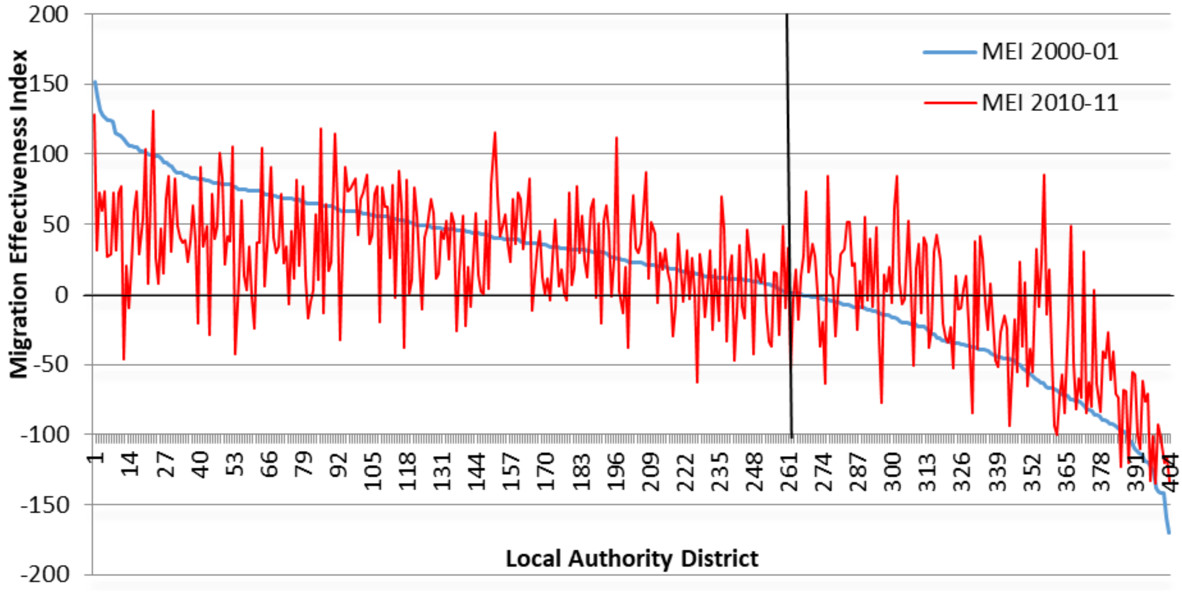
There are likely to be significant variations to the roughly equal split between the number of LADs with positive and negative MEI values for migrants of all ages. This is exemplified in the case of the students and young workers age group. The spatial variation in migration effectiveness in the two census periods for the students and young workers age group is shown in Figure 4.8. In this case, only 94 out of 404 LADs recorded positive MEI scores in 2000-01 and many of these were university towns and cities with Cambridge and Oxford being at the top end of the ranking with MEI vales of 50 and 54 respectively in 2001. The highest MEI scores were Southampton with 81 and Belfast with 78. Strabane and Eilean Siar in Northern Scotland sit at the other end of the ranking with a score of -125 and -105 in 2001 and several of the LADs in Northern Ireland are among the LADs with highest negative MEI in both periods. Not only does the graph indicate the asymmetry of flows in this age group but it also illustrates the tendency for positive MEI values to be more positive in 2010-11 and negative MEI values to be more negative. There are several exceptions to this trend, among which the most prominent is Harrogate in North Yorkshire, with a positive MEI of 4 in 2000-01 but having a negative MEI value of 73 in 2010-11. Harrogate's net balance switched from a gain of 757 in 2001 to a loss of 214 in 2011 due primarily to a decline in inflows but also to an increase in outflows.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.8: UK local authority districts ranked by their migration effectiveness index for students and young workers age groups in 2000-01

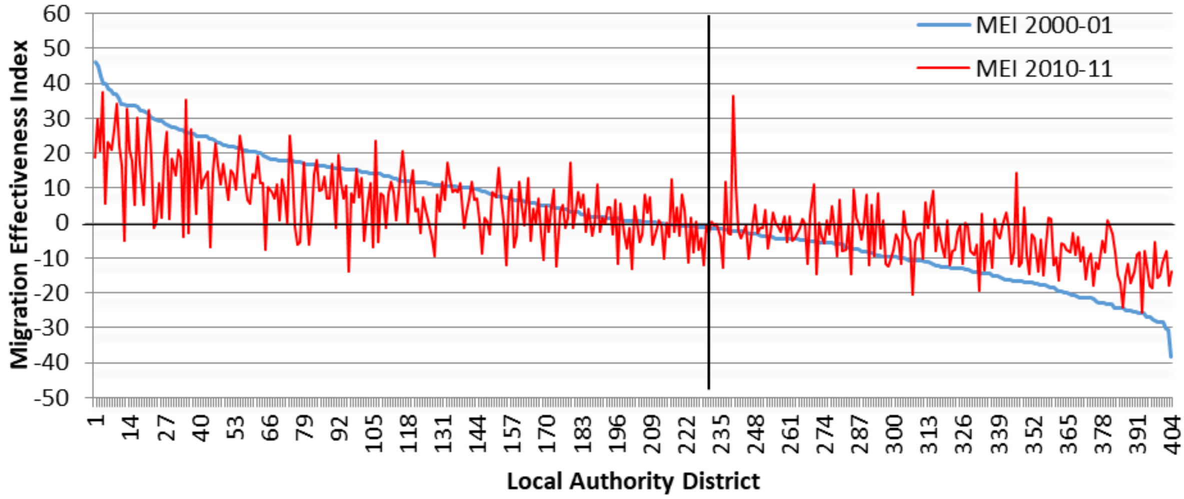
Similar to the variation shown in the student and young workers age group, the variation in the district MEI for the family age groups in Figure 4.9 is considerable and the differences between the two one-year periods are well defined. In this case, around two thirds of the districts have positive MEI values with the remainder having negative balances but all are within an MEI value of plus or minus 130, compared with the student and young works age groups whose extremes are around plus or minus 100.



Source: Estimates based on data from 2001 and 2011 Censuses

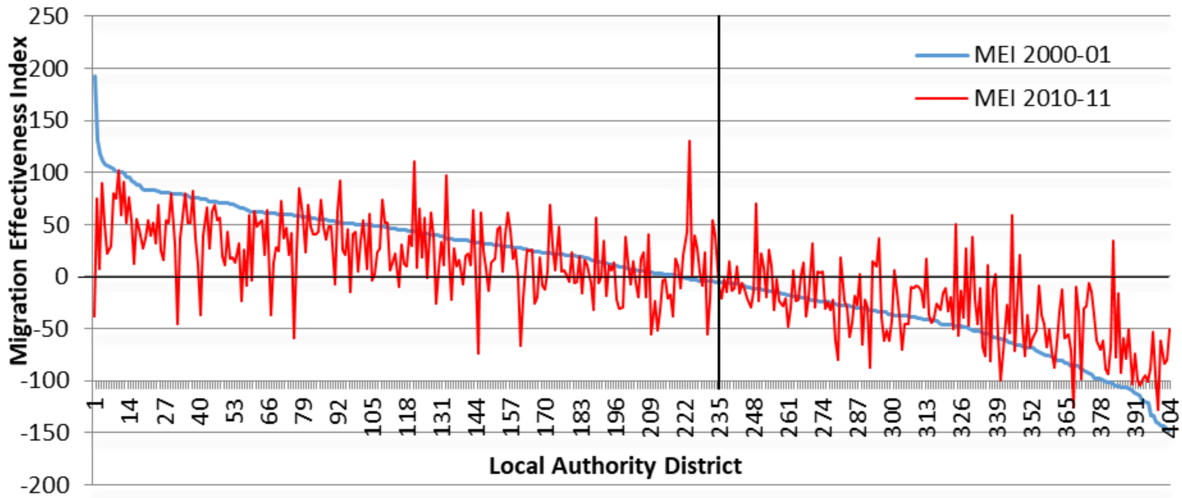
Figure 4.9: UK local authority districts ranked by their migration effectiveness index for the family age groups in 2000-01

In Figure 4.10, the ranked MEI values for districts for the mature worker age group are plotted and the graphs show that around two thirds of districts have negative MEIs, the variation is not extensive in either period but the MEI values in 2010-11 for districts with high positive MEIs in 2000-01 have fallen in almost all cases. On the other hand, the MEI values for migrants in the retire age groups, shown in Figure 4.11 show more variation in both periods but with decreases in the migration effectiveness between the two periods at both ends of the district ranking, i.e. districts with high positive MEI values in 2000-01 had lower positive MEI values in 2010-11 and districts with high negative MEI values in 2001 had lower negative values in 2010-11.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.10: UK Local Authority Districts ranked by their Migration Effectiveness Index for the mature worker age groups in 2000-01

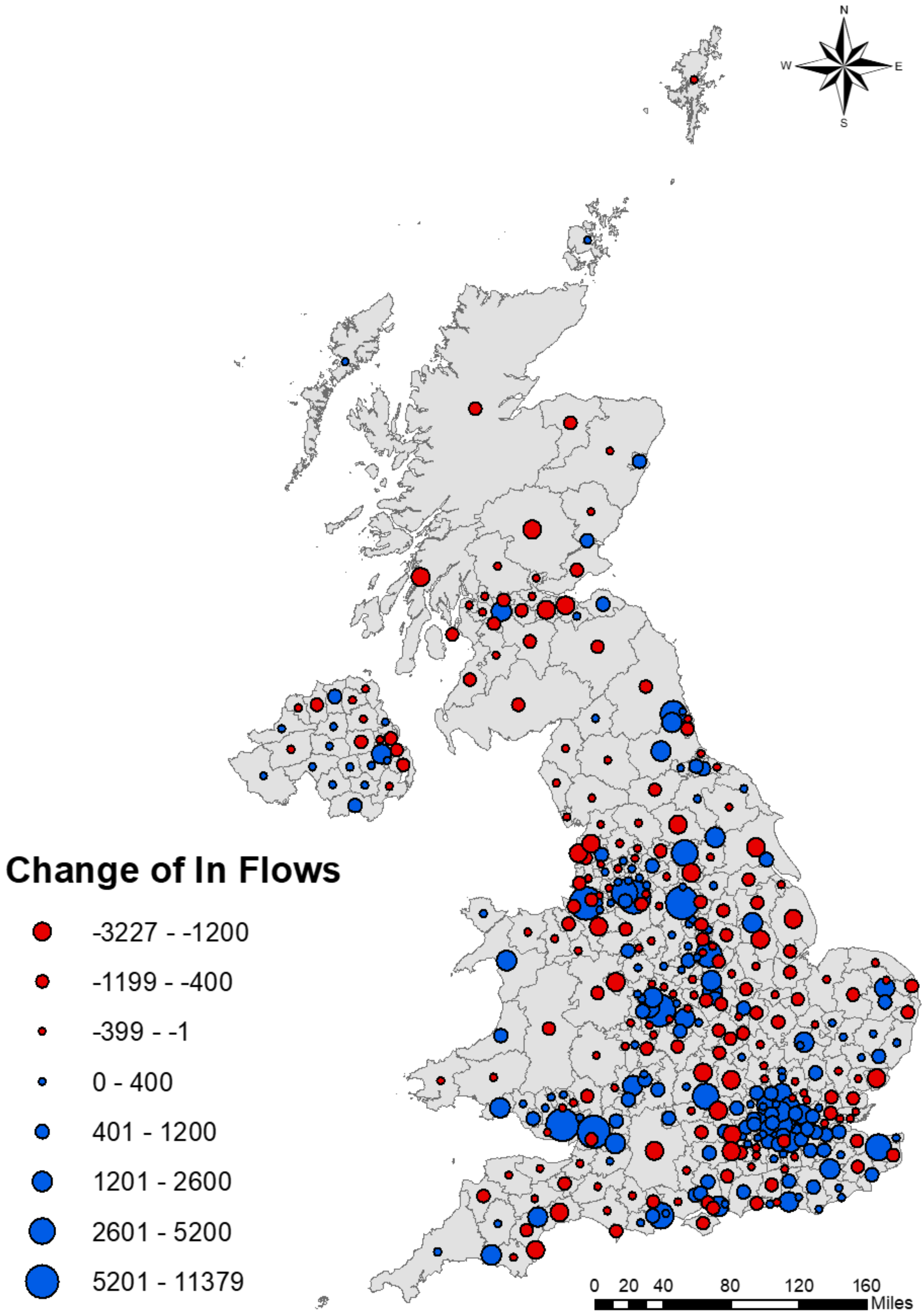


Source: Estimates based on data from 2001 and 2011 Censuses

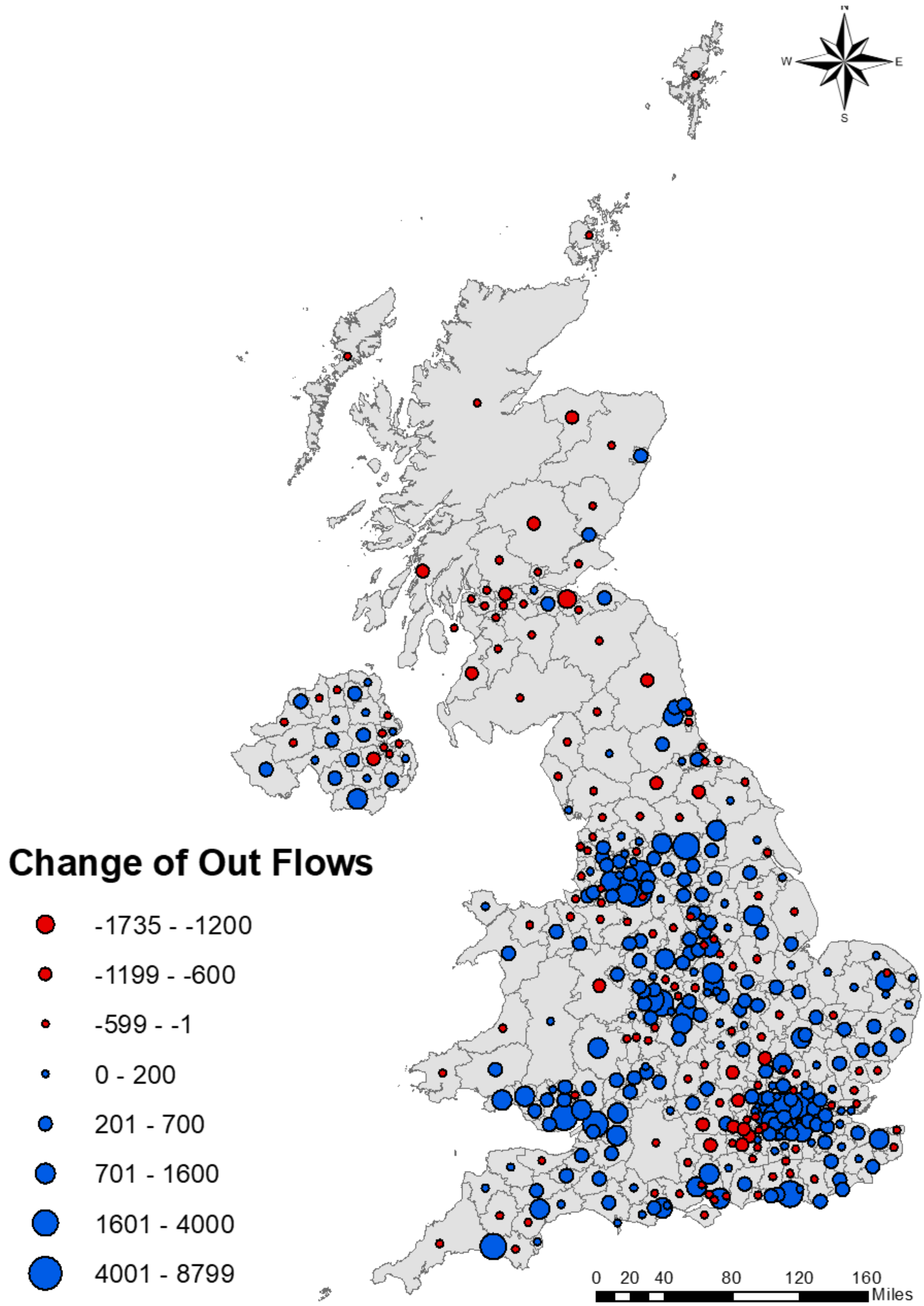
Figure 4.11: UK Local Authority Districts ranked by their Migration Effectiveness Index for retired age groups in 2000-01

In summary, inter-district migration in aggregate terms within the UK had become more uniform and less effective in redistributing the population in 2010-11 but the range of values and the changes between the time periods varies by broad age group and the evidence suggests that the district inflows and outflows of the migrants in the student and young worker age groups have become more unequal. In the next section, the component flows that constitute net migration are considered in more detail.

Net migration and migration effectiveness are both important indicators of internal migration impact (Bell et al., 2002) but net migrants do not exist (Rogers, 1990) since they do not reveal the number of individuals arriving in or departing from a LAD. The marginal totals of the inter-district origin-destination migration matrix for aggregate flows are the gross in-migration (column) and gross out-migration (row) totals, and these measures provide a clearer explanation of net changes. i.e. is net migration increase due to higher in-migration or lower out-migration of both? The maps in Figure 4.12 provide a visual comparison between the changes in inflows and outflows between 2000-01 and 2010-11 for LADs across the UK. Manchester and Tower Hamlets have the highest change of inflows from 2000-01 to 2010-11 with an influx of 11,380 and 9,705 respectively as well as the highest change of outflows with an increase of 8,800 in Tower Hamlets and 6,358 in Manchester. Some of the largest inflow decreases can be found in East Riding of Yorkshire and Edinburgh, with a decrease of 3,228 and 2,333 respectively. Edinburgh experienced the highest decrease of outflows from 2000-01 to 2010-11 by 1,735, followed by Rushmore with a decrease of 1,180. The analysis of theses maps are also useful to understand if there has been a population redistribution. In Manchester, Tower Hamlets and Southwark for example, there are high inflows but also high outflows, and although these are highly active LADs, they do not reshape the UK population. Birmingham and Liverpool on the other hand have much higher inflows showing some changes in their population growth, whilst Islington and Newham have high outflows contribution to a reduction in their respective population.


N
W
E
S
Change of In Flows
-3227 - -1200
-1199 - -400
-399 - -1
0 - 400
401 - 1200
1201 - 2600
2601 - 5200
5201 - 11379
0 20 40 80 120 160
Miles

a. Inflows



b. Outflows

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.12: Changes in migration inflows and outflows in the UK by local authority district, 2000-01 to 2010-11

As expected, Greater London has large volumes of in-migration and out-migration as it is the nation's capital; many different types of people with different motives enter and exit this region. To summarise differences by age, Table 4.6 presents the top three in-migration destinations for each age group in the two periods. Students play a significant role in migration flows, with major destinations in both periods being Manchester, Leeds and Birmingham. According to the Primary Urban Area (PUA), Centre for Cities data (Elledge, 2016), Manchester, Leeds and Birmingham are the top UK cities with the most students, with London being on top of the list. In this analysis, London is excluded as a single entity since the LADs in London refer to the City of London and 32 to boroughs.

Table 4.6: Top in-migration flow destinations, 2000-01 and 2010-11

	Family		Students and young workers		Mature workers		Retired	
2001	Wands-worth	18,034	Leeds	15,225	Cornwall	3,383	Cornwall	2,630
	Lambeth	16,920	Manchester	14,349	Wiltshire	2,055	Wiltshire	1,749
	Wiltshire	14,173	Birmingham	13,983	East Riding of Yorkshire	1,904	East Lindsey	1,512
2011	Wands-worth	22,377	Manchester	20,623	Cornwall	2,911	Cornwall	2,910
	Lambeth	20,281	Leeds	19,491	Wiltshire	2,491	Wiltshire	2,039
	Birmingham	16,669	Birmingham	17,383	Birmingham	2,214	Arun	1,468

Source: Estimates based on data from 2001 and 2011 Censuses

The family group is also a major component of the UK's in-migration flows, with largest inflows attracted to Wandsworth and Lambeth. In 2010-11, Birmingham became attractive to more families than in 2000-01, surpassing Wiltshire. Wandsworth is a borough of south-west London and is growing in population, especially for children aged 0-14 and young adults (Wandsworth Council, 2014). The London borough of Lambeth attracts a large number of people in the family age group due to its central location. For mature workers and the retired population, Cornwall and Wiltshire are primary destinations; both counties in the South West are consistently the leading districts for in-migration flows for people aged over 45.

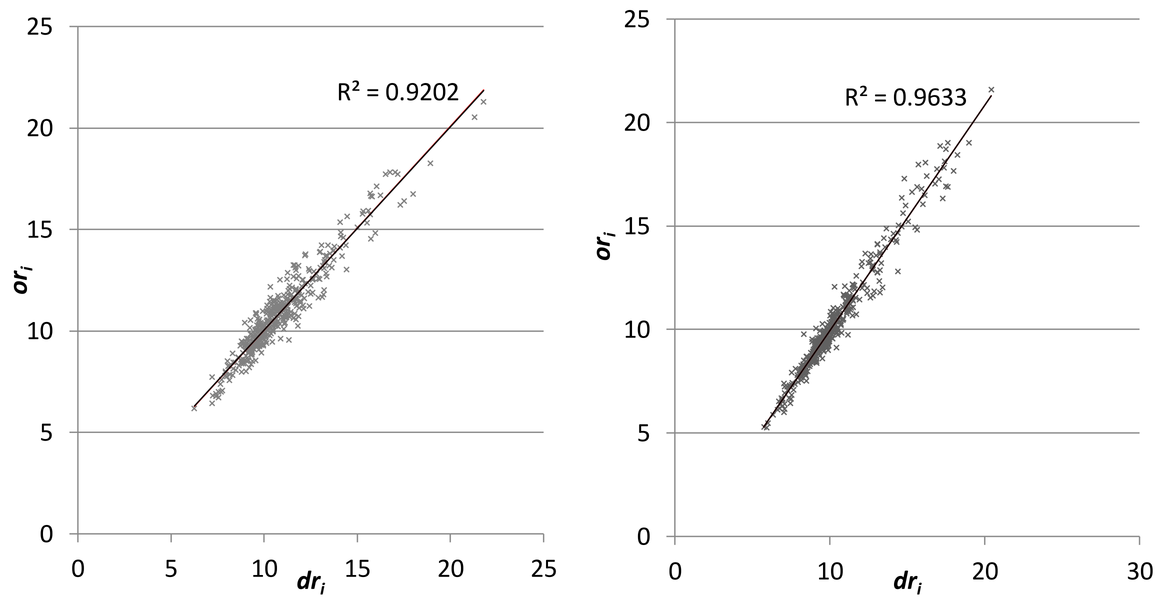
The relationship between the rates of the two component flows provides additional information about the migration taking place; some districts may have large net migration rate balances (negative or positive) but involve relatively low rates of in-migration and out-migration whereas high rates of in-migration and outmigration may cancel out leaving net migration rates close to zero. The gross in-migration rate for district i, dr_i, is calculated as:

$$\mathrm{dr_i} = (\mathrm{D_i}/\mathrm{P_i})\,\mathrm{x}\,100 \qquad (4.2)$$

where D_i refers to total in-migration to district i and P_i is the population of the district, and the gross out-migration rate of district i, or_i, is calculated as:

$$\mathrm{or_i} = (\mathrm{O_i}/\mathrm{P})_\mathrm{i}\ \mathrm{x}\,100 \qquad (4.3)$$

where O_i represents total out-migration from district i (Stillwell and Harland, 2010). When the gross in-migration and out-migration rates are plotted against one another, the correlation coefficients and the regression lines show that the rates are strongly related (Figure 4.13). This association has long been recognised (e.g. Mueser and White, 1989, for the USA). Oxford, Cambridge, Wandsworth and Manchester represent the far right points in both 2000-01 and 2010-11, having the highest rates of both in-migration and out-migration. In 2000-01 the points on the bottom far left, i.e., the districts with the lowest rates were Cookstown, Strabane and Newry and Mourne (all in Northern Ireland) compared to Magherafelt, Strabane and Cookstown in 2010-11. The coefficient of determination shown in Figure 4.13 is higher in 2010-11 than in 2000-01 providing further evidence that gross inflows and outflows are becoming more alike.

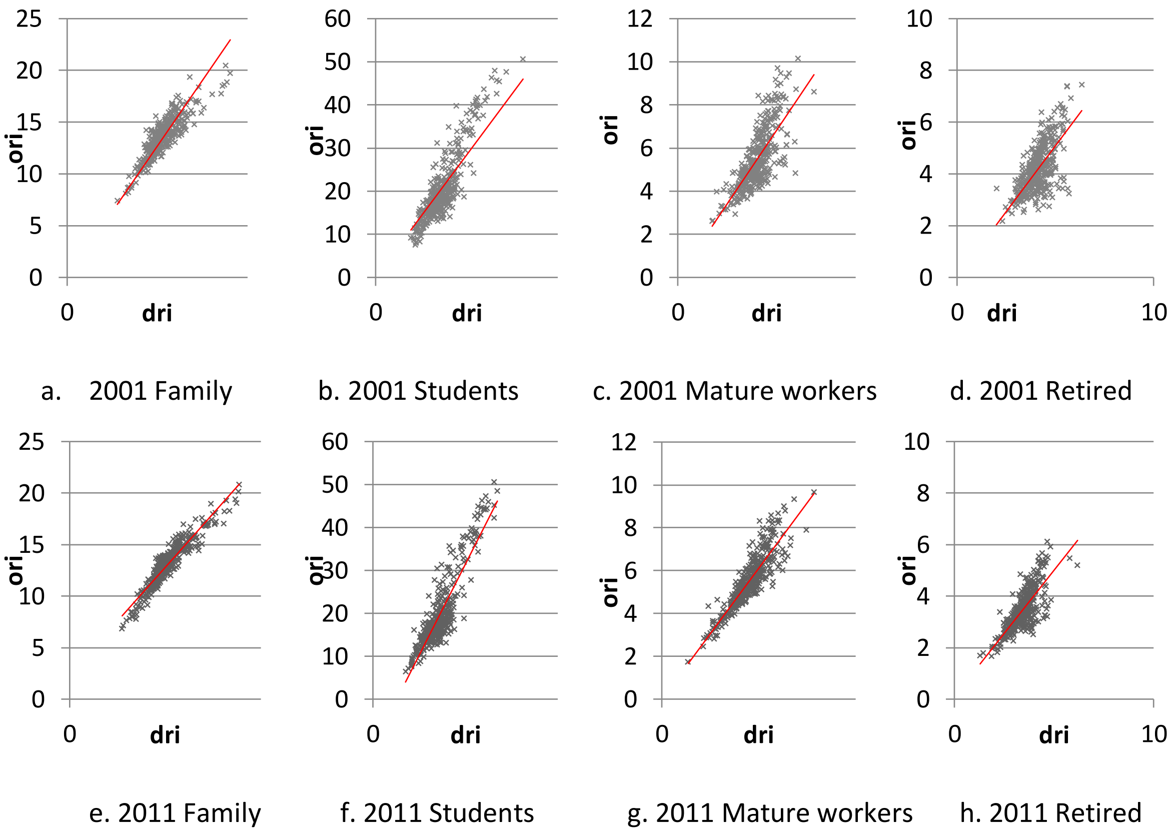


a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.13: Scatterplots of gross in-migration and out-migration rates by district, 2000-01 and 2010-11

Figure 4.14 shows the scatterplots of gross in-migration rates versus and gross out-migration rate for each broad age group. All age groups have positive correlation coefficients and the all-age coefficient increases from 0.96 to 0.98 from 2000-01 to 2010-11 (Table 4.7). Whereas the correlation coefficient shows the strength and direction of the linear relationship between the rate variables, the r^2 statistic gives the proportion of the variance in the in-migration rate that is explained by the out-migration rate; it indicates how well the regression line fits the data points in the scatterplot. The r^2 values in all age groups, including the 15-24 year olds, increase between 2000-01 and 2010-11 suggesting that patterns of in-migration and out-migration have become more alike over the decade, thus reducing the migration effectiveness. Whilst the r^2 values for family age group increase from 0.76 in 2000-01 to 0.88 in 2010-11, the change for the student group is marginal, from 0.79 to 0.80. The greatest increase is for the mature workers age group, whose coefficient of determination increases from 0.58 in 2000-01 to 0.79 in 2010-11.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.14: Gross in-migration and out-migration rate relationships for four age groups for districts of the UK, 2000-01 and 2010-11

Table 4.7: Regression parameters and correlation statistics for relationships between in-migration and out-migration rates by age group, 2000-01 and 2010-11

		Intercept (a)	Slope (b)	Correlation Coefficient, r	r-squared
2001	Family	3.467	0.760	0.873	0.76
	Students and young workers	-7.933	1.286	0.890	0.79
	Mature workers	-0.166	1.053	0.761	0.58
	Retired	0.294	0.946	0.651	0.42
2011	Family	2.362	0.834	0.940	0.88
	Students and young workers	-10.984	1.413	0.894	0.80
	Mature workers	-0.010	1.019	0.889	0.79
	Retired	0.100	0.980	0.775	0.60
Total 2001		0.036	1.001	0.959	0.92
Total 2011		-0.953	1.089	0.981	0.96

Source: Estimates based on data from 2001 and 2011 Censuses

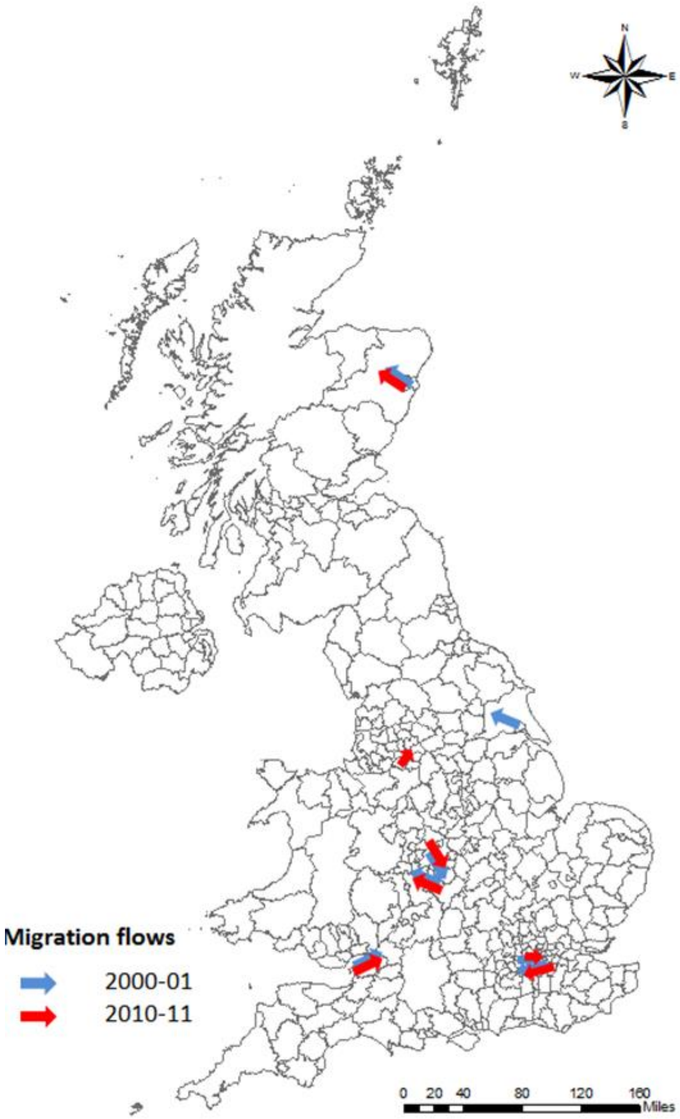
In the final two sections of the chapter, the directional flows taking place between and within the LADs that make up the spatial system, have been examined respectively.

4.6 Inter-district migration

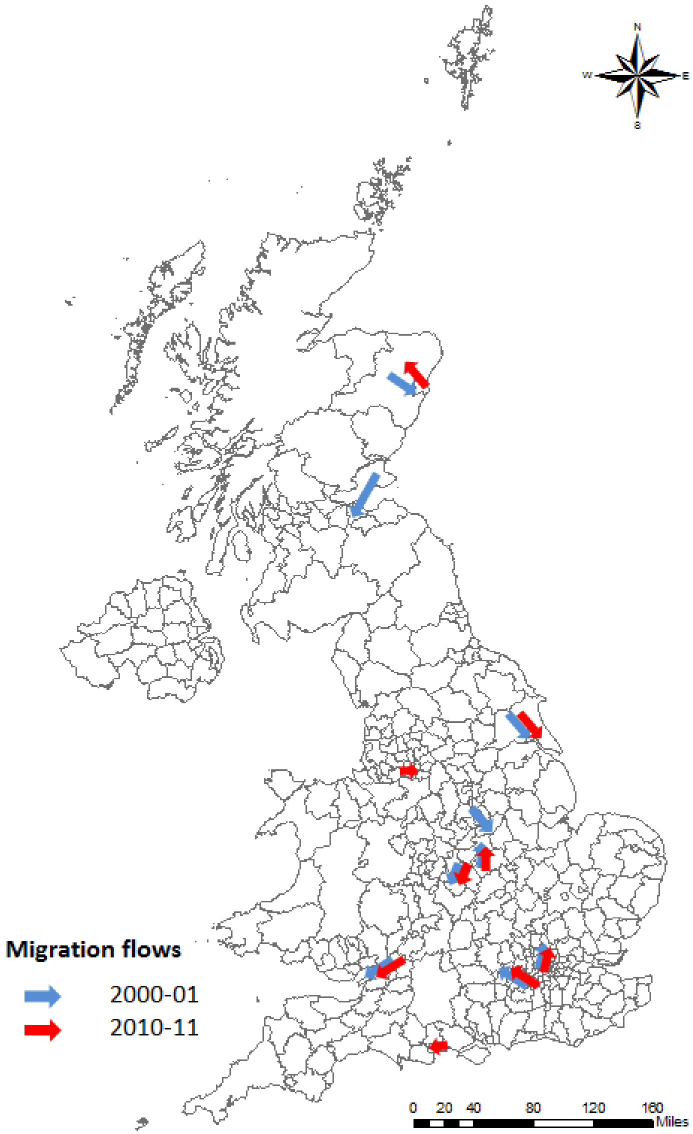
The volume of data involved in analysing the flows in the inter-district matrix is considerable. In the all-age migration matrix and in each of the age-group matrices there are 162,812 (404*403) cells that have the potential to contain non-zero values.

Figure 4.15 shows a graphical representation of the results displayed in Table 4.8 for each broad age group. The first map represents the family age group, with numerous flows around the Greater London area, Bristol and Birmingham for both years. The biggest difference between 2000-01 and 2010-11 is that in 2000-01 Kingston upon Hull had strong migration flows to East Riding of Yorkshire, but not in 2010-11; and strong migration flows from Manchester to Trafford only appeared in 2010-11. The second map shows the biggest migration flows for the students and young workers age group migrating towards Bristol, Warwick and Kingston upon Hull for both years. But the difference is that in 2000-01 there are strong flows from Fife to Edinburgh and from Nottingham to Rushcliffe and in 2010-11 there are flows from Manchester to Salford and from Poole to Bournemouth. All lot of migration flows can be found in the north of England, east of Scotland and around Birmingham for the mature workers age group. Most migration flows are similar for both years with the exception of Newcastle upon Tyne to North Tyneside in 2000-01. Lastly, the retired age group shows strong migration flows out of Bristol to neighbouring LADs and to and from Solihull and Birmingham for 2000-

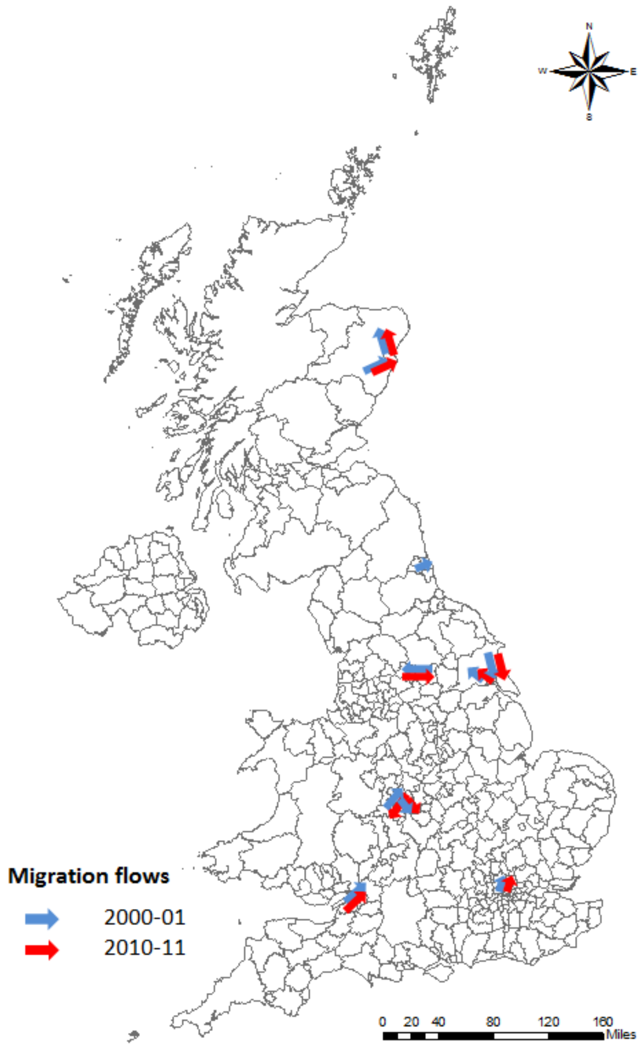
01 and 2010-11. The longest distance travelled can be found in 2000-01, with a migration flow from Glasgow city to South Lanarkshire. Expect for this specific migration flow, the maps in Figure 4.15 show that the highest migration flows involve short distances within all age groups.



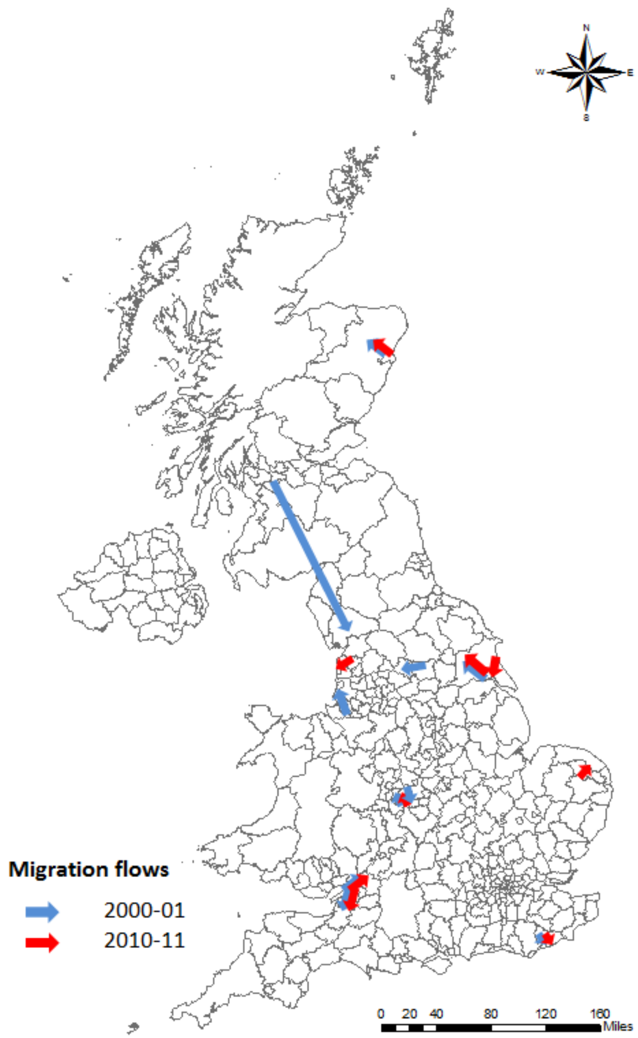
a. Family



b. Students and young workers



c. Mature workers



d. Retired

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.15: Origin and destination Inter-Local Authority District migration flows, 2000-01 and 2010-11

4.7 Intra-district migration

Intra-LAD migration is the diagonal component of each migration matrix and is a much easier variable to analyse, Although these data are not incorporated into the scale and zonation analyses in Chapters 5 and 6, it is useful to understand the variation in intensity and spatial pattern of moves that will be of shorter-distance and contain a higher proportion that are home-based. As seen in section 4.1, the intra-LAD migration accounted for almost 60% of all migration flows in the UK in both periods. The upper section of Table 4.8 shows that when looking at the different age groups, the total number of intra-LAD migrants decreased between the two periods in the family and retirement age groups, whereas numbers of student and young workers and mature workers increased between the two periods. However, the lower section of this table shows that that the intra-LAD migration rate for the student age group decreased by 0.45% whereas only the rate for mature workers increased.

Table 4.8: Total intra- Local Authority District migration by age group, 2000-01 and 2010-11

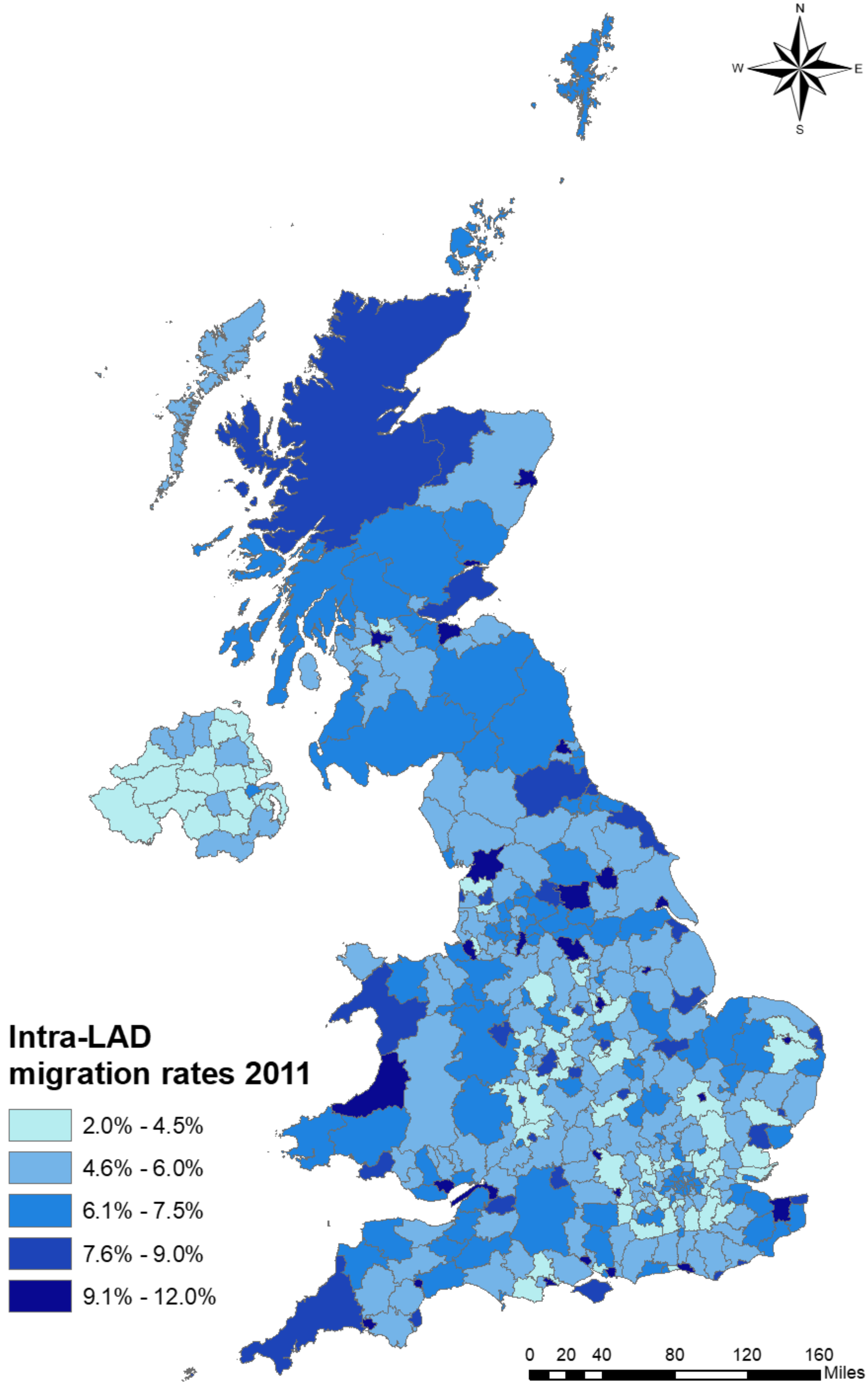
	Family	Students	Mature worker	Retired	All-age
Migration flows					
2001	2,384,415	916,985	357,943	322,405	3,981,748
2011	2,364,540	1,045,375	404,582	292,168	4,106,665
Difference	-19,875	128,390	46,639	-30,237	124,917
Migration rates (%)					
2001	8.09	11.13	3.11	2.52	6.34
2011	7.88	10.69	3.15	1.97	5.95
Difference	-0.21	-0.45	0.04	-0.55	-0.39

Note: Inconsistencies in all area total when compared with Table 4.1 due to rounding issues.

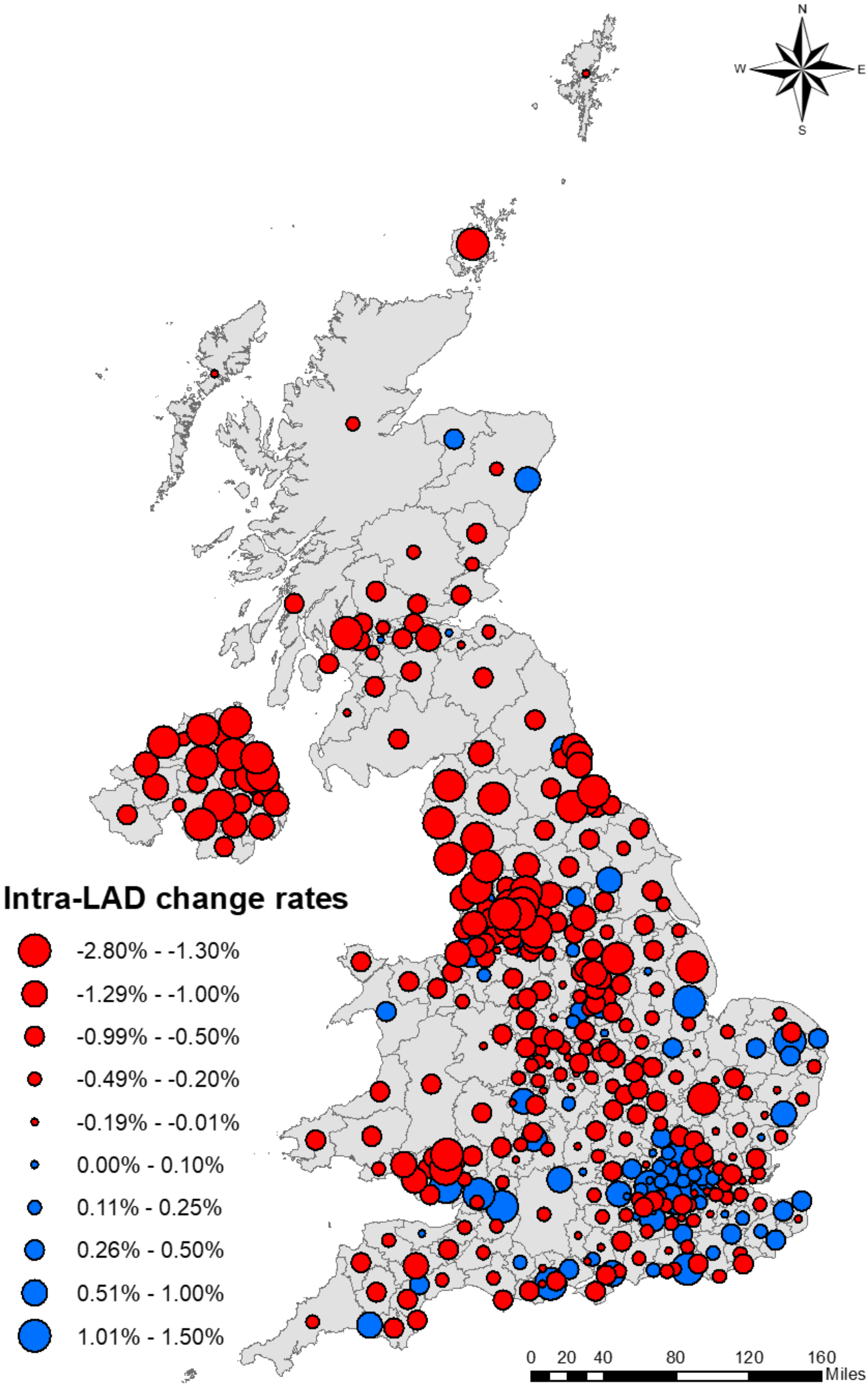
Source: Estimates based on data from 2001 and 2011 Censuses

The highest intra-LAD migration rates can be found in largely populated areas such as Oxford, Brighton and Hove and Southampton with rates of 11.69%, 11.51% and 11.39% respectively in 2010-11 as shown in Figure 4.16a. Some of the lowest intra-LAD migration rates are found in Northern Ireland where Castlereagh, Moyle and Magherafelt are towards the bottom of this list, with 2.45%, 3.09% and 3.23% of migration rates respectively in 2010-11. Central England also contains low rates, with South Bucks at 2.50% and Oadby and Wigston at 2.67%. Figure 4.16b highlights which of these LADs experience the most changes between both censuses. The map indicates that Northern Ireland and north east of England had high negative changes of intra-LAD migration rates, whereas the Greater London area and the south east of Wales had high positive changes of intra-LAD migration rates. Bournemouth, Norwich and Cardiff are the leading LADs with high positive changes with 1.42%, 1.39%

and 1.33% of migration rates respectively. Coleraine, Orkney Islands and Blackburn with Darwen are the highest LADs with high negative changes with a reduction of -2.77%, -2.19% and -2.13% respectively from 2001 to 2011. The map suggests that a north-south division exists for intra-LAD migration, where the majority of LADs with negative migration changes are located in the north and the majority of LADs with positive migration changes are located in the south of the UK.



a. Intra-rates 2010-11



b. Change of intra rates, 2000-01 to 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 4.16: Intra- Local Authority District migration rates in the UK by district

4.8 Conclusion

This chapter has investigated the differences between migration propensities and patterns evident from the census-based estimates of internal migration reported by ONS for 2000-01 and 2010-11; some of which are of interest in their own right but others may have implications for scale and zonation analysis. Because the analysis of the spatial dimension cannot be examined when looking at scale and zonation effects (carried out in the next chapters), this chapter has therefore built a comprehensive understanding of the data sets being used at the BSU level and, in particular, help support the LAD-based analysis of scale and zonation effects reported in the next chapter (Chapter 5).

This chapter has shown what the data tell us about internal migration at BSU level in the UK in the two time periods, starting with aggregate migration intensity and two measures of migration impact and then decomposing the net balances into their gross out- and in-migration components before considering flows between and within LADs. The chapter has shown that internal migration increased between the two periods, but the rate of migration decreased for both longer-distance migration between LADs and shorter-distance migration within LADs. Overall, the volume of net migration has increased. However, the rate of both long-distance (between LAD) and short-distance (within LAD) migration has decreased, which is consistent with Champion and Shuttleworth (2016b). The chapter showed variations in migration rates between nations and between age groups, with age group 20-24 exhibiting the highest migration intensities in each period. This change differs by age group, with the 20-24 group showing the highest intensity and the largest increase. Pre-2001 results have shown that the 20-24 age group always had the highest migration intensities, as shown by Pandit (1997); and the results in this chapter shows how this trend is still continuously increasing over time.

Familiar in terms of long established trends and those seen in 2001, the pattern of all age net migration losses from more urban areas and gains in non-urban areas was shown to have been maintained in 2010-11 and a sixfold classification was used to show the patterns of net migration change differed between four broad age groups, with the 15-24 year olds standing out as having a pattern of increasing net losses in rural areas, the reverse of that shown by the family age group. The patterns of change for mature workers and retired age groups were characterised by increasing or reducing net losses from the central core of the UK and increasing or reducing net gains in the peripheral areas.

The analysis of migration effectiveness suggested that the impact of migration on redistributing the population has increased between the two periods for those in the student age group but decreased in other age groups. The patterns of gross inflows and outflows that constitute the LAD net migration were explored and the relationship between these components allowed a more balanced migration system and has shown to have increased between 2000-01 and 2010-11 for the aggregate rates, and most significantly for the mature workers age groups. Stillwell et al. (2000) have shown that the overall effectiveness of net migration has declined from the 1970s to the 1090s in the UK, but this has now changed, as this chapter shows how the migration effectiveness has been increasing since 2000-01.

Finally, a new summary measure of inter-district migration was computed, showing the changing patterns of intra-district migration that showed a divide between increasing rates in the south and declining rates in the north. In summary, inter-district migration in aggregate terms within the UK had become more uniform and less effective in redistributing the population in 2010-11 but the range of values and the changes between the time periods varies by age group and the evidence suggests that the district inflows and outflows of 15-19 year old migrants have become more unequal.

No analysis has been reported in the academic literature of the changes taking place in spatial patterns of internal migration in these two periods, based on census data that are consistent between the two periods, both in definitional and geographical terms. The chapter has therefore provided some new insights into internal migration in the UK but these insights have been predominantly focused on migration at the district scale. In the chapters that follow, the aim is to consider how migration indicators, some of which have been reported in this chapter, vary according to scale and to the alternative ways in which territory is sub-divided.

Chapter 5: Scale and zonation effects on migration intensity and impact

5.1 Introduction

Migration indicators are important as they allow us to review and analyse the decisions made by migrants and help us to compare behaviours of different age groups and better understand trends that have taken place over time. In Chapter 4, selected migration indicators were introduced and used for spatial analysis at a single spatial scale, that of local authority districts (LADs), across whole of the UK. The purpose of the analysis reported in the current chapter is to establish what variations exist in all-age and age-specific migration when the selected indicators are computed for zone systems at different spatial scales and with different configurations of zones at the same scale. The chapter also aims to identify what changes have taken place in scale and zonation effects between the two periods, 2000-01 and 2010-11.

The chapter draws on methodology used in the IMAGE project which involved making comparisons of internal migration between countries with different spatial systems in order to build global 'league tables' based on different migration indicators, as reviewed in Chapter 4. Comparative analysis of aggregate or all-age migration in different countries was at the heart of the IMAGE project (Bell et al., 2015; Rees et al., 2015) whereas the focus of this chapter is on what MAUP effects occur when the input data are matrices of age-specific migration flows for the same national system of BSUs. Moreover, since the analysis reported in this chapter involves comparing schedules of migration indicators for different age groups over the scale range, it has been necessary to produce new statistics that measure the total effects of scale and zonation. In addition to identifying how the indicators change with scale and zonation, this chapter also tries to relate the discussion to key points that emerged from the literature review from Chapter 2, particularly in relation to variations in age-specific migration indicators (e.g. Rogers and Castro, 1981).

Matrices of migration flows between LADs for two time periods are used as the input data for the IMAGE Studio. The software aggregates these data for Basic Spatial Units (BSUs) into different configurations and computes migration indicators for sets of Aggregated Spatial Regions (ASRs) at different spatial scales. The variation in the mean values of each indicator as the number of ASRs changes provides a measure of the scale effect whereas the variation around the mean values of different indicators at each scale, measured by the range between the maximum and minimum, will provide a measure of the zonation effect.

Following a summary of the spatial aggregation process used by the IMAGE Studio in section 5.2, section 5.3 contains a preliminary analysis to establish how many scales should be used in the aggregation and how many iterations should be specified by the user. Three selected indicators are used to confirm how sensitive the MAUP effects are to choice of the number of scales and of iterations. Recognising that processing time is an issue, the chapter provides a pragmatic rationale for the choices made for processing each of the age-specific data sets. Scale and zonation effects for three variables using all-age migration between 2000-01 and 2010-11 are presented in section 5.4 whilst section 5.5 explores the MAUP effects for different age groups in the two time periods before investigating the relationship between the variables using a variant of the index of net migration impact as defined by Rees et al. (2017) in section 5.6. Conclusions are drawn in section 5.7.

5.2 The aggregation process

In order to merge BSUs into ASRs, a multiple aggregation option is available within the Aggregation Subsystem of the IMAGE Studio. This requires the user to specify a scale increment with which to aggregate BSUs on an iterative basis as well as the number of zone configurations required at each scale. Implementing the aggregation process involves choosing a spatial algorithm that is fed automatically with normalised data from the Data Preparation Subsystem of the IMAGE Studio to produce zone centroid coordinates, inter-zonal distances, zone contiguities, inter-zonal flow matrices and zone populations for each set of zones (ASRs) which can then be used to compute global migration indicators and their summary statistics. Two algorithms are available for aggregating initial BSUs to larger ASRs based on the automated Initial Random Aggregation (IRA) procedure first introduced by Openshaw (1977).

The initial IRA algorithm provides a high degree of randomisation to ensure that the resulting aggregations are different during the iterations (Stillwell et al., 2016). The IRA-wave aggregation algorithm is a hybrid version of the former algorithm with strong influences from the mechanics of the Breadth First Search (BFS) algorithm. If N ASRs are required, the first step of the IRA-wave algorithm is to select N BSUs randomly from the initial set of BSUs and assign each one to an empty region (ASR). Using an iterative process until all the BSUs have been allocated to the N ASRs, the algorithm identifies the BSUs contiguous with each ASR, targeting only the BSUs without an assigned ASR and adds them to each ASR respectively. Figure 5.1 is an example of the method of aggregating 16 BSUs into two ASRs.

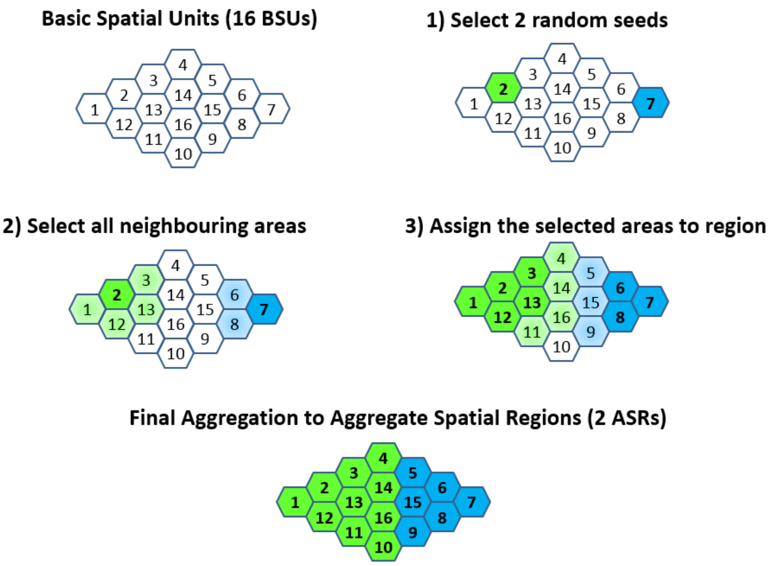
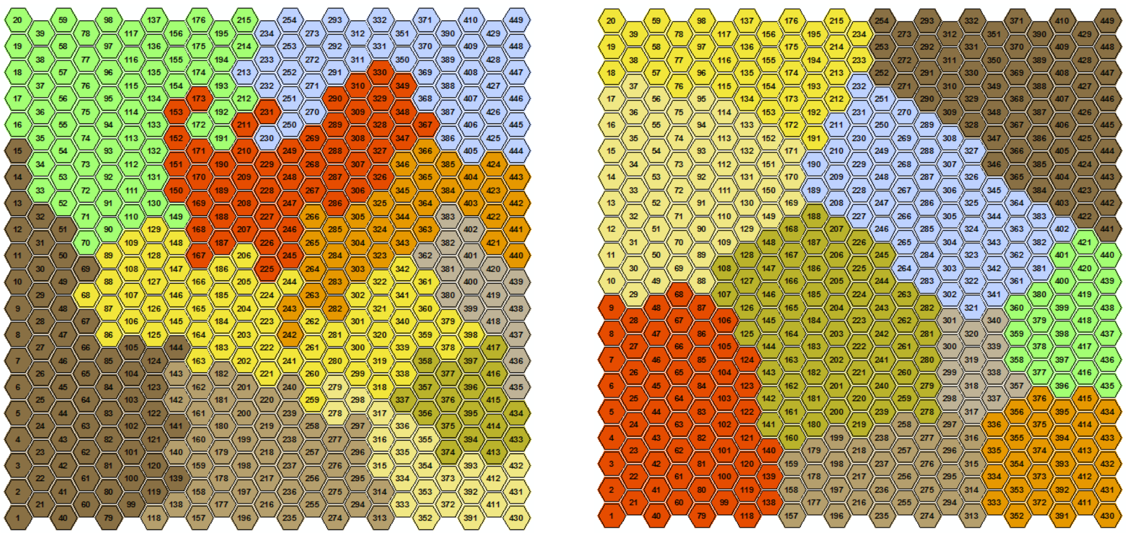


Figure 5.1: Example of IRA-wave process of aggregating basic spatial units

Two advantages of using the IRA-wave algorithm are its speed in producing a large number of initial aggregations and the fact that it produces relatively well-shaped regions in comparison to the more irregular shapes derived using the IRA algorithm. Figure 5.2 contains examples of the results of the two algorithms based on using artificial data (Stillwell et al., 2016) and demonstrates the how the IRA-wave algorithm creates much more regular and less fragmented ASRs than the IRA algorithm.



a. Initial Random Aggregation (IRA) b. Initial Random Aggregation (IRA-wave)

Source: Stillwell et al. (2016)

Figure 5.2: Artificial tessellation examples of Initial Random Aggregation routines

Openshaw's (1977) initial IRA algorithm was updated to support the needs of the IMAGE project by adding an iterative aggregation process to generate multiple solutions, i.e., sets of new ASR polygons given a number of scale steps and a number of iterations at each scale as specified by the user (Daras, 2014). The IMAGE Studio follows Openshaw's Fortran algorithm, with additional object-oriented principles implemented (Stillwell et al., 2014). One benefit of this approach is the use of objects instead of matrices, as they avoid the sustained sequential processes and result in faster random aggregation (Daras, 2006).

From a user perspective, the algorithm for multiple aggregations consists of five steps, the first two of which are defined by the user. Step 1 involves setting the scale increment (step) of the aggregation process which refers to the requested number of ASRs to be produced at each scale. For example, if there are 200 BSUs and the user aggregates them using a scale step of 20 zones, then the aggregations will take place for 20, 40, 60, 80, 100, 120, 140, 160, 180 and 200 ASRs. Step 2 is where the number of iterations required at each scale is specified by the user. The number of iterations is the number of the various ASR configurations that the algorithm will produce at each scale, e.g., 10 or 20 or 200 configurations at each scale. Step 3 aggregates the BSUs to ASRs using the IRA algorithm. Step 4 calculates and stores the data (centroids, distances, contiguities, flows and populations) for the new ASRs. Lastly, step 5 resets the number of ASRs using the scale increment (step) and repeats steps 3-5 until the lowest possible number of ASRs has been reached (Daras, 2014). Steps 3-5 are therefore undertaken automatically by the IMAGE Studio. The final outputs of the Aggregation Subsystem are stored in a tree directory structure where each directory represents a different aggregation scale. Inside each directory there are sets of files containing the different zonation configurations for each aggregation. Once the data have been aggregated and stored, the user can choose which migration indicators to compute for each zone configuration at each scale and which basic statistics should be used to summarise the results.

5.3 Identification of optimum step size and number of iterations using all-age migration data for 2010-11

When using the IMAGE Studio to analyse the scale and zonation effects relating to internal migration flows for a country, there are therefore two key questions:

(i) What should the scale step be for a system of 404 BSUs?

(ii) How many iterations at each ASR scale are appropriate?

In answering these two questions and choosing a scale step and number of iterations, there are two important considerations. First, it is important to think about the cost of processing time when analysing MAUP effects for data sets for 12 age groups for two periods of time, i.e. repeated aggregation for 24 large datasets. Stillwell et al. (2018) have investigated the speed at which the alternative IRA algorithms produce solutions when starting from a set of 404 BSUs, together with the time taken to produce a full set of migration indicators. Table 5.1 shows the respective runtime greediness of the IRA and the IRA-wave algorithms, together with the time taken for the aggregation of migration flows and other data for the new ASRs and the calculation of migration indicators. Thus, for example, when using a single matrix of flows between 404 BSUs, with a step size of 50 and creating 100 different zonations at each scale, the data aggregation is achieved in under 10 minutes and the computation of a full set of migration indicators takes a further half an hour. On the other hand, if a scale step of one is chosen with 100 iterations at each scale, the total aggregation time increases to six and a half hours and the computation of indicators takes a further 20 hours. Given these processing times, it is necessary to take a pragmatic view on the choice of parameters.

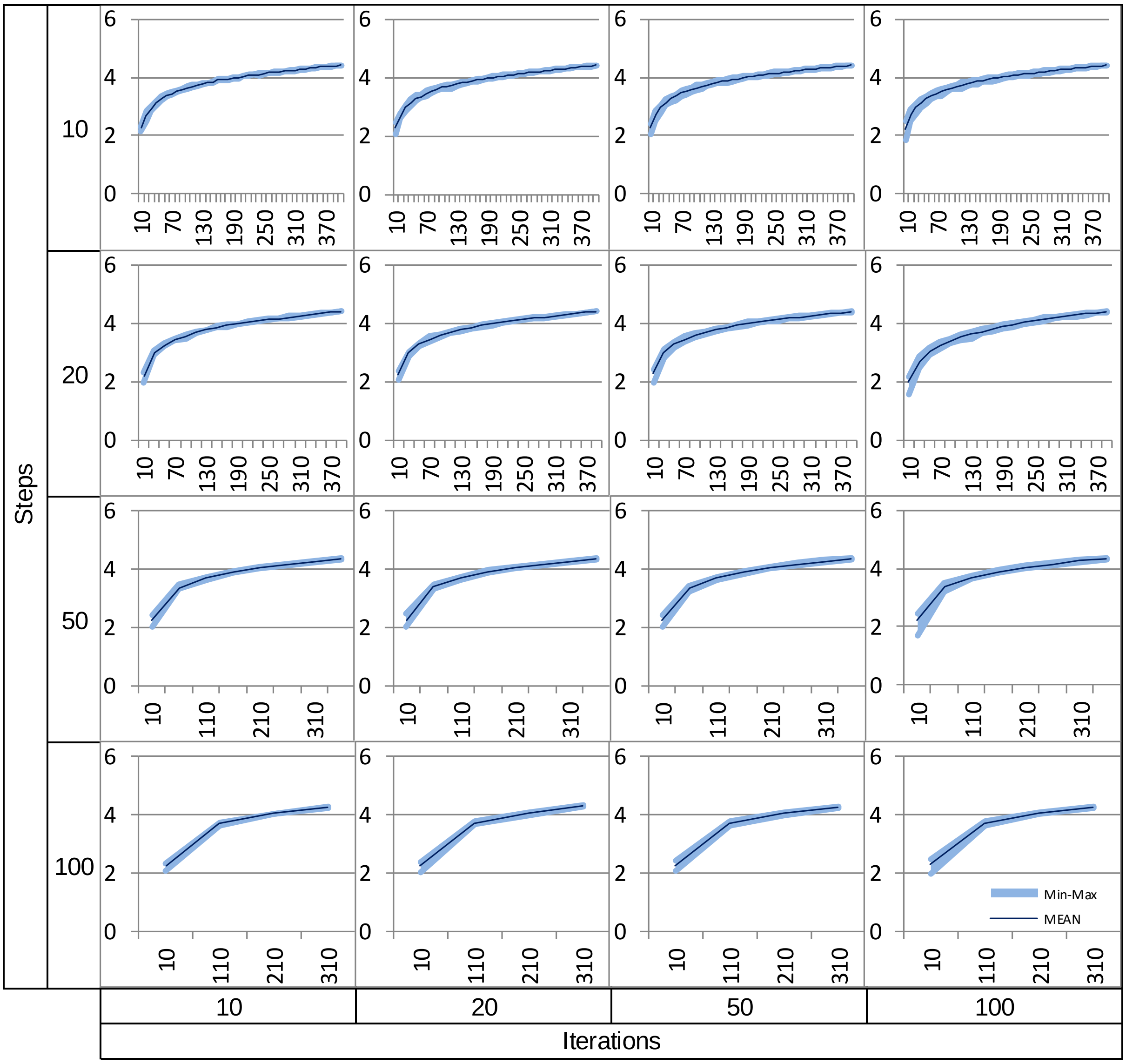
Table 5.1: Time processing costs when using 404 local authority districts using different step size and number of iterations

Step size	Number of iterations	IRA time (mins)	IRA-wave time (mins)	Data aggregation (hours)	Indicator calculations (hours)
1	10	0.58	0.45	0.64	2.05
1	100	5.51	4.19	6.28	20.13
1	500	25.14	21.83	31.41	100.64
1	1000	50.28	43.66	62.82	201.27
10	10	0.06	0.05	0.06	0.21
10	100	0.58	0.43	0.65	2.05
10	500	3.04	2.21	3.25	10.26
10	1000	5.8	4.7	6.8	20.52
20	10	0.03	0.03	0.03	0.12
20	100	0.31	0.24	0.35	1.16
20	500	1.58	1.17	1.75	5.79
20	1000	3.17	2.35	3.51	11.58
50	10	0.02	0.01	0.02	0.05
50	100	0.17	0.11	0.15	0.5
50	500	0.84	0.55	0.74	2.55
50	1000	1.73	1.11	1.48	5.09

Source: Stillwell et al. (2018, p.705)

The second issue to be considered is the likely sensitivity of the scale and zonation effects to scale step size and number of iterations, i.e. does it matter if the step size is 10 or 20 or that the number of iterations is 50 or 100? In order to check how sensitive the effects are to the choice of parameters, a series of tests were undertaken with the 404 BSUs and the all-age migration matrix and population data. The results of computing scale and zonation effects for three variables – the crude migration Intensity (CMI), the migration effectiveness index (MEI) and the aggregate net migration rate (ANMR) –using a combination of four step sizes (10, 20, 50 100) and four numbers of iterations (10, 20, 50, 100) are shown in Figures 5.3, 5.4 and 5.5.

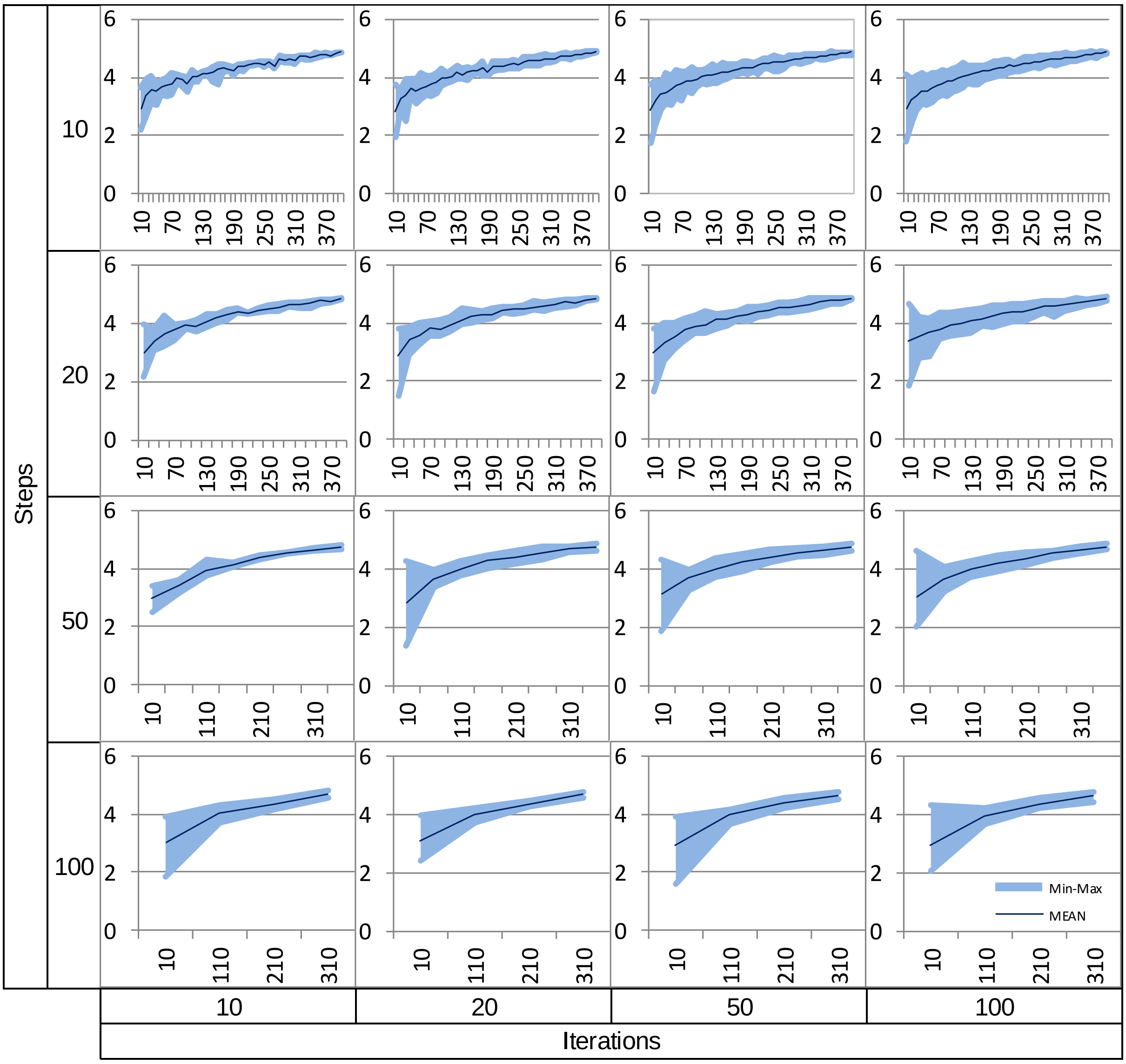
Each graph in Figure 5.3, for example, plots the mean CMI value of all the iterations at each scale against the number of ASRs so the thin black line represents the scale effect, whereas the zonation effect as shown by the light blue shading is the difference between the maximum and minimum value of all the configurations at each scale. The graphs have been organised into a matrix in which the rows represent different scale steps and the columns represent different numbers of iterations. Thus, the top left hand graph shows the scale and zonation effects for the CMI when the scale step and the number of iterations are both 10, whilst the bottom right-hand graph shows the effects when the scale step is reduced to 100 (giving only points on the graph) with 100 iterations at each of the scales.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.3: Scale and zonation effects for crude migration intensity, 2010-11

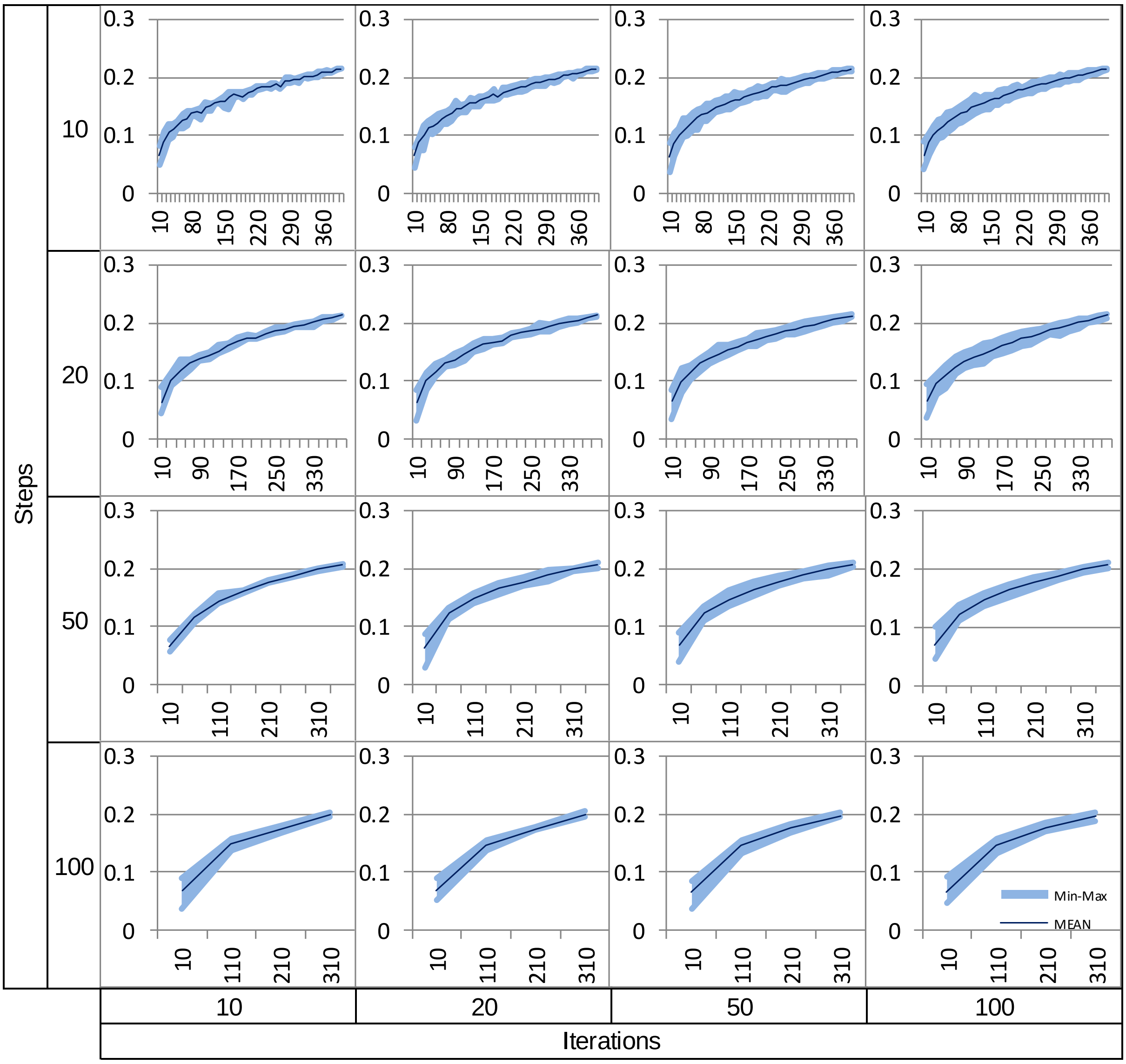
The CMI does show a strong scale effect but it does not change significantly according to the step size or the number of iterations. The most obvious difference is, as expected, that the CMI schedule becomes less smooth as the number of scale steps increases. A stepsize or 20 or less would be preferred in order generate a smooth schedule. The matrix of graphs shown in Figure 5.4 illustrate the scale and zonation effects for the second indicator, the MEI, using the same stepsize and iteration categories. In this case, whilst there is evidence of quite a significant zonation effect as the range increases as the ASRs get larger, the mean, minimum and maximum schedules show the same pattern but with differing levels of crudeness according to the step size.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.4: Scale and zonation effects for migration effectiveness index, 2010-11

The last indicator used to identify the optimal scale level and number of iterations is the ANMR shown in Figure 5.5. Similar to the MEI indicator, the zonation effect becomes more significant as the number of iterations increases but is less apparent than for the MEI. As with the other two indicators, the larger step size results in a more disjointed ANMR schedule but the overall patterns of scale and zonation effect are repeated.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.5: Scale and zonation effects for aggregate net migration rate, 2010-11

This analysis suggests that there is no reason to spend excessive amount of time running the IMAGE Studio with a very small step size and very large numbers of iterations because the overall characteristics of the scale and zonation effects are identifiable with parameters that are feasible from a pragmatic perspective, i.e. that are not going to take an inordinate amount of computer processing time. This experimentation suggests that 10 is an appropriate step size. Reducing the step size below 10 adds considerably to the amount of time and increasing the step size above 10 causes a certain loss of detail in the results. The results of the experiments suggest that 50 iterations at each step is realistic. Using more than 50 iterations appears to add relatively little detail to the effects whilst extending the processing time for aggregation and indicator computation significantly. Thus, the results reported in the following sections use the mean and range values of the three indicators based on a step size of 10 with 50 configurations/zonations at each scale.

5.4 Scale and zonation effects on all-age migration indicators in 2000-01 and 2010-11

As indicated previously, the variation in the mean values of each indicator as the number of ASRs changes provides a measure of the scale effect whereas the variation around the mean values of different indicators at each scale will provide a measure of the zonation effect. In this section, the scale and zonation effects associated with the three indicators of migration introduced previously (CMI, MEI and ANMR) are examined in more detail using the matrices of all age migration for 2000-01 and 2010-11. Whilst the CMI is an indicator of migration intensity, the two other indicators are both measures of impact. The three indicator variables have the following algebraic relationship for aggregate inter-zonal migration at any particular scale:

$$\text{CMI} = \text{MEI} / \text{ANMR} \tag{5.1}$$

or

$$\text{ANMR} = \text{CMI} * \text{MEI} \tag{5.2}$$

In other words, the intensity of migration in the system is determined by dividing the MEI by the ANMR or the impact of migration as defined by the ANMR is the product of the CMI as a measure of intensity and the MEI as a measure of impact. The intensity of migration is determined by the various explanatory factors discussed in Chapter 2 including household financial decisions and individual life course plans (Kaufmann, 2006) as well as macro-economic or housing market conditions. All age migration intensity, or the overall level of mobility, has been used as indicator of development (Bell et al., 2015; Champion et al., 2018), but it conceals important variation by age as reviewed in Chapter 2. The impact indicators, on the other hand, are aggregate measures of how the population is being redistributed through migration with time series data providing evidence of whether spatial patterns in different countries are following some theory of mobility transition (e.g. Zelinsky, 1971; Rees et al., 2016).

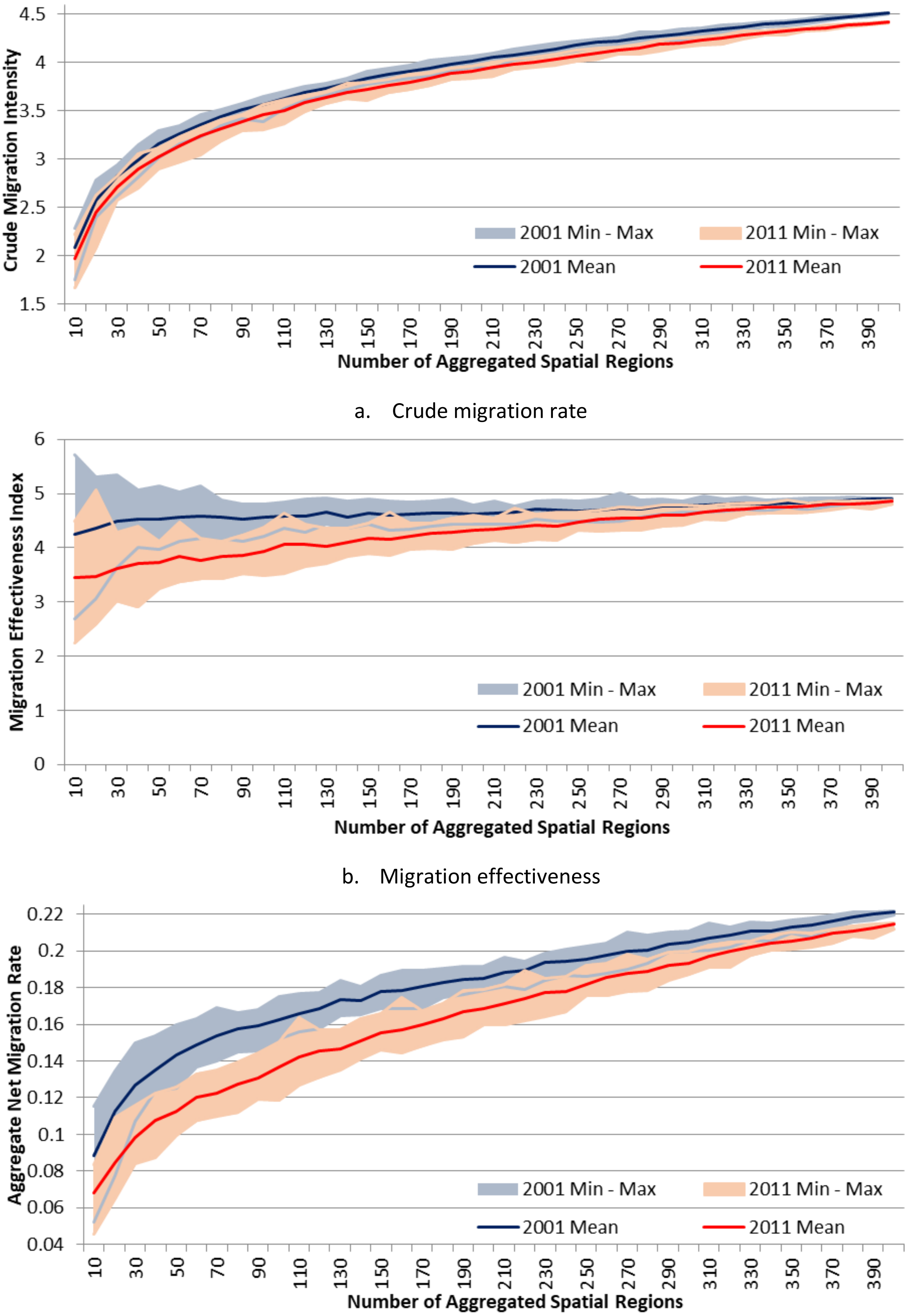
The IMAGE Studio has been used to investigate the effects of scale and zonation on each of these indicators. Aggregations have been run in scale steps of 10 from 10 to 400 ASRs with 50 iterations at each scale. Figure 5.6 shows the scale and zonation effects on these three indicators and how they compare between 2000-01 and 2010-11. Minimum/maximum boundaries are shown in the graphs, rather than confidence intervals, because the minimum/maximum values shows the extremes that the migration indicator values extend to; thereby capturing an accurate measure of the zonation effect. The shape of each line (blue for 2000-01 or red for 2010-11) provides a visual representation of the scale effect, as the number of ASRs increases on the horizontal axis from 10 to 400 whilst the range around the mean (the shaded area) gives an indication of the zonation effect at each scale. The three graphs at each scale are not directly comparable, because the scales on the y axis are different for each case.

The mean CMI in 2000-01 varies across the scale range, falling from 4.5 migrants per 1,000 population with 400 ASRs to 2.2 per 1,000 between 10 ASRs. The relationship between the CMI and scale is not linear; the scale effect becomes progressively larger as the number of ASRs gets smaller, particularly when below 100 zones. The mean value of the CMI at 400 ASRs in 2010-11 is 4.42, reflecting the decreased propensity to migrate between LADs in the more recent period, but the scale effect is parallel to that in 2000-01. Whereas there is clear evidence of the effect of scale on the CMI for both periods, the zonation effect is much less pronounced in both cases.

In contrast to the CMI schedules, the mean MEI exhibits a more constant, linear relationship with scale; the MEI value for 2000-01 drops from 5 to 4.7 until it reaches 30 ASRs and the schedule then starts to show a small scale effect by dropping to 4.2 at 10 ASRs. In 2010-11, the MEI decreases across all ASRs starting from 4.9 at 400 ASRs to 3.5 at 10 ASRs. The observation that the MEI is, to a certain extent, scale independent, confirms with the findings from several other countries around the world, as reported in Rees et al. (2018). On the other hand, Figure 5.6b illustrates that there is significant zonation effect with the MEI; the way in which BSUs are configured into different ASRs becomes increasingly noticeable as the ASRs increase in size and the extent of the zonation effect is similar in both time periods.

Figure 5.6c indicates that the results for the mean ANMR sit between those of the CMI and MEI, not surprising since the ANMR is a product of these two indicators. The non-linear mean ANMR profile suggests a lesser scale effect than the mean CMI with the 2010-11 values being consistently lower than in 2000-01. The mean ANMR experiences quite a strong decrease after 250 ASRs for both years respectively and the zonation effect does not tend to increase as the number of ASRs is reduced, as it dies with the MEI.

So, these results demonstrate the extent to which migration intensity and impact varies according to the scale and the zonation system used to measure migration. They confirm the relative scale independence of the MEI. We will return to the relationship between these three indicators later in the chapter.



a. Crude migration rate

b. Migration effectiveness

c. Aggregate net migration rate

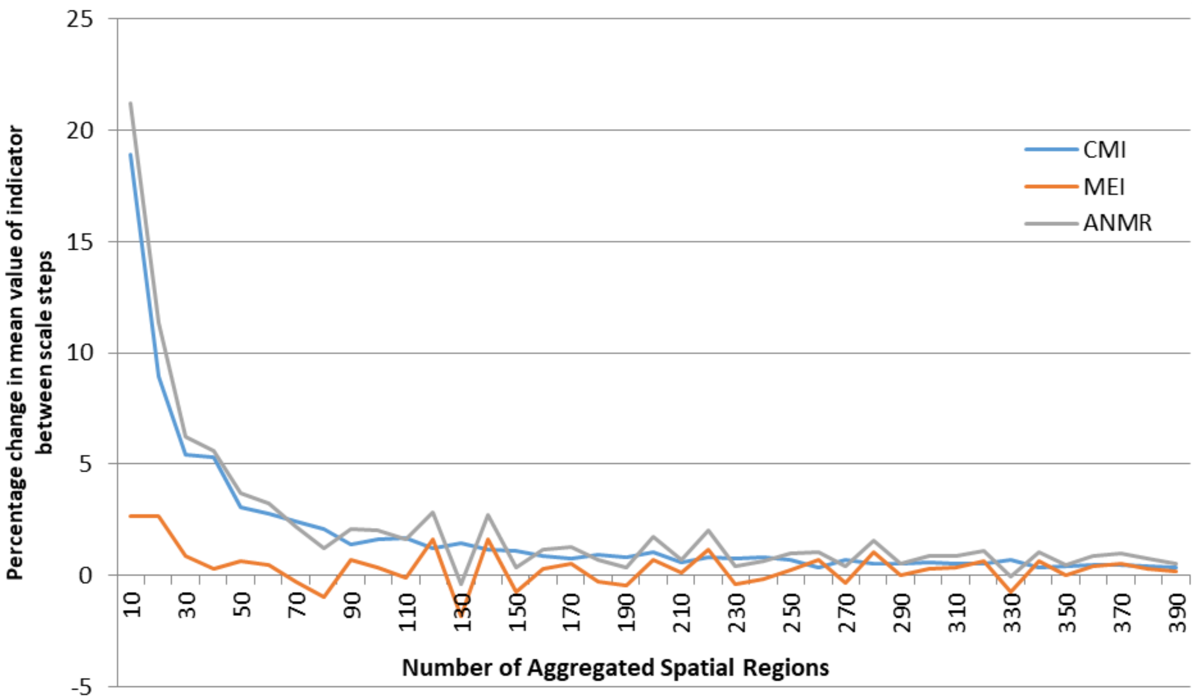
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.6: Scale and zonation effects on three migration indicators, 2000-01 and 2010-11

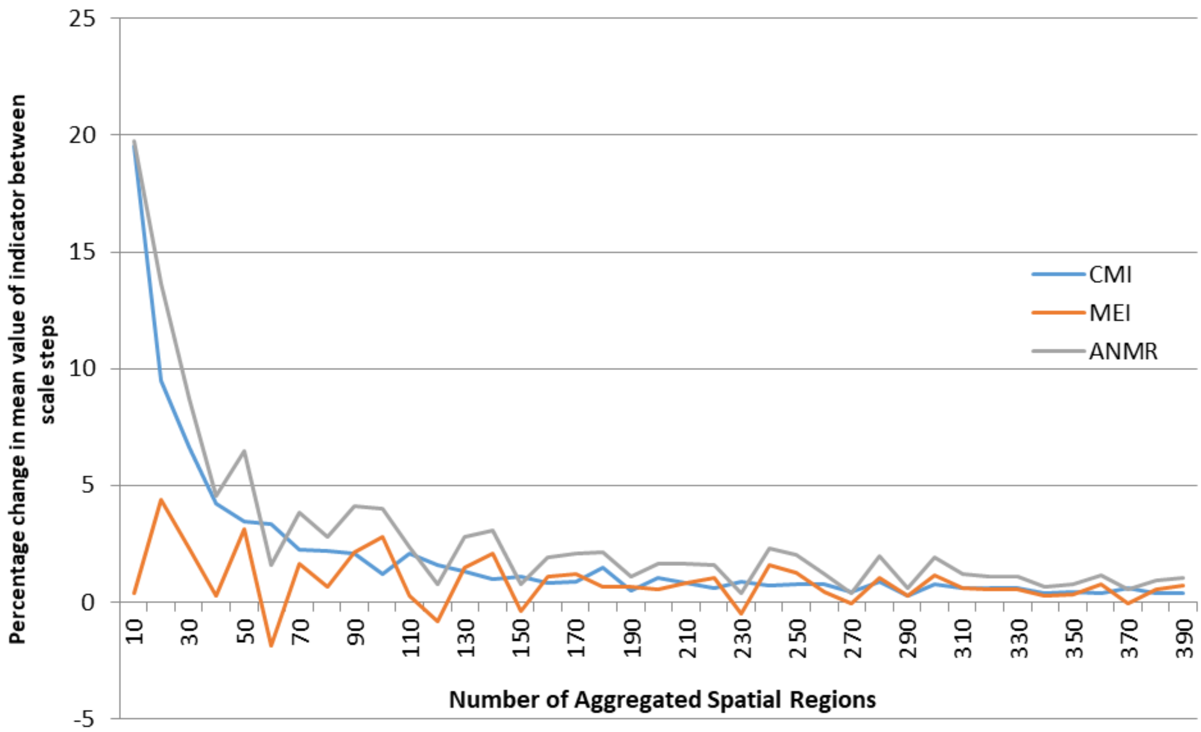
Figure 5.6 allows us to visualise the scale and zonation effects associated with the selected indicators but does not provide a numeric measure of these effects to facilitate comparison. In order to quantify how the scale effect varies for each indicator, one approach is to compute the percentage change between successive mean values at each step for each indicator value. This can be defined for the CMI as follows:

$$\text{Percentage change in Mean CMI} = \frac{(\text{Mean CMI}_{n+1} - \text{Mean CMI}_{n})}{\text{Mean CMI}_{n+1}} \times 100 \tag{5.3}$$

This equation shows the mean value of the CMI at scale step n+1 minus the mean CMI value at scale step n divided by mean CMI value at scale step n+1 multiplied by 100. These percentage changes between scale steps are plotted on the graphs in Figure 5.7 allowing us to compare the scale effects of different indicators directly. Figure 5.7a shows the percentage changes by scale step for three indicators, CMI, MEI and ANMR for 2000-01, emphasising that the scale effects for the CMI and the ANMR are far greater than for the MEI. Figure 5.7b demonstrates that the scale effect of the CMI and ANMR are still stronger than the MEI in 2010-11. In 2000-01, after 60 ASRs all indicators have a percentage change of less than 3%, whereas in 2010-11 this occurs after 110 ASRs. The results confirm that the MEI is more scale independent than the CMI and the ANMR when the ASRs get larger and fewer in number.



a. 2000-01



b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.7: Percentage change by scale step, three indicators, 2000-01 and 2010-11

A 'total scale effect' can be quantified by summing up the percentage changes of the mean values of each indicator between each scale step. The total scale effect shown in Table 5.2 for the CMI has increased from 0.74 in 2000-01 to 0.77 in 2010-11 whilst that for the MEI increased from 0.14 in 2000-01 to 0.34 in 2010-11. The total effect is largest for the ANMR, increasing from 0.87 in 2000-01 to 1.10 in 2010-11. A 'total zonation effect' can also be computed by adding together the difference between the minimum and maximum values of an indicator at each scale step. The magnitude of the MEI total zonation effect when compared with that of the CMI or the ANMR is evident from Table 5.2 in both 2000-01 and 2010-11. Although the total scale effect is comparable between indicators, because it looks at the sum of percentage changes, the total zonation effect is not easily compared, as it uses the mean and therefore the range values for each indicator will be different.

Table 5.2: Total scale and zonation effects for each indicator, 2000-01 and 2010-11

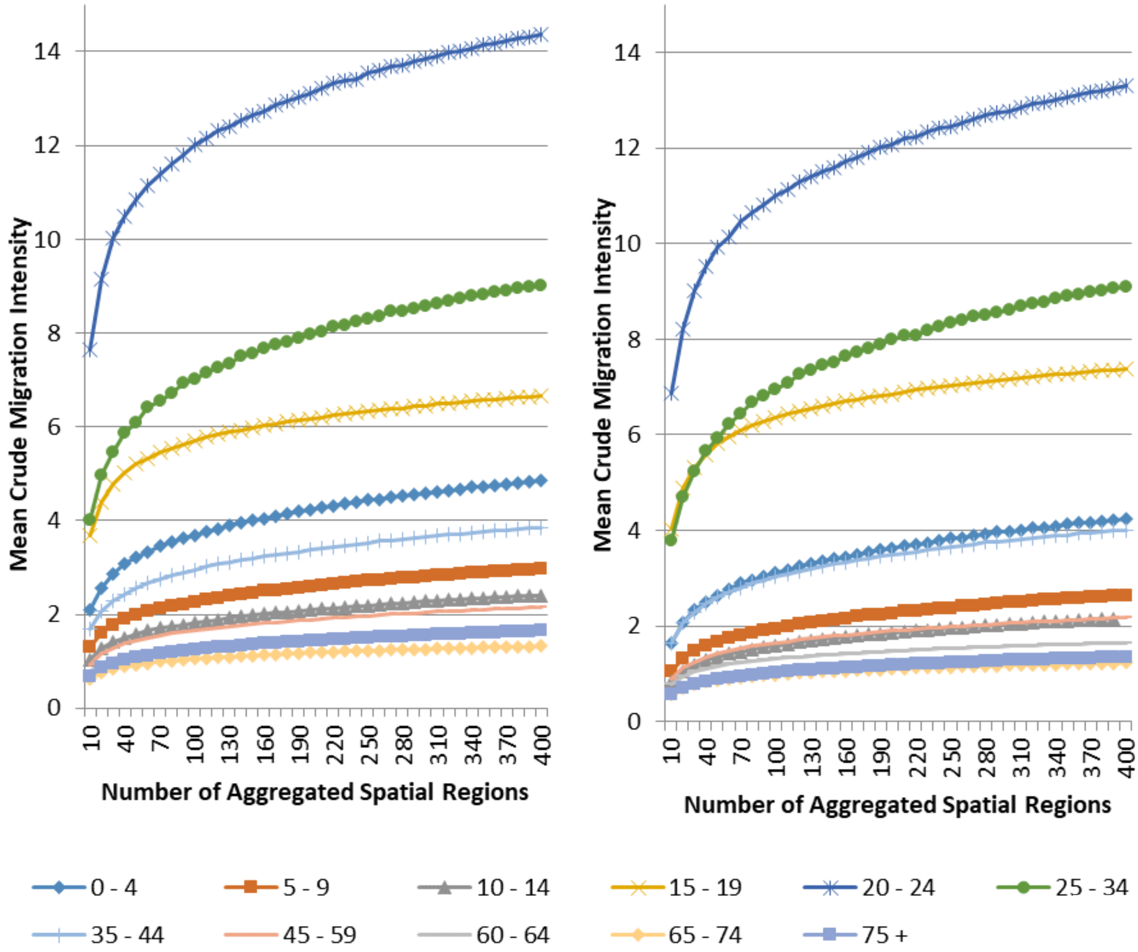
	Total scale effect		Total zonation effect	
	2000-01	2010-11	2000-01	2010-11
Crude Migration Intensity	0.74	0.77	5.85	6.22
Migration Effectiveness Index	0.14	0.34	23.23	25.03
Aggregate Net Migration Rate	0.87	1.10	0.76	0.82

Source: Estimates based on data from 2001 and 2011 Censuses

5.5 Scale and zonation effects on migration indicators for age groups in 2000-01 and 2010-11

As indicated in Chapter 2, previous studies published in the literature have demonstrated how propensities and patterns of internal migration vary by age (e.g. Dennett and Stillwell, 2010, using census data for Great Britain). A familiar age-profile of national migration rates has been presented in Chapter 4 together with evidence of spatial variations in net, gross and directional patterns and of changes between 2000-01 and 2010-11. In this section, we ask whether scale and zonation matter as far as migration intensity and impact are concerned when age-specific migration streams are considered, what variations from the all age scale and zonation profiles can be observed, and why might these variations might occur. The same three indicators – CMI, MEI and ANMR – are used for the age group analysis.

The two graphs in Figure 5.8 exemplify how the mean national CMI values can be compared for each age group. The graphs contain plots of the mean CMI value against the number of ASRs so the schedules represent the scale effects for each the 11 age groups in 2000-01 in Figure 5.8a and 2010-11 in Figure 5.8b. The schedules commence on the right hand side with rates equivalent to those shown in the migration age schedule in Chapter 4 (Figure 4.1). Thus, the 20-24 year olds have the highest rates, whereas the lowest rates are for the 65-74 year olds. The CMIs for each age group decline from right to left as the number of ASRs gets smaller. The schedules are non-linear but have a regular shape relative to one another. The graphs suggest that three age groups stand out as having a comparatively large scale effect and high CMI values; these are the 15-19, 20-24 and the 25-34 year olds. Although the CMI values for the 20-24 age group decrease between the two time periods, the scale effect remains strong. The CMI values for the 15-19 age group show an increase between 2000-01 and 2010-11 whilst the CMI for the 0-4 year olds drops. Corresponding to the age migration schedule shown in Chapter 4, lower CMI values are associated with the older age groups and appear to remain less dependent although the percentage drop in CMI between scales of 400 and 10 is 53.12% for age group 65-74 in 2010-11 compared to 48.42% for age group 20-24. The total scale effects for each age group are reported later in the chapter.

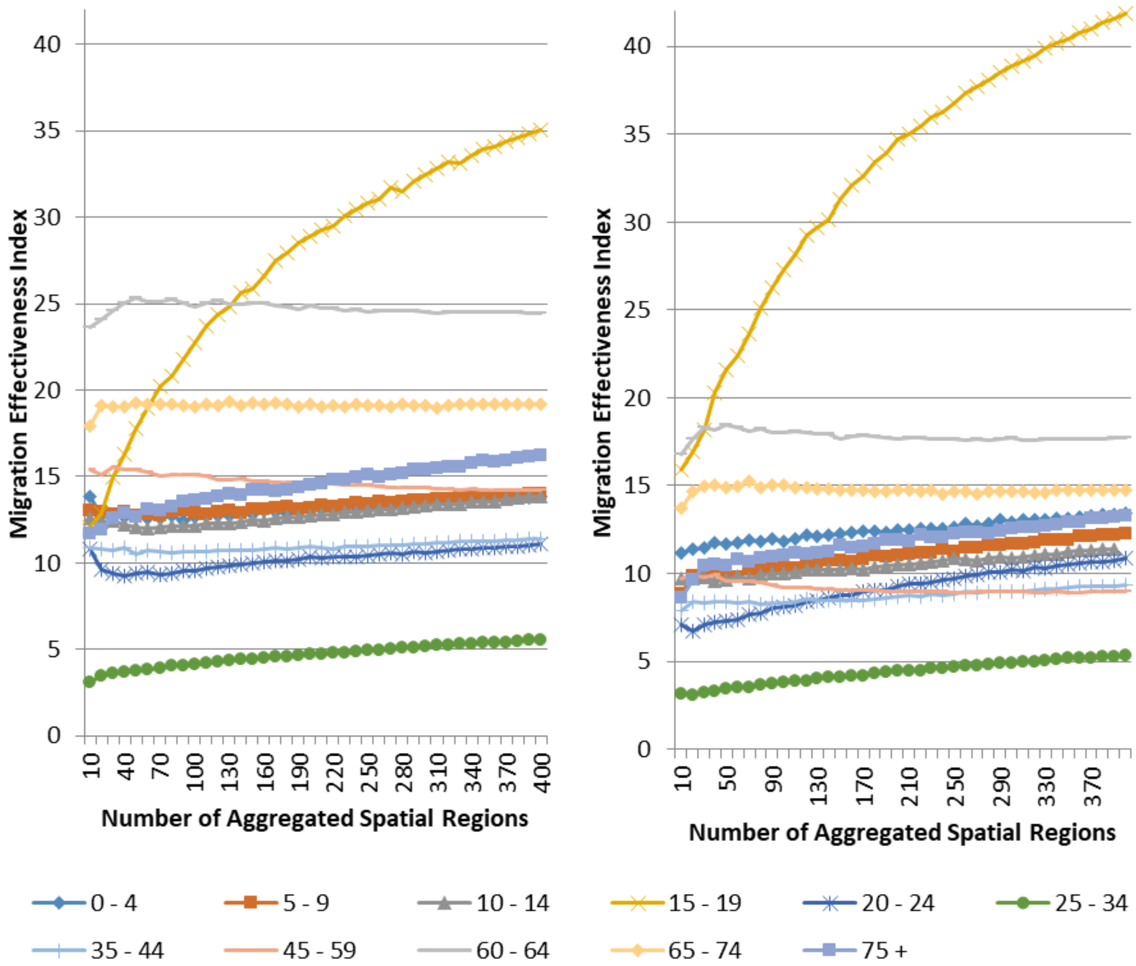


a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.8: Crude migration intensity by scale for age groups, 2000-01 and 2010-11

Whereas the CMI schedules shown in Figure 5.8 are as expected, the age-specific MEI schedules illustrated in graphs in Figure 5.9 showing how the MEI values change according to the number of ASRs indicate a totally different order. In general, the MEI schedules are linear and much more scale independent, with the 60-64 year olds having the highest level of MEI and 0-4 year olds the lowest. In other words, internal migration is much more important in redistributing the elderly than it is for the children and their parental age groups. In fact, as the number of ASRs gets smaller, the mean MEI values appear to increase for those in the 60-64 and 65-74 age groups as well as those aged 45-59, that is until the number of ASRs gets below 50. The anomaly amongst the age groups appears to be those aged 15-19 whose mean MEI is much higher at BSU level but whose value reduces significantly as the number of ASRs gets smaller and the size of the zones gets larger. Moreover, the scale effect for this age group increases from 2000-01 to 2010-11. This age group contains the students who migrate to their places of higher or further education and those spatial pattern of net migration is almost the reverse of that of other age groups, as shown in Chapter 4. Both graphs in Figure 5.9 indicate that scale is therefore only an important consideration for 15-19 year olds; the impact of migration measured by the MEI for this highly mobile group reduces by more than half when the number of ASRs falls from 400 to 50.



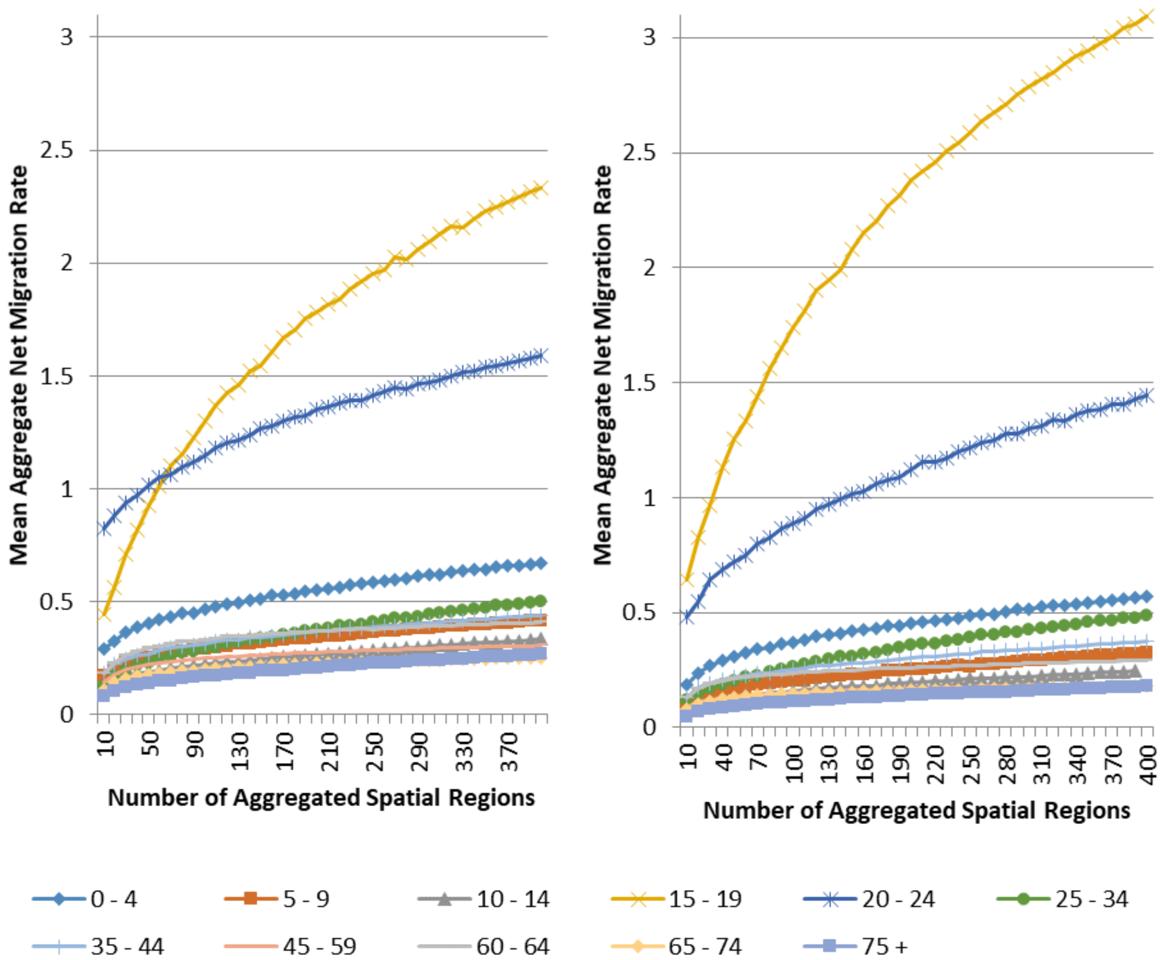
a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.9: Migration effectiveness by scale for age groups, 2000-01 and 2010-11

The influence of the scale effect of the MEI on that of the ANMR for the 15-19 year old age group is shown in Figure 5.10. The ANMR for the 15-19 year olds has a strong scale effect particularly in 2010-11. The 20-24 year olds also show a strong scale effect, but they experience a decrease between the two time periods. The remaining nine age groups do not show the same degree of scale effect as the CMI with the majority experiencing a lower ANMR in 2010-11 than in 2000-01.

In summary, the observation that the mean ANMR has a scale effect suggests that the CMI has a greater influence on population redistribution via internal migration than the MEI. These results are similar to those identified by Stillwell et al. (2018). However, in terms of MEI, the scale level is rather insignificant for all age groups apart from those aged 15-19, whose ANMR is determined more by MEI than by CMI and for whom the scale level chosen is much more important. As noted in Chapter 2, Ravenstein (1885) predicated his laws of migration on the basis of migration intensities at county level. The results for the UK that have been presented in this section suggest that migration intensity, as well as indicators of migration impact, will vary according to scale and according to the age group of the migrants involved. The impact of migration is a function of both intensity and effectiveness and we examine this relationship later in the chapter more fully, after comparing age groups on the basis of their total scale and zonation effects.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.10: Aggregate net migration rate by scale for age groups, 2000-01 and 2010-11

As indicated previously, the schedules graphed in Figures 5.8 to 5.10 provide a visualisation of the scale effects for different age groups but because the values of indicators at BSU level are different, a more precise method of comparison is required. A total scale effect can be computed by summing the differences between the mean indicator values at consecutive scales. The process is repeated for each age group for both time periods to provide a comparative overview of the aggregate scale effect for the CMI, MEI and ANMR. The results are shown in Table 5.3 quantify some of the observations made in the previous graphs. Notably, across the age groups, the values of the scale effects are much larger for CMI and ANMR than they are for MEI. In terms of specific age groups, the CMI shows strong scale effects for the 15-19 age group in 2010-11 with a calculated total scale effects of 0.92 which is a substantial increase from 2000-01 where the total scale effect was much weaker at 0.57. The eldest three age groups, 60-64, 65-74 and 75+, have a consistently strong scale effects with values ranging from 0.73 to 0.84 in 2000-01 and from 0.72 to 0.85 in 2010-11.

The total scale effect for the MEI is highest for the 15-19 age group with a total value of 1.04 in 2000-01 but decreased significantly to 0.16 in 2010-11. No other age groups between both time periods have total scale effects comparable to the 15-19 year olds in 2000-01 and mostly range between 0 and 0.57, with the exception of the 45-59 year olds showing negative values of the total scale effect at -0.08. In 2010-11, the total scale effect for the 20-24 age group was 0.95, a higher than all other age groups whose values range between 0.05 and 0.53, with the exception of the 60-64 year olds showing negative values of the total scale effect at -0.08 . Negative scale effect in this case occurs when some ASRs have higher MEI values than a smaller ASRs, resulting in an average negative value; but in this case the defences are very minimal and although a negative value is present the results signifies that there are very little to no scale effect.

Similar to the MEI, the ANMR shows a relatively strong total scale effect for the 15-19 year olds, with a total value of 1.57 in 2000-01 decreasing to 1.07 in 2010-11. The 20-24 age group on the other hand increased from 0.64 in 2000-01 to 1.50 in 2010-11. The total scale effect is the lowest for the elder age groups ranging from 0.76 to 0.78 in 2010-11.

Table 5.3: Total scale effects for indicators by age group, 2000-01 and 2010-11

	Crude Migration Intensity		Migration Effectiveness Index		Aggregate Net Migration Rate	
Age group	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11
0 - 4	0.80	0.77	0.00	0.34	0.81	1.10
5 - 9	0.79	0.91	0.07	0.18	0.86	1.08
10 - 14	0.82	0.89	0.09	0.32	0.92	1.19
15 - 19	0.57	0.92	1.04	0.16	1.57	1.07
20 - 24	0.61	0.58	0.02	0.95	0.65	1.50
25 - 34	0.78	0.64	0.57	0.42	1.32	1.06
35 - 44	0.80	0.84	0.04	0.53	0.85	1.36
45 - 59	0.80	0.86	-0.08	0.17	0.72	1.01
60 - 64	0.73	0.85	0.03	-0.08	0.75	0.77
65 - 74	0.73	0.72	0.07	0.05	0.79	0.76
75 +	0.84	0.73	0.32	0.07	1.14	0.78

Source: Estimates based on data from 2001 and 2011 Censuses

The graphs in Figure 5.8 to 5.10 have illustrated the scale effect but have excluded any visualisation of the zonation effect. These graphs become too muddled when the range values are included so, in order to compare between age groups effectively, the total zonation effects have been computed and presented in Table 5.4. Each value is a summation of the maximum value minus the minimum value (the range) for an indicator, divided by the mean, at each scale.

Division by the mean standardises for variation in the indicator between age groups. The results of the total zonation effects are shown in Table 5.4 with the strongest for the CMI observed for the 25-34 age group with a total zonation effect value of 2.42 in 2000-01 and 2.88 in 2010-11. The strongest total zonation effect for MEI can be found amongst the 15-19 and 25-34 year olds with values of 7.53 and 8.04 in 2000-01, and 7.00 and 8.41 in 2010-11 respectively. The lowest total zonation effect for MEI is shown by the 45-74 year olds with a values ranging between 4.43 and 4.59 in 2000-01, decreasing to values between 4.33 and 4.48 in 2010-11. The total zonation effect values for the ANMR show a similar pattern to those of the MEI with strong effects for the 15-19 and 25-34 age groups with values of 7.86 and 8.14 in 2000-01 and values of 7.07 and 8.92 in 2010-11 respectively. In 2010-11, it becomes more apparent that the younger ages groups have a great zonation effect overall than the population aged between 45 and 74.

Table 5.4: Total zonation effect for indicators by age group, 2000-01 and 2010-11

	Crude Migration Intensity		Migration Effectiveness Index		Aggregate Net Migration Rate	
Age groups	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11
0 - 4	1.88	2.52	5.03	6.96	5.16	7.48
5 - 9	1.76	2.08	4.86	6.50	4.91	7.00
10 - 14	1.68	2.01	5.26	6.19	5.18	6.28
15 - 19	1.23	1.24	7.53	7.00	7.86	7.07
20 - 24	1.80	1.81	4.42	5.84	4.56	6.18
25 - 34	2.42	2.88	8.04	8.41	8.14	8.92
35 - 44	1.94	2.22	5.25	6.55	5.29	6.49
45 - 59	1.66	1.70	4.43	4.33	4.63	4.38
60 - 64	1.56	1.49	4.59	4.34	4.68	4.56
65 - 74	1.44	1.68	4.48	4.48	4.59	4.67
75 +	2.18	1.67	6.23	7.44	6.86	7.51

Source: Estimates based on data from 2001 and 2011 Censuses

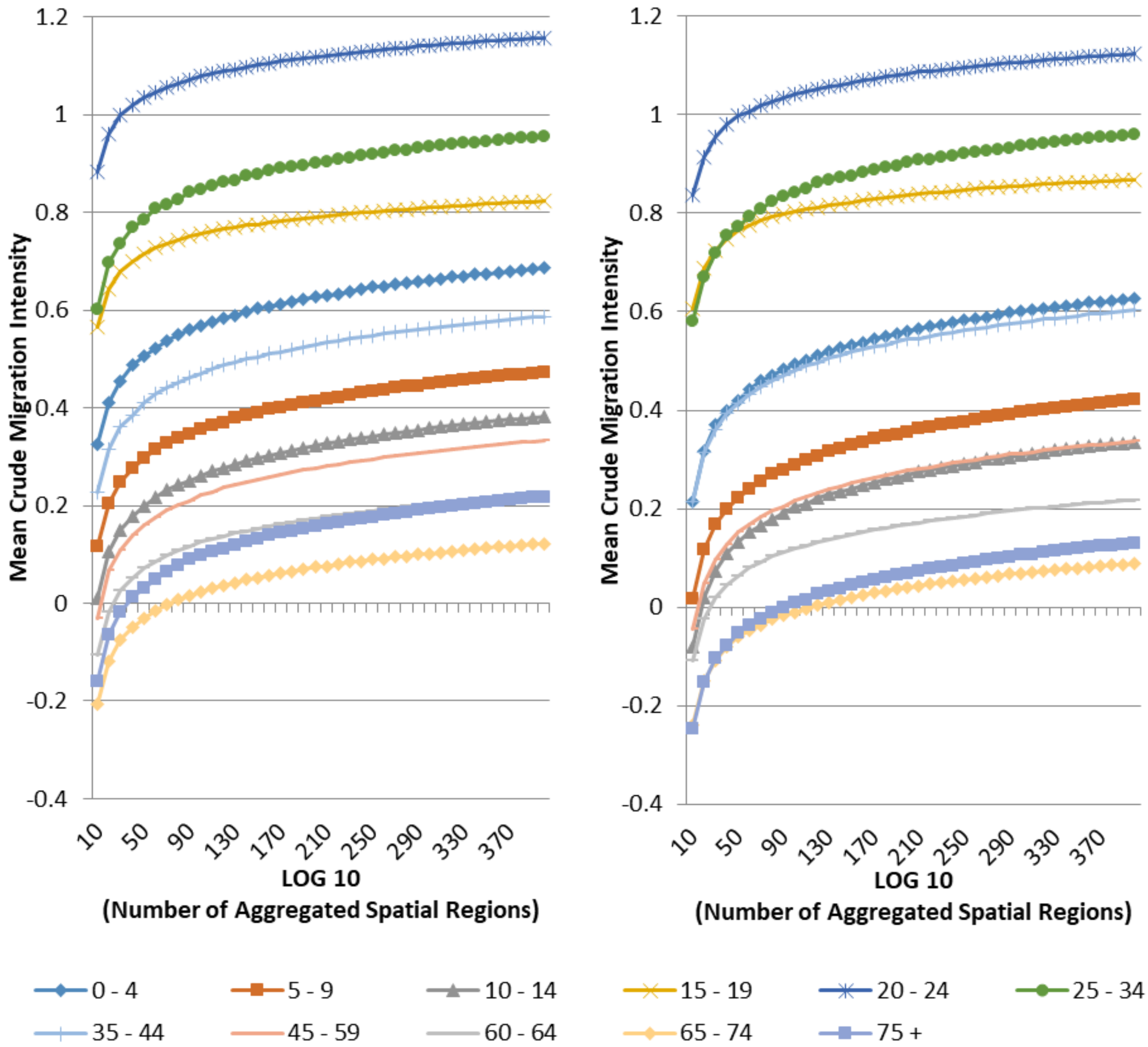
Table 5.3 and 5.4 have shown the total impact of the scale and zonation effects by age groups over the two different time periods for the CMI, MEI and ANMR. These values summarize this impact with quantified values to be able to compare them with each other and to validate all observations made in Figures 5.8 to 5.10. Some of the key results have shown that lower CMI values are associated with the older age groups and appear to remain less dependent. Whilst the MEI has shown that the 15-19 age group is almost the reverse of that of other age groups, which is consistent with the results in Chapter 4, whose mean MEI is much higher at BSU level but whose value reduces significantly as the number of ASRs gets smaller and the size of the zones gets larger. The ANMR is showing an increasingly strong scale effect for the 15-19 age group, and the 20-24 year olds show strong scale effect, but with a decrease between the two time periods. All other age groups do not show the same degree of scale effects as the CMI with the majority experiencing a lower ANMR in 2010-11 than in 2000-01. The scale effect for the ANMR has demonstrated that the CMI has a greater influence on population redistribution via internal migration than the MEI.

5.6 Relationship between CMI and MEI by age group

Courgeau (1973) stated that when comparing migration impact, the modelled slope of the ANMR is determined by its components, the CMI and the MEI. As indicated previously in equation 5.2, the ANMR can therefore be computed as the product of the CMI and the MEI at any spatial scale. Rees et al. (2017) have implemented a cross-national comparison of migration impact by using the linear regression slopes of the logged values of the CMI and the MEI calculated at each of the scale steps with different numbers of ASRs. This represents a method for comparing the migration impact of different age groups within the UK between the two time periods and for clarifying the respective roles of the CMI and MEI in determining the ANMR in each case. To look at how the two components of ANMR vary in relation to one another for different age groups, Rees et al. (2017) suggested an Index of Net Migration Impact (INMI) defined as:

$$\text{INMI} = (\text{CMI slope for an age group/Average CMI slope for all age groups}) * (\text{Mean MEI for an age group/Average MEI for all age groups}) \tag{5.4}$$

Following Rees et al. (2017) method, all three values (CMI, MEI and ANMR) are plotted using the common logarithms of the number of regions. Figure 5.11 illustrates this for the CMI with all age groups for 2000-01 and 2010-11. This approach is valuable for providing a clearer visualisation of the differences in the scale effects between different age groups.



a. 2000-01 b. 2010-11

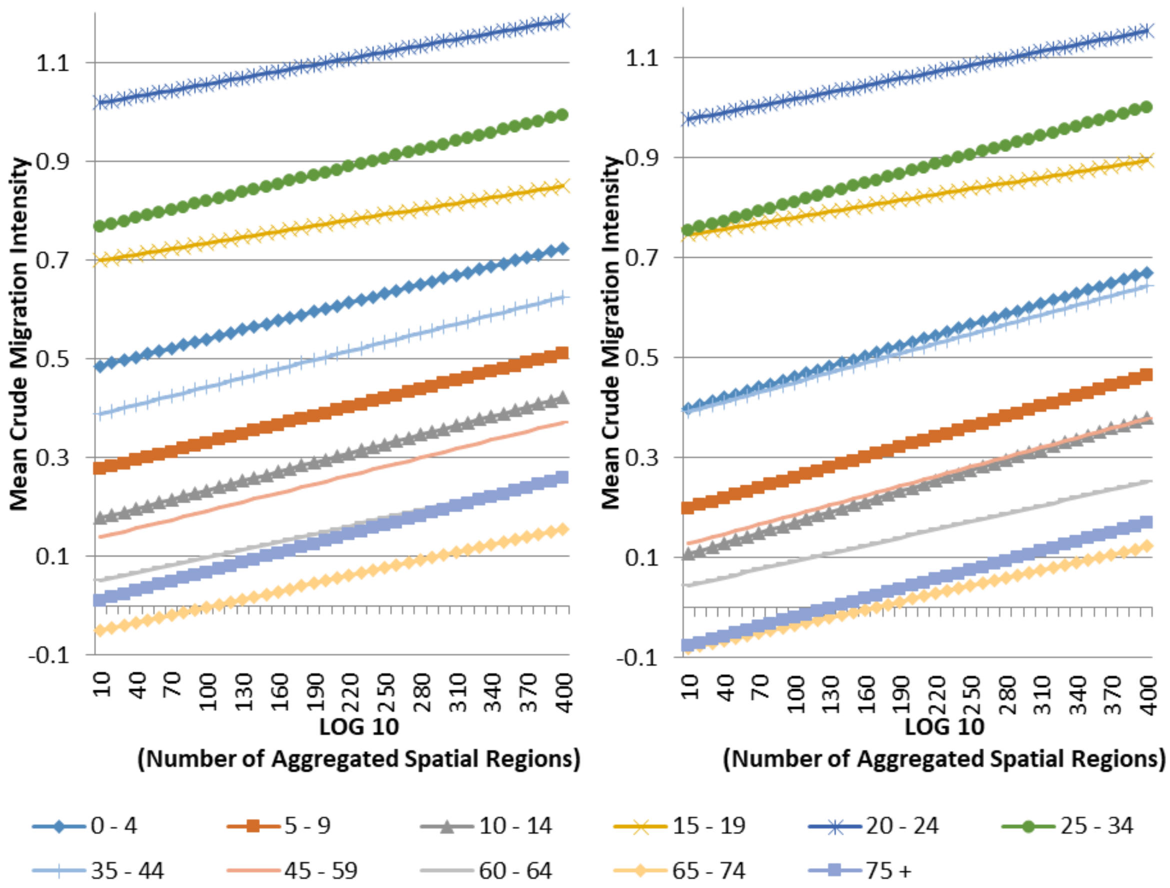
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.11: Logged crude migration intensity for age groups, 2000-01 and 2010-11

The graphs shown in Figure 5.11, after applying the logarithmic transformation are not linear but following Courgeau's (1992) method, the relationships between the CMI values and the logarithms of the number of ASRs can be calibrated by fitting linear regression models. The results are shown in Figure 5.12 and allow a better understanding on how the CMI slope differs between age groups. This shows for example, that the 20-24, 25-34 and 15-19 year olds have the highest Y-intercept, and that all the slopes are positive.

What these results are showing is that there are significant scale effects when considering rates for fewer and larger regions. Although the scale effects looks to be similar for different age groups, it is important to be aware that the slopes of the schedules start at different points, there is therefore a need to compute total scale effects to get a better comparative measure. Similarly to Figure 5.11 and

5.12, the model migration schedule used by Rogers and Castro (1981), shows that the migration patterns have strong regularities within age patterns, where each age group experiences a rate change as the number of ASRs reduces.



a. 2000-01 b. 2010-11

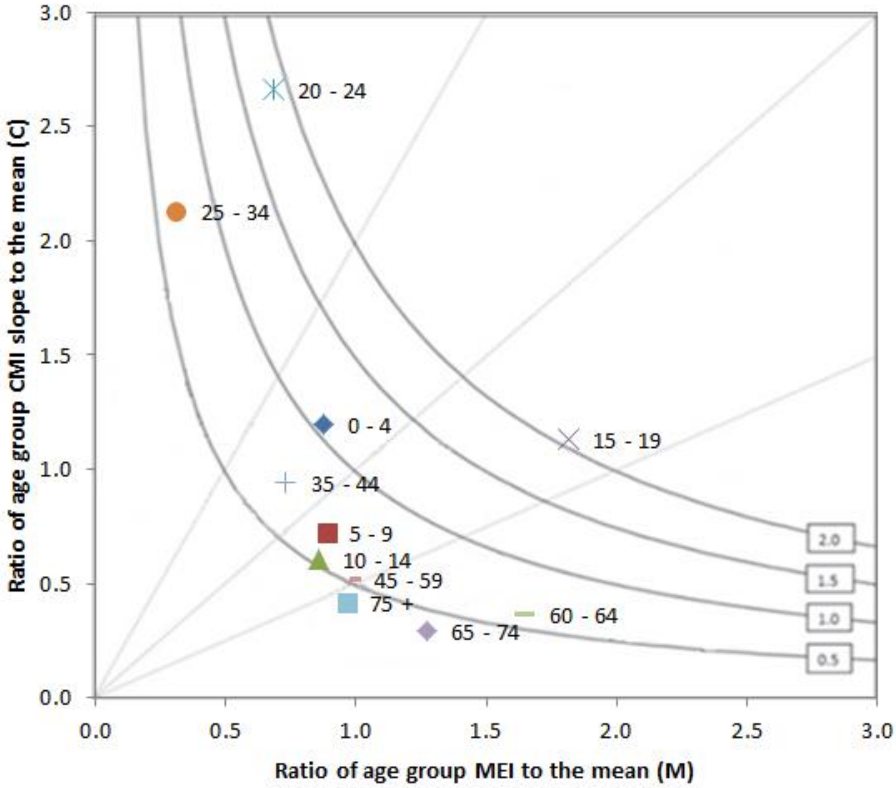
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.12: Linear regression lines of the logged crude migration intensity, age groups, 2000-01 and 2010-11

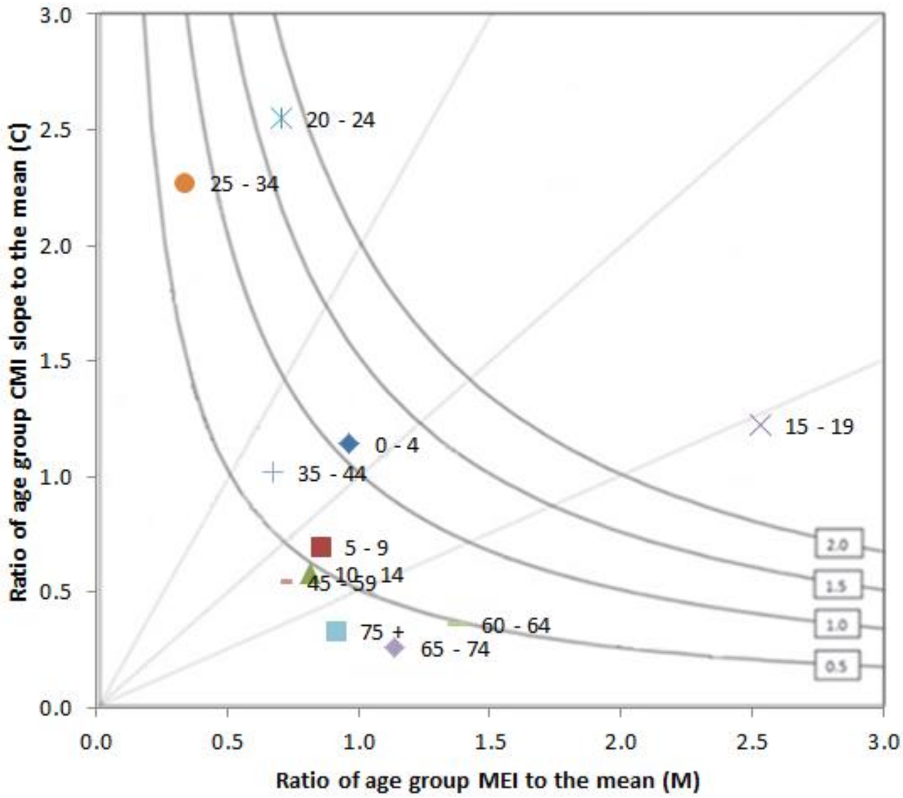
Figure 5.12 showed the logged values as suggested by Rees et al. (2017), but the results presented here for the different age groups show negative CMI values for the 65-74 age group in 2000-01 and for the 65-74 and 75+ age groups in 2010-11. This is not ideal. A similar approach was also adopted for the MEI and ANMR, and although the MEI did not show negative values, all age groups for the ANMR showed negative values, with the exception of the 20-24 age group in 2000-01 and the 15-19 age group in 2010-11. The logged values in this scenario add problems for interpretation and therefore this step has not be implemented in this analysis.

Rather than following the method by Rees et al. (2017) of logging all values, the MEI and CMI slope will be plotted using their original values. In order to compute the INMI, the CMI slope for an age group is divided by the average CMI slope for all age groups; this is then multiplied by the mean MEI for an age group divided by the average MEI for all age groups. This is repeated for each individual age group for 2000-01 and 2010-11. Similar to the ANMR, the INMI is the product of two ratios, which allows for the comparison of multiple age groups with regard to aggregate population redistribution, distinguishing the relative contributions of migration intensity and migration effectiveness (Rees et al., 2017).

Figure 5.13 shows the ratio of the CMI slope against the ratio of the MEI using two scatterplots, one for each time period. The surface of the plot in Figure 5.13 represents the INMI for each age group, and the contour lines (0.5, 1.0, 1.5, and 2.0) link points of equal migration impact. All INMI values above 1.0 demonstrate an above average effect of migration in redistributing population and INMI values below 1.0 show an effect below average. The radial lines help divide the plot to show the relative contributions of the CMI and the MEI, with the principal diagonal dividing the plot at a point where the two indicators demonstrate an equal effect on the population redistribution. The top graph (Figure 5.13a) shows the INMI for the 11 age groups in 2000-01. It can be observed that the 15-19 year olds exhibit the highest net migration impact, driven by above average MEI and CMI slope relative to the average. But this age group has a higher MEI ratio than CMI slope ratio, and the MEI ratio has become more significant over the decade; whereas the 20-24 and 25-34 age groups have the highest CMI but a low MEI, these values remained roughly the same across both time periods. The majority of the age groups remain in centre of the graph with a balance of CMI and MEI for 2000-01 and 2010-11. The older migrant populations have higher MEI ratios and lower CMI slope ratios in both time periods.



a. Age groups, 2000-01



b. Age groups 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 5.13: Index of net migration impact by age group, 2000-01 and 2010-11

It can be concluded that the 15-19 year olds have the highest INMI of 2.05 in 2000-01, increasing to 3.09 in 2010-11, and that the lowest INMI can be found amongst the older age groups with an INMI of 0.37 for the 65-74 age group and 0.40 for the 75+ group in 2000-01, decreasing to an INMI of 0.30 for the 65-74 age group and decreasing to 0.31 for the 75 and above group. This demonstrates that it is students and young workers that have highest net migration impact and this increased for the 15-19 year olds, whereas the net impact of net migration declined between 2000-01 and 2010-11 for those aged over 45. 20-24 year olds and 25 to 34 year olds exhibit patterns that are intense, as the move a lot, but that are not particularly efficient, as there is a lot of movement in each direction. The older age groups, on the other hand, are less intense but more efficient, suggesting more unidirectionality. These groups for example, tend to move to areas for retirement.

5.7 Conclusion

The results reported in this chapter have shown that there was a small reduction in the overall intensity of migration between LADs between the two censuses, but variations in both intensities and impacts on population redistribution for certain age groups have been observed.

The analysis of migration effectiveness in Chapter 4 has shown that the impact of migration on redistributing the population has increased between the two periods for those in the student age group but decreased in other age groups. One key feature in this chapter has therefore been the increase of MEI for the 15-19 years olds between 2001 and 2011, contrary to the MEIs for older working and retirement age groups which show that the trend to move to more rural LADs has reduced over the decade.

The analysis of the scale and zonation effects of migration within the UK shows that the CMI and the ANMR rates are scale sensitive, whereas the MEI tends to be less scale dependent with the exception from the 15-19 age group. The 15-19 age group is highly mobile and moves take place between all parts of the UK, whether for relocation for further/higher education or to seek employment (Zaiceva, 2014). A pronounced scale effect for MEI for 15-19 age group occurs because, unlike other age groups, as the scale changes to fewer ASRs, the ratio of net migration to total migration reduces significantly.

The chapter has used a new measure to quantify the impact of net migration and show the differential roles of CMI and MEI on the ANMR for different age groups. The most significant change between the two time periods has been the increased impact of the net internal migration of those aged 15-19.

In the next chapter, the focus of attention transfers to the distances over which these migrants travel and the implications this has for spatial connectivity at different geographical scales.

Chapter 6: Migration Distance and Connectivity

6.1 Introduction

Geographical patterns of net migration in the UK originate from the redistribution of different subgroups of the population driven by a wide variety of motivations, as reviewed in Chapter 2, some of which relate to decentralisation (counterurbanisation) (Champion, 2005), where migrants disperse down the urban hierarchy from large cities into smaller settlements and rural areas, or where migrants move towards large cities from more rural areas (urbanisation) (Stillwell and Hussain, 2010). There is also a substantial amount of movement between/within urban areas and rural areas. Whilst the intensity and patterns of inter-district flows have been examined in Chapter 4 using a number of indicators, no results have been reported in the thesis hitherto that consider the distances over which migrants travel, the frictional effect of distance on the propensity to migrate, and the extent of connectivity between different parts of the country in terms of migration interaction. This chapter therefore deals with three further indicators of migration: distance migrated, the frictional effect of distance on migration and zonal connectivity.

As with other interaction phenomena, distance has an inverse effect on interaction: the further places are apart, the less interaction flows will occur between them. In other words, closer places are more connected than other places. Tobler's (1970) First Law of Geography states that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p.236). Migration is a process that connects places and it is well-known (e.g., Clark and Huang, 2004; Stillwell and Hussain, 2010) that places close to one another will have stronger migration links than places more distant from one another. In other words, the distance between places has a frictional effect on migration flows in general terms, although this is not to say that migrants with different motivations will travel similar distances or experience the same distance decay effects.

The relationship between distance and migration may take different functional forms as outlined by Taylor (1975) and gravity models (since Ravenstein) were initially calibrated using regression methods to identify the precise relationship between distance and migration, the so-called distance decay or beta parameter, a measure of the frictional effect of distance on migration. Spatial interaction models were developed by Wilson to constrain the projected results (migration matrix) to known marginal totals of out-migration and/or in-migration (e.g. Wilson, 1967).

This chapter focuses on the question of whether these indicators are sensitive to scale and zonation effects. The history of gravity modelling studies would suggest that distance and connectivity are sensitive to scale since the larger and fewer zones there are between which migration takes place, the greater the distances involved and therefore one might expect to find fewer migrants, less connectivity and a higher frictional effect of distance. But what is the exact relationship? Is it linear? Results from the IMAGE Studio for countries around the world (Stillwell et al., 2016) suggest that the distance decay parameter may be much less scale dependent that one might imagine.

In this chapter, spatial interaction models will be calibrated at different scales and for different zonations to quantify how the distance decay parameter varies using all-age data and what differences are apparent between age groups. The results also provide insights into the extent to which indicators change over time. This analysis is important from a practical point of view because gravity or spatial interaction models are used for historical estimation and future projection (not only with migration but also with many other interaction variables (e.g., shopping model for flow of goods/income between origins and destinations). In the case of population estimation and projection, the decay parameter calibrated using observed data available at one spatial scale may be required in a model that distributes migration at another spatial scale, begging the question as to whether the parameter needs adjusting for scale effect and whether scale or zonation dependence varies between age groups and well as between time periods.

The chapter begins by considering the various ways in which migration distance is measured and explaining how distances between Basic Spatial Units (BSUs) and Aggregated Spatial Regions (ASRs) are computed by the IMAGE Studio. Section 6.2 also reports the so-called 'global' migration distance that measures the mean distance migrated between BSUs, in this case local authority districts (LADs), for the 11 age groups before examining the variation in distances of in-migration to and out-migration from LADs across the UK in the two periods. The section finishes by identifying the scale and zonation effects on global mean migration distance. Section 6.3 then explores the distance decay parameters associated with all-age and age-group flows using the modelling functionality available in the IMAGE Studio. The theory of spatial interaction modelling and the calibration method used in the Studio are explained. However, a problem of matrix sparsity is encountered when calibrating models for certain age groups and therefore some aggregation of age group data is undertaken before the models are used to demonstrate the scale and zonation effects on the distance decay parameter.

Movements between LADs result in levels of connectivity between different areas which can be measured using a simple index of connectivity. Patterns of connectivity are mapped at LAD level for selected age groups before scale and zonation effects on the mean index of connectivity are investigated. Some conclusions are drawn in the final section.

6.2 Migration distance

6.2.1 Measuring distance

When people migrate, the distance over which they travel can be measured in different ways. Physical distance has been commonly used as an appropriate variable but several scholars have suggested that time distance, cost distance or social distance are worthy alternatives. One reason why physical distance has been popular is because it is relatively easy to measure although a variety of approaches to measurement have been used by different authors. Most of the early gravity modellers used physical distance (Reilly, 1931); some of the more traditional algebraic definitions of distance decay are given by Zipf (1946) and Stewart (1948). Lowry (1966) used airline distances in his model of migration between states in the USA but also experimented with social distance, time distance, travel cost measures and Manhattan distance. Network or road distance is another way of measuring physical distance (Shahid et al., 2009). Social distances measure how far an individual is from his/her social group defined by race, status, class and basically any criteria that allow this individual to interact or connect to a specific group (Akerlof, 1997), whilst the Manhattan distance measures distance between the origin and destination in a grid-based environment (Craws, 2017).

Stouffer introduced a new measure of distance opportunities in a paper published in the *American Sociological Review* in 1940. Stouffer's law of intervening opportunities states that "the number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities" (Stouffer, 1940, p.846). In a later paper, Stouffer (1960) introduces an additional competing migrants effect, which consists of the total number of migrants leaving an area as close or closer to the destination than the migrants at the origin, as well as migration being inversely proportional to the number of opportunities between the origin and the destination (Stouffer, 1960). Lee (1996) on the other hand, hypothesized that distance can be viewed as an intervening obstacle.

Euclidian distance has been used as a means of measurement in the application of various forms of modelling UK migration data in more recent times, such as spatial interaction models calibrated using mathematical methods (Stillwell, 1978) or statistical techniques like Poisson regression (Flowerdew, 1991). More recently, MIGMOD (MIGration MODeller) was developed as a system for modelling migration in two stages: stage 1 involving out-migration from each origin zone and stage 2 distributing out-migration to different destinations, in order to assess the effects of various strategies on population movements in England and Wales (Fotheringham et al., 2004). Distance variables between the study zones were used, using attributes of origins that might influence out-migration rates and attributes of destinations that might influence their attractiveness to migrants, for example: spatial structure, demography, economic, employment, housing, social, environment and access to service and amenities. In this model, inter-area distance is measured by a distance weighted average ratio where proximate locations are weighted more heavily in the calculation than more distant ones. Alternatively, Stillwell and Thomas (2016) used origin and destination zone centroids for the measurement of distance and proposed a new approach to estimating intra-zonal distance based on the availability of migration data at a number of spatial scales.

Thus, even though previous studies have shown a diversity of methods for defining and measuring migration distance, the key message is that distance, however it is measured, is a key indicator of migration behaviour and a necessary variable when modelling internal migration flows. In this chapter the inter-centroid measurement of distance between LADs is used, computed by the IMAGE Studio. At BSU level, for each flow between any two LADs, the corresponding distance travelled is computed as the straight-line or Euclidian distance in kilometres from the origin LAD's geographic centroid to the destination LAD's geographic centroid. It is likely that a better measure of distance would be derived by using population-weighted centroids of origin and destination zones (Bell et al., 2002; Niedomysl et al., 2017), but this alternative is not computed by the IMAGE Studio because of the computational complexities when zones are aggregated. The IMAGE Studio requires centroid data in order to compute aggregated distances at BSU level, and when the BSUs are being aggregated into ASRs, the Studio minimises the average distances between the BSUs that are being aggregated for each new ASR to avoid creation of irregular shapes (Daras, 2014). The distances between BSUs are calculated using the Pythagorean formula for Cartesian systems (Stillwell et al., 2014):

$$d_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{6.1}$$

where d_{ij} is the distance between the two BSU centroids i and j, and x_i, x_j, y_i, y_j are the Cartesian coordinates of points i and j respectively.

The distances between ASRs for each new aggregation are computed by the IMAGE Studio on the basis of the initial distances between the BSUs. Each distance between a pair of ASRs is calculated as the mean of the distances between the BSUs that constitute both origin and destination ASRs. The formula for computing the distance d_{AB} between ASRs A and B is:

$$d_{AB} = \frac{\sum_{i \in A} \frac{\sum_{j \in B} d_{ij}}{m}}{n} \tag{6.2}$$

where d_{AB} is the distance between the ASR A and ASR B, i is the BSU member of ASR A, j is the BSU member of ASR B and n and m are the number of BSUs in ASRs A and B respectively (Stillwell et al., 2014).

6.2.2 Global migration distance for BSUs

The global mean migration distance indicator computed in the IMAGE Studio is a measurement of the mean distances migrated between each origin BSU and each destination BSU as:

$$\mathrm{GMMD} = \sum_{i \neq j} \sum_{j \neq i} \mathrm{d_{ij}} / \mathrm{nm} \qquad (6.3)$$

where d_{ij} is the distance between the centroid of origin LAD i and destination LAD j, n is the number of origin LADs and m is the number of destination LADs; in this case, n = m = 404.

Table 6.1 shows the global internal migration indices for the mean migration distance by age groups for 2000-01 and 2010-11. The overall mean distance of migration in 2000-01 was 47.4km and this average value declined to 42.8km in 2010-11; in other words, migrants were moving over shorter distances in the later period. There are significant variations in the mean migration distances by age in both periods, with the 15-19 age group maintaining the longest mean migration distance in both time periods. This is to be expected since this age group will include students travelling from their place of domiciles to their places of study, a migration phenomenon that has traditionally taken place over longer distances as students move away from home often for the first time. Like all other age groups, the mean migration distance for the 15-19 year olds falls, but the extent of the fall is less than most other groups. Those aged 20-24 also have above average mean migration distances in both periods although the decline over time is less for this group than for those five years younger. Migration distances are lowest for the younger age groups and for the over 75s, due to the corresponding constraints on the mobility of individuals at both ends of the age spectrum. Children aged 0-14 are less likely to move longer distances because of school commitments and the evidence in Table 6.1 suggest that their migration distances have fallen by over 30% in each of the three groups involved. The elderly tend to migrate over shorter distance because of health reasons or to be nearer to family and the mean migration distances of the three post-retirement groups have all declined by less than 10%. Mean migration distances for the working age groups (25-59) are all closer to the all-age average but have fallen by over 20% in each case.

Why has the mean migration distance fallen between the two periods? It can only be speculated, but it is likely that some explanations are linked to the decline in overall migration intensity. In other words, there may be compositional effects due to ageing and a shift towards age groups that are less inclined to move over longer distances (Bell et al., 2018). Alternatively, there may be factors responsible for changing migration behaviour such as: students attending higher education are increasingly inclined to live at home; the increase in renting accommodation rather than owner occupation may result in decreasing distances migrated because renters tend to move over shorter distances, particularly since the financial crisis (Karahan and Rhee, 2017); technological and transport advances, including 'teleworking', have acted as substitutes for migration, particularly over longer distances (Cooke and Shuttleworth, 2017); and increasing levels of place attachment or rootedness, as suggested has occurred in the USA by Frey (2009) and Cooke (2011).

Table 6.1: Global mean migration distance (km) by age group, 2000-01 and 2010-11

	2000-01	2010-11	% Change
0 - 4	39.83	30.23	-32%
5 - 9	42.81	31.23	-37%
10 - 14	41.53	31.24	-33%
15 - 19	68.32	63.80	-7%
20 - 24	58.90	50.95	-16%
25 - 34	47.85	39.09	-22%
35 - 44	46.78	37.67	-24%
45 - 59	51.63	41.97	-23%
60 - 64	58.43	53.43	-9%
65 - 74	54.06	52.07	-4%
75+	42.98	39.78	-8%
All	47.74	42.77	-12%

Source: Estimates based on data from 2001 and 2011 Censuses

6.2.3 Mean out-migration and in-migration distances for BSUs

Whilst the global mean migration distance is a single measure of distance moved across the whole system of BSUs, measures of migration distance can also be derived at BSU level for each LAD as the mean out-migration distance:

$$\mathrm{MOMDi} = \mathrm{d}_{\mathrm{i}\,*} = \frac{\sum_{\mathrm{j}} \mathrm{d}_{\mathrm{ij}}}{\mathrm{n} - 1} \qquad (6.4)$$

and the mean in-migration distance:

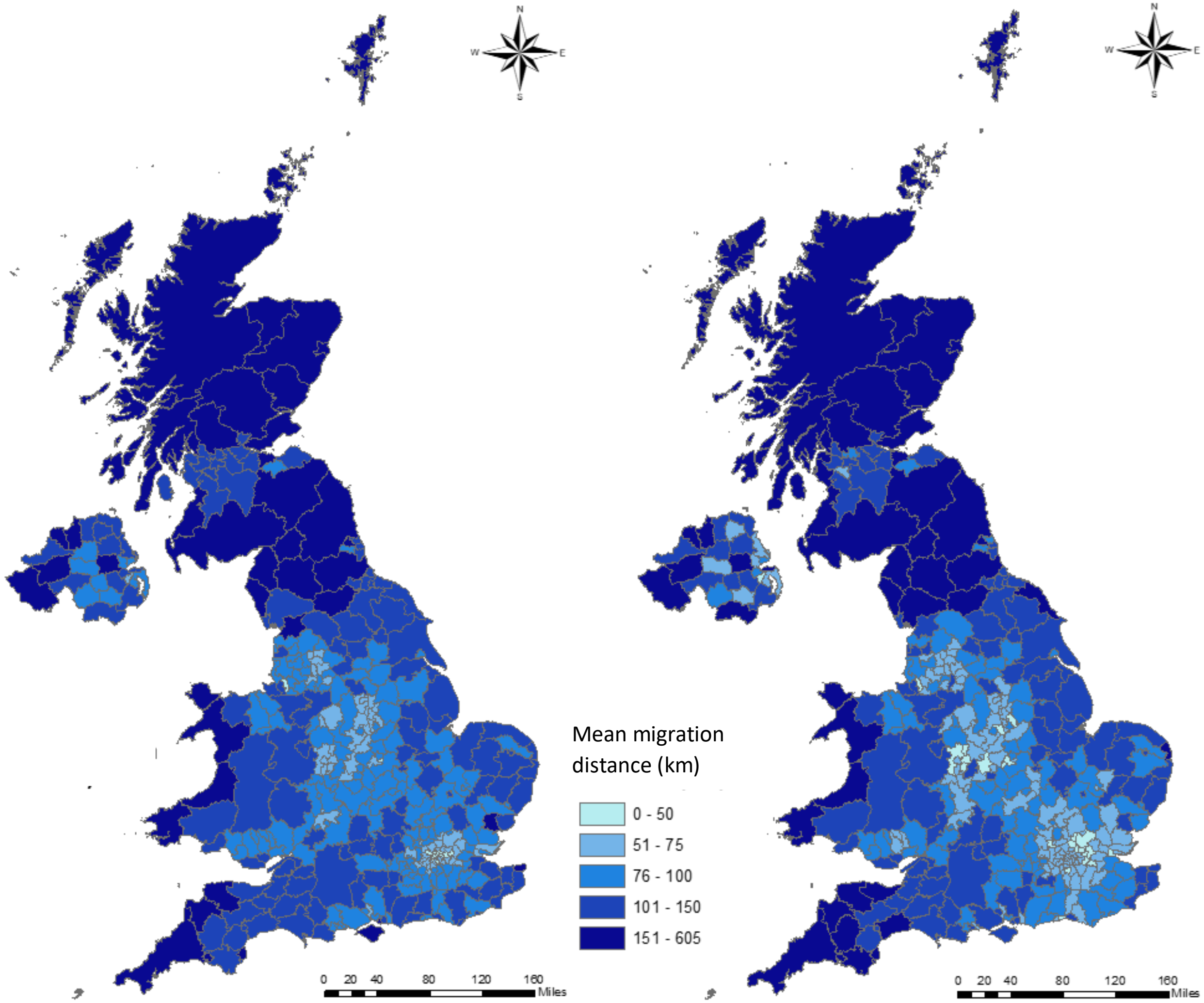
$$\text{MIMDj} = d_{*j} = \frac{\sum_i d_{ij}}{n-1} \tag{6.5}$$

Mean all-age out-migration and in-migration distances are mapped in Figure 6.1 for 2000-01 and 2010-11. All four maps show that the highest in-migration and out-migration distances can be found, as expected in the more remote areas of the UK, whereas the shortest distances can be found in the areas surrounding Greater London, in the Midlands and in the North West, the more metropolitan areas of the central parts of the country. Relatively short migration distances are also observed in areas surrounding major cities in Wales (Cardiff) and Scotland (Glasgow and Edinburgh). There are subtle differences that suggest more short distances and fewer long distances in 2010-11 than in 2000-01.

Each of the maps shows LADs categorised into five different classes according to the mean distance of out-migration or in-migration; the shortest distance category, for example, contains very few LADs across all the maps; 13 LADs had a mean out-migration distance of 0-50km in 2000-01 compared with 17 in 2010-11. For the mean in-migration distance, 23 LADs were in the shortest category in 2000-01 and 39 LADs in 2010-11. Oadby and Wigston, Camden and Kensington and Chelsea LADs had the smallest mean out-migration distances ranging between 38 and 43km in 2000-01 with Oadby and Wigston, Islington and Knowsley LADs having out-migration distances in the same range in 2010-11. Barking and Dagenham, Broxbourne and Knowsley LADs show the smallest mean in-migration distances of 33km, 37km and 41km respectively in 2000-01 and Barking and Dagenham, Knowsley and Bexley LADs have distances of 35km, 36km and 39km respectively in 2010-11. All these LADs are either London boroughs or metropolitan districts.

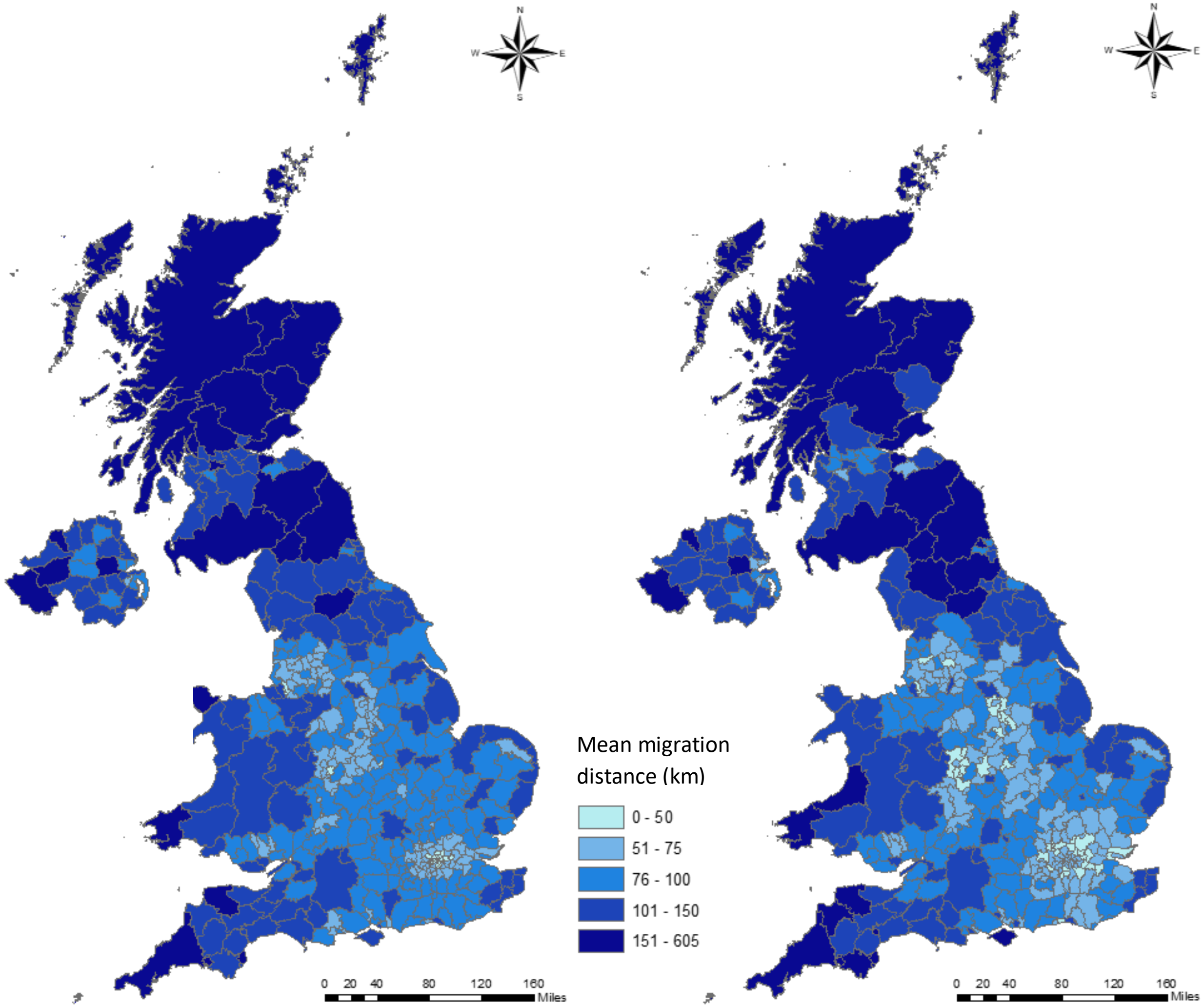
The darkest shading category contains LADs with the highest in-migration and out-migration distances, between 151 and 605km. The number of LADs in this category decreases over time, as there are 50 LADs in this category for in-migration in 2000-01 and 32 LADs in 2010-11. The most remote LADs (Shetland Islands, Orkney Islands and Eilean Siar) have the highest mean in-migration distances of 602km, 472km and 414km respectively in 2000-01 and remain in the same order with 579km, 446km and 386km in 2010-11. These are the UK's most peripheral rural districts. When looking at the out-migration distances, a similar pattern can be identified and the number of LADs falls from 44 in 2000-01 to 30 in 2010-11. The same three remote LADs have the highest mean out-migration distances of 599km, 375km and 347km respectively in 2000-01 and 552km, 387km and 382km respectively in 2010-11.

The majority of LADs (118) have average in-migration distances of between 51 and 75km in 2000-01, and this total increased to 128 LADs in 2010-11. On the other hand, the majority of LADs (156) had mean out-migration distances between 76 and 100km in 2000-01; this figure decreased slightly to 151 LADs in 2010-11 but this category still remained the most common. Thus, the maps shown in Figure 6.1 suggest that variations in the patterns of in-migration and out-migration distance do exist and are explained by the fact that out-migrants from LADs in more metropolitan areas are moving further than in-migrants to those LADs, particularly in the arc across central England stretching from the North West to London and the South East. Further insights into this variation may be evident from the patterns for different age groups.



a. Out-migration, 2000-01

b. In-migration, 2000-01



c. Out-migration, 2010-11

d. In-migration, 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

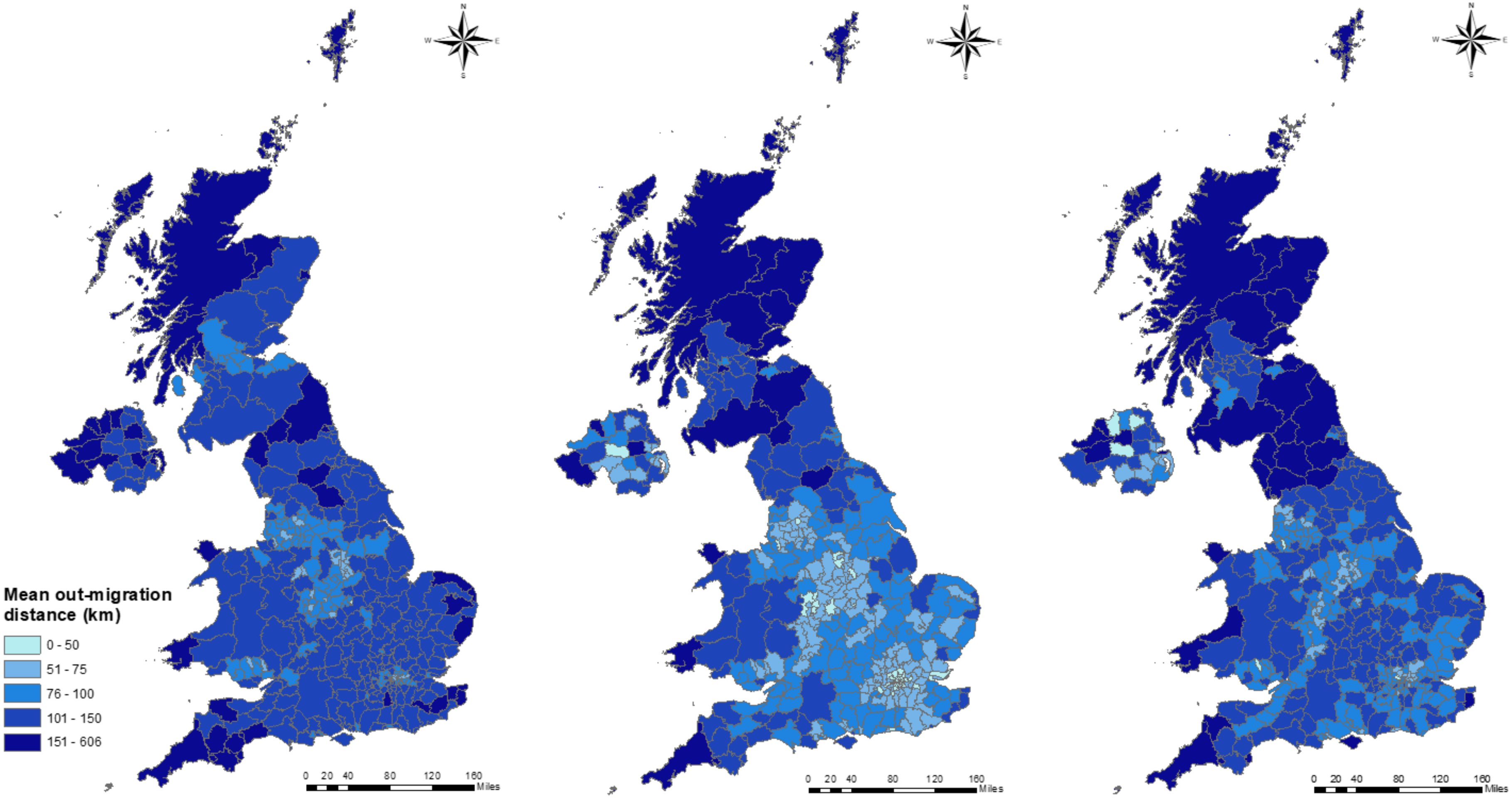
Figure 6.1: Mean out-migration and in-migration distances by district, all ages, 2000-01 and 2010-11

Rather than showing maps of out-migration and in-migration distances by LAD for each age group, the variation in geographical patterns is illustrated using a selection of three age groups: those aged 15-19 who have the longest global mean migration distance; those of working/family age 35-44, whose pattern is likely to also represent those in the child age groups, and whose mean migration distance is close to the average; and those aged 65-74, the post-retirement age group which has seen the least change over time. The six maps illustrated in Figure 6.2 demonstrate how the mean distances of out-migration and in-migration vary for selected age groups for 2010-11. The mean in-migration distance for this age group is constant between 51 and 150km, as only a small number of LADs have in-migrants moving further than 151km, with Shetland Islands, Orkney Islands and Eilean Siar having the biggest mean in-migration distances of 450km, 385.2km and 335.3km respectively. Forty-nine LADs are in the shortest in-migration distance category, with Cannock Chase, Brentwood and Sandwell (all in the West Midlands) with the lowest distances ranging between 32.2 and 34.9km. To summarise: the shortest distances are associated with urban areas, whilst the longest distances are associated with the peripheries of the UK. The mean out-migration distance for the 15-19 age group is significantly skewed with 233 LADs appearing in the 101 and 150km category. Only one LAD falls into the 0 to 50km category, Oadby and Wigston LAD, with a mean out-migration distance of 49km; this LAD has a high concentration of students, as this is where numerous student halls from the University of Leicester affecting these results, as students migrate from all over the country. Shetland Islands, Orkney Islands and Eilean Siar LADs are amongst the 46 LADs with the highest mean out-migration distances.

The 15-19 year olds have high out-migration distances across the country but lower in-migration distances in various parts of north, midland and southern England. This phenomenon might be caused by students leaving most LADs to go to higher education institutes some distance away but in-migration LADs (metropolitan) draw migrants from closer origins and thus in-migration distances are shorter.

The 35-44 age group has a slightly different representation of mean out-migration distances, the majority of 146 LADs falling into the 51 to 75km category and 120 LADs in the 76 to 100km category. Thirty-eight LADs are part of the smallest out-migration distance category, including Kensington and Chelsea with the smallest recorded distance of 33km for this age group. Migration distance is far greater in the north as job opportunities might be slimmer there than other parts of the country, similarly better facilities might be available to their families to improve their quality of life. Alternatively, migration distances are very short in the south and the midlands, especially in the Greater London Area, where a move over a great distance is not required to find an alternative location to support a family.

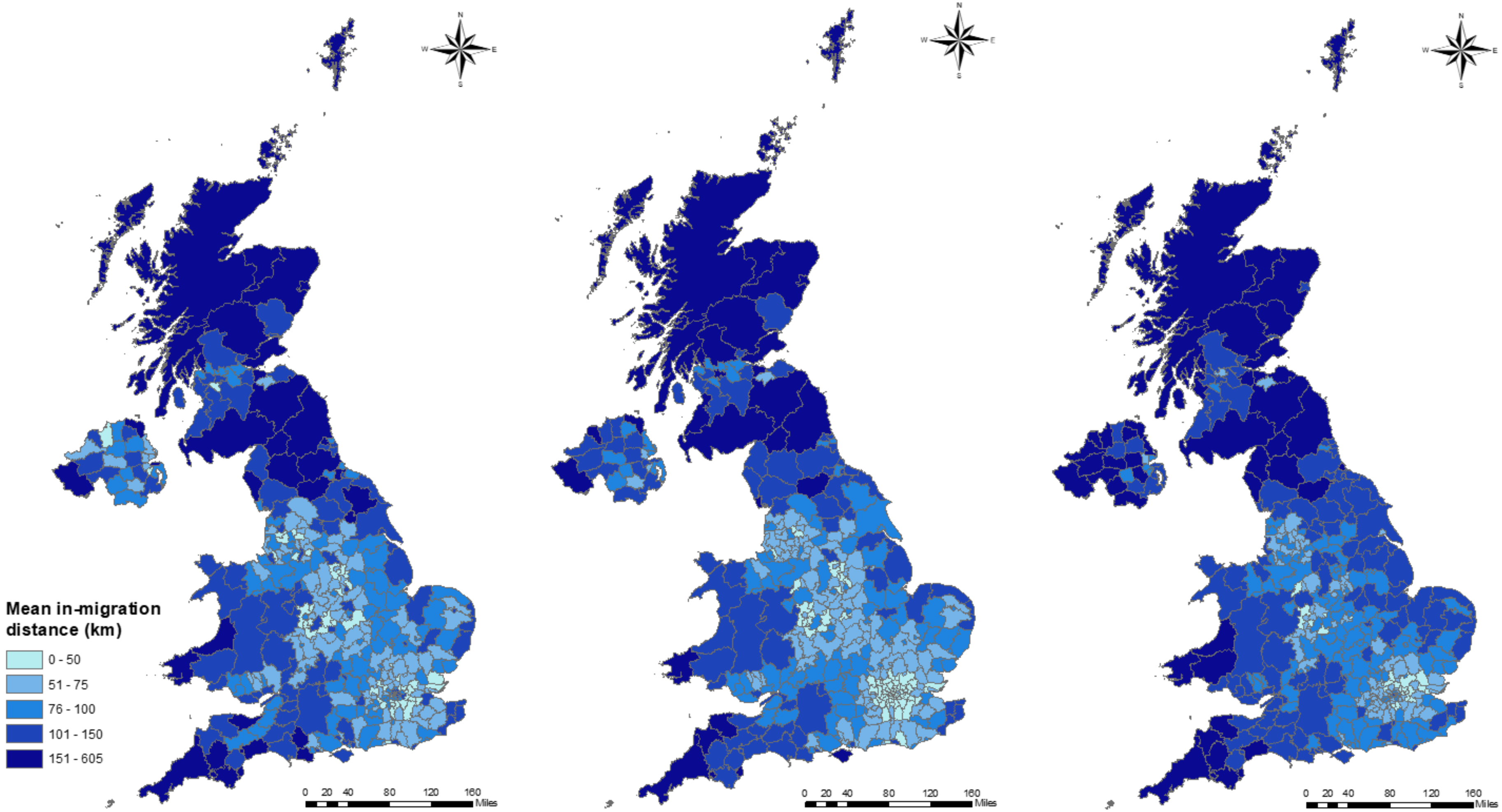
The 65-74 age group shows that the majority of LADs (120) have a mean in-migration distance of between 76 and 100km. Only 35 LADs have migrants moving shorter distances of between 0 and 50km, with Harlow, Broxbourne and Bexley having distances of only 26 to 29km. The longest mean in-migration distance recorded for the 65-74 age group in 2010-11 is that of 647.7km for migrants to the Shetland Islands, which is amongst the 50 LADs falling into the category of moving 151km and over. There are a larger number of LADs with a mean out-migration distance for the 65-74 age group of between 76 and 150km, with 164 LADs in the 76 to 100km category and 149 LADs in the 101 to 150km category. Only six LADs are recorded with short mean out-migration distances, including Newtownabbey, Castlereagh and Knowsley LADs, all of which have distances ranging from 28 to 34km.



a. Out-migration, 15-19

b. Out-migration, 35-44

c. Out-migration, 65-74



d. In-migration, 15-19

e. In-migration, 35-44

f. In-migration, 65-74

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.2: Mean out-migration and in-migration distances by district, selected age groups, 2010-11

The average of the mean out-migration and mean in-migration distances across all BSUs for all ages and for different age groups are shown in Table 6.2. The in-migration and out-migration distances in Table 6.2 do not equal each other as there are discrepancies when averaging already averaged values. For example, the mean in-migration distance is 196.8 for Antrim, 60.4km for Ards and 98.5km for Armagh resulting in an average of 118.6km; whilst the mean out-migration distance is 160.7km for Antrim, 89.5km for Ards and 93.7km for Armagh resulting in an average of 114.6km. Taking the average of the OMMD and IMMD can also cause some variation to the total MMD, where the MMD for some age groups might go down, whilst the IMMD and the OMMD can go up. This is the case for all three age groups over the age of 60, where the IMMD and the OMMD is increasing, but the global mean migration distance shown in Table 6.1 is decreasing.

The results show that the overall distance measure for the all-age group has fallen by 9.5% for in-migration and by 8.3% for out-migration. This trend conforms with the declining distance of migration reported by Champion and Shuttleworth (2016a) using data from the Longitudinal Study. As mentioned previously, there are a several reasons why distance decline has occurred. One of the main reasons for this phenomenon is likely to be the increase of single person households and more complex and fluid household structures that do move frequently but move short distances. Another reason is likely to involve changing information and communication technologies (ICT) and the way they are being used; i.e. new computing technologies that do not require long distance moves for work reasons (Green, 2017). However, Northern Ireland has shown to keep increasing their total MMD over the decade, with Larne, Ards and Cookstown showing increasing migration distances.

There is significant variation in the averages of the mean distances of in-migration and out-migration for different age groups. The average mean in-migration distance varies from a minimum of 89.8km for the 75+ age groups to a maximum of 113.4km for the 20-24 age group in 2000-01. In 2010-11, migrants in the 10-14 age group (school children) have the shortest mean travel distance of 84.5km and those in the 20-24 age group (young adults in education or employment) remain with the furthest travel distance of 105.4km which is 6.5% less than in the previous decade. Also the 20-24 age group still has the longest travel distance caused by moves to higher education or to seek better employment, the distance they travel is on the decrease probably due to an increase of young people staying in their parental home for longer, and/or move frequently in and out of their parental home before establishing a stable independent household (Lennartz et al., 2016). The 15-19 age group migrants (including students) also experienced a significant drop of 11.8% in the in-migration distance, from 105.6km in 2000-01 to 94.5km in 2010-11. The only age groups where migrants experience an increasing in-migration distance between the two time periods are those aged 60-64, 65-74 and 75+; with those in the 65-74 age group demonstrating the biggest increase of 4.7% from 100.4km in 2000-

01 to 105.3km in 2010-11. This might be due to grandparents being willing to move slightly longer distances to be nearer their families, perhaps offering care support for grandchildren in times of rising child care costs.

Table 6.2: Average of the mean migration distances, by age groups, 2000-01 and 2010-11

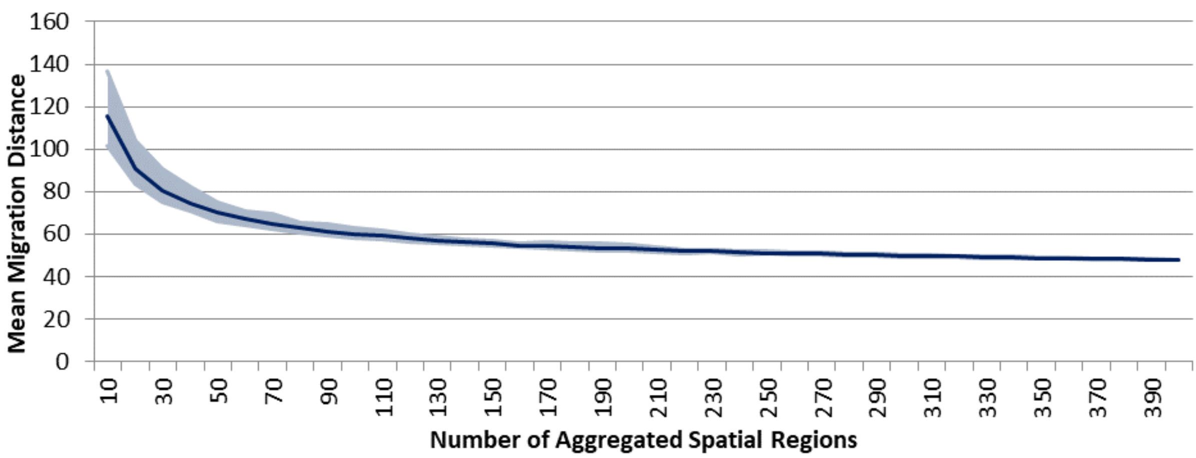
	Average mean in-migration distances			Average mean out-migration distances		
	2000-01	2010-11	% Change	2000-01	2010-11	% Change
0 - 4	98.2	84.8	-15.8	100.4	85.4	-17.6
5 - 9	101.4	89.2	-13.7	104.4	90.3	-15.6
10 - 14	97.6	84.5	-15.6	99.3	85.7	-15.9
15 - 19	105.6	94.5	-11.8	122.4	117.4	-4.3
20 - 24	113.4	105.4	-7.5	114.7	107.6	-6.5
25 - 34	98.2	88.3	-11.2	99.9	89.9	-11.2
35 - 44	98.5	88.3	-11.5	99.8	89.4	-11.6
45 - 59	96.5	90.3	-6.9	101.7	92.7	-9. 7
60 - 64	101.7	102.3	+0. 6	110.7	107.8	-2.7
65 - 74	100.4	105.3	+4. 7	106.3	109.3	+2.7
75+	89.8	90.0	+0.2	91.0	91.4	+0.5
All	102.6	93.7	-9.5	106.0	97.9	-8.3

Source: Estimates based on data from 2001 and 2011 Censuses

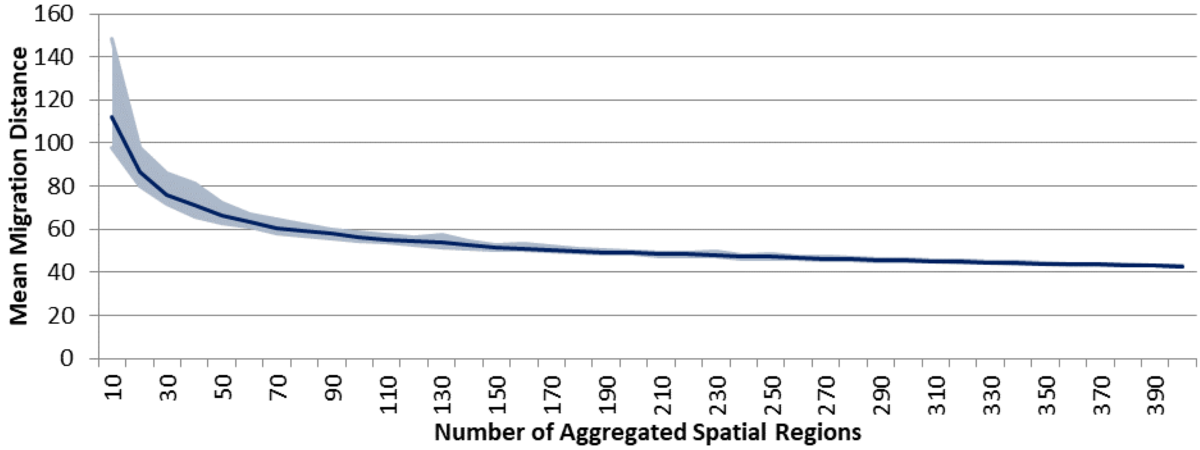
In terms of the average out-migration distance, those in the 75+ age group appear to have the shortest average distance travelled of 91km in 2000-01, with a small but positive increase of 0.5% to 91.4km in 2010-11. The 65-74 age group is the only other age group sharing an increase in the out-migration distance with an increase of 2.7%. In 2010-11, the small out-migration distance travelled can be observed by the 0-4 age group as 85.4km after experiencing a decrease of 15.6%. Migrants in the 15-19 age group have the highest average out-migration distance travelled in both years with 122.4km in 2000-01 decreasing to 117.4 in 2010-11. Migrants in the 20-24 age group are close behind where an average out-migration distance of 114.7km is apparent in 2000-01, which falls to 107.6km in 2010-11. So overall, the average out and in migration distances decline across the board between 2000-01 and 2010-11, except in the two/three oldest age groups. Largest declines are evident in the family age group (0-14 and 25-44), who might want to remain in the same school district for their children or maintain their children's social network by not moving to far away.

6.2.4 Scale and zonation effects on migration distance

When computing the scale and zonation effects on the mean migration distance indicator, the IMAGE Studio has to recalculate the distances between zones at each scale and for each zonal configuration. Local indicators of migration distance are not computed because there is a different zone configuration for every aggregation. The effects of scale and zonation on the global mean migration distance (MMD) indicator for all ages for 2000-01 and 2010-11 are shown in Figure 6.3, The relationship is not linear; as the number of ASRs decreases and the ASRs get larger (moving from right to left on each graph), the mean migration distance increases, thus creating a scale effect which appears to become more evident between 10 and 90 ASRs in 2000-01 and between 10 and 100 ASRs in 2010-11. By the time the aggregation has reached 90 ASRs, the mean migration distance has increased from 47.8km (at 400 ASRs) to 61km but it then increases to 115.7km at the scale of 10 ASRs. A zonation effect can also be seen to be larger when the number of ASRs are small and becomes less significant as the number of ASRs increases. Mean migration distances have fallen slightly between 2000-01 and 2010-11 but the scale effects on distance are significant but very similar in both periods whereas the zonation effects are less significant but similar between the two periods.



a. 2000-01

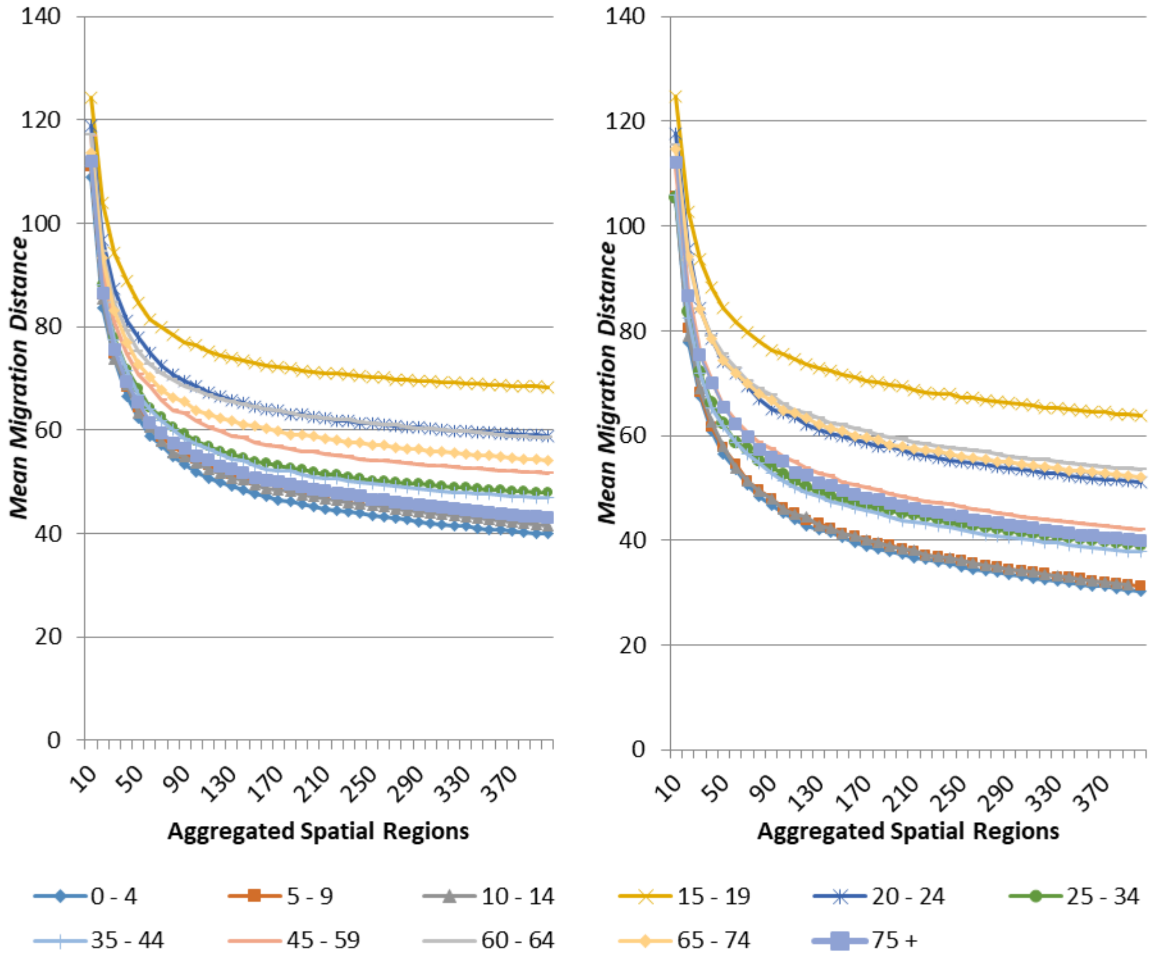


b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.3: Scale and zonation effects for the mean migration distance, all ages, 2000-01 and 2010-11

Figure 6.4 presents the mean migration distances for different age groups at different spatial scales and shows different scale effects. There is a wider distribution of mean distances by age group in 2010-11 than in 2000-01 and the 15-19 age group appears to have the least scale effect despite having the longest distance travelled across all scales in both years, ranging from a mean value of 68.4km at 400 ASRs to 124.4km at 10 ASRs in 2000-01, and 63.9km at 400 ASRs to 124.6km at 10 ASRs in 2010-11. The scale effect for this age group becomes more apparent at 100 ARS for both time periods.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.4: Scale effects for the mean migration distance by age group, 2000-01 and 2010-11

All age groups demonstrate significant scale effects which are becoming larger over time. In 2000-01, the scale effect becomes more evident between 10 and 100 ASRs and between 110 and 400 ASRs the scale effect is much less noticeable for the majority of age groups. In 2010-11, the scale effect also becomes more evident between 10 and 100 ASRs but the scale effect is consistently visible for all ASRs. Table 6.3 highlights this occurrence where the total scale effect in 2010-11 is consistently higher than in 2000-01 for all age groups. The total scale effect is calculated by adding the percentage change of the mean values of each indicator between each scale step. These results suggest that the influence of scale on the results of analysing migration distance have become more important.

Table 6.3: Total scale and zonation effects of the mean migration distance, by age groups, 2000-01 and 2010-11

	Total scale effect	Total zonation effect	Total scale effect	Total zonation effect
	2000-01		2010-11	
0 - 4	0.95	2.60	1.18	3.20
5 - 9	0.90	2.62	1.16	2.88
10 - 14	0.93	2.83	1.15	2.90
15 - 19	0.57	1.99	0.64	2.39
20 - 24	0.67	2.28	0.80	2.84
25 - 34	0.81	2.43	0.94	2.56
35 - 44	0.82	2.70	0.98	2.46
45 - 59	0.77	2.36	0.92	2.50
60 - 64	0.66	1.87	0.74	2.07
65 - 74	0.71	2.31	0.76	2.22
75 +	0.91	2.71	0.98	2.86

Source: Estimates based on data from 2001 and 2011 Censuses

Table 6.3 also shows the total zonation effect of the mean migration distance for all age groups for 2000-01 and 2010-11. The total zonation effect is calculated by adding together the difference between the minimum and maximum values at each scale step. The total zonation effect also needs to be standardised by dividing the difference between the minimum and maximum values by the initial mean migration distance. The zonation effect shows different patterns across all age groups, with the all age groups except those aged 60-64 showing a decrease in the zonation effect. The 15-19 and 20-24 age groups have the strongest increase in the zonation effect as well as a high zonation effect. This means that the student and young worker age groups become harder to predict on how far they are willing to move; since they are better connected (see section 6.4 Index of Connectivity later), they have more options to find work or further their education across the country.

6.3 Frictional effect of distance

The frictional effect of distance is the concept of defining how much effort by migrants is required to move from one place to another. This so called effort can be based on physical energy as well as financial burdens and social disruption. Distance is therefore a key variable in influencing people's decisions about how far they are willing to move. It has been measured and used in many different ways within migration models (as mentioned earlier in the chapter), and its frictional effect has been quantified in many different studies of internal migration models in different countries, at different scales and for different time periods (e.g. Lowry, 1966; Office of the Deputy Prime Minister (ODPM), 2002; Stillwell et al., 2016).

Whilst early gravity models used statistical regression techniques to quantify the relationship between migration and distance, spatial interaction models (SIMs) were developed initially by Wilson (1967; 1971; 1974) based on entropy-maximising methods (Senior, 1979). One of the first analyses of internal migration in the UK using SIMs is reported in Stillwell (1978) whereas one of the most recent studies of migration using SIMs is that of Dennett and Wilson (2011), where multiple versions of a model were run to calibrate a best-fit general distance decay parameter for a whole system.

Wilson's family of SIMs (1971) is based on the introduction of constraints such that a migration flow matrix is predicted in which the outmigration flows from each origin to all destinations must sum to known out-migrant totals and in-migration flows into each destination from all origins must sum to known destination in-migration totals. If both these constraints are included, the SIM is known as a doubly constrained model; if one of the constraints applies, then the model is singly constrained; an unconstrained model occurs when there are no out-migration or in-migration constraints and a constant is used to ensure that the sum of the predicted flows equals the sum of the observed flows in the matrix.

The purpose of using a SIM in this chapter is to derive the frictional effect of distance as a migration indicator. Since matrices of migration flows are available with known marginal totals, a doubly constrained model can be calibrated that has the following structure:

$$\mathrm{M_{ij}} = \mathrm{A_i}\ \mathrm{O_i}\ \mathrm{B_j}\ \mathrm{D_j} \mathrm{d_{ij}}^{-b} \tag{6.6}$$

where M_{ij} is the migration flow between spatial units i and j, O_i is the total out-migration from spatial unit i and D_j is the total in-migration into each destination spatial unit j, A_i and B_j are the respective balancing factors defined as:

$$\mathrm{A_i} = \frac{1}{\sum_{\mathrm{i}} \mathrm{B_j}\ \mathrm{D_j}\ \ \mathrm{d_{ij}}^{-b}}, \mathrm{i} \neq \mathrm{j} \tag{6.7}$$

and

$$\mathrm{B_j} = \frac{1}{\sum_{\mathrm{i}} \mathrm{A_i}\ \mathrm{O_i}\ \ \mathrm{d_{ij}}^{-b}}, \mathrm{j} \neq \mathrm{i} \tag{6.8}$$

that ensure the out-migration and in-migration constraints are satisfied:

$$O_i = \sum_j M_{ij}, i \neq j \tag{6.9}$$

and

$$D_j = \sum_i M_{ij}, j \neq i \tag{6.10}$$

and dij^{-b} is the distance term expressed as a negative linear function to the power *b* where *b* is referred to as the distance decay parameter. In Wilson's derivation, the relationship between distance and the interaction variable is represented by an exponential function (exp^{-bdij}) rather than a linear power function but a power function is preferred here because no intra-zonal migrants are included in the model.

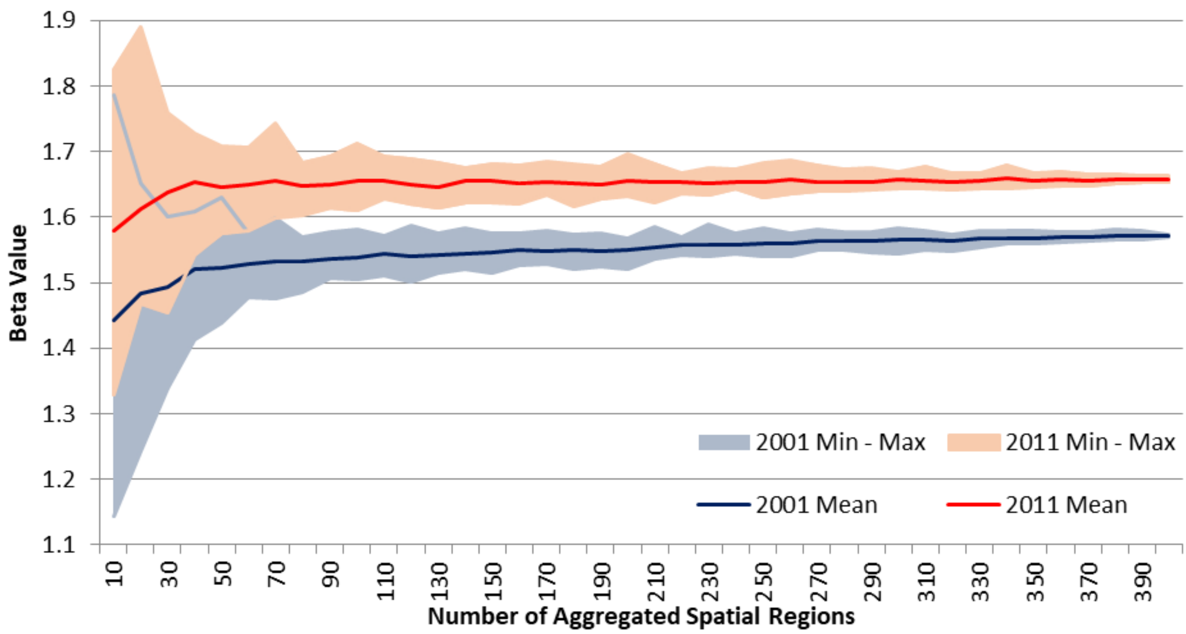
The SIM calibration method requires a migration matrix of flows between zones, a matrix of distances between the same zones and an initial value for beta (*b*), the distance decay parameter, and a value for incrementing the parameter on alternate iterations. Initially, both the balancing factors are set to the value of 1 by the software. Then, with Bj set 1, Ai is calculated and this value is then used to calculate Bj. The new value of Bj is then used to recalculate Ai and successive iterations are undertaken with the new values of Bj included in the Ai calculations and vice versa. Eventually convergence should occur when the values of Ai and Bj do not change between iterations. A balancing factor convergence criteria can be specified which is suggested to be 0.001 (Stillwell, 1983). An initial *b* value of 1 is chosen for the first run of the model and an optimum parameter is found automatically by the model program using a Newton Raphson subroutine in which an increment value (0.01 in this case) is added to the initial *b* after the first model run and on alternate model runs. The optimum or best fit value of *b* is found when the mean migration distance calculated from the matrix of predicted flows is equal (or within very close proximity) to the value of the mean migration distance computed from the observed migration flow matrix. Mean migration distance is therefore used as the convergence criterion in the spatial interaction model.

A doubly constrained SIM is capable of generating an internally consistent flow prediction; the calibration of the SIM allows the distance decay parameters to be measured using the parameters appropriate for behavioural interpretation (Stillwell, 1991). Ultimately, the SIM it is trying to determine the optimal value for the beta parameter, effectively fitting a model to the data. To generate inter-zonal estimates of distance for LADs in the UK, the SIM has been calibrated with data from the 2001 and 2011 Censuses. In the next sub-sections, the all-age and age-specific beta values are reported (together with the predicted mean migration distances) and the mean absolute deviation statistic is used to assess the goodness-of-fit of the SIM.

6.3.1 Beta value

The beta value or distance decay parameter is calibrated by the SIM. A higher beta value means that the impact of distance on migration is greater. In this research, a linear power function is used rather than an exponential one. Linear functions change at a constant rate per unit interval, whilst an exponential function changes by a common ratio over equal intervals; both are available in the modelling subsystem in IMAGE Studio. Taylor (1975) identifies other possible functions. Misrepresentations due to inaccuracies in measuring distance should be smaller with the use of a linear function than with an exponential one (Rodriguez-Bachiller, 1983). The reason that a linear power function was chosen for the analysis in our case was because inter-LAD flows are being modelled and intra-LAD flows are excluded. The latter includes a lot more short-distance movements where the exponential decline with distance is more apparent. Previous research in the UK (Stillwell et al., 2014) suggests that a linear form provides a better fit when modelling longer-distance flows and this proved to be the case with the data used in the inter-LAD flow analysis reported in this chapter.

Figure 6.5 is a visual representation of the scale and zonation effects of the mean beta value for 2000-01 and 2010-11. A high beta value would suggest a stronger distance decay effect, but Figure 6.5 shows that the beta value remains relatively stable with a value of 1.5 between 40 and 400 ASRs in 2000-01, increasing to 1.6 from 20 to 400 ASRs in 2010-11, with a small decrease at lower ASRs. Figure 6.5 therefore suggests that the beta value is scale independent, a result that is consistent with results reported for the UK and other countries by Stillwell et al. (2016). In other words, although the distance of migration increases as the number of zones in the system gets smaller, the frictional effect of distance on migrants remains the same. Figure 6.5 also indicates that the frictional effect of distance as measured by the distance decay parameter increases between 2000-01 and 2010-11 as the mean migration distance declines (Figure 6.3 and Section 6.3.2). However, unlike the relatively small and insignificant zonation effect on the mean migration distance, the zonation effect on the decay parameter gradually increases as the zones gets larger, particularly when the number of ASRs falls below 100. In other words, the configuration of zones for systems with less than 100 zones can have quite significant effect of the parameter value, increasing rapidly as the number of ASRs gets below 40.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.5: Scale and zonation effects of the mean beta value, 2000-01 and 2010-11

The intention was to use the SIM in the IMAGE Studio to calibrate beta values for the 11 different age groups. However, while running each of the age group matrices, an error occurred for certain age groups: “Balancing factor iteration exceeded max rounds: 500 stopping”. This error means that the balancing factors in the SIM are not converging after 500 iterations and therefore an optimal beta value is not being calibrated and the model cannot predict a flow matrix. It became apparent that the cause of the problem was an excess of zero flows in certain matrices which prevent the balancing factors from being able to converge. As indicated above, the first thing that happens in the SIM, once the initial beta value has been chosen is that the balancing factors for each zone (Ai and Bj) in the system are computed, using an iterative convergence method. If the matrix is too sparsely populated, the balancing factors will not converge and therefore no calibration will be possible. This problem arises with the migration matrices for certain age groups when the number of zones gets larger and the proportion of zero cells increases. There comes a point when it becomes impossible for the SIM to meet the constraint that the sum of the predicted values in each row equals the observed row total (the observed out-migration total from zone i) or the sum of the predicted values in each column equals the observed column total (the in-migration total to zone j).

Six matrices were affected by this problem, involving age groups at either end of the age range: the young (0-4, 5-9, 10-14) and elderly (60-64, 65-74 and 75+). Table 6.4 shows the total count and percentage of zeros within matrices for each age group in 2000-01 and 2010-11. Some of the zero percentages are very high. The percentage of zeros for the 10-14 year olds reaches 90% in 2000-01 and 86% in 2010-11 whereas the percentage for the 60-64 age group is 93% in 2000-01. Contrast these proportions with the all-age matrix where 38% of cells contain zeros in 2000-01 and only 28% in 2010-11. SIMs are designed to model flows rather than non-interaction and there are limits on the ability of the model to calibrate when the number of zones is large and the matrix is relatively sparsely populated.

Table 6.4: Total count and percentage of zero cells in the BSU matrices by age group, 2000-01 and 2010-11

	Zero Count	Zero %	Zero Count	Zero %
	2000-01		2010-11	
0 - 4	140,105	86	129,088	79
5 - 9	144,695	89	138,604	85
10 - 14	147,688	90	141,056	86
15 - 19	131,006	80	114,498	70
20 - 24	113,581	70	92,391	57
25 - 34	106,763	65	88,663	54
35 - 44	125,636	77	106,704	65
45 - 59	132,982	81	110,025	67
60 - 64	152,606	93	139,315	85
65 - 74	150,202	92	138,894	85
75+	150,558	92	140,449	86
All	62,824	38	43,390	27

Source: Estimates based on data from 2001 and 2011 Censuses

Since there are too many zero cells to allow the model to calibrate a decay parameter in these age groups, the 11 age groups have been aggregated into four broad groups, as seen in Table 6.5, each of which represents a broad stage in the life course. By using the four broad age groups, the SIM runs without any convergence problems and, as seen in Table 6.5, all zero percentages are below 85%. There is also a significant difference between the two censuses, as there is a significant drop in zero cells from 2000-01 to 2010-11.

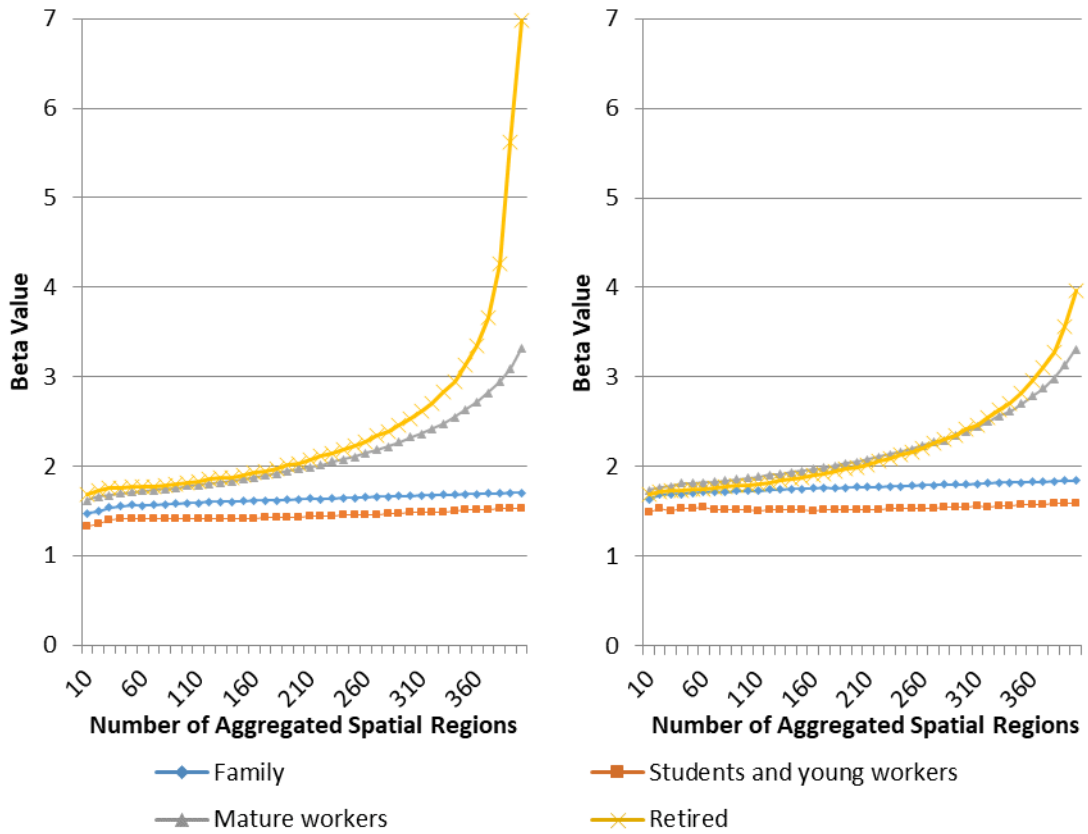
Table 6.5: Total count and percentage of zero cells in the BSU matrices by broad age group, 2000-01 and 2010-11

Definition	Age group	Zero Count	Zero %	Zero Count	Zero %
		2000-01		2010-11	
Family	0-14 & 25-44	88,093	54	71,414	44
Students and young workers	15-24	102,962	63	80,779	49
Mature workers	45-59	132,982	81	110,025	67
Retired	60+	137,600	84	117,711	72

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.6 shows the scale effects of the mean beta values by broad age group for 2000-01 and 2010-11. The family and student and young workers age groups, whose matrices contain more non-zero cells, show low and consistent beta values for both years, although a small increase can be observed from 2000-01 to 2010-11. A high beta value suggests that the distance decay effect is greatest for those in the retired (60) age category and there appears to be a significant scale effect in the beta value as the number of ASRs gets smaller. The value increases from 1.69 at 10 ASRs to 6.99 at 400 ASRs. The retired age group also demonstrates the biggest change between the censuses, as the beta value was lower in 2010-11 with 3.97 at 400 ASRs, suggesting that older migrants were less affected by distance in 2000-01, certainly at the BSU scale. Although the mature worker age group retained similar beta values in both periods, they also have high beta values with 3.32 at 400 ASRs in 2000-01 and 3.31 in 2010-11. The evidence from these model results, with the number of zero cells reducing as the number of ASRs reduces, suggests that the beta values are to a certain extent reflecting matrix sparsity.

It is also noticeable that the scale effect on the beta value of the ‘mature workers’ group in 2010-11 is such that for large numbers of ASRs, the beta value is lower than that of the ‘retired’ group, but as the number of ASRs reduces, the beta value ‘crosses over’ and becomes higher than that for the ‘retired’ group. Therefore, scale is important in terms of ranking the age groups using the distance decay parameter as a migration indicator. The retired and mature workers age groups are the most affected by migration distance, whilst the family and student and young workers are less affected; this means that the older the population becomes, the more reluctant to move furthers distances they become.



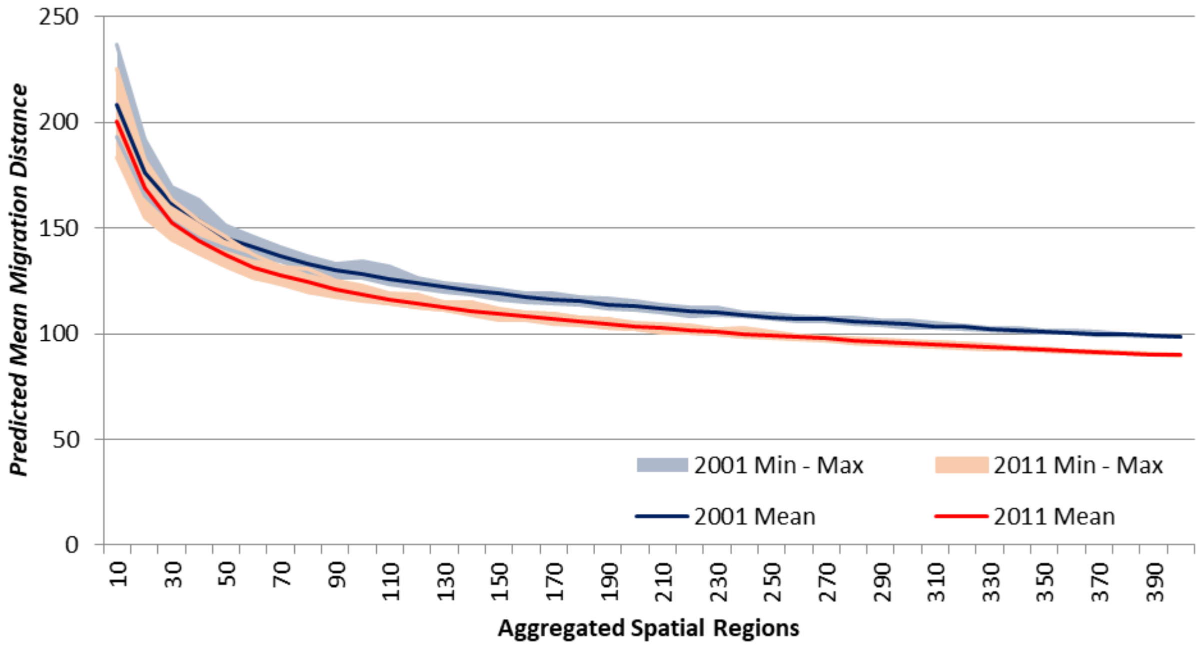
a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.6: Scale effects of the mean beta value by broad age group, 2000-01 and 2010-11

6.3.2 Predicted mean migration distance

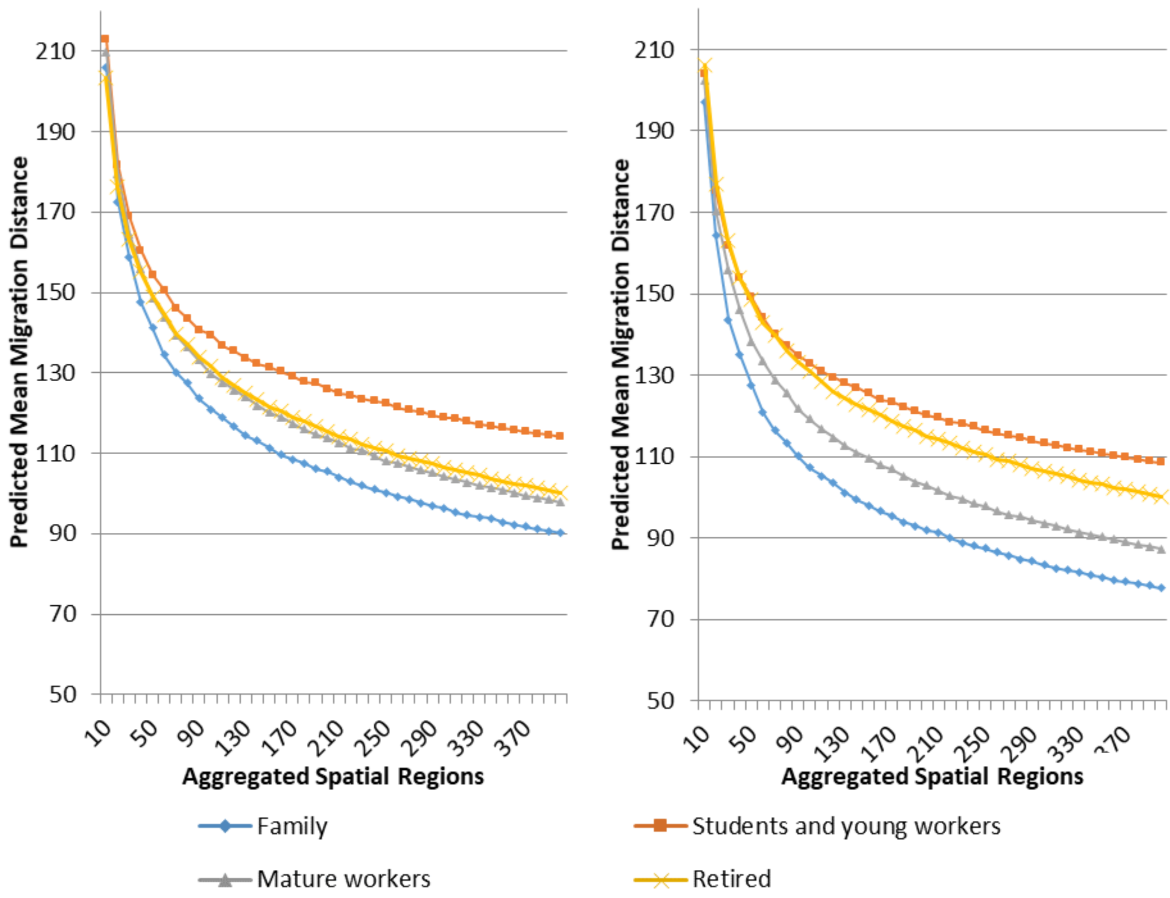
A predicted mean migration distance (PMMD) is computed by the SIM which is exactly the same as the observed mean migration distance (discussed previously) and defines how far migrants actually move. The optimum beta value is determined when the difference between the mean migration distances in the predicted and observed matrices is negligible. Figure 6.7 shows the scale and zonation effects of the PMMD for both 2000-01 and 2010-11 on the same graph. As demonstrated previously, the scale effect shows that as the scales get smaller, migrants move greater distances, from 80 to 10 ASRs this becomes more apparent where the PMMD goes from 130km to 182km in 2000-01 and from 124km to 200km in 2010-11. The zonation effect can only be observed at larger scales as it becomes smaller as the number of ASRs increases. Figure 6.7 is included to facilitate comparison between the distance measures in the two periods.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.7: Scale and zonation effects of the Predicted Mean Migration Distance, 2000-01 and 2010-11

The scale effects for the broad age groups are shown in Figure 6.8. It can be observed that for all the age groups migrants move greater distances as the scale get smaller. The PMMD increases from 131km at 150 ASRs to 213km at 10 ASRs in 2000-01 for the ‘student and young workers’ age group and declines to 121km at 150 ASRs and 204km at 10 ASRs in 2010-11. This decrease in PMMD over the decade suggests that students and young workers travel fewer long distances as the scales get bigger. Similar to the ‘student and young workers’ age group, the family, mature workers and retired age groups have shown a decrease in the PMMD between 2000-01 and 2010-11.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.8: Scale effects of the predicted mean migration distance by broad age group, 2000-01 and 2010-11

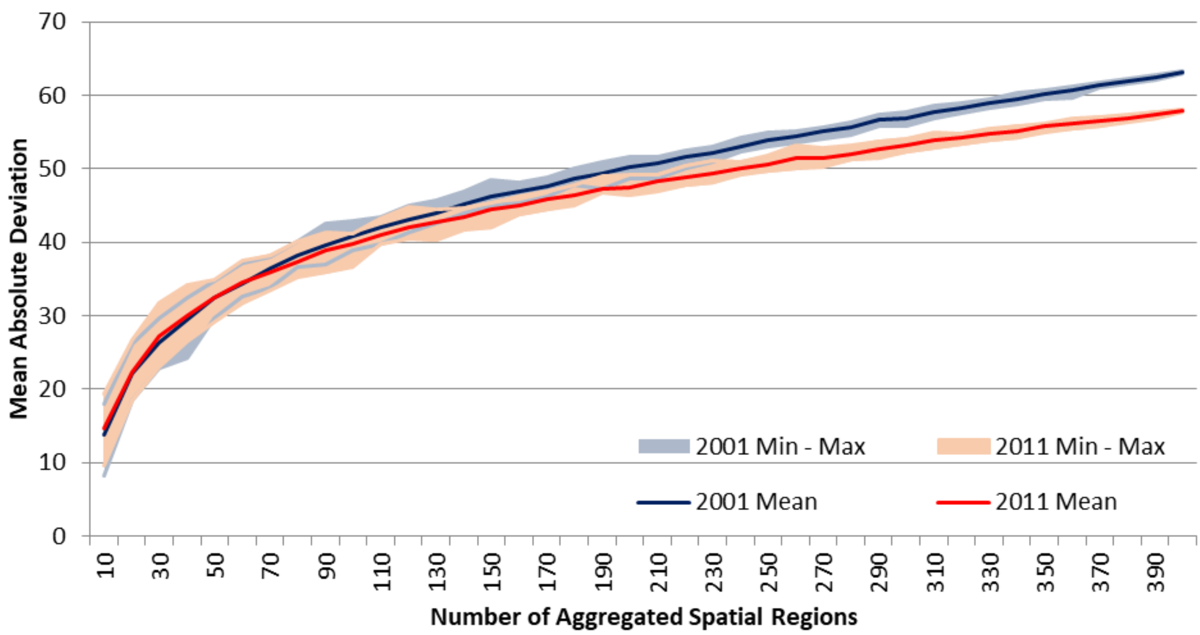
6.3.3 Mean absolute deviation

The mean absolute deviation (MAD) statistic is the average difference between the flow of migrants in each cell of the matrix predicted by the model and the respective observed value. It is one measure of goodness-of-fit of a SIM calibrated using the IMAGE Studio. The more similar the flows in the predicted and observed matrices are, the higher goodness-of-fit of the model is. One measure of fit is the MAD statistic, the mean absolute difference between the predicted and observed flow across all non-diagonal cells of the matrix, which is calculated as:

$$\text{MAD} = \sum_{ij}\left|\text{Pred } M_{ij} - \text{Obs } M_{ij}\right| / n(n-1) \qquad (6.11)$$

where the Pred M_{ij} is the predicted flows and the Obs M_{ij} is the observed flows and n is the number of zones in the system. A smaller MAD value would signify that the goodness-of-fit is high, whereas a larger value of the MAD value would indicate that goodness-of-fit is poor. If the latter is the case, the assumption can be made that the model is not generating a predicted matrix that is representative of the actual distribution of migration flows. Figure 6.9 visualises the MAD for both sets of census data, showing similar patterns in both years. In 2000-01, the MAD increases as the number of ASRs increases from 37 at 80 ASRs to 63 at 400 ASRs; in 2010-11, the MADs increases from 37 at 80 ASRs to 57 at 400 ASRs. When the number of ASRs gets smaller, the MAD in both years is very similar with a value of 14 at 10 ASRs increasing steeply to the 37 at 80 ASRs. Figure 6.9 demonstrates that for small numbers of ASRs, the predicted and observed values are closer and become further away as the number of ASRs increases.

The zonation effect of the MAD is low across scale, ranging from 9% to 20% but becomes even less significant at smaller scale levels where the zonation effect ranges within 0.5 of the mean. The data have shown that the MAD and its inequality only increase as the zones increase in size. The MAD value drops as zones gets bigger and a better fit of model can be observed as the number of zones get smaller. For smaller numbers of ASRs (e.g. under 60 ASRs) the 2010-11 model fits better than that for 2000-01.

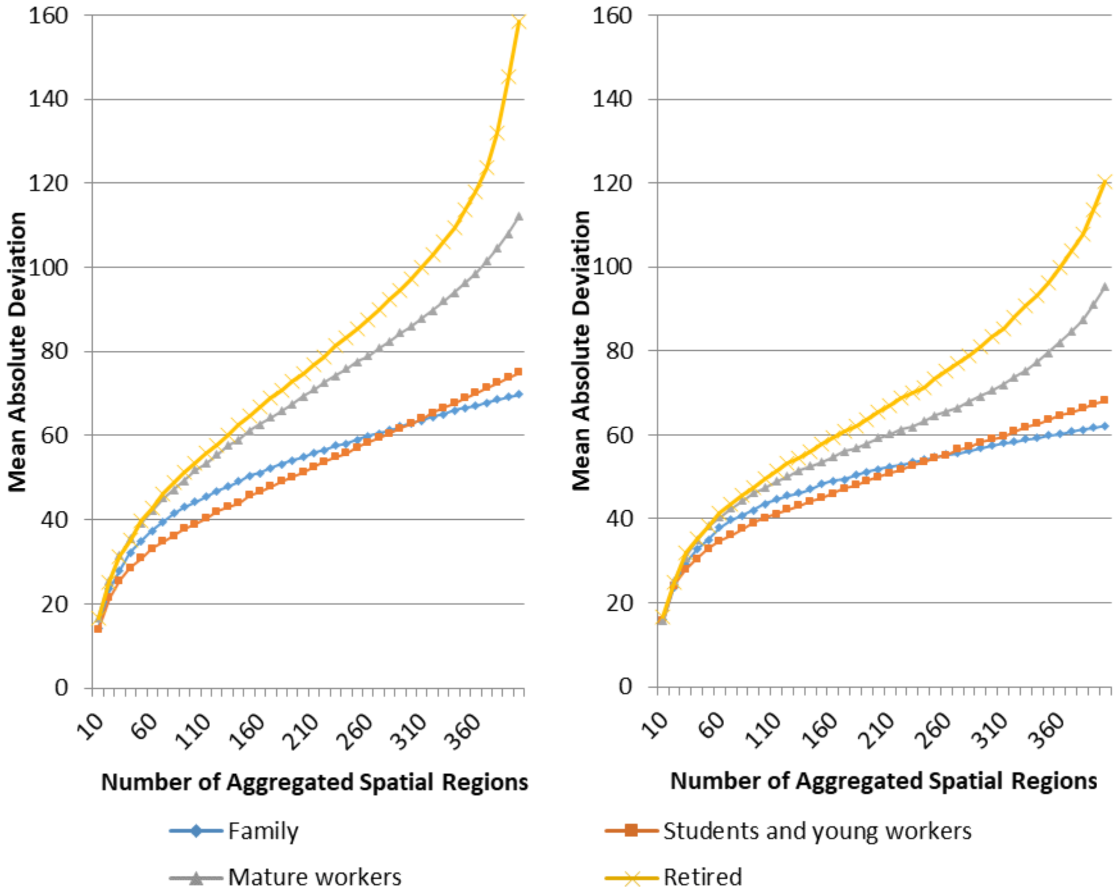


Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.9: Scale and zonation effects of the mean absolute deviation, 2000-01 and 2010-11

Figure 6.10 shows the scale effects of the MAD statistic by broad age group for 2000-01 and 2010-11. This figure shows that the mean deviation is much larger at smaller scale levels for all age groups in both but the MAD is lower for all age groups in the second period. The MAD can be observed in 2000-

01 for the retired age group as ranging from 16.58 at 10 ASRs to 158.61 at 400 ASRs. Although the retired age group has experienced a significant decrease over the 10 year period, it still has the highest MAD value of 16.8 at 10 ASRs going up to 120.33% at 400 ASRs in 2010-11. This figure demonstrates that, at larger scales, model fits are much better than at smaller scales; thus scale is important when modelling migration. There is also 'crossover' in two of the age group schedules, indicating that model fits are better for 'students and young workers' than for family migrants when there are a large number of zones being used but the situation is vice versa when the modelling is taking place with smaller numbers of zones.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.10: Scale effects of the mean deviation by broad age groups, 2000-01 and 2010-11

6.4 Index of connectivity

Whilst distance and its frictional effect are both indicators of migration relating to the migrants themselves, an alternative approach is to consider area connectivity. Table 6.4 has already illustrated one measure of connectivity, that of the number and proportion of cells in the migration matrix that have no migration count. The reverse of this is the index of connectivity (IC) is a simple measure of the proportion of spatial units that are connected by a migration flow involving one or more persons (Daras, 2014). The IC is used to analyse the existence and importance of linkages between spatially distributed geographical areas (Samia et al., 2015). The IC gives us a better understanding of the extent of connectivity; a higher connectivity index may represent better conditions for the respective populations while some obstacles also may exist, causing the connectivity index to decrease (Samia et al., 2015). Better conditions, in this context, might mean that roads, motorways and public transport facilitate inter-zonal connectivity. The IMAGE Studio computes a simple global IC as a number between 0 and 1 (or 100%), where 0 represents no connections between zones and 1 (or 100%) represents a situation where all zones are connected to all other zones in a system of interest. Local indices of connectivity can be calculated for inflows to and outflows from each zone. These IC measures can be adopted for use when analysing migration flows between zones.

6.4.1 Global connectivity

Table 6.6 shows the total count and percentage of non-zero cells in the BSU matrices by age group for 2000-01 and 2010-11, in order to highlight and compare zonal connectivity for each age group. In 2000-01, 62% of all the off-diagonal cells (162,812 cells in total) in the all age matrix had a value greater than zero which indicates that these are connected to other BSUs, and this proportion has increased in 2010-11 to 73%. Furthermore, Table 6.6 also indicates that LADs were most connected by migrants aged 25-34 with a global IC of 35% in 2000-01, rising to 46% in 2010-11. Areas were least connected by flows of elderly migrants but this connectivity did increase significantly between 2000-01 and 2010-11. The figures in Table 6.6 suggest that despite the decline in migration intensity and the mean distance that people have migrated, LAD connectivity increased across all age groups between 2000-01 and 2010-11. This might it be due to the increasing number of people moving between LADs for example, according to Table 4.1, the number of inter-LAD migrants increased from 2.66 to 2.79 million, as well as a possible improvement of technology or better transport communication systems.

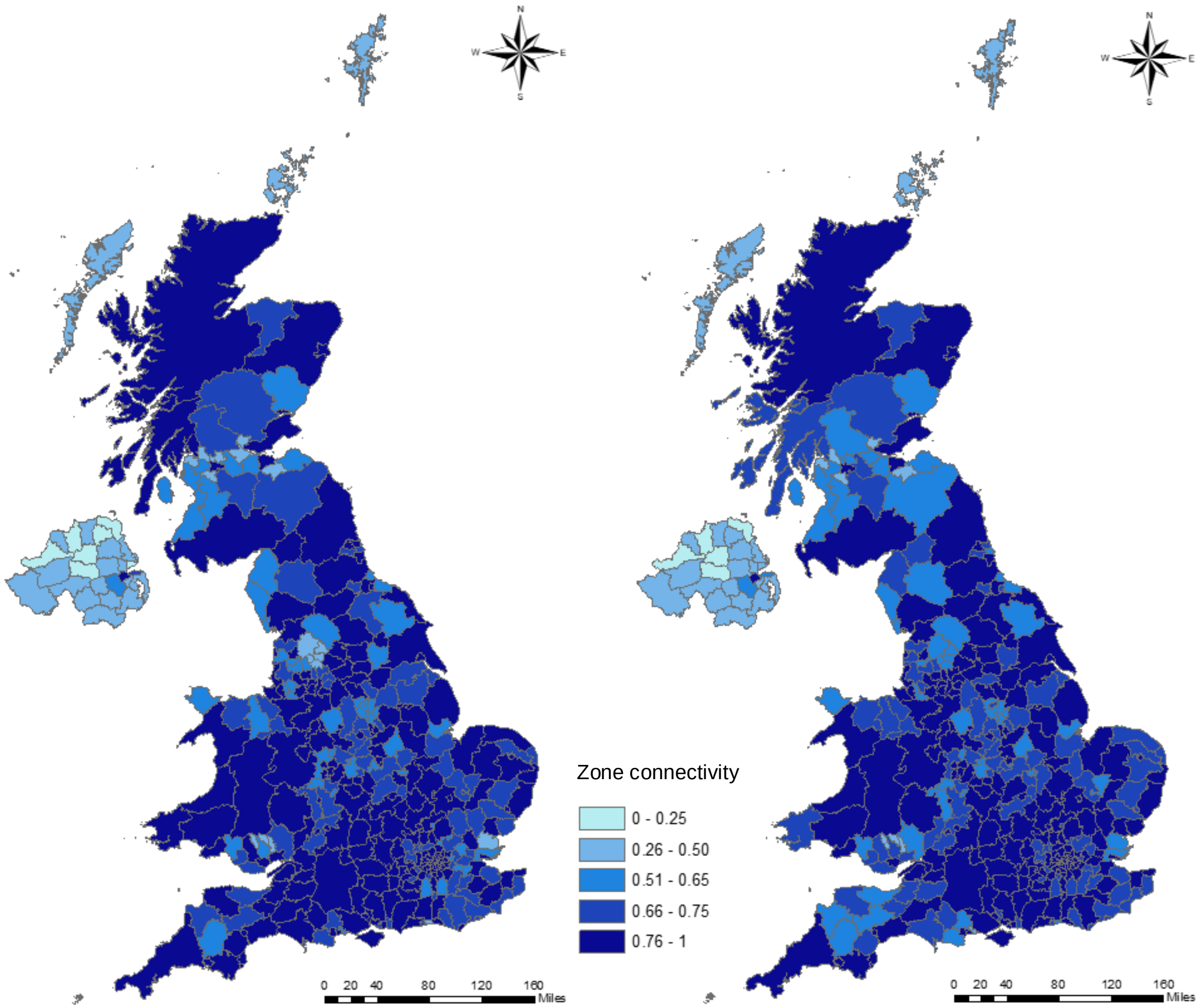
Table 6.6: Total count and percentage of non-zero cells in the basic spatial unit matrices by age group, 2000-01 and 2010-11

	Non-zero Count	Non-zero %	Non-zero Count	Non-zero %
	2000-01		2010-11	
0 - 4	23,111	14	34,128	21
5 - 9	18,521	11	24,612	15
10 - 14	15,528	10	22,160	14
15 - 19	32,210	20	48,718	30
20 - 24	49,635	30	70,825	43
25 - 34	56,453	35	74,553	46
35 - 44	37,580	23	56,512	35
45 - 59	30,234	19	53,191	33
60 - 64	10,610	7	23,901	15
65 - 74	13,014	8	24,322	15
75+	12,658	8	22,767	14
All	100,392	62	119,826	73

6.4.2 In-migration and out-migration connectivity

As the Image Studio software only calculates the global IC, additional calculations were made using the in-migration and out-migration flows for each LAD; an in-migration IC for LAD i is the percentage of other LADs that have an inflow to LAD i and an out-migration IC for LAD i is the percentage of other LADs that receive at least one migrant from LAD i.

The maps in Figure 6.11 show how the all-age in-migration and out-migration IC percentages vary across the UK for all ages in 2010-11. Whilst seven LADs have exactly the same in-migration and out-migration IC, the majority of LADs have less than a 10% difference between their in-migration and out-migration ICs. The biggest difference is in Oadby and Wigston, a predominantly urban LAD in the heart of Leicestershire, where the in-migration IC is 83% and the out-migration IC is 57%. Gravesham, a rural LAD in the south east of England, experiences the opposite where the out-migration IC is higher with 68% compared to the 55% of in-migration IC. LADs in central Scotland are lower than elsewhere in Great Britain in both periods. In Northern Ireland, where connectivity is lower, urban LADs tend to have low in-migration and out-migration IC compared to the rural LADs. This is likely to be due to the Catholic/Protestant religious divide which suppresses the propensity to migrate outwith the communities to which individuals of the respective faiths belong.



a. In-Index of Connectivity, 2010-11

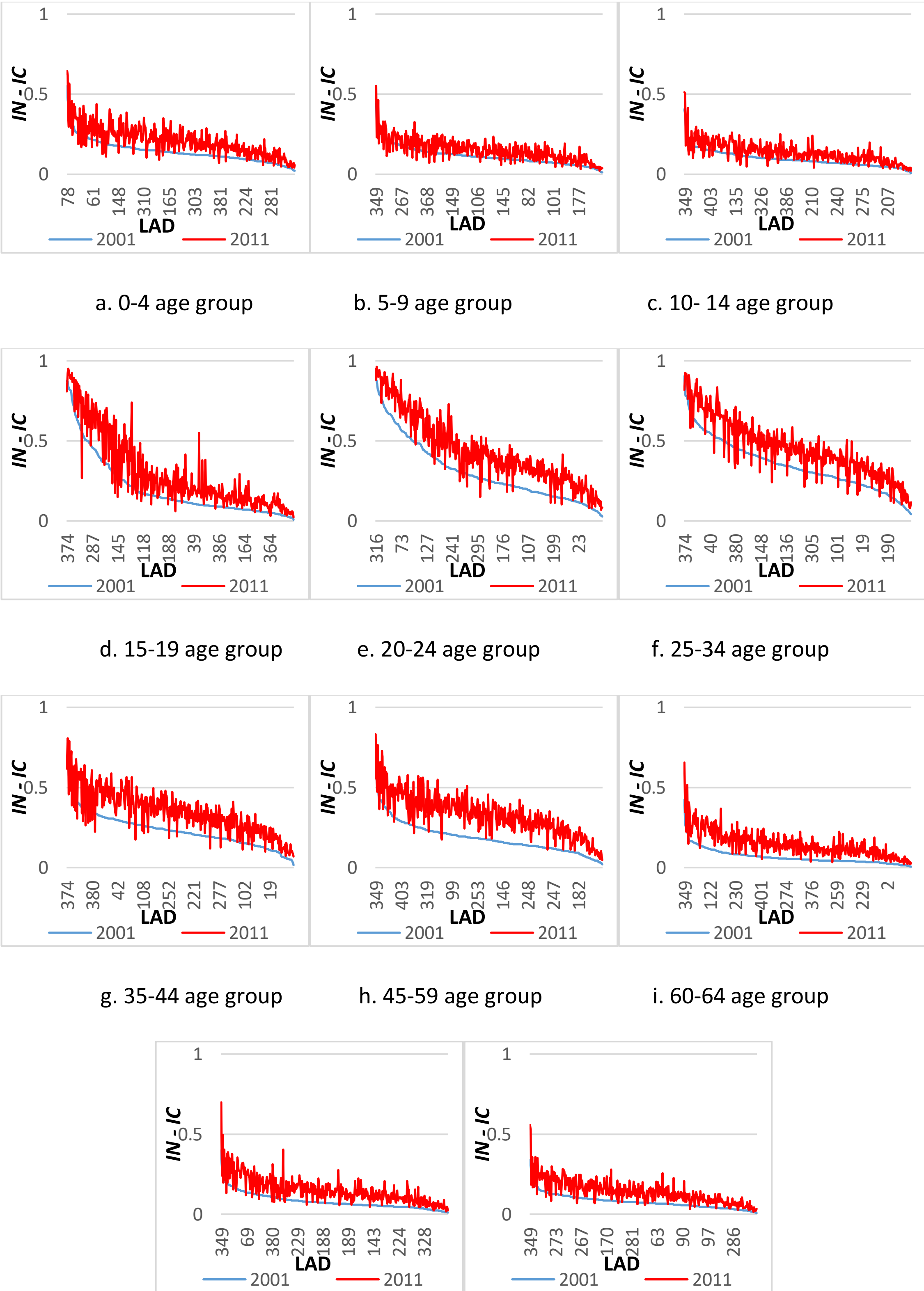
b. Out- Index of Connectivity, 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.11: In-migration and out-migration connectivity indices for local authority districts, all ages, 2010-11

Figure 6.11 only reports connectivity for 2010-11 for all-age migrants. In order to summarise changes between the two periods for different age groups, each graph in Figure 6.12 shows in-migration IC values ranked on their 2000-01 IC values (blue line) from the largest to the smallest in-migration IC. The red line is the 2010-11 IC values for the equivalent LADs. All 11 graphs demonstrate that in 2010-11 the in-migration ICs for the majority of LADs are significantly higher than in 2000-01, indicating that the UK is becoming better connected over time, with the highest in-migration IC values amongst the 15-19, 20-24 and 25-34 age groups. Manchester has an IC of 95% for the 15-19 age group and 96% for the 20-24 age group, possibly influenced by student discounts on public transport e.g. the 16-25 Railcard (TFGM, 2020). Whereas Wandsworth has an IC of 92% for the 25-34 age group in 2010-11 potentially cause by a multi-million pound investment of the council to improve Wandsworth's roads and pavements for cyclists, pedestrians and drivers (Wandsworth Council, 2019).

The most significant increase in the in-migration ICs can be found in Tower Hamlets with a 52% increase for the 15-19 age group, possibly due to a very high jobs density from the Docklands business district (Hastings, 2003). Richmondshire also experienced a significant increase of 40% in the in-migration IC for the 20-24 age group, where a quarter of the jobs there are from HM Forces, which could be the leading cause for attracting young workers (Hastings, 2003). The 5-9 and 10-14 age groups have the smallest maximum increase of 17% in Reigate and Banstead and 18% in Birmingham. All other age groups have a maximum increase of the in-migration IC from 2000-01 to 2010-11 ranging between 23% and 33%. The biggest decrease of 29% in the in-migration IC is located in Harrogate and affected the 15-19 age groups, while all other age groups experience a minimum decrease ranging from 4% to 13%, which can possibly be explained by increasing house prices, average income dropping and with increasing retail vacancy rates (Harrogate Borough Council, 2016). The 20-24 age group has the largest variation whereas the 5-9 and 75+ age groups show little variation across LADs. Furthermore, the graphs for older age groups (60+) show very few LADs with lower IC values in 2010-11 whereas the graph for the 25-34 age group shows that quite a number LADs where the IC value has fallen. Since in the 2010-11 the in-migration IC has increased across all age groups, all the in-migration IC show higher figures, but maintain the same level of variation.



a. 0-4 age group

b. 5-9 age group

c. 10- 14 age group

d. 15-19 age group

e. 20-24 age group

f. 25-34 age group

g. 35-44 age group

h. 45-59 age group

i. 60-64 age group

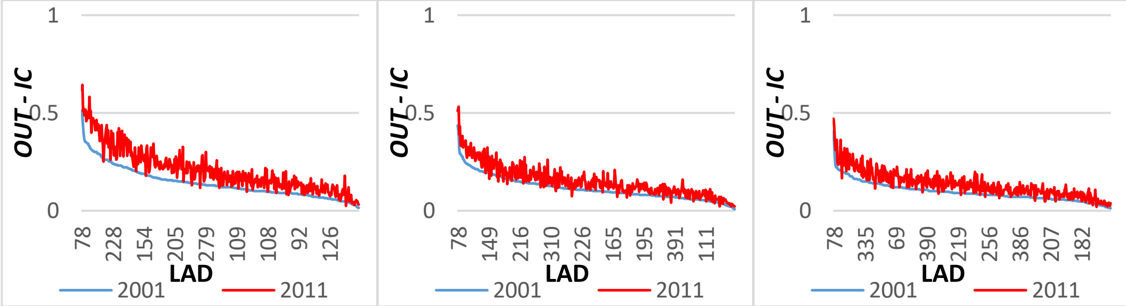
j. 65-74 age group

k. 75+ age group

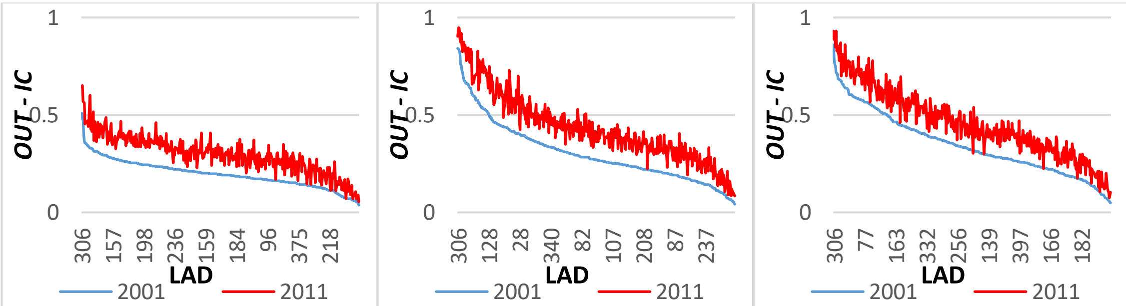
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.12: In-migration index of connectivity, by district, by age group, 2000-01 and 2010-11

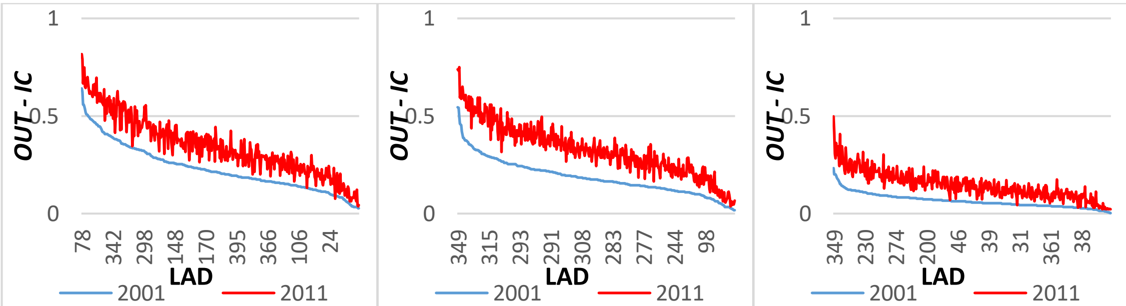
Figure 6.13 shows the out-migration ICs for all LADs for 2000-01 and 2010-11 for each of the 11 age groups. Similar to Figure 6.12, each graph shows out-migration IC values for LADs ranked according to the 2000-01 values from the largest to the smallest in order to compare age groups and better visualise the occurred changes in 2010-11. The 20-24 and 25-34 age groups show the highest values for the out-migration ICs for both years. The highest out-migration IC can be found in Manchester with 95% for the 20-24 age groups while Birmingham had the highest out-migration IC of 93% for the 25-34 age group in 2010-11. Birmingham for the 20-24 age group has also experience the biggest out-IC increase of 30%. The 11 age graphs also show that there are very few LADs who experienced a negative change between 2000-01 and 2010-11, as most LADs have a change greater than 1%. Some exceptions can be found in the 75+ age groups, where West Dunbartonshire went from an out-IC of 7% to 5%. This might be caused by a decrease in the public transport usage or for the 75+ age group, possibly due to a decreasing ability of driving resulting in them having no car. While a significant number of LADs had lower in-migration connectivity in 2010-11, there are only a very small proportion of LADs who had lower out-migration connectivity in 2010-11, and most of these were in the 5-9 age group.



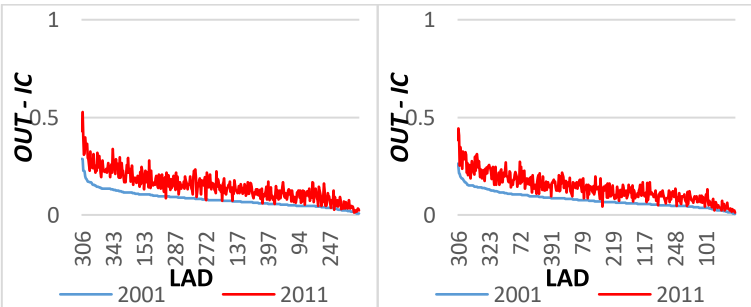
a. 0-4 age group b. 5-9 age group c. 10- 14 age group



d. 15-19 age group e. 20-24 age group f. 25-34 age group



g. 35-44 age group h. 45-59 age group i. 60-64 age group



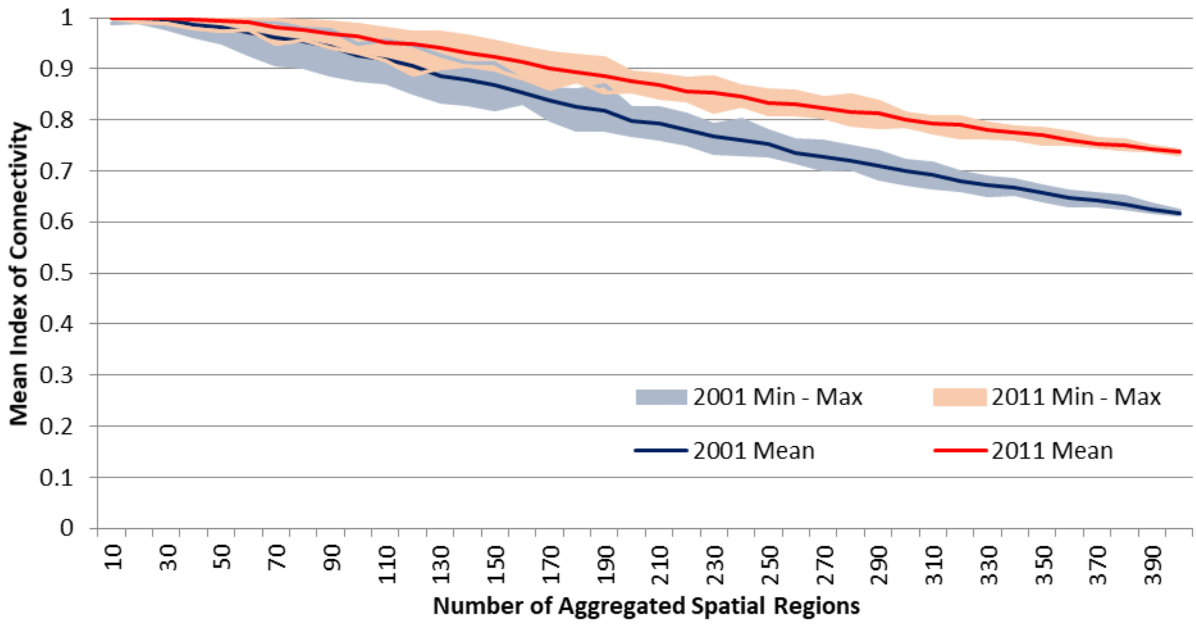
j. 65-74 age group k. 75+ age group

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.13: Out-migration index of connectivity, by district, by age group, 2000-01 and 2010-11

6.4.3 Scale and zonation effects on connectivity

The final step in analysing the IC is to compute the respective scale and zonation effects. Figure 6.14 shows the IC values for all ages in 2000-01 and 2010-11. At a first glance, it can be observed that both years show very linear trends over scale although the scale effect is much less pronounced when ASRs get larger as everywhere becomes connected to everywhere else (i.e. there is a top limit of 1). In 2010-11, the IC is greater with a value of 0.74 at 400 ASRs compared to 0.62 in 2000-01, as shown in Table 6.6. The zonation effect remains consistent between both time periods: the zonation effect is very small at 10 and 400 ASRs and at is largest at 120 ASRs.



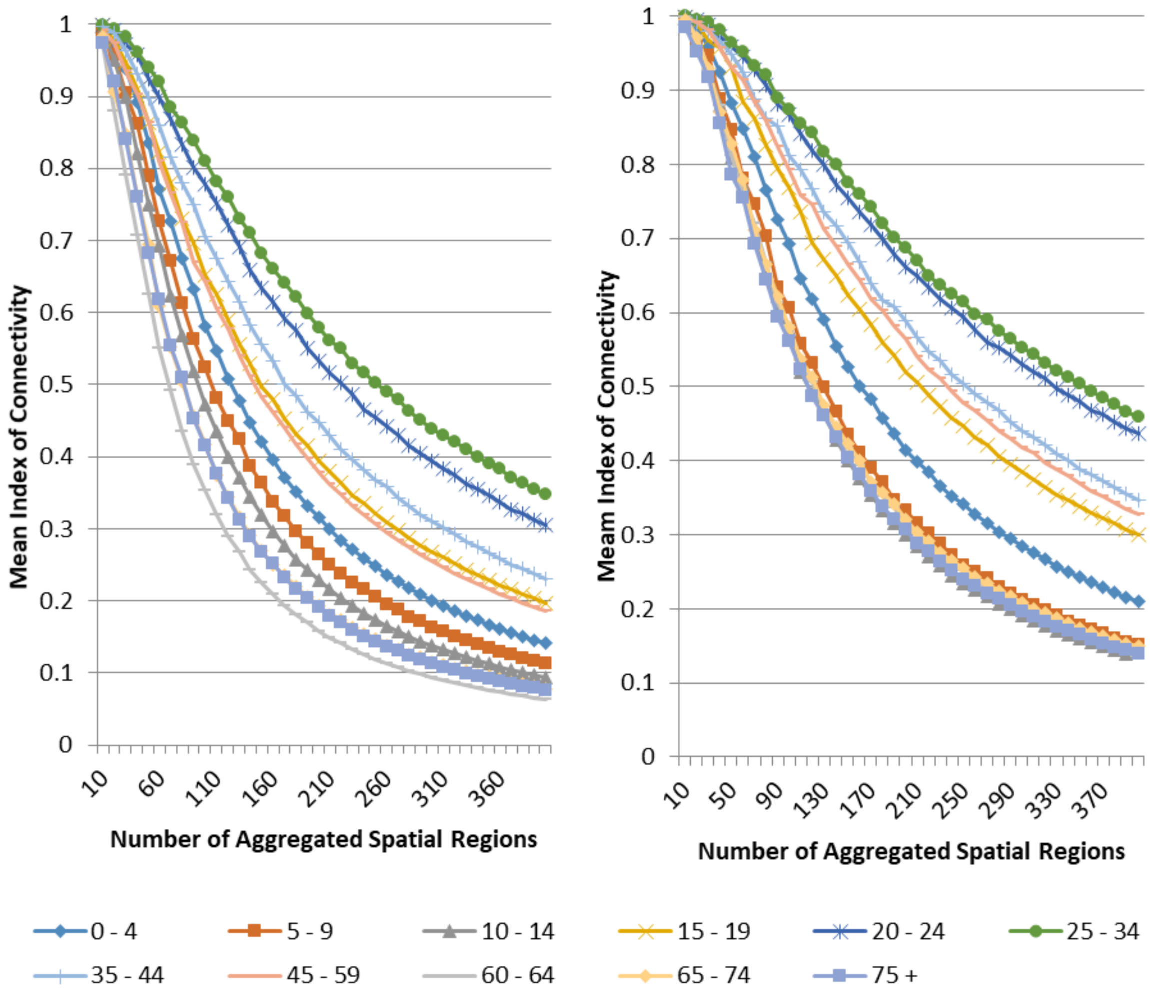
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.14: Mean connectivity index by scale, all ages, 2000-01 and 2010-11

When analysing the different age groups, the graph in Figure 6.15 shows different age-group trajectories compared to the all ages schedule as the lines are mostly concave rather than linear. The 25-34 year olds have a trajectory with the highest area connectivity and least scale effect whereas the 60-64, 65-74 and 75+ groups show the lowest connectivity but largest scale effects. Connectivity is also consistently higher in 2010-11 across all age groups, as all age group have a higher IC at 400 ASRs in 2010-11 compared to 2000-01.

The scale effect for the 15-19 age group is greater than that of the 45-59 age group in 2000-01 but vice versa in 2010-11 and the 60-64, 65+ and 10-14 age groups have very similar scale effects in 2010-

11. Another observation is that the IC is increasing over time, while previous findings have also shown that the migration distance has decreased. In other words, the UK population moves shorter distances but areas have become more connected.



a. 2000-01

b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 6.15: Mean connectivity Index by scale and age group, 2000-01 and 2010-11

6.5 Conclusion

The first aim of this chapter was to quantify how the distance decay parameter varies using all-age data and what differences are apparent between age groups. The results obtained have shown that distance is a key variable in influencing people on how far they are willing to move and incorporating a measurement of distance decay into a migration model is crucial. Similar results were also observed by Niedomysl (2011). It is apparent that the distance of migration had decreased between 2000-01 and 2010-11; the UK population moves shorter distances but places are more connected by migration in 2010-11 than they were in 2000-01, which has been the most significant change between the two time periods. Possible explanations have been offered for these changes. This conclusion is an important contribution to the debate on whether the address-changing population is becoming more or less mobile over different distances.

Unlike distance moved and connectivity, for which there are significant scale affects, the distance decay parameter appears to remain scale independent across much of the scale range. There are clear variations in the distance, decay and connectivity indicators for the various age groups which comprise the aggregate flows. This suggests that it is important to select the appropriate scale level when analysing migration distance or migration connectivity as the results will be influenced by which scale is chosen, in comparison to the distance decay parameter, where there results will portray the same conclusion regardless of which scale level is applied. The calculated beta value has also shown that the retired and mature workers age groups are the most affected by migration distance, whilst the family and student and young workers are less affected. These results demonstrate that the older the population becomes, the more reluctant to move further distances they become.

Now that the patterns of and changes in migration distance, distance decay and connectivity have been identified and the scale and zonation effects have been revealed when using LADs across the whole of the UK, the following chapter will investigate the patterns, effects and changes over time of each of the indicators used in this and the previous chapter when BSUs are used for one region at a more detailed spatial scale.

Chapter 7: Scale and Zonation Effects on Migration Indicators for Smaller Geographical Areas

7.1 Introduction

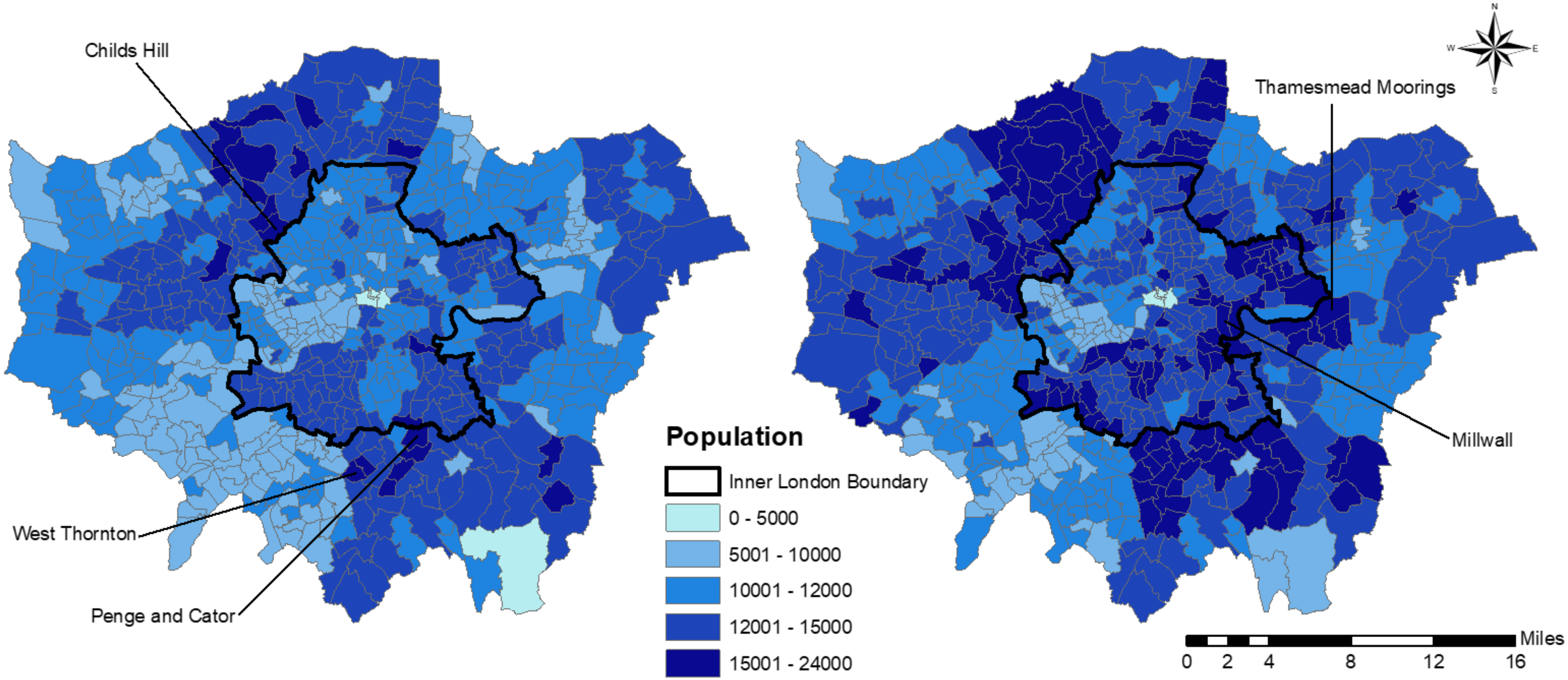
Thus far, a comprehensive analysis of internal migration has been undertaken and reported in the last three chapters using a selected set of migration indicators based on a UK-wide set of local authority districts (LADs) as basic spatial units (BSUs) with consistent boundaries between 2001 and 2011. In this chapter the aim is to move to a system of spatial units that are much smaller in size that LADs; as indicated in Chapter 4, the census provides age group migration data at ward scale. One advantage of using flows between smaller spatial units such as wards is that a much larger proportion of internal migration is captured in the analysis at the outset, including a higher proportion of shorter-distance moves for housing reasons, i.e. residential mobility. However, it is not possible to undertake a nationwide analysis at ward level because of the problem of matrix sparsity and therefore the focus is on one single region – Greater London (GL).

Greater London is selected as the case study region for a number of reasons: firstly, population densities are high across this region and migration flows/rates are also high which helps avoid the problem of sparse matrices when analysing age-specific migration between small areas; secondly, migration within London is responsible for approximately 12.5% of UK total internal migration in 2010-11 so the analysis involves a significant proportion of total migration but the motivations for moving over shorter distances are likely to be different to those moving between LADs; and thirdly, there are interesting patterns of spatial deconcentration taking place within London that an analysis by age will help us to understand much better as well as identifying the scale and zonation effects.

The chapter begins by explaining how London's population has changed between 2001 and 2011 as a context for the migration analysis in Section 7.2. Thereafter, Section 7.3 examines the spatial patterns of migration intensity, migration effectiveness and net migration at BSU level before investigating the scale and zonation effects. Given that migration data are available from the census at district (borough) level and have been used in previous chapters, Section 7.3 also contains a comparison of the crude migration intensity computed for the 32 boroughs with an optimum set of 32 ASRs generated by the IMAGE Studio, in order to assess whether migration intensity is being measured genuinely when using the borough boundaries. Section 7.4 then examines the mean distances migrated within GL, the frictional effect of distance and ward connectivity as well as their scale and zonation effects, before conclusions are drawn in Section 7.5.

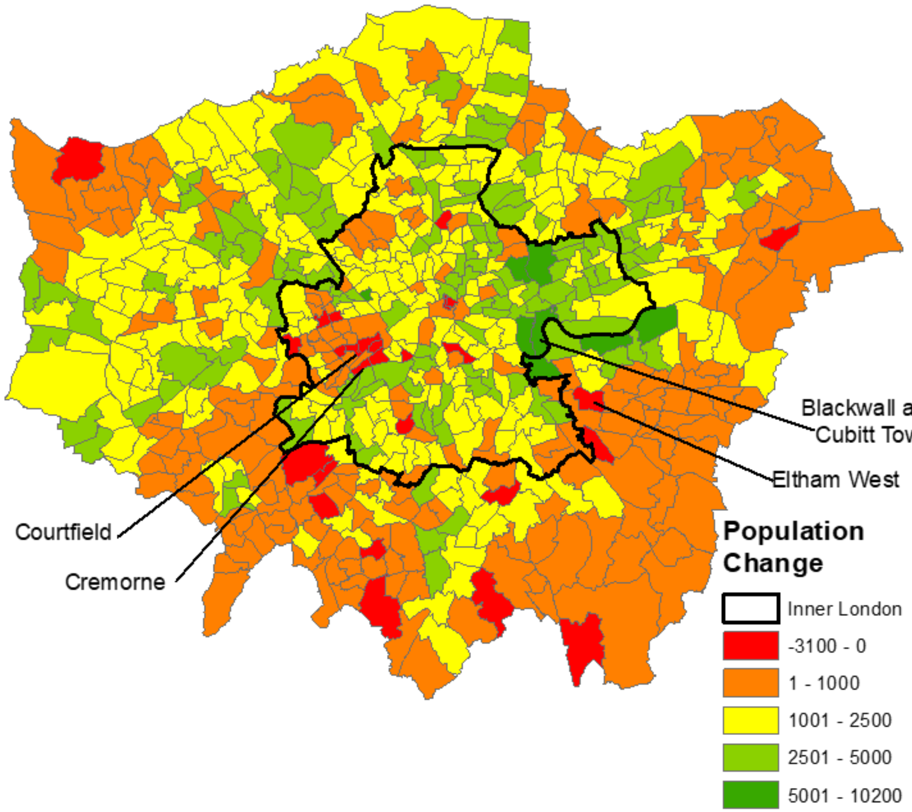
7.2 Greater London's population and internal migration

As the hub of the UK's internal migration network and the country's most populated city, GL is an ideal target for examining internal migration at ward level. The GL 'region' has the highest population density amongst all urban areas in the UK with over 5,000 inhabitants per km^2 in 2001 (Pointer, 2005) compared to 4,000 inhabitants per km^2 in Birmingham (ONS, 2011b). GL experienced a 12.3% increase in population from 7,172,085 in 2001 to 8,173,941 in 2011. GL consists of the City of London plus 32 boroughs which are equivalent to LADs, containing 633 census wards in 2001 and 628 in 2011 (ONS, 2011). Maps a and b in Figure 7.1 show ward population counts in 2001 and 2011, having merged certain census wards in 2001 to match those in 2011 and thus achieve zone consistency. Childs Hill, Penge and Cator, and West Thornton were the most populated wards in 2001, ranging from 16,498 to 17,261 inhabitants. In 2011, Millwall, Childs Hill and Thamesmead Moorings were the most populated wards, each containing between 19,730 and 23,084 usual residents.

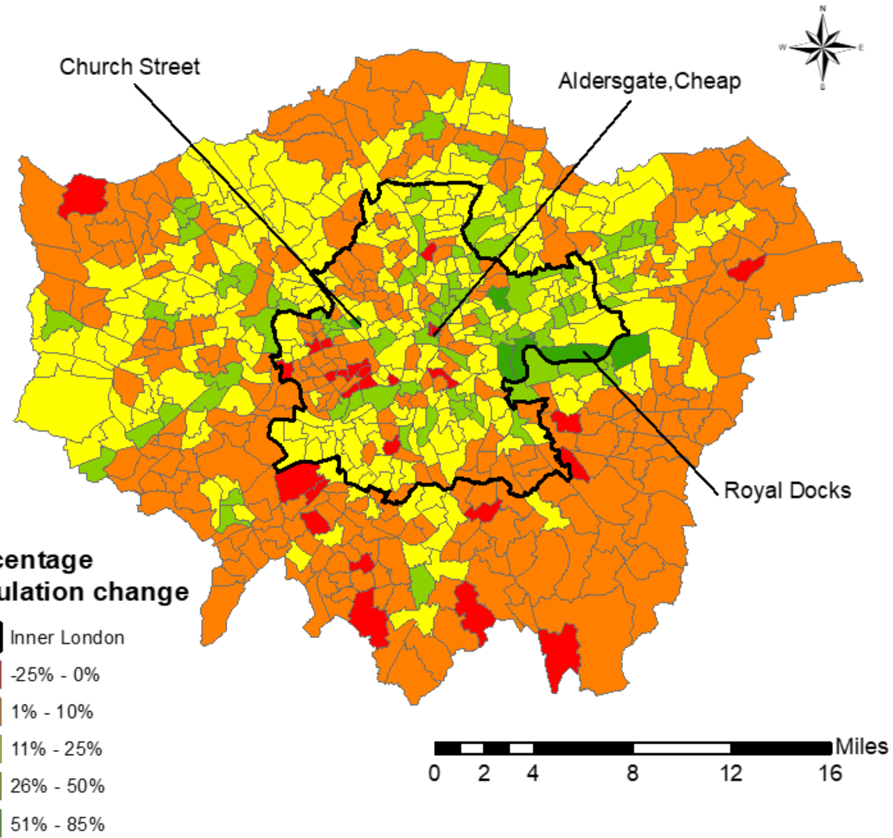


a. Population 2001

b. Population 2011



c. Population change



d. Percentage population change

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.1: London's population by ward, 2001 and 2011

The change in population from 2001 to 2011 can be observed in Figure 7.1c. Whilst population growth is highest in a number of wards to the east of central London, there is evidence of lower growth in the peripheral areas of Outer London, particularly in the south and east. In some cases where extreme changes have taken place, some explanatory factors can be identified. The biggest increases in population size occurred in Millwall (+10,192), in Thamesmead Moorings (+7,975) and in Blackwall and Cubitt Town (+7,522). These three wards have some common characteristics, with a mostly employed population, a low retirement population and an even lower student population; and with the average age being between 29 and 31. In comparison, the GL ward average in 2001 had a mean age of 36 and consisted of 11% of its population in the retirement age group, 69% in the working age groups with the remaining 20% being children (Open Government Licence, 2014). These ward statistics suggest that the population increase here can be attributed to family growth and positive in-migration. This is caused by prosperous employment and desirable working neighbourhoods.

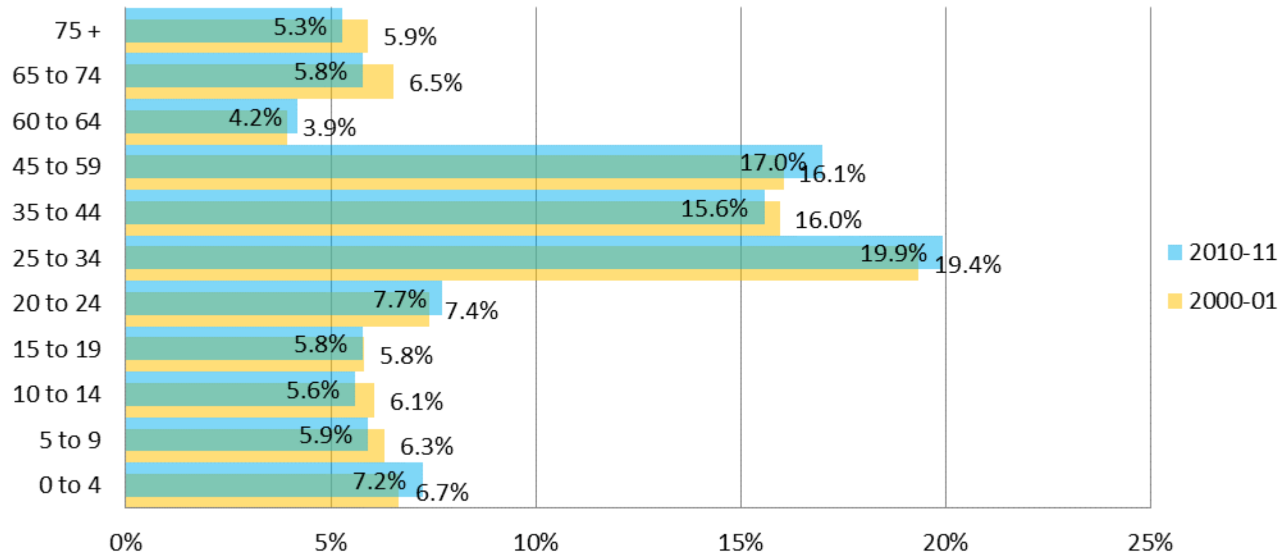
However, as Figure 7.1 demonstrates, not all wards experienced population increase; some saw population declines, the biggest being in Eltham West (-3,039), Cremorne (-1,326) and Courtfield (-645). Even though these wards have rather low unemployment rates, they have a high retired population, which suggests these wards experience natural population decline.

The highest percentage growth in population occurred in Church Street with an increase of 81%, closely followed by Millwall (79%) and Royal Docks (73%). There has been a particular focus on regeneration in Church Street, with an addition of 1,750 new homes, creating more public space and by improving street markets and retail places in addition of creating a better balance between car traffic and pedestrians and bicycle traffic (City of Westminster, 2018). The Royal Docks have experienced similar developments but here there is more focus on business development, becoming one of London's biggest business and financial districts; there is also a focus on new offices and new residential areas have been created to accommodate the new work force. Millwall, on the other hand, has been under redevelopment into a residential area since the 1980s when heavily industrialised.

The largest percentage decrease was in Eltham West (-23%), followed by Cremorne (-14%) and Aldersgate, Cheap (-8%). Eltham West has a high crime rate with an average of 91 reported crimes a month according to the local police having a potential effect to the population, making it less desirable (Metropolitan Police Service, 2018). In comparison, some of the lowest crime rates can be found in the Kingston upon Thames borough where wards such as Coome Vale, Tudor and Old Malden had a monthly average of 26, 29 and 30 reported crimes respectively, and the monthly average crime rates across all London wards in 2010-11 was 62 (Metropolitan Police Service, 2019). Cremorne is home to one the former waste centres of London, and has now become the preferred access point to the newer

Thames Tideway waste tunnel; the ongoing projects around waste disposition had negative effects to local residence. Due to its small population, Aldersgate, Cheap is easily affected by any population change, since any changes in the total numbers have a large impact on the percentage change.

To better understand the changes in particular age groups, Figure 7.2 shows the age group proportions of total population in 2001 and 2011. The 25-34 year olds represented 19.4% of the population of GL in 2001, increasing to 19.9% in 2011. It can be concluded that the GL population is characterized by having a population that is largely of working age population with mostly 25-59 year olds, and which increased between 2001 and 2011 as a whole, whereas the populations of 5-14 year olds and those aged over 65 actually declined in relative terms between 2001 and 2011.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.2: Population age distributions of Greater London in 2001 and 2011

Total migration within GL increased from 651 to 864 thousand in the years between the two censuses and the overall intensity of migration also increased by nearly 1.5%, from 9.09% in 2000-01 to 10.58% in 2010-11 (Table 7.1). Comparison of inter-ward and intra-ward migration in GL indicates that many more people in GL moved from one ward to another rather than within the same ward but in both cases, the rate of migration increased. In the case of inter-ward migration, the rate increased by 1.33% whilst the rate of mobility within wards showed a smaller rise from 1.22% in 2000-01 to 1.38% in 2010-11.

Table 7.1: Migration in Greater London, 2000-01 and 2010-11

	2000-01			2010-11		
Migration flow	Flow	Share (%)	Rate (%)	Flow	Share (%)	Rate (%)
Inter-ward	564,260	86.56	7.87	751,986	86.99	9.20
Intra-ward	87,579	13.44	1.22	112,481	13.01	1.38
All migration flows	651,839	100.00	9.09	864,467	100.00	10.58

Source: Estimates based on data from 2001 and 2011 Censuses

Moves between GL and the rest of the UK must also be acknowledged to obtain a comprehensive understanding of the volume of migration associated with the capital, including those inflows and outflows involved in the escalator concept (Fielding, 1992). Table 7.2 shows migration flows from the rest of the UK into GL and from GL to the rest of the UK as recorded in each census. Whilst both in-migration to GL and out-migration from GL increased over the decade, the flows leaving GL stayed higher than the flows moving into GL for both time periods and the rate of out-migration to the rest of the UK actually declined between 2000-01 and 2010-11. The net effect of moves to and from GL resulted in a net migration loss for the region as a whole of 31,624 in 2000-01 which reduced to 17,794 in 2010-11. However, these net losses through internal migration were offset by significant net international immigration in each of the years in question, as observed by Nygaard (2011), who has demonstrated that the UK as well as the London area has experienced a consistent annual net international immigration in the twenty-first century.

Table 7.2: Migration in and out of Greater London from/to the rest of the UK, 2000-01 and 2010-11

	2000-01			2010-11		
Migration flow	Flow	Share (%)	Rate (%)	Flow	Share (%)	Rate (%)
Moves from rest of UK to GL	155,723	42.86	0.30	187,347	45.39	0.34
Moves from Greater London to rest of UK	207,578	57.14	2.89	225,372	54.61	2.76
All migration flows	363,301	100.00	0.62	412,719	100.00	0.65

Source: Estimates based on data from 2001 and 2011 Censuses

7.3 Intensity, effectiveness and net migration

The IMAGE Studio has been used to calculate three 'local indicators' to measure migration intensity (MI), migration effectiveness (ME) and net migration (NM) for the 628 wards of GL that are consistent between the two censuses before three 'global indicators' – the crude migration intensity (CMI), the migration effectiveness index (MEI) and the aggregate net migration rate (ANMR) – are computed for every set of ASRs in scale steps of 10 from 10 to 620 ASRs with 50 iterations at each scale, in order to determine the scale and zonation effects

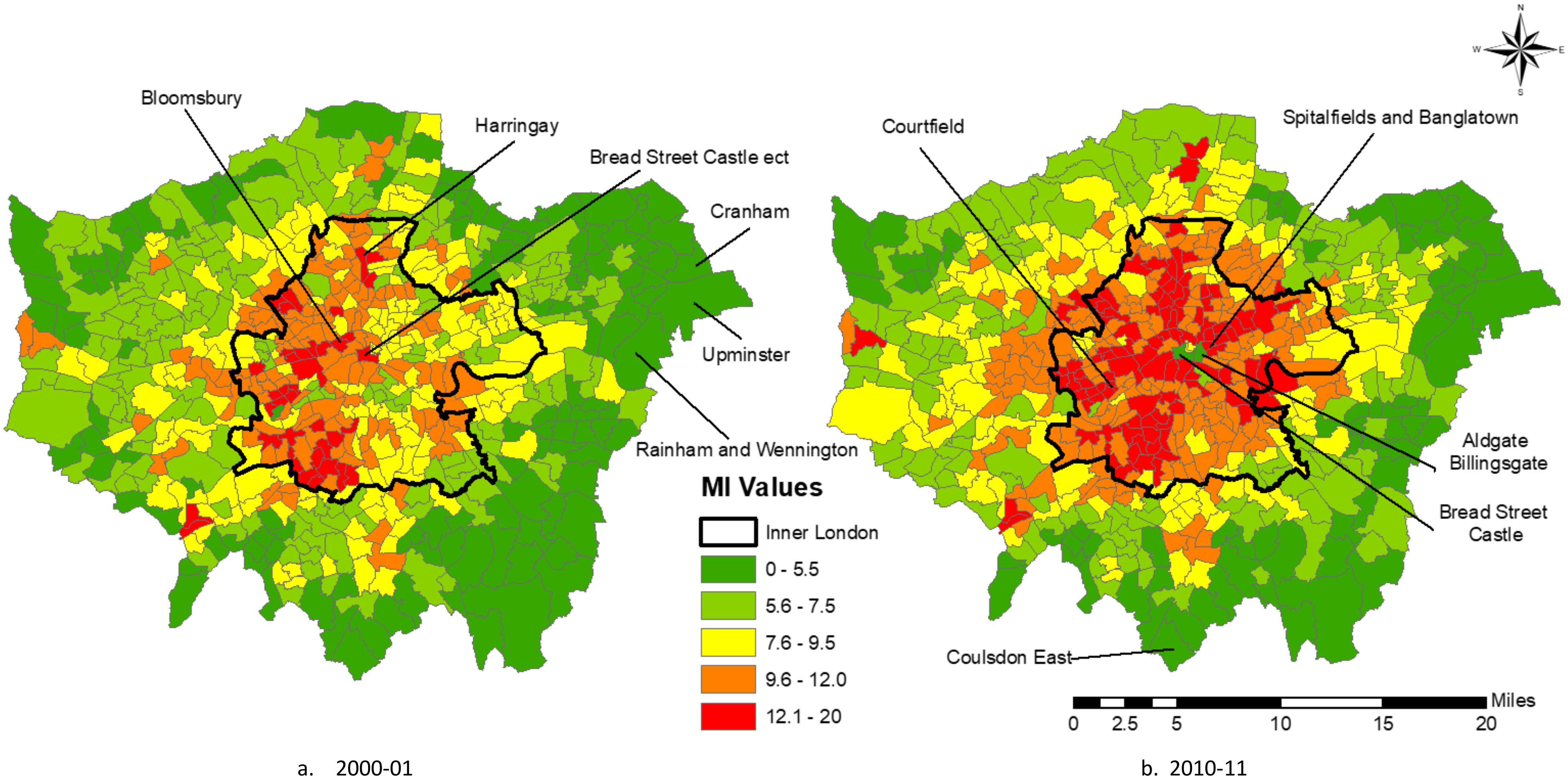
7.3.1 Migration intensity

Migration intensity can be calculated for each BSU either by using the turnover or the churn divided by the population times 100 and divided in half (Dennett and Stillwell, 2008). 'Turnover' is a measure of the intensity of migration into and out of a BSU while 'churn' includes these flows but also the flows that take place within each BSU. Figure 7.3 shows the intensity indicator using the turnover values for BSUs (wards) in 2000-01 and 2010-11. GL has more wards with high turnover in 2010-11 (104 wards in the top category) than it did in 2000-01 (38 wards in the top category), as highlighted in red in the maps in Figure 7.3. The spatial pattern is very clear; wards with high turnover are mostly in Inner London whereas wards with low turnover are in Outer London.

The highest values in 2000-01 can be found in wards of Bread Street Castle with a turnover of 19.1%, Bloomsbury (16.7%) and Harringey (14.9%); compared to the lowest values in Upminster (3.4), Cranham (3.3%) and Rainham and Wennington (3.1%) wards. In 2010-11, the highest turnover values are found in Bloomsbury (18.4%), Courtfield (17.3%) and Spitalfields and Banglatown (16.3%) wards compared to Bread Street Castle and Aldgate Billingsgate wards with no migration flows and Coulsdon East with a turnover value of 3.1%.

Having a high MI in Bloomsbury for both time periods is not a surprise, since this ward consists of multiple academic and medical institutions, with eight colleges and universities including the University of London. So, a high mobility in this ward is most likely to be due to the presence of students; 92.2% of Bloomsbury's population has a qualification compared to the GL average of 82.4% and the national average of 77.3%, indicating that better educated residents are prevalent here (Open Government Licence, 2014). Courtfield ward contains some desirable neighbourhoods having an average house price of £863,750 compared to the GL average of £292,000 in 2011, in addition to having a prosperous job market, which is attracting a variety of people seeking work and/or a better place to live, and therefore creating a stronger MI (Open Government Licence, 2014). Spitalfields and Banglatown on the other hand is a ward which has a higher unemployment rate, but is also home for many students which contributes to the growing MI. Bread Street Castle is rather unusual since it had a strong MI in 2001 but zero MI in 2011. Consisting of mainly schools, churches, government and office buildings, the residential population is very small with less than an estimated of 400 domiciles with the majority being flats. Similarly, Aldgate Billingsgate has a MI of zero in 2010-11 due to a very small residential population, as it consists mainly of government and office buildings.

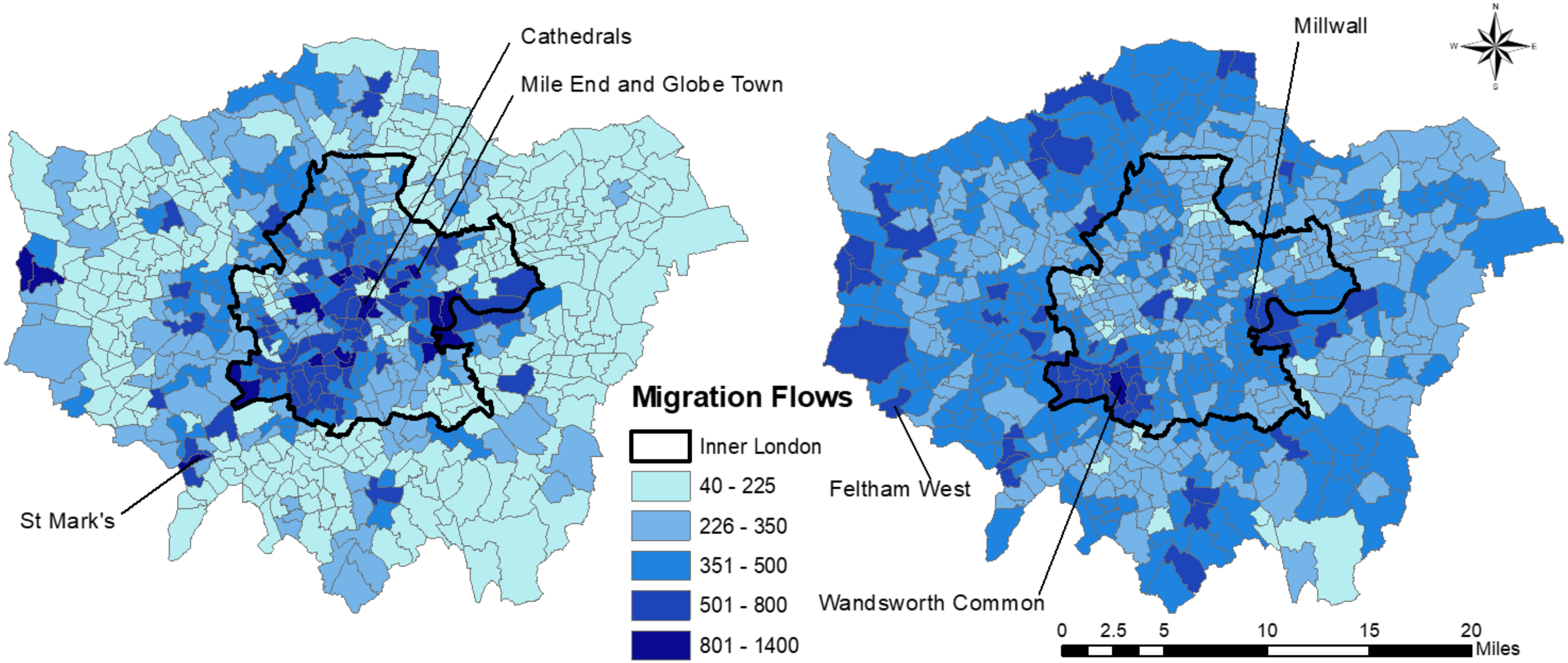
A high MI value indicates strong migration activity across ward boundaries and the spatial pattern observed in maps a and b in Figure 7.3 of high values in central and inner areas and lower values in outer wards occurs partly because the MIs for the wards do not contain flows to and from elsewhere in the UK and consequently wards nearer the edge of the region, which are likely to have more moves across the GL boundary, have lower MIs. This pattern reveals one disadvantage of using a set of zones for one region: people moving from central and Inner London to the outskirts or *vice versa* will be included but people moving similar distances from Outer London to other parts of the South East and beyond or *vice versa* are not included.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.3: Local migration Intensity for wards of Greater London, 2000-01 and 2010-11

To highlight these discrepancies, Figure 7.4 therefore shows the migration flow between the rest of the UK and the GL area and *vice versa* for 2010-11. All flows seen here are flows that are not used in the rest of the analysis. There is a total migration flow of 187,347 moving from the rest of the UK into the GL. The wards with the highest inflow from the rest of the UK are: St Mark's, Cathedrals and Mile End and Globe Town wards with migration flows ranging from 1,262 to 1,344. Mile End and Globe Town, for example, experienced a significant growth in the in the Bangladeshi community and some other minorities. Although the white British population still make up for the majority in this ward, these ethnic communities have grown from 2001 to 2011. Generally, migration inflows are concentrated in inner London area with some exceptions in the west of Outer London as shown in Figure 7.4a. The spatial pattern of outflows is much less clear-cut although wards along the western border with the counties in the South East appear to have relatively large flows (Figure 7.4b). Over 225,300 migrants moved from the GL to the rest of the UK in 2010-11; wards with the highest out-migration flows include Wandsworth Common, Feltham West and Millwall with migration flows ranging from 710 to 885.



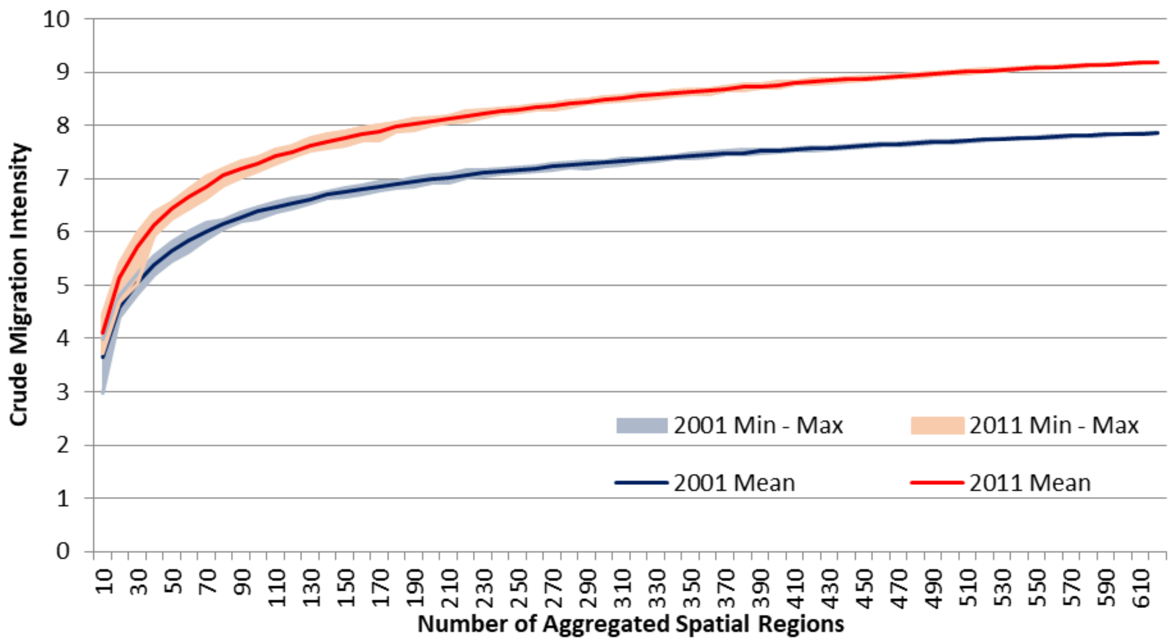
a. From UK to Greater London

b. From Greater London to UK

Source: Estimates based on data from 2011 Census

Figure 7.4: Migration flows between Greater London and the rest of the UK, 2010-11

Figure 7.5 reveals that people migrated between wards within GL at a greater intensity in 2010-11 than they did in 2000-01. Moreover, the crude migration intensity (CMI) curve for 2010-11 is consistently higher than that in 2000-01 across all scales. This increase in residential mobility could be linked to the increase in households in the private rental sector in GL, which is well known as being more mobile that the owner-occupier sector (Hulse and Yates, 2017). Based on this graph, it can be concluded that the CMI indicator in both periods exhibits a pronounced scale effect, with the mean value falling from over 7.8 per 1,000 in 2000-01 when 620 ASRs are used to less than 4.0 per 1,000 when only 10 ASRs are used. The CMI indicator in 2010-11 drops from over 9.2 per 1,000 when 620 ASRs are used to less than 4.2 per 1,000 when only 10 ASRs are used. The decline is particularly apparent when the number of ASRs is reduced to around 100, when the two curves begin to show more convergence. Figure 7.5 also displays the minimum and maximum values of CMI at each spatial scale respectively, indicating the extent of the range which represents the zonation effect. It is apparent that the variation around the mean is relatively small and increases as the number of ASRs gets smaller, the populations of the ASRs get larger and the volume of inter-ward migration declines.



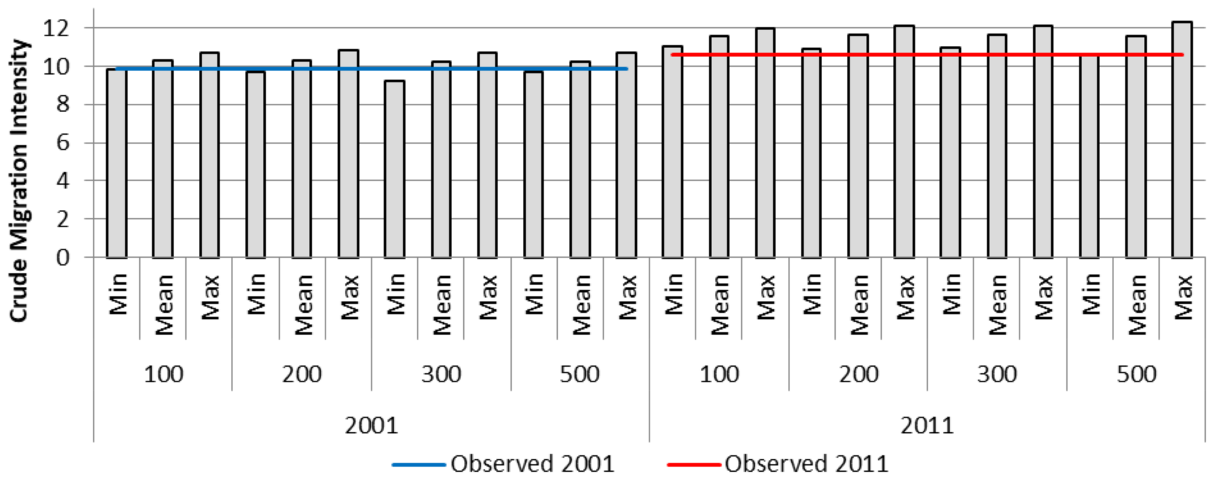
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.5: Mean values of crude migration intensity by scale, Greater London, 2000-01 and 2010-11

7.3.1.1 Comparison of observed and estimated CMI at borough level

Observed data are directly available from the census on migration flows and intensities of migration between the 32 boroughs of GL in both periods. It is therefore possible to compare these 'observed' CMI value with mean CMI estimated using the IMAGE Studio for 32 ASRs as a means of validating the CMI for the borough system; i.e. does the CMI give a reliable measure of mobility when borough borders are used or does the MAUP results in bias? As described previously in Chapter 3, Westminster ward in 2011 was aggregated with the City of London. The observed inter-borough CMI values for 2000-01 and 2010-11 were calculated directly from the census to compare against the estimated CMI means computed by the IMAGE Studio. The observed inter-borough CMI value is 9.9 in 2000-01 and 10.6 in 2010-11 for 32 ASRs. Figure 7.5, which shows the estimated CMI means computed in steps of 10 with 100 iterations, indicates that mean CMI value for 30 ASRs is 10.2 in 2000-01 and 11.4 in 2010-11, and for 40 ASRs the estimated CMI values are 10.8 in 2000-01 and 12.2 in 2010-11. It is expected that the observed CMI value should have been between 9.6 and 10.0 at 30 ASRs or between 10.4 and 11.0 at 40 ASRs in 2000-01; and between 10.0 and 12.0 at 30 ASRs or between 11.8 and 12.8 with 40 ASRs in 2010-11.

When the IMAGE Studio is used to compute the estimated CMI for exactly 32 ASRs, the mean value is actually very similar to the observed rate. The rate or inter-borough migration in London lies within the min-max range shown in Figure 7.6, suggesting that the observed rate based on one set of administrative district boundaries is giving a reasonable measure of inter-borough migration but delivers a slightly lower rate than the mean rate estimated when considering a large number of different configurations of wards into 32 ASRs. Figure 7.6 shows the estimated mean CMI values for 32 ASRs with four different iteration levels (100, 200, 300 and 400). It can be observed that by using more iterations, the minimum and maximum CMI values increase slightly for both years, but the mean values remain stable around 10.2 for 2000-01 and 11.6 for 2010-11. The graph in Figure 7.6 therefore confirms that the ward boundaries used to record migration flows in the census tend to underestimate the real rate of migration (as estimated by the IMAGE Studio based on many different boundary configurations) but this underestimate is marginal. In other words, the results indicate that the boundaries defining the administrative boroughs of GL are not significantly distorting the measure of migration intensity.

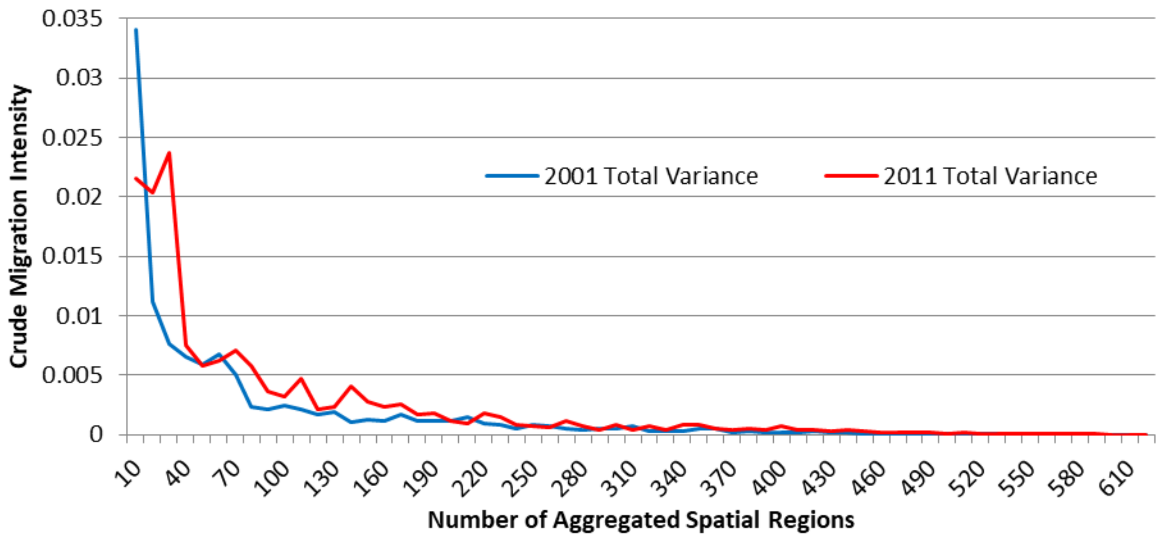


Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.6: Different iteration levels at 32 aggregated spatial regions for 2000-01 and 2010-11

7.3.1.2 Variation in the zonation effect by scale

As shown in Figure 7.5, the IMAGE Studio also provides the aggregated output results by scale based on the CMI variance at each scale and each configuration. The variance measures of how far each value in the data set is from the CMI mean and can be interpreted as an indication of the zonation effect at each scale. Figure 7.7 provides a comparison between the minimum and the maximum CMI values in the two time periods in scale steps of 10 from 10 to 620 ASRs with 50 iterations at each scale. The graphs show that there is little to no variance at smaller scales (larger numbers of ASRs) for both time periods from the BSU scale up to around 230 ASRs. Thereafter, the variance begins to widen and there is greater fluctuation in CMI in 2010-11 than in 2000-01 between 70 and 230 ASRs. At large scales (smaller numbers of ASRs), the variance becomes more significant with a CMI variance of 0.021 in 2010/11 and 0.034 in 2000-01 when the BSUs are aggregated to 10 ASRs. In 2010-11, the highest CMI variance is not at 10 ASRs as it was in 2000-01, but peaks at 30 ASRs with a variance of 0.023 having risen from 0.0075 at 40 ASRs. At smaller scale levels the calculated CMI values are very precise and match the data, but as the scales get larger and areas are being aggregated, the CMI values encounter variations that are farther away from the data causing the data to be less specific.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.7: Variation in the variance of crude migration intensity by scale, Greater London, 2000-01 and 2010-11

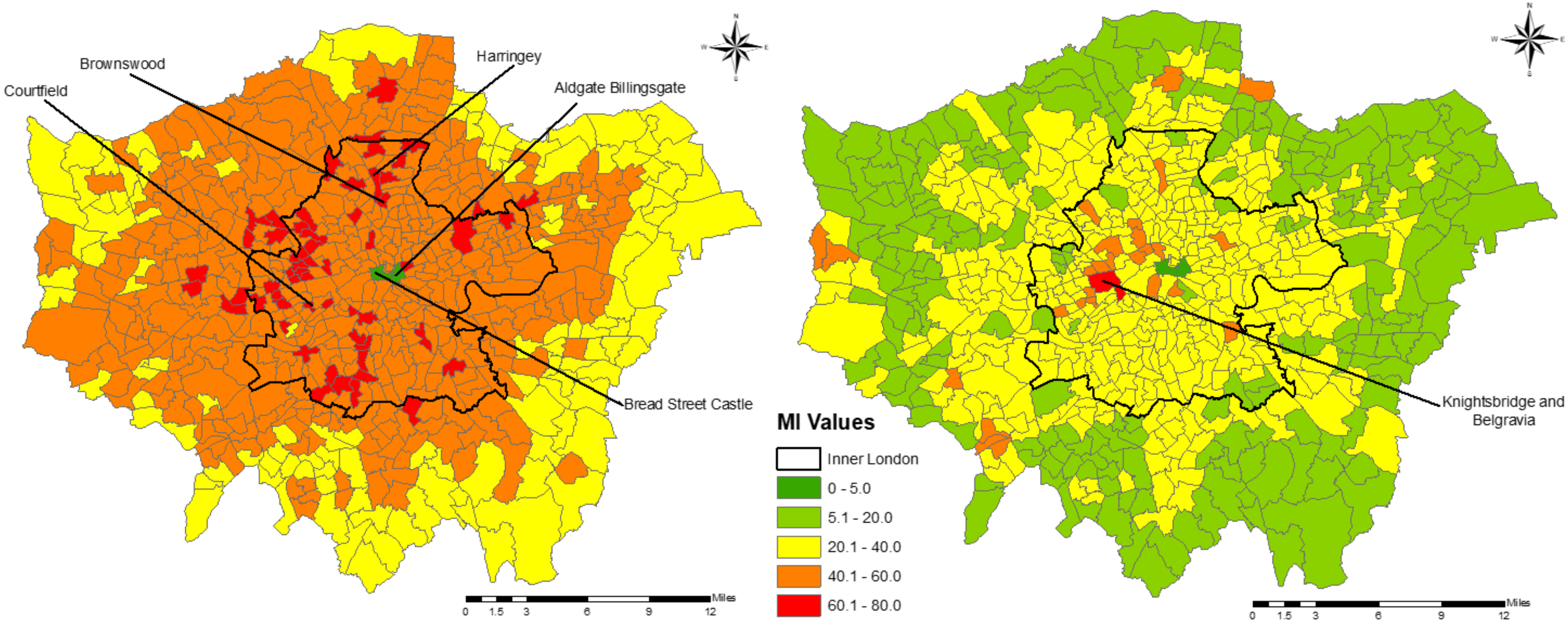
7.3.1.3 Age-specific migration intensities

Before analysing the scale and zonation effect of the age-specific migration intensities, the MI values for the four broad age groups defined earlier in the thesis (family, students and young workers, mature workers and retired) are mapped out in Figure 7.8 to exemplify the different spatial patterns in 2010-11. The same shading intervals are used for each of the maps in order to facilitate comparison between age groups. The family age group has the highest migration rates whilst the mature workers have the lowest migration rates, showing a similar pattern than observed at national level in Chapter 5. The family age group shows relatively high migration rates representing a large proportion of the population, and this population experiences a lot of change, whether it is expanding the family or career driven, causing this age group to relocate to adapt to these changes. The map of MIs for the family age group (Figure 7.8a) has a definitive spatial pattern of high MIs for wards in the inner areas and lower MIs for wards in the outer areas, whereas the map for the mature workers age group (Figure 7.8c) with lower rates shows greater equality across the wards of GL, although the map does show higher rates in more central wards and lower rates in outer wards.

Harringey, Courtfield and Brownswood are the wards with the highest MIs for the family age group, ranging between 70 and 75 per 100. This is not surprising as these wards have a predominantly younger population, with Harringey having 58% of its population aged between 20 and 44, and less than 8% aged 65 and over. Bread Street Castle and Aldgate Billingsgate, on the other hand, have a MI of zero, indicating that there are wards that have no turnover (inward or outward) migration, due to a very low population with less than 400 residents in each ward. The highest MI values for the mature worker age group are for wards Courtfield (8.4) Lancaster Gate (8.1) and Abbey Road (7.6). Lancaster Gate, for example, is one of the least deprived wards in the UK with a strong local economy with primarily a managerial, administrative and professional workforce, making it attractive for the mature workers.

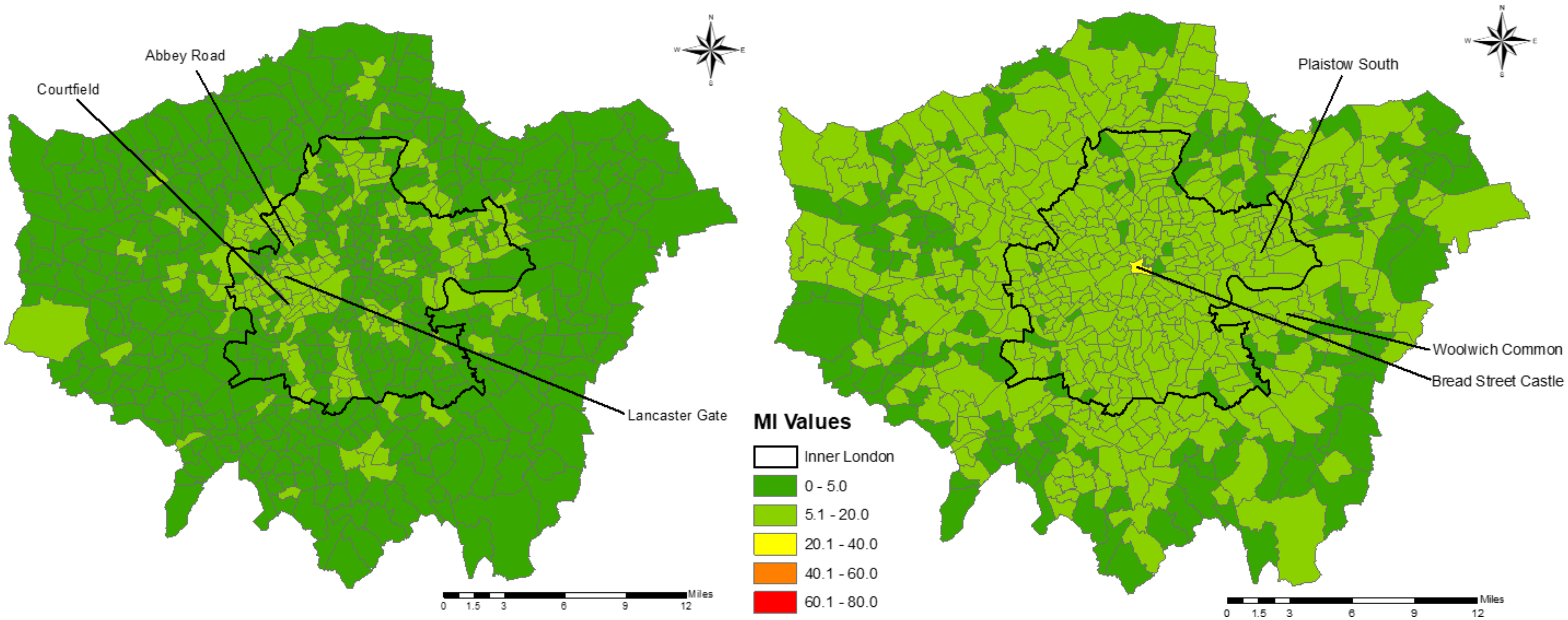
The students and young workers age group (Figure 7.8b) has fewer high migration wards compared to the family age group although the most active ward with a MI of 79.4 per 100 is Knightsbridge and Belgravia. This ward is not only home to Hyde Park, one of the largest parks in central London, and the Royal Albert Hall, but also the Royal Academy of Music and parts of Imperial College, both of which have student residences nearby. Wards in Outer London tend to have much lower MIs in this age group with a few exceptions such as Grove, St Marks and South Twickenham with a MI of 52.7, 47.1 and 45.9 per 100 respectively.

Migration intensities for the retired age group (Figure 7.8d) are higher than those for the mature workers but remain lower than the family and the students and young worker age groups with Bread Street Castle (22.2), Woolwich Common (14.5) and Plaistow South (14.5) as their most active wards. Whilst Bread Street Castle is the most active migration ward for the retired, it has no activity for all other age groups. All wards in both the mature workers and retired age groups have migration rates below 20 per 100. Generally speaking, the spatial pattern of MI for the retired age group exhibits the lower rates for wards near or adjacent to the GL boundary with the rest of the South East.



a. Family

b. Students and young workers



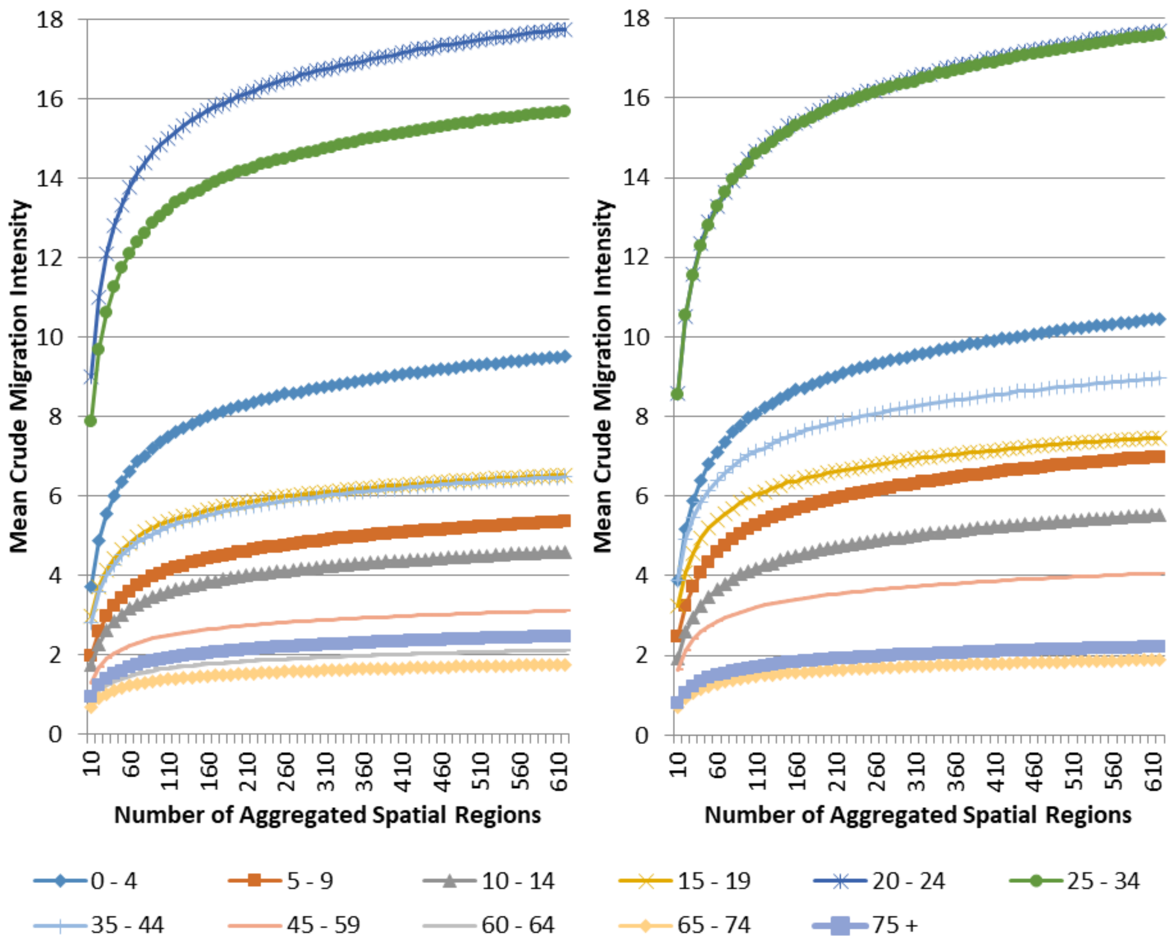
c. Mature workers

d. Retired

Source: Estimates based on data from 2011 Census

Figure 7.8: Local migration intensities for wards of Greater London in 2010-11

Across all the more disaggregated age groups, the average CMI for all wards has increased from 2000-01 to 2010-11 with the exception of the 20-24 year olds and the 65-74 year olds where the CMI has decreased. GL has experienced a high influx of house prices over the past decade, which could have a knock-on effect for these age groups who would like to relocate at a key life stage (graduating university/retirement), but may not have the necessary means to do it as they used to (Cameron et al., 2005). The 75+ age group average CMI remained constant over the decade. Figure 7.9 presents the mean estimated CMI values for different age groups in 2000-01 and 2010-11 at different scales. Both graphs show that migration intensities vary considerably by age group and that the effects of changing scale vary from one age group to another. There are also some interesting differences between age-specific CMIs in the two periods. In 2000-01, the 20-24 year olds are clearly the most active migratory group and their mean CMI schedule is much the same ten years later in 2010-11. However, it is apparent that the CMI for the 25-34 age group has increased considerably, possibly because of staying more in rental housing due to high and increasing prices of housing; and has an almost identical scale effect to the 20-24 age group in 2010-11. The 0-4 year olds, moving with their parents, for both years have the third highest migration intensities, with higher values for BSUs in 2010-11 than in 2000-01. Increases in CMI are apparent for the other age groups, particularly those age 35-44, but not for the 65-74 year olds whose CMI for BSUs is slightly lower in 2000-01 (1.75 at 610 ASRs) compared with 2010-11 (1.89 at 610 ASRs). A key point here is that different age groups appear to exhibit very different scale effects for CMI, i.e., the CMI for 20-24 year olds declines relatively rapidly with scale, whereas that of the 65-74 and 75+ year olds appears almost scale independent. However, it must not be forgotten that the CMIs for each age group at 610 ASRs are different and this needs to be taken into account to achieve consistent comparison.

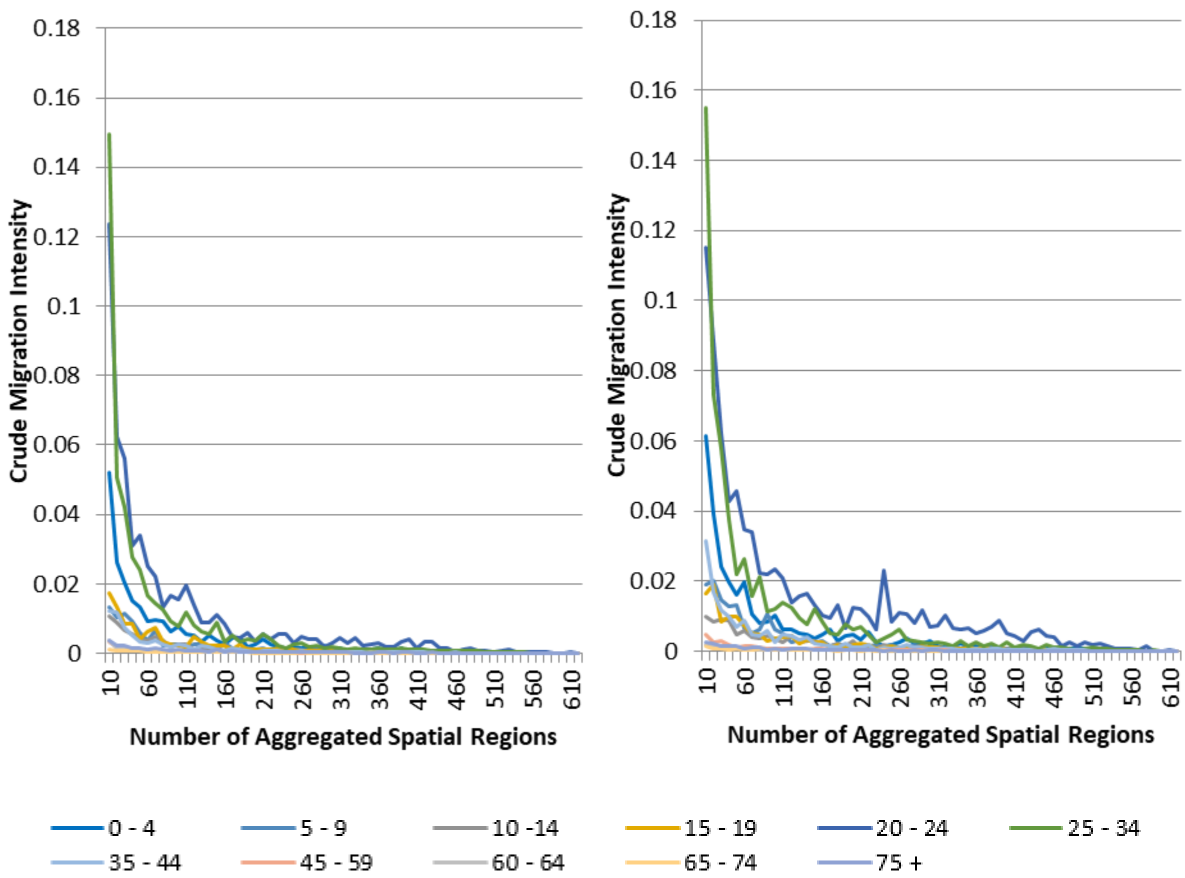


a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.9: Age-specific crude migration intensities by scale, Greater London, 2000-01 and 2010-11

At larger scales (i.e., with 10 ASRs), the 25-34 age group experiences the highest range variation in both periods (Figure 7.10). The 20-24 age group also has a strong zonation effect with large ASRs, and is the age-group that has the higher CMI range values from 50 to 510 ASRs in both periods but particularly in 2010-11. The 0-4 age group also shows a greater zonation effect for the larger ASRs and a small increase between 2000-01 and 2010-11. Similar to the results seen in Figure 7.7, the bigger the spatial scale is, the larger the zonation effect for CMI among the different age groups will be but for some age groups, the zonation effect is much less and some (5-9, 10-14, 65-74 and 75+) experience almost no variation between the two time periods.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.10: Variation in crude migration intensity, by scale, age groups, 2000-01 and 2010-11

These results have demonstrated that the migration intensity is dominated by the 20-24 age group, with the 25-34 and 0-4 age groups also being relatively high. The 0-4 age group has a strong correlation with the 20-24 and 25-34 age groups, because the 20-24 and 25-34 age groups are considered their parental age group and young children will move wherever their parents decide to go (Hay, 1979).

In order to make a more consistent comparison of the scale effects, a total scale effect can be computed by summing the differences between the mean indicator values at consecutive scales. The process is repeated for each age group for both time periods to offer a comparative overview of the total scale effect for the CMI. The results shown in Table 7.3 quantify some of the observations made in the previous graphs. However, the evidence suggests that the age groups with the highest rates do not have the largest total scale effects. The 10-14 and 75+ age groups have high total scale effects in both periods despite having relatively low CMIs. The total scale effects have increased over time for some age groups (with the 15-19 age group showing the highest increase from 0.75, the lowest in 2000-01, to 1.00, the highest in 2010-11), scale effects for several age groups (0-4, 5-9, those aged 35-

74) have declined. The total zonation effects have also been computed in Table 7.3 using the maximum value minus the minimum value, or the range, divided by the mean and adding them all together. Division by the mean standardises for variation in the indicator between age groups. The results show that the strongest total zonation effect for the CMI is observed for the 65-74 and75+ age groups despite having the lowest CMIs in both periods. Whilst the values of total effects in Table 7.3 do allow comparison to be made between age groups, the values do not have any interpretative value in themselves.

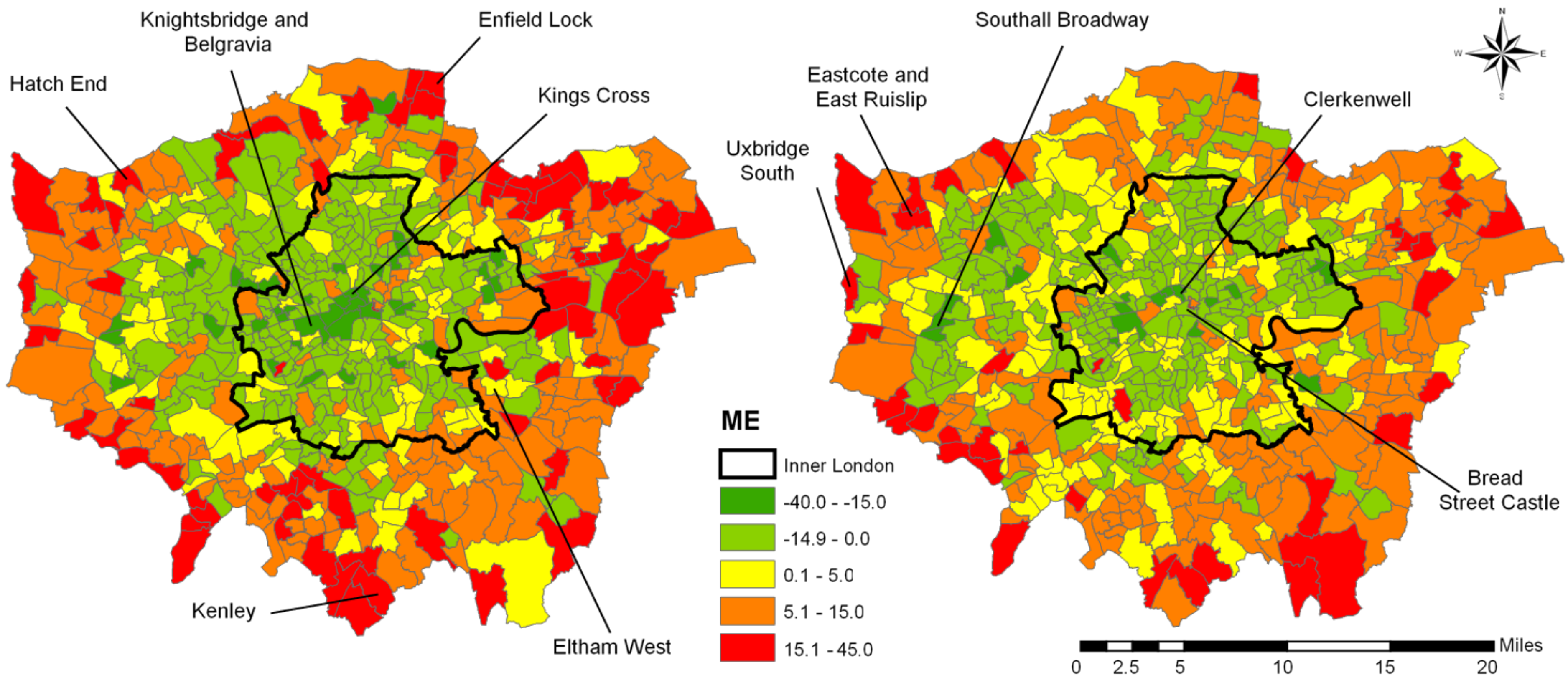
Table 7.3: Total scale and zonation effects for crude migration intensity by age group, Greater London, 2000-01 and 2010-11

	Total Scale effect		Total Zonation effect	
Age groups	2000-01	2010-11	2000-01	2010-11
0 - 4	0.89	0.77	1.90	*2.05*
5 - 9	*0.95*	*0.94*	*2.34*	*2.33*
10 - 14	*0.92*	*0.99*	*2.34*	*2.23*
15 - 19	0.75	*1.00*	1.74	1.73
20 - 24	0.65	0.80	1.36	1.78
25 - 34	0.66	0.69	1.37	1.44
35 - 44	0.80	0.69	1.55	1.50
45 - 59	0.82	0.80	1.57	1.58
60 - 64	0.89	0.87	*2.60*	1.92
65 - 74	0.88	*0.90*	*2.39*	*2.05*
75 +	*0.91*	*0.92*	*2.71*	*2.54*
All age	0.73	0.77	1.38	1.51

Source: Estimates based on data from 2001 and 2011 Censuses

7.3.2 Migration effectiveness

As indicated previously, migration effectiveness (ME) is an alternative indicator of net migration that can be used to measure the impact of migration. ME has been computed for each individual BSU and Figure 7.11 illustrates the local effectiveness indices for each ward for 2000-01 (7.12a) and 2010-11 (7.12b). The dominant pattern is that high positive ME is experienced in Outer London wards, many on the border with other counties in the South East, while high negative MEIs are mostly located in the inner parts of GL. In other words, outer wards are efficient at gaining population through migration, whilst Inner London wards are efficient at losing population through migration. This pattern is strongly visible in both time periods but has diminished slightly in 2010-11. It demonstrates the regularity of deconcentration in GL in all directions from the inner to the outer areas of the city. The highest ME in 2000-01 can be found in Enfield Lock (43.5), Kenley (32.2) and in Hatch End (31.0) wards compared to Uxbridge South with an ME of 31.9, Eastcote and East Ruislip (30.1) and Enfield Lock (24.7) in 2010-11, all of which are wards on or near the GL boundary with the rest of the South East. The most negative ME is located in Bread Street Castle, Southall Broadway and Clerkenwell ward,s whose values range from -38.1 to -25.5 in 2000-01, and Knightsbridge and Belgravia, Eltham West and Kings Cross wards, whose ME values range from -39.6 to -29.7 in 2010-11. The biggest difference between both time periods can be seen with Bread Street Castle, with an ME score of -38.1 in 2000-01 moving to zero in 2010-11. Eltham West has also experienced a significant ME change with a value of 4.7 in 2000-01 and -38.6 in 2010-11.



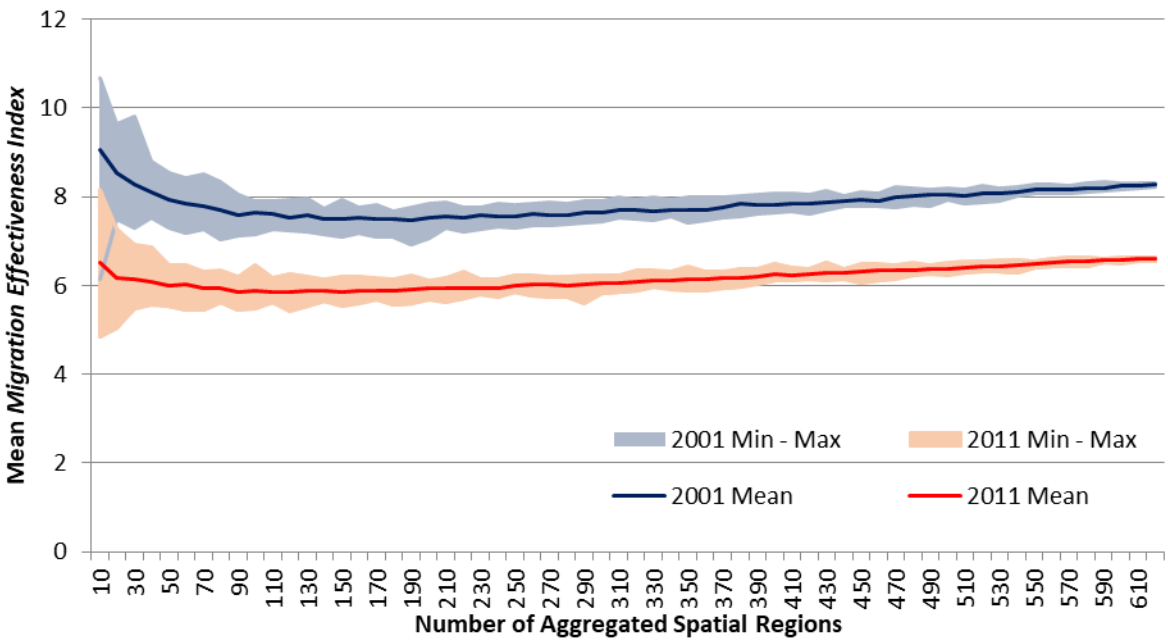
a. 2000-01

b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.11: Local migration effectiveness for wards of Greater London, 2000-01 and 2010-11

Figure 7.12 shows the mean values of migration effectiveness index (MEI) by scale for 2000-01 and 2010-11. The mean MEI in 2000-01 falls marginally across all ASRs with values from 8.2 to 7.6 until it reaches 130 ASRs and then starts to show a small scale effect by increasing to 9.1 at 10 ASRs. In 2010-11, the results show a similar profile, with the MEI values dropping marginally across all ASRs with values from 6.6 to 7.8, even though there is a small increase from 20 to 10 ASRs when the MEI is 6.5, indicating that the MEI in 2010-11 is more constant over scale than in 2000-01. It can be concluded here that the MEI is more scale independent than the CMI, because the CMI schedules change considerably more across scale than the MEI schedules. However, there appears to be a scale effect for systems of less than 100 zones with MEI values increasing (when CMI values are falling); in other words, for systems with smaller numbers of zones, migration becomes a more important redistributor of the population despite having lower intensity. A zonation effect is also visible, increasing strong over scale with a maximum MEI zonation of 4.5 in 2000-01 decreasing to 3.3 in 2010-11 at 10 ASRs.

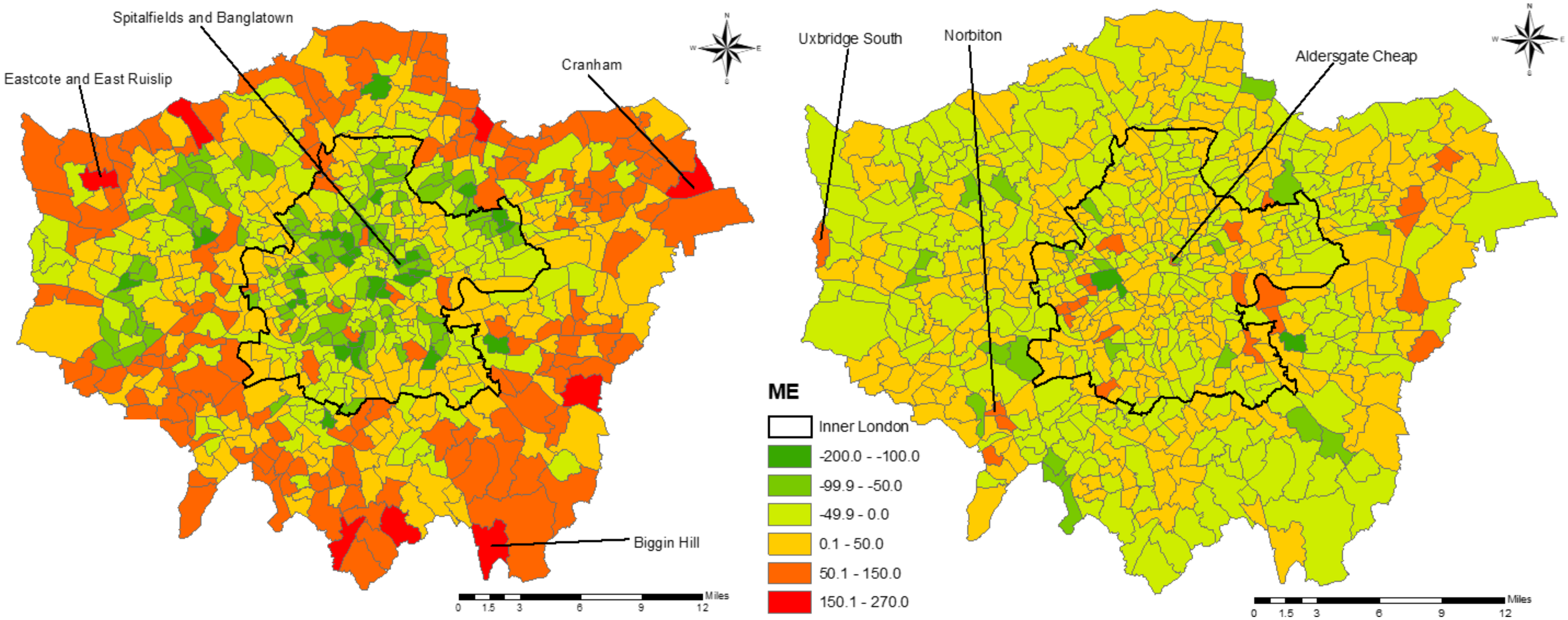


Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.12: Mean values of migration effectiveness index by scale, Greater London, 2000-01 and 2010-11

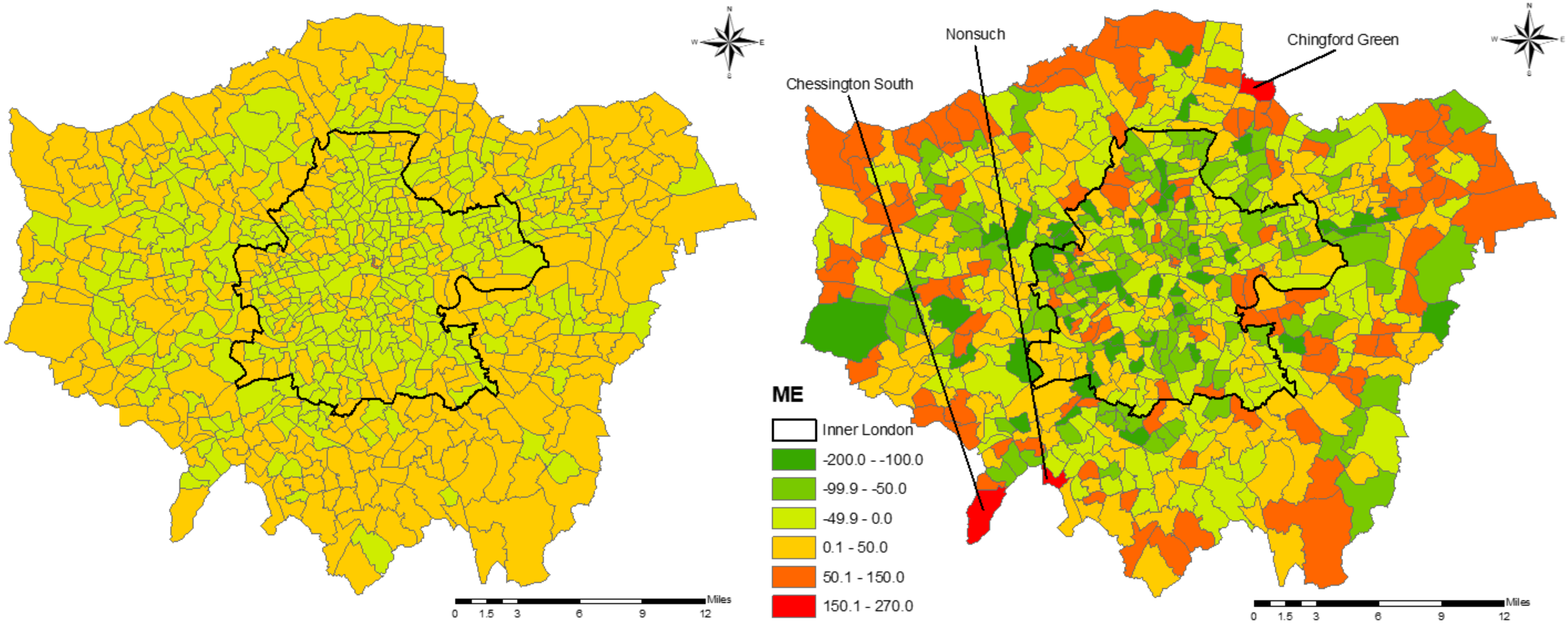
7.3.2.1 Age-specific migration effectiveness

Figure 7.13 shows the local ME scores for wards of GL in 2010-11 for the four broad age groups. Low ME values will indicate well balanced migration streams and counter-streams whilst high ME values are a sign of greater irregularities between out-migration and in-migration, resulting in high net gains (positive ME value) or losses (negative ME value). The family age group (Figure 7.13a) has the highest positive ME in Eastcote and East Ruislip, Cranham and Biggin Hill wards with values of 267.9, 194.4 and 187.3 respectively. The family age group also shows the highest positive ME values are for wards mostly located towards the outer boundary of GL whilst the most negative ME wards remain in the centre such as Spitalfields and Banglatown with a value of -198.2. The pattern for the retired age group (Figure 7.13d) also shows a significant number of wards with high positive ME in outer areas including Chingford Green in the north and Nonsuch and Chessington South in the south, with values ranging from 150.0 to 171.2. But unlike the family age group, the ME value for the retired group per ward is more fragmented across GL. The students and young workers group (Figure 7.13b) only has a few wards where ME is positive and high, such as Aldersgate Cheap (111.1), Uxbridge South (105.4) and Norbiton (78.0), due to the fact that these wards are predominantly occupied by students and workers with professional occupations; but has more than half of its wards with negative ME values. The pattern of ME for the mature workers age group (Figure 7.13c) shows least spatial variation with positive and negative values all in the two categories around zero. These maps confirm that deconcentration in GL is being driven by those in the family and retired age groups.



a. Family

b. Students and young workers



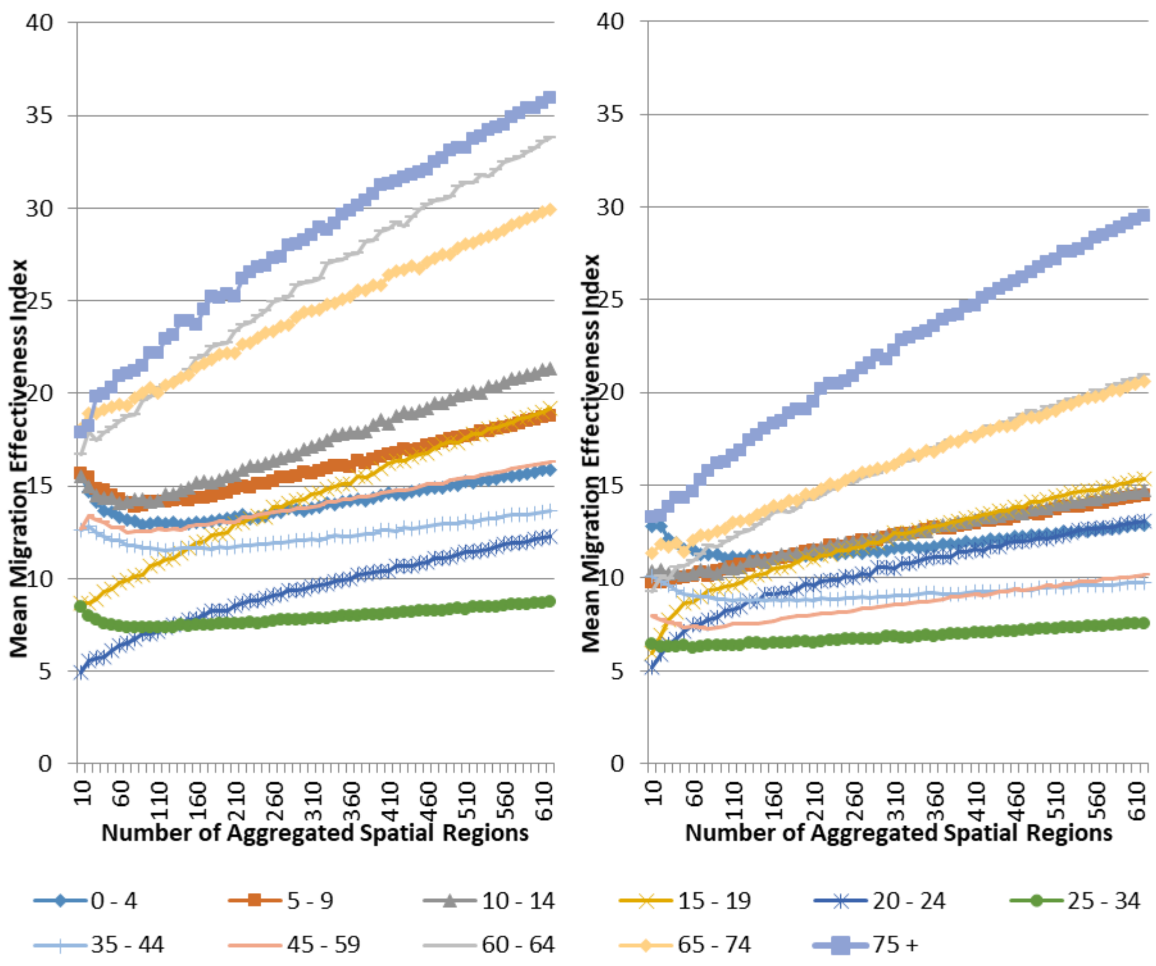
c. Mature workers

d. Retired

Source: Estimates based on data from 2011 Census

Figure 7.13: Local migration effectiveness for wards of Greater London in 2010-11

Figure 7.14 shows the global MEI values for different age groups in 2000-01 and 2010-11 at different scales. The graphs for both time periods show that migration effectiveness varies considerably by age group and that the effects of changing scale vary from one age group to another. It can be observed that all age groups, apart from the 20-24 and 25-34 age groups, are above the all-age schedule shown in Figure 7.12. This suggests that many of the gains and losses experienced by different age groups are cancelled out when all the age groups are clustered together, resulting in a relatively low all-age MEI. There are also some changes between both time periods. In both years, the 60-64, 65-74 and the 75+ age groups have the highest values which decreased in absolute terms from 620 ASRs to 10 ASRs. The 75+ age group, for example, has an MEI of 29.5 in 2000-01 decreasing to 13.4 at 10 ASRs. The MEI decreased over time for this age group with an MEI of 35.9 at 620 ASRs in 2010-11 dropping to 17.9 at 10 ASRs. The 25-34 age group MEI on the other hand has a scale effect in 2000-01 that falls from a value of 7.6 at 620 ASRs to 6.4 at 10 ASRs.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.14: Age-specific migration effectiveness index by scale, Greater London, 2000-01 and 2010-11

Figure 7.14 also shows that crossovers of the age-specific MEI schedules over scale take place. Thus, for example, the mean MEI for the 25-34 age group in 2000-01 is the lowest across scale when the number of ASRs exceeds 100, but the 20-24 age group has the lowest mean MEI for 10-100 ASRs. In other words, the ranking of age-specific groups on the basis of MEI is scale dependent, as well as the mean MEI values themselves.

Table 7.4 shows the total scale and zonation effects for all the different age groups, indicating that there have been various changes between the two time periods and between each age group. Unlike the CMI where a constant increase in the slope was observed as the number of ASRs increases, the MEI falls and rises across scale. The total scale effect was therefore calculated using the absolute differences between scales to avoid the negative and positive values cancelling out. The majority of age groups have shown a decrease in total scale effect from 2000-01 to 2010-11 with the 60-64 having the biggest drop from a total scale effect of 0.78 in 2000-01 to 0.47 in 2010-11. The 75+ age group is the only one having maintained its scale level of 0.73, whilst the 20-24, 25-34 and 65-74 have shown an increase from 2000-01 to 2010-11. The 25-34 age group MEI has the biggest difference increasing from 0.37 in 2000-01 to 0.99 in 2010-11.

The all age zonation effect has increased for 8 of the 11 age groups with the 20-24 year olds having one of the biggest zonation effects (9.42) in 2000-01 increasing to 10.92 in 2010-11. The 60-64 age group had the biggest zonation effect of 9.49 in 2000-01 but this decreased to 9.11 in 2010-11. Thus, in most cases, the zonation effects have increased over time whilst the scale effects declined. In other words, whilst the MEI varies less across the scale spectrum, the variation in MEI due to the zonal configuration at each scale has become more important.

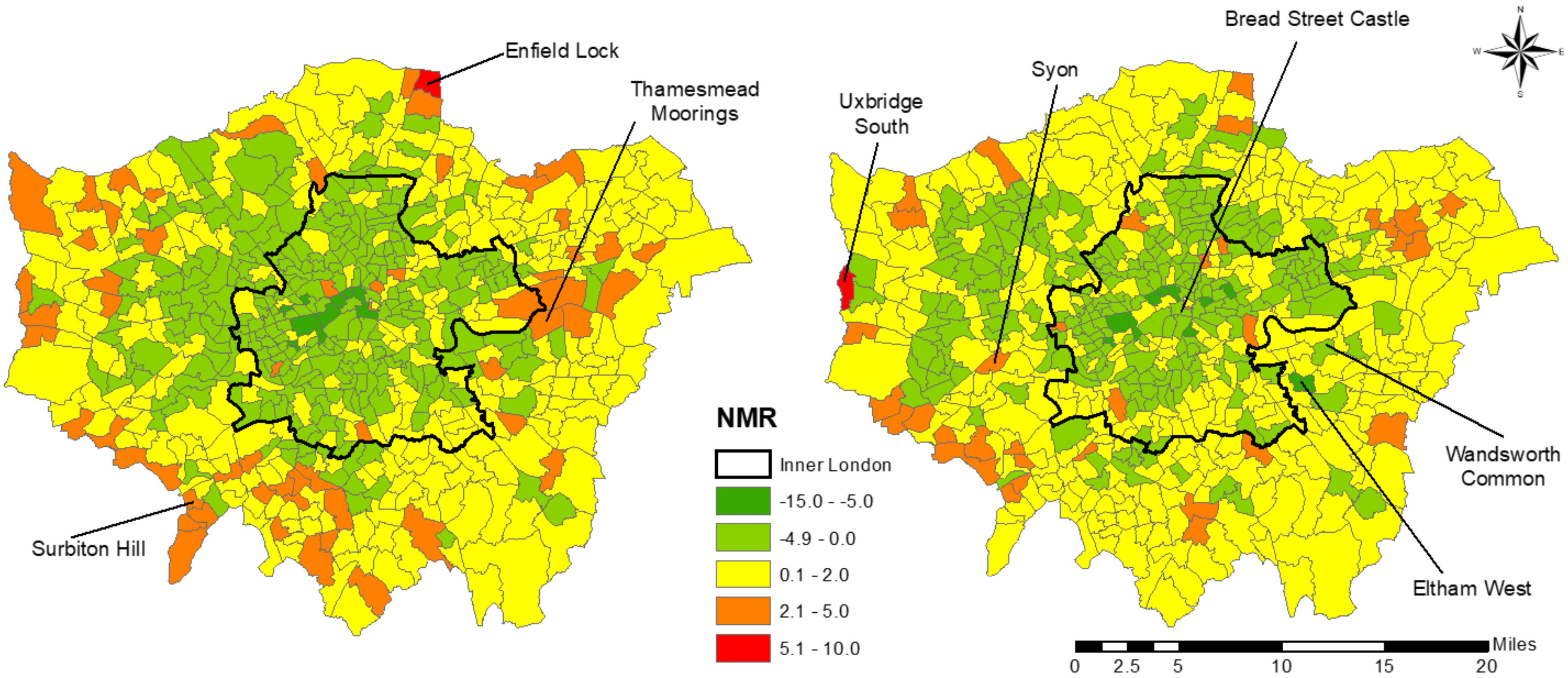
Table 7.4: Total scale and zonation effects for Migration Effectiveness Index by age group, 2000-01 and 2010-11

	Total Scale effect		Total Zonation effect	
Age groups	2000-01	2010-11	2000-01	2010-11
0 - 4	0.52	0.28	6.32	6.22
5 - 9	0.50	0.41	7.30	8.45
10 - 14	0.57	0.49	7.95	8.77
15 - 19	*0.82*	0.54	8.92	*9.38*
20 - 24	*0.90*	*0.95*	*9.42*	*10.92*
25 - 34	0.37	*0.99*	5.41	5.98
35 - 44	0.37	0.34	5.80	5.42
45 - 59	0.43	0.34	6.76	8.02
60 - 64	0.78	0.47	*9.49*	*9.11*
65 - 74	0.54	0.88	7.82	8.64
75 +	0.73	0.73	8.65	*9.51*
All age	0.38	0.28	5.05	5.50

Source: Estimates based on data from 2001 and 2011 Censuses

7.3.3 Net migration rates

The net migration rate (NMR) standardises net migration by population size and therefore, is a more consistent indicator for comparison purposes than the net migration balance itself. Figure 7.15 shows maps of the NMRs in 2000-1 and 2010-11 and how they have changed from one period to the next. Similar patterns to the ME can be observed, with the high positive values for wards located on or near the GL border and the higher negative values in the inner areas. The highest rates of net migration gain are Enfield Lock with 6.7 per 100, in Thamesmead Moorings with 4.6 per 100 and in Surbiton Hill with 3.9 per 100 in 2000-01. Enfield Lock, for example, was very popular at the time due to continuous improvement in public transport as well as the construction of new roads which contributed to the increasing migration gains (Enfield Council, 2019). Similarly, Thamesmead Moorings underwent a public transport improvement as well as improvements in the housing sector. In 2010-11, the highest NMR are in Uxbridge South with 7.4 per 100, in Syon with 4.3 per 100 and in Wandsworth Common with 3.8 per 100. The highest percentage increase between both time periods is in Bread Street Castle increasing from -14.5 per 100 in 2000-01 to 0 per 100 in 2010-11, which is consists of a very small population with less than 1,700 in 2011. The biggest decrease in NMR is in Eltham West with a 7.3 per 100 decrease to a -6.8 per 100 in 2010-11. Eltham West underwent some urban development in the early 1900s, but its popularity is decreasing, mainly due to increasing crime rates.



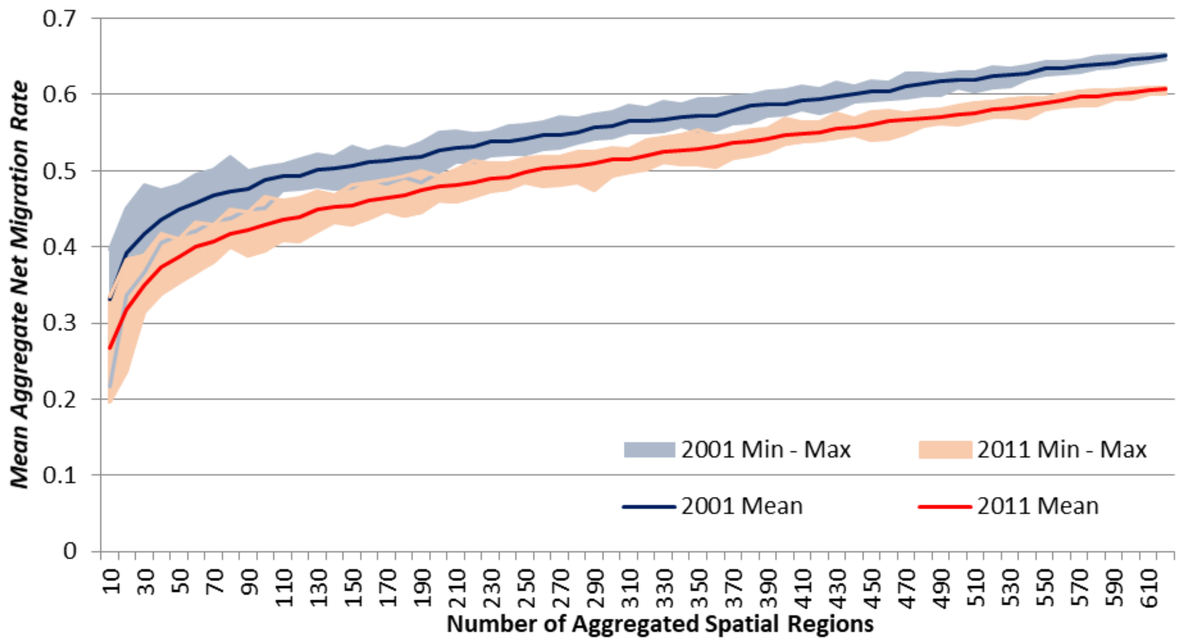
a. 2000-01

b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.15: Local net migration rate for wards of Greater London, 2000-01 and 2010-11

The aggregate net migration rate (ANMR) calculated in the IMAGE Studio at different scales is shown in Figure 7.16 for 2000-01 and 2010-11. The graph has a similar profile to the CMI with quite a strong scale effect, with the 2000-01 values being consistently higher than those for 2010-11. At the maximum of 620 ASRs where the highest ANMR is shown, the 2000-01 line shows 65.1 per 100 compared to the 60.1 per 100 shown in 2010-11. At the other end of the scale at 10 ASRs, 2000-01 the ANMR for 2000-01 is 33.1 per 100 and for 2010-11 is 0.26.7 per 100. The ANMR also experiences a more rapid decrease when the scale has less than 90 ASRs for both years respectively. So the impact of net migration, as well as intensity and effectiveness, in 2000-01 and 2010-11 depends on what scale is used. The zonation effect is visible in Figure 7.16 for the ANMR, even though at 620 ASRs it is very low with a zonation less than 1 per 100, at 10 ASRs it is stronger with a zonation greater than 18 per 100 in 2000-01 and 14 per 100 in 2010-11.



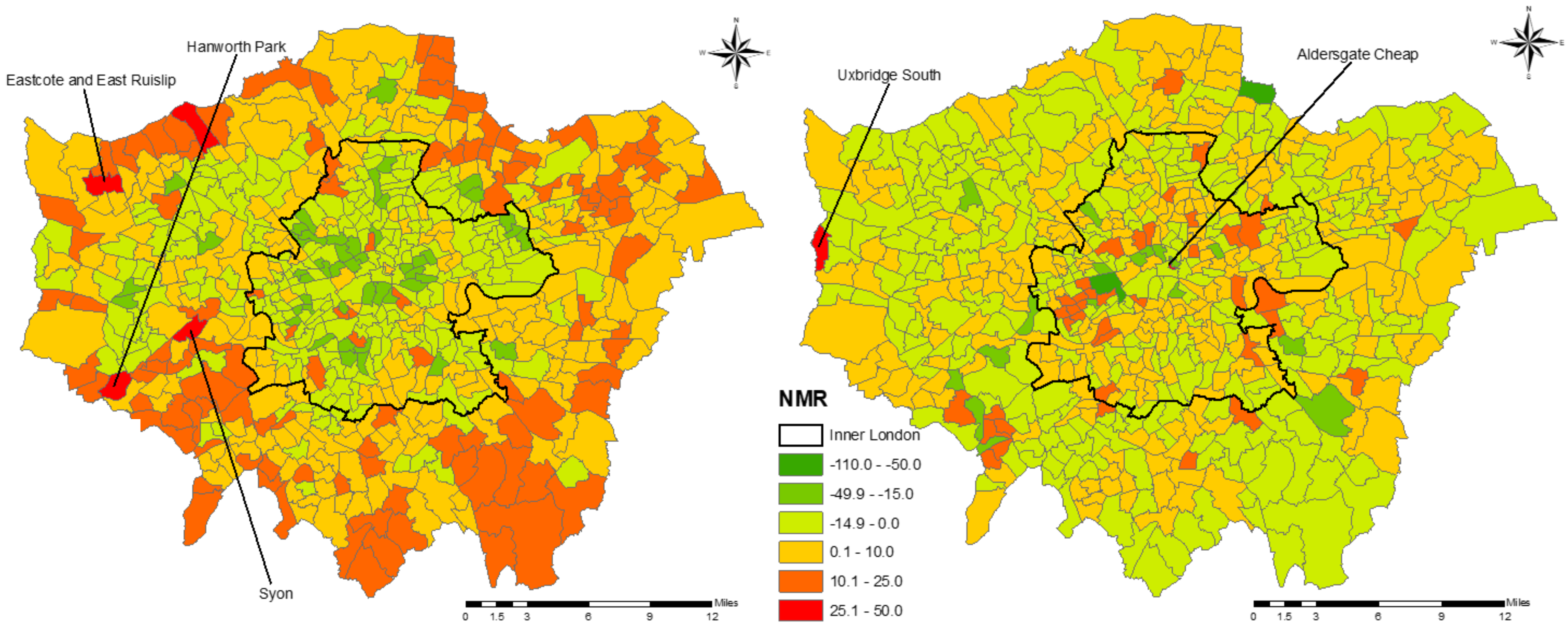
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.16: Mean aggregate net migration rate by scale, Greater London, 2000-01 and 2010-11

7.3.3.1 Age-specific net migration rates

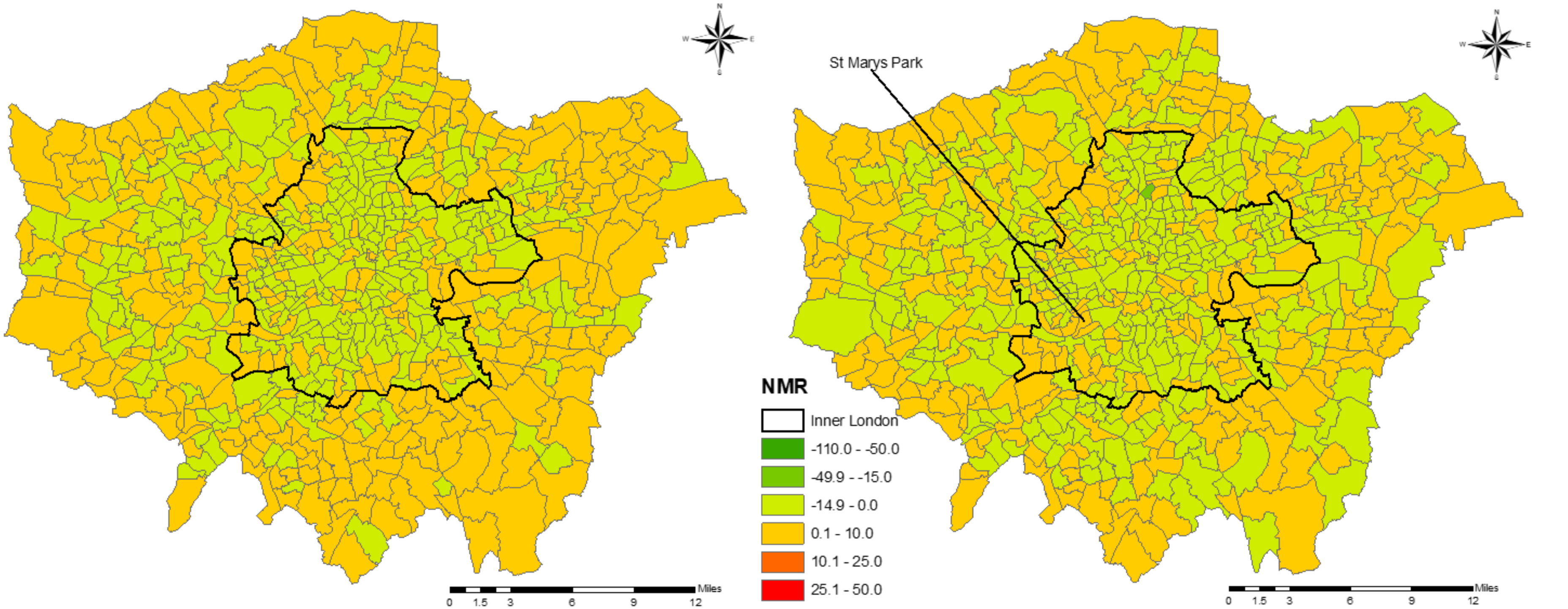
Figure 7.17 shows the local NMR for wards of GL in 2010-11 for the four broad age groups. The family age group (Figure 7.17a) has the most positive NMR wards across GL, with Eastcote and East Ruislip, Syon and Hanworth Park having the highest values, ranging between 26.1 and 38.4 per 100. Wards with high positive NMR values are mostly located on the GL border with negative values in more central areas. The students and young workers age group (Figure 7.17b) has fewer wards with high NMR across GL than the family age group and there are only two wards, Aldersgate Cheap and

Uxbridge South, that have a higher NMR than in the family age group with a rate of 38.6 and 44.9 per 100 respectively. The maps of NMRs for mature workers (Figure 7.17c) and retired people (Figure 7.17d), like the maps for ME values, show all wards having values close to zero, with a maximum of 9.9 per 100 in St Marys Park for the retired age group.



a. Family

b. Students and young workers



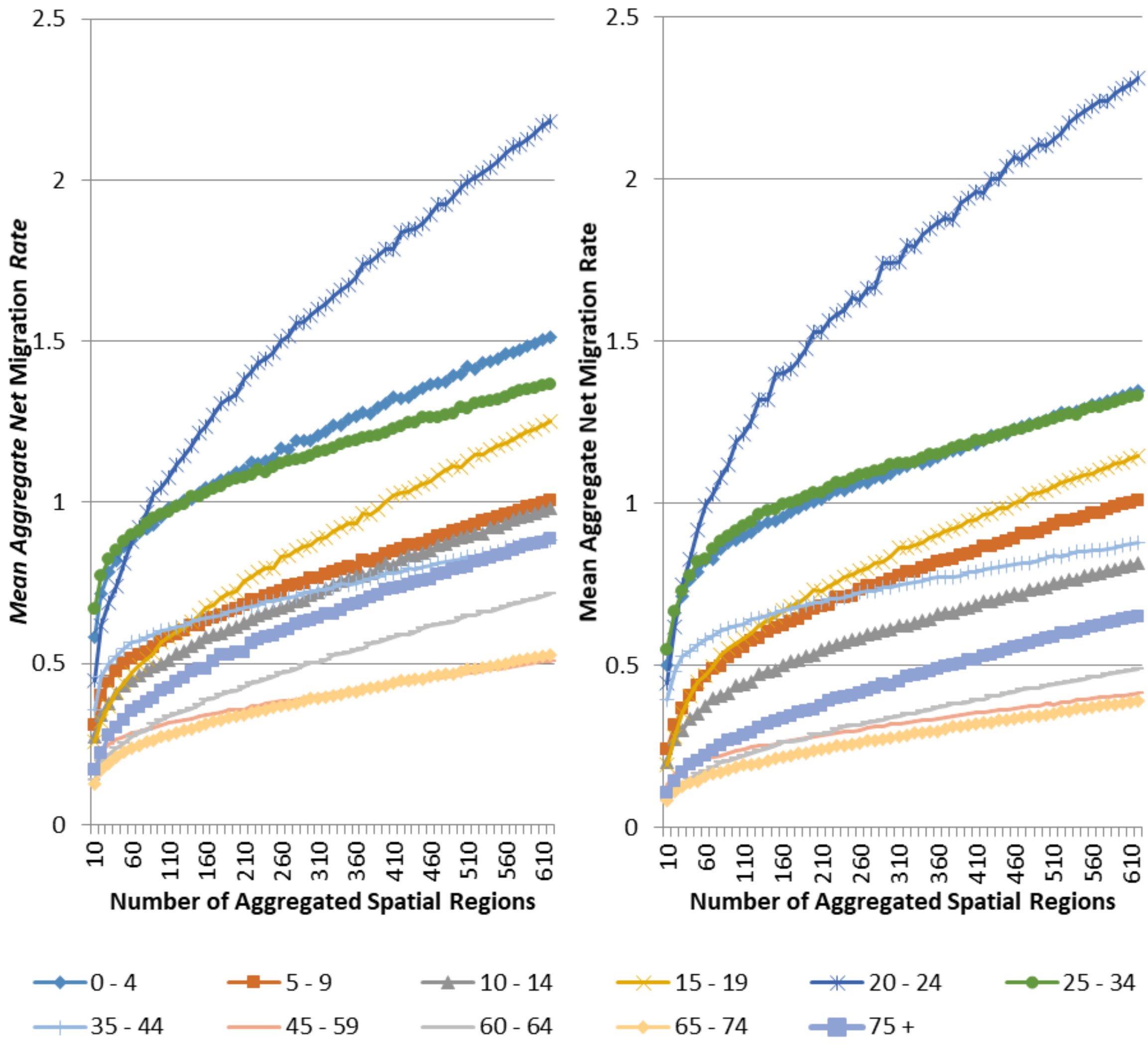
c. Mature workers

d. Retired

Source: Estimates based on data from 2011 Census

Figure 7.17: Local net migration rates for wards of Greater London in 2010-11

Figure 7.18 shows the ANMR for each age grouping in 2000-01 and 2010-11. The 20-24 age group stands out with an ANMR of 2.2 per 100 at 620 ASRs moving to 0.4 per 100 at 10 ASRs in 2000-01 with similar values of 2.3 per 100 at 620 ASRs and 0.4 per 100 at 10 ASRs in 2010-11. While the younger and middle aged age groups show high ANMR and a more defined scale effect, the older age groups show low ANMRs and smaller scale effects. The 5-9 and 20-24 age groups are the only ones who experience an increased ANMR from 2000-01 to 2010-11, whereas all other age groups have experienced a decrease in the ANMR over time.



a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.18: Age-specific aggregate net migration rates by scale, Greater London, 2000-01 and 2010-11

Table 7.5 helps to better identify the total scale and zonation effects for ANMRs by age group for 2000-01 and 2010-11. Similar to the MEI, the ANMR shows a relatively strong total scale effect for the 15-19 year olds, with a total value of 1.53 in 2000-01 decreasing to 1.34 in 2010-11. The total scale effect for the 20-24 age group on the other hand increased from 1.54 in 2000-01 to 1.67 in 2010-11. The elderly age groups, 65-74 and 75+, also show strong total scale effects from 1.49 to 1.67 in 2010-11. The total scale effect is the lowest for the 0-4, 34-44 and 45-59 age groups ranging from 0.78 to 0.86 in 2010-11. The total zonation effect values for the ANMR show a similar pattern to those of the MEI with strong effects for the 15-19 and 20-24 age groups with values of 9.95 and 9.48 in 2000-01 and values of 9.47 and 11.54 in 2010-11 respectively. In 2010-11, it becomes more apparent that the 25-34 and 35-44 age groups have much lower zonation effect compared to other age groups. There is also evidence the total zonation effect has increased for all age groups over time, with the exception of the 0-4 and 60-64 age groups who have experienced a decrease.

Table 7.5: Total scale and zonation effects for aggregate net migration rate by age group, Greater London, 2000-01 and 2010-11

	Total Scale effect		Total Zonation effect	
Age groups	2000-01	2010-11	2000-01	2010-11
0 - 4	0.93	0.80	6.40	6.29
5 - 9	1.13	0.95	7.07	8.21
10 - 14	1.24	*1.37*	8.12	8.65
15 - 19	*1.53*	1.34	*8.95*	*9.47*
20 - 24	*1.51*	*1.67*	*9.48*	*11.54*
25 - 34	0.70	*1.55*	5.39	6.20
35 - 44	0.87	0.86	5.63	5.47
45 - 59	1.06	0.78	6.62	7.84
60 - 64	*1.56*	1.11	*9.62*	*9.30*
65 - 74	*1.37*	*1.67*	7.80	8.69
75 +	*1.57*	*1.49*	*8.79*	*9.74*
All age	0.66	0.80	5.00	5.57

Source: Estimates based on data from 2001 and 2011 Censuses

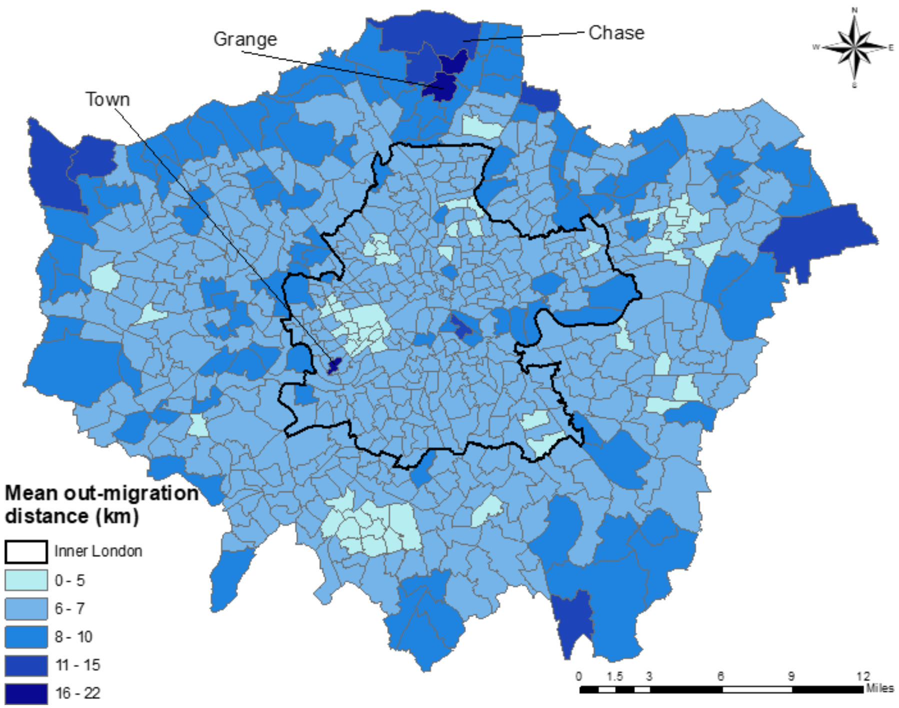
7.4 Migration distance and its frictional effect

7.4.1 Out-migration and in-migration distance at BSU level

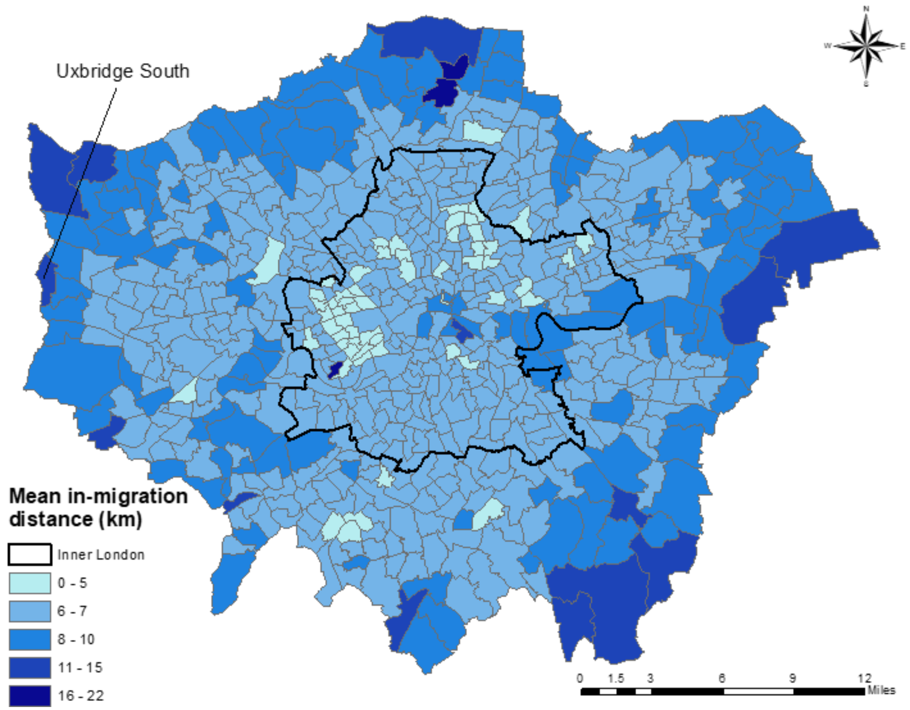
As discussed in Chapter 6, there are multiple ways to measure the distances travelled by migrants. In this chapter, the IMAGE Studio is used to compute the distance at BSU level measured by the straight-line or Euclidian distance in kilometres from the geographic centroid of the origin BSU to the geographic centroid of the destination BSU. Wards are the BSUs in this analysis. When zonal aggregation is performed, the distance between ASRs is the mean distance between the component BSUs of the origin and destination ASR in each case.

Figure 7.19 maps the mean out-migration and in-migration distances by ward for 2000-01 and 2010-11 to better understand the mean migration patterns within GL. In all four maps there is a tendency for those living in wards close to or adjacent to the border of GL, to have moved further, but there are anomalies. For out-migration, the wards with the highest mean distances in 2000-01 are Town, Grange and Chase with a mean distance of 21.7km, 18.4km and 12.2km (Figure 7.19a). In 2010-11, the Town and Grange wards retain the highest mean out-migration distance, but have experienced a decrease as they have a mean distance of 21.5km and 17.9km (Figure 7.19c). The number of wards whose out-migrants moved shorter distances, from 0 to 5km, have increased from 52 wards in 2000-01 to 87 in 2010-11. Whilst the majority of wards had a mean out-migration distance from 6 to 7km, the number of wards in this distance band decreased from 459 in 2000-01 to 449 in 2010-11.

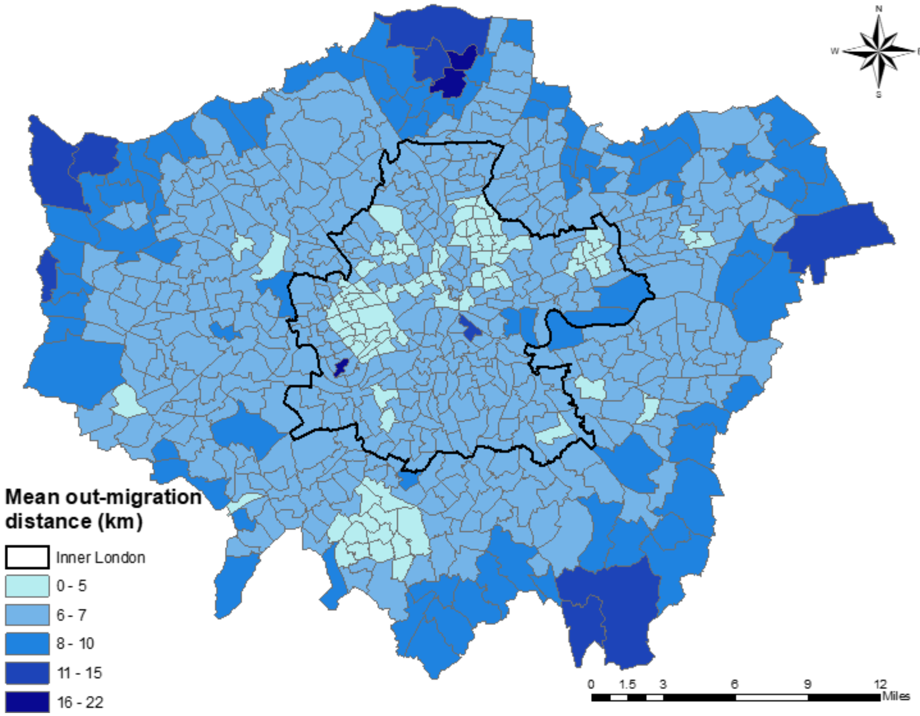
The mean in-migration distance has a similar pattern across GL with the number of wards with migrants moving short distances of 0 to 5km, increasing from 59 in 2000-01 (Figure 7.19b) to 126 in 2010-11 (Figure 7.19d). These wards include Springfield, Boleyn and East Ham North, each of which has a mean in-migration distance less than 3.5km in 2010-11. The majority of wards have an in-migration distance in the 6 to 7km range, and there has been a decrease from 428 wards in 2000-01 in this range to 408 wards in 2010-11. The highest in-migration distance can be found in Town, Grange and Uxbridge South wards with distances of 20.9km, 17.6km and 12.7km in 2000-01. In 2010-11 Town has decreased to 20.5km and Grange has decreased to 17.3km. The mean out-migration and in-migration distances have decreased over time across all wards in GL indicating that although the rate of migration is increasing, migrants are moving shorter distances than they used to. This in line with findings across the UK as a whole (Chapter 6).



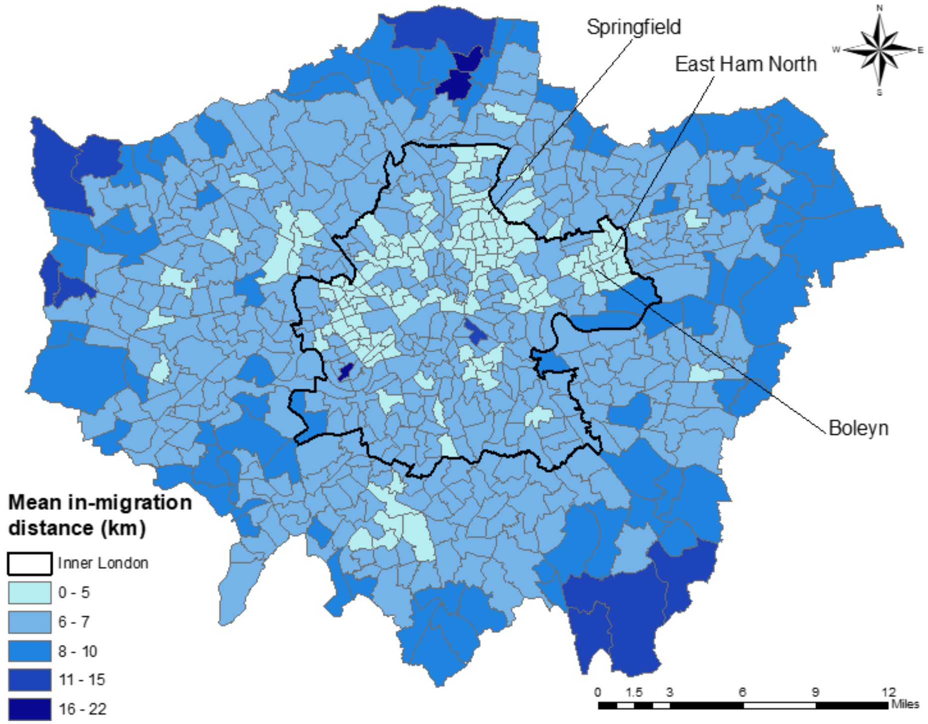
a. Out-migration, 2000-01



b. In-migration, 2000-01



c. Out-migration, 2010-11



d. In-migration, 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.19: Mean out-migration and in-migration distances by wards of Greater London, all ages, 2000-01 and 2010-11

The average (all-age) mean in-migration and out-migration distances in Table 7.6 do not equal each other as there are discrepancies when averaging already averaged values for all the age groups and the mean in-migration distance has declined for all age groups except 0-4 and 35-44. This table confirms the observation that the out-migration distance has decreased over time. The highest decrease (7.5%) in the average mean in-migration distance was experienced by the 10-14 age group whilst the 60-64 age groups had the smallest decrease (3.3%) over time. The 20-24 and the 25-34 age groups have the highest in-migration and out-migration distances travelled for both time periods but also experienced a decrease in the distance travelled. For the average mean out-migration distances, the 10-14 age group has experienced the biggest decrease (9.7%) whilst the 0-4 and 35-44 year olds are the only age groups showing an increase in the out-migration distance by 0.83% and 0.94% respectively. This increase indicates that couples with young children are moving further to find suitable housing or to have access to better schools to accommodate their expanding families. The results have shown that, overall, migrants moved shorter distances in 2010-11 than they did a decade earlier, as observed at LAD scale in Chapter 6. But in GL, a lot more migration flows were housing based moves (residential mobility) over shorter distances as GL significantly underbounds its urban area and therefore its labour and housing market areas (Champion and Shuttleworth, 2015).

The MMDs are much shorter in GL than in the UK as a whole as one might expect given the difference between the two spatial systems. The variation by age is the same as in the UK, with the exception of the 35-44 age groups showing increasing MMD in GL whilst they are decreasing at national level. The 35-44 age group consists of families who possibly want to settle down and could therefore a decreasing desire to move further away, as they may want to retain their social group and keep their children within their community/schools. Since GL is a fast-paced environment and with its quick changing housing market, further moves are more popular, allowing families to improve their quality of life with a new job, a better commute or to be in a better school environment. Other age groups showing differences between GL and the national level are the 65-74 and 75+ age groups with a decrease of the MMD in GL but showing an increase in the UK at LAD level. This difference is potentially linked to urban to rural migration at national level after retirement, whilst GL is linked to a more numerous short distance housing adjustment (Warnes, 1993).

The MMD percentage decline is lower in London than in the UK potentially due to the higher proportion of residents moving just for housing reasons in GL.

Table 7.6: Average of the mean migration distances, by age groups, Greater London, 2000-01 and 2010-11

	Average mean in-migration distances			Average mean out-migration distances		
	2000-01	2010-11	% Change	2000-01	2010-11	% Change
0 - 4	5.5	5.3	-3.31	5.2	5.3	+0.83
5 - 9	5.2	4.9	-6.18	4.9	4.7	-3.95
10 - 14	5.2	4.9	-7.45	5.2	4.7	-9.73
15 - 19	6.1	5.8	-4.98	6.9	6.6	-5.24
20 - 24	7.0	6.6	-5.93	7.4	7.2	-2.62
25 - 34	7.1	6.7	-5.54	7.0	6.8	-3.40
35 - 44	6.2	6.0	-3.47	5.9	6.0	+0.94
45 - 59	5.9	5.7	-4.72	5.9	5.7	-3.80
60 - 64	5.8	5.6	-3.25	5.4	5.3	-1.93
65 - 74	5.7	5.4	-5.10	5.5	5.3	-3.34
75+	5.9	5.5	-6.49	5.6	5.4	-3.44
All age	6.5	6.1	-6.29	6.4	6.2	-3.67

Source: Estimates based on data from 2001 and 2011 Censuses

7.4.2 Global migration distance for BSUs

Table 7.7 shows the global internal migration indices for the mean migration distance by age groups for 2000-01 and 2010-11. The results in this table confirm the decrease of the mean migration distance for all age groups from 2000-01 to 2010-11, with the exception of the 60-64 age group, whose distance migrated remained constant. The biggest decreases can be found in the 10-14, 20-24 and 75+ age groups, whilst the smallest decrease can be found within the 0-4 and 35-44 age groups. The 20-24 age group maintain the longest mean migration distance travelled in both time periods, despite falling by 8% over the decade.

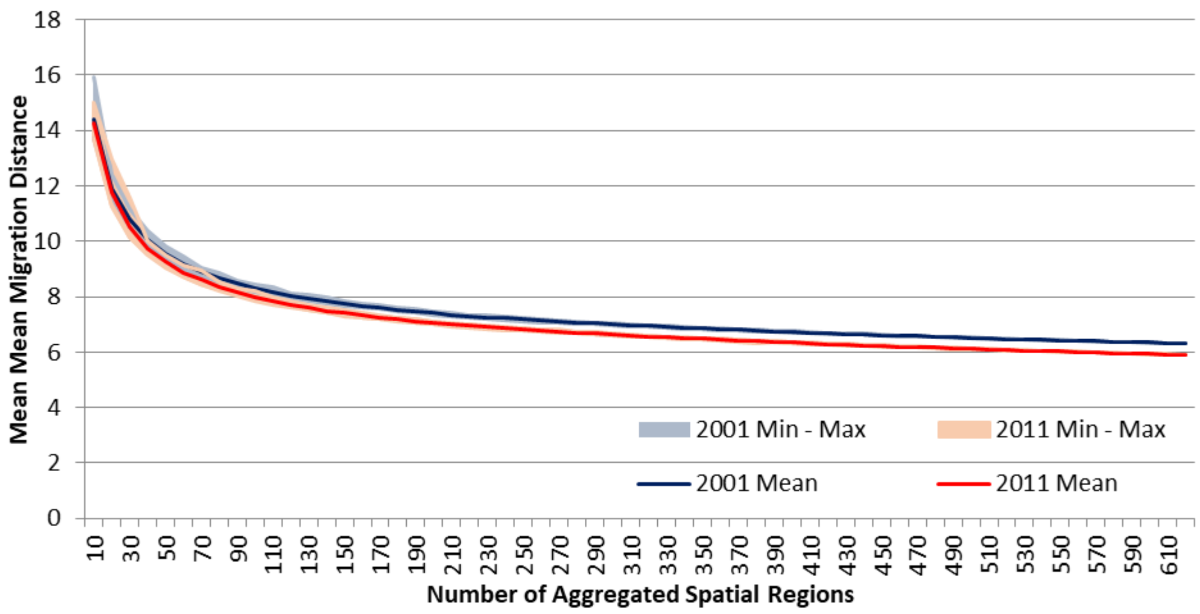
Table 7.7: Global mean migration distance by age groups, Greater London, 2000-01 and 2010-11

	2000-01	2010-11	% Change
0 - 4	4.60	4.45	-3.26
5 - 9	4.26	4.00	-6.10
10 - 14	4.38	4.06	-7.31
15 - 19	5.81	5.60	-3.61
20 - 24	6.30	5.84	-7.30
25 - 34	6.07	5.66	-6.75
35 - 44	5.12	4.99	-2.54
45 - 59	4.99	4.78	-4.21
60 - 64	4.61	4.61	0.00
65 - 74	4.71	4.51	-4.25
75+	4.92	4.56	-7.32
All age	5.56	5.23	-5.94

Source: Estimates based on data from 2001 and 2011 Censuses

7.4.3 Scale and zonation effects on migration distance

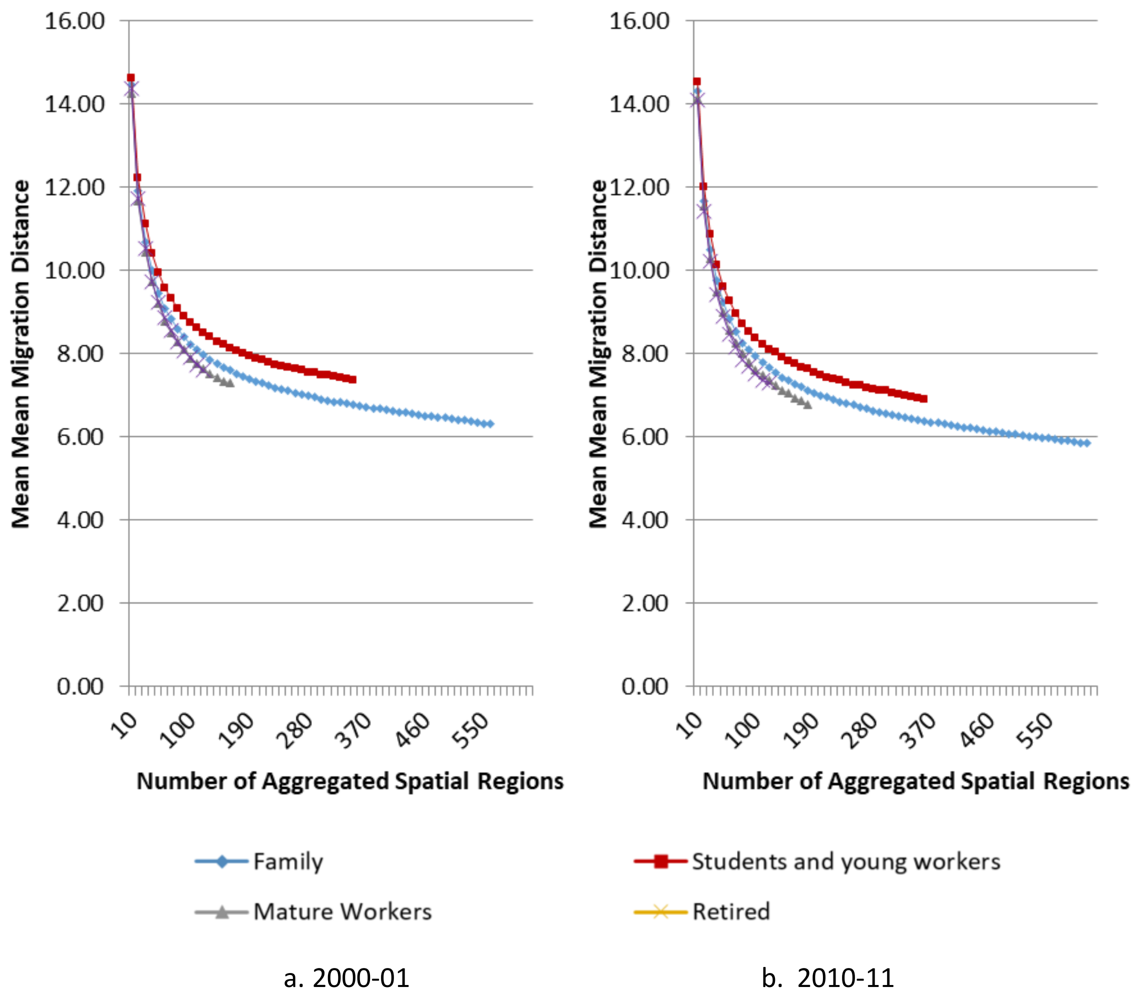
Mean migration distance (MMD) is important in the spatial interaction model (SIM) because the optimum beta parameter, or distance decay parameter, is identified when the MMD predicted by the SIM is equal to the observed MMD computed from the original data. Figure 7.20 shows the scale and zonation effects of the MMD in 2000-01 and 2010-11, where it can be observed that the MMD decreases as the number of ASRs get larger. Thus the scale effect shows that as the scales get smaller, migrants move greater distances; from 90 to 10 ASRs this becomes more apparent where the MMD increases from 8.5km to 14.4km in 2000-01 and from 8.1km to 14.3km in 2010-11. The zonation effect is stronger at larger scales and becomes smaller as the number of ASRs increases.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.20: Scale and zonation effects of the mean migration distance, Greater London, 2000-01 and 2010-11

The mean MMD for the 11 different age groups have also been calculated using the SIM in the IMAGE Studio. This has shown the same issues as encountered in Chapter 6, where an excess of zero values in the matrix resulted in the following error: "Balancing factor iteration exceeded max rounds: 500 stopping". This error means that the balancing factors in the SIM are not converging and therefore a beta value is not being calibrated and the model cannot predict a flow matrix. One potential solution to the problem is to add a constant value to each cell of the migration flow matrix as explained in Chapter 6, but rather than experimenting with this approach, the age-specific migration matrices were aggregated into the four broad age groups used previously, but even with the aggregated matrices, the large number of zero flows between wards means that the model is not able to calculate the beta value for the complete set of ASRs. This is why the MMD schedules for the broad age groups shown in Figure 7.21 end at different numbers of ASRs. The family age group has the least proportion of zeros, and this is apparent in the graph, showing the MMD being computed for 560 ASRs in 2000-01 and 610 ASRs in 2010-11. All the age groups show a similar pattern to that of the all age group, with a decrease in the MMD as the scales become smaller.



Source: Estimates based on data from 2001 and 2011 Censuses

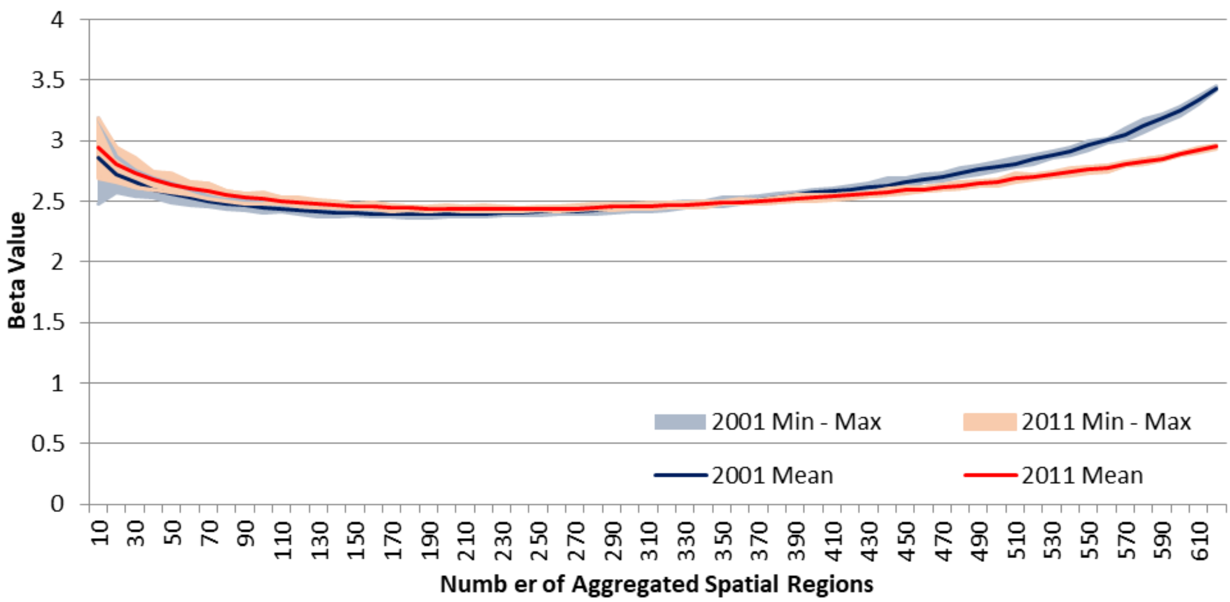
Figure 7.21: Scale effects of the mean migration distance by broad age group, Greater London, 2000-01 and 2010-11

7.4.4 Frictional effect of distance

In order to measure how much effort is required for migrants to move from one place to another, the frictional effect of distance is computed. Distance is therefore a key variable in influencing people on how far they are willing to move. A distance decay parameter is computed within the IMAGE Studio by calibrating a doubly constrained SIM at BSU level and for each set or ASRs.

The beta value or distance decay parameter is a calibrated automatically by the SIM. A higher beta value means that the impact of distance on migration is greater. In this research a linear power function is used to capture the migration-distance relationship since the data do not include migration within wards; an exponential function tends to be more suitable when intra-zonal flows are included, which is not the case here. Figure 7.22 shows the scale and zonation effects of the mean beta value for 2000-01 and 2010-11. This graphs shows a convex curve, with the beta value initially decreasing as the number of ASRs decrease from 620 to 250, and then increasing slowly as the scales gets larger. The difference between both time periods is mostly visible at smaller scales, where the beta value reaches 3.43 at 620 ASRs in 2000-01 compared to 2.95 in 2010-11. A small zonation effect for the beta value can be observed, showing an increase at larger scale levels. There is also crossover around 300 ASRs with the 2010-11 beta value being higher that the 2000-01 value for larger zones and lower for smaller zones. In other words, the frictional effect of distance is larger in 2000-01 than in 2010-11 when the scale involves over around 300 zones but is smaller when the scale involves less than around 300 zones.

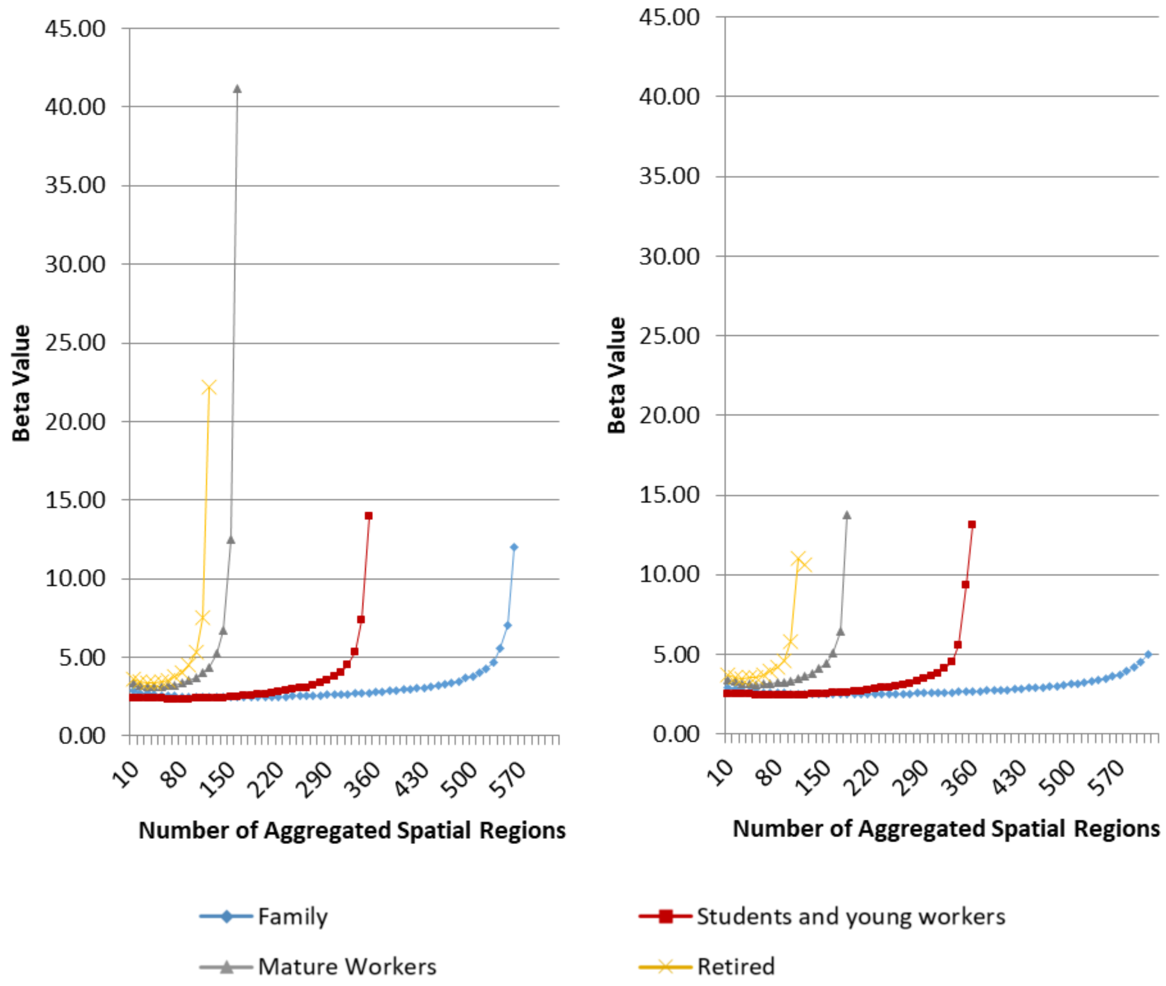
Compared to the LADs at national level, where the mean beta value remains relatively stable with a small decrease as ASRs get larger and fewer, demonstrating a scale independence, the beta value for GL shows an opposite effect as the beta value increases when ASRs get larger and when they get smnaller; this demonstrates that depending on what scale level is selected, the beta value for the GL will vary. A strong zonation effect for the national level was observed at larger scales and becomes much less significant as the scale level increases. The zonation effect is much less significant for migration within GL, demonstrating that the GL data are more true to the real data than the national level data. Given that much of the migration within GL is likely to be residential mobility, the increase in the frictional effect when ASRs are larger may be due to household preference to move relatively shorter distances but allows the same job to be retained. On the other hand, increases in the beta value at scales with smaller ASRs may occur because people want to move to a different neighbourhood and avoid short distance moves.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.22: Scale and zonation effects of the mean beta value, Greater London, 2000-01 and 2010-11

As with the MMD, the SIM was not able to compute the beta values at all scales as there were too many zeros within the matrices with larger numbers of zones. Figure 7.23 therefore shows the scale effects of the mean beta value by broad age group for 2000-01 and 2010-11. The convergence problem is clearly visible as these age group do not show beta values for the full range of ASRs. Each of the schedules for this indicator shows initial stability across scale until the problem of sparsity sets in and the beta value starts to increase, slowly at first and then rapidly until the point where parameter calibration in the model fails to take place. The retired age group has the most wards with no migration activity and the SIM stops calibration at 120 ASRS, compared to the family age group where the SIM is able to compute a beta value up to 560 ASRs in 2000-01 and up to 610 ASRs in 2010-11. This demonstrates that there is more migration activity between wards for the family age groups than the retired age group, but the difference in the beta values indicates that distance has a marginally greater impact on the retired age group than on the family age group in both time periods. The beta values decrease from 2000-01 to 2010-11 for all age groups, but most significantly for the mature workers from 41.14 in 2000-01 at 160 ASRs to 13.77 in 2010-11 at 180 ASRs. The students and young workers have shown the smallest decrease in the beta value from 13.99 at 350 ASRs in 2000-01 to 13.12 at 360 ASRs in 2010-11, suggesting that migration for this age group is not influenced by distance and that other factors are more important, e.g. universities or employments opportunities. Whilst matrix sparsity causes the beta parameter to rise sharply for certain age groups at different numbers of ASRs, there is some evidence of scale independence until this problem kicks in.



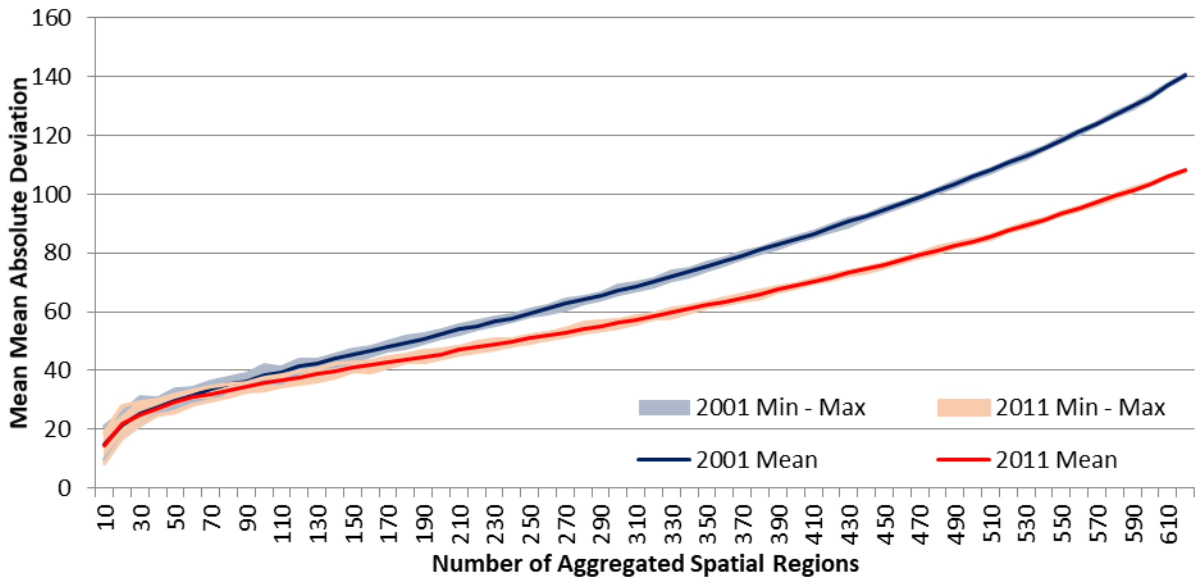
a. 2000-01 b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.23: Scale effects of the mean beta value by broad age group, Greater London, 2000-01 and 2010-11

7.4.5 Mean absolute deviation

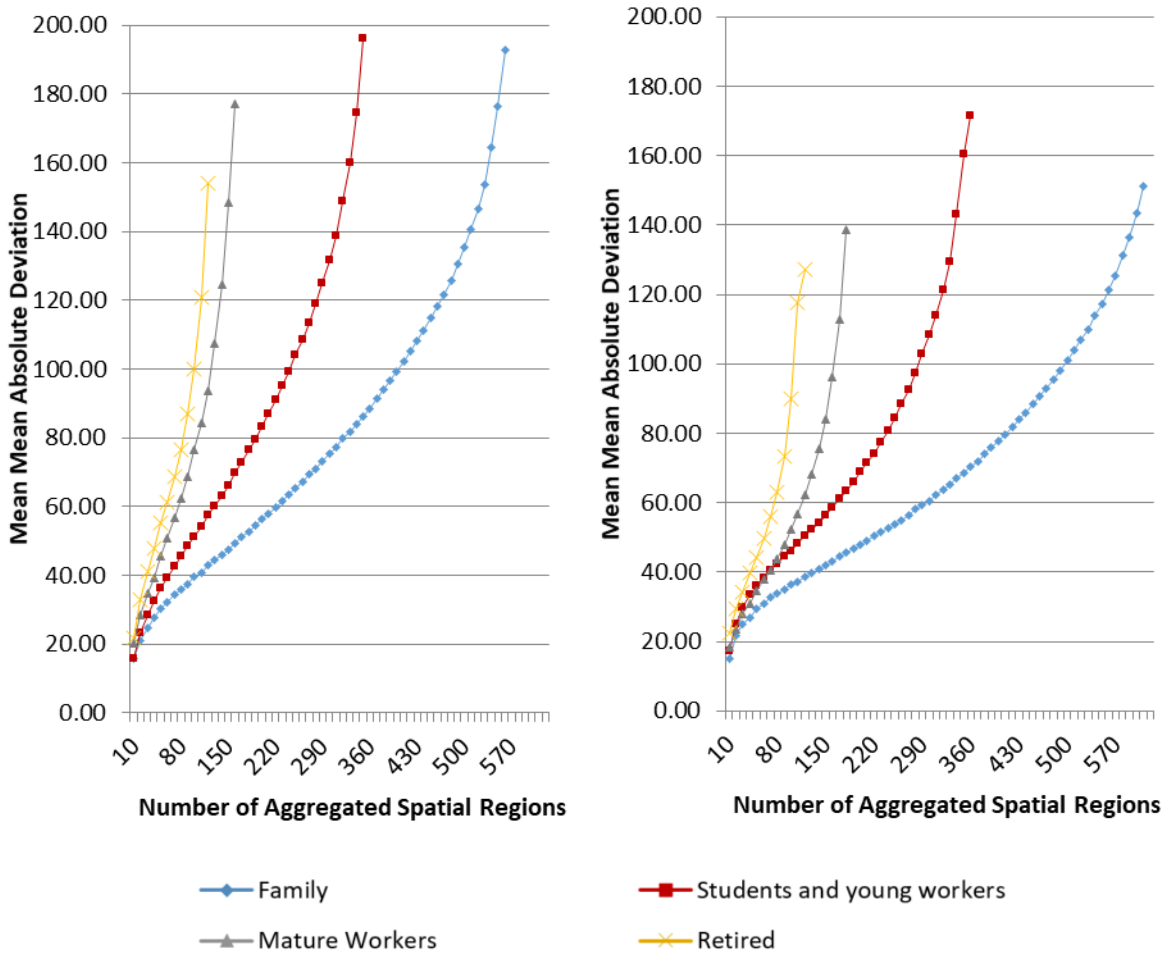
As explained in Chapter 6, the mean absolute deviation (MAD) statistic is the average difference between the flow of migrants in each cell of the matrix predicted by the model and the respective observed value. It is one measure of goodness-of-fit of the SIMs calibrated using the IMAGE Studio. The greater the similarity between the flows in the predicted and observed matrices, the better is the goodness-of-fit of the model. A smaller MAD value would signify that the goodness-of-fit is high, whereas a larger value of the MAD value would indicate that goodness-of-fit is poor. If the latter is the case, the assumption can be made that the model is not generating a predicted matrix that is representative of the actual distribution of migration flows. Figure 7.24 shows the scale and zonation effects of the MAD for 2000-01 and 2010-11, where it can be observed that both time periods have a similar trajectory. The MAD increases quite sharply from 10 ASRs to 50 ASRS reaching a MAD of 29 for both years. The MAD then increases consistently to reach a MAD of 140 at 620 ASRs in 2000-01 and 108 at 620 ASRs in 2010-11. These results demonstrate that for small numbers of ASRs, the predicted and observed values are closer and become further away as the number of ASRs increases, i.e., the model fits improve as the spatial units increase in size. The zonation effect is low, ranging from 8.3% to 19.9% at 10 ASRs and decreases as the scales get smaller. The resulting data have shown that the MAD and its inequality only increase as the zones increase in size.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.24: Scale and zonation effects of the mean absolute deviation, Greater London, 2000-01 and 2010-11

Figure 7.25 shows the scale effects of the MAD statistic by broad age group for 2000-01 (7.25a) and 2010-11 (7.25b). Again, the excess of zero values has caused the SIM model to stop prematurely, as is visible in the graph. Nevertheless, the results do show similar patterns as observed in Figure 7.24, where for larger scales, the predicted and observed values are closer and become further away as the scales become smaller. The model fit is best for the family age group at all spatial scales and worst for the retired age group. These results suggest that to produce a model that fits reasonably well, it is necessary to reduce the number of zones in the system from 620 to a much smaller number and to fewer still if modelling flows by age group.



a. 2000-01 b. 2010-11

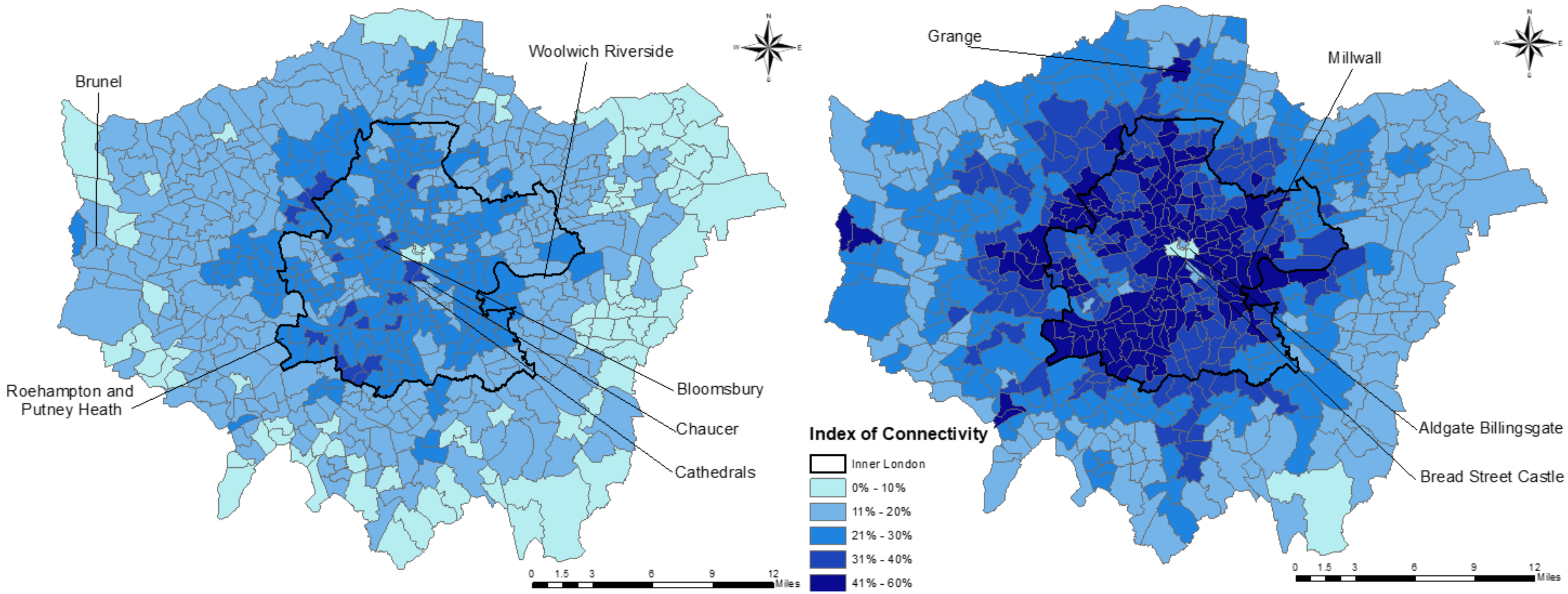
Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.25: Scale effects of the mean absolute deviation by broad age groups, Greater London, 2000-01 and 2010-11

7.5 Index of connectivity

The index of connectivity (IC) defined in Chapter 6, is used to analyse the existence and importance of linkages between spatially distributed geographical areas. Many connection links between wards exist through migration; the IC therefore provides a measure to quantify the extent of connectivity. The IMAGE Studio computes a net migration IC, where for each ward it is the percentage of all other wards that this ward either gains migrants from or loses migrants to, and that has a maximum value of 100% when all zones are connected to all other zones in the system.

Figure 7.26 shows how the net migration IC is represented in GL for the net migration of all ages in 2000-01 (7.26a) and 2010-11 (7.26b). The general pattern indicates more central wards – mainly but not exclusively in Inner London – have greater connectivity than those further out. A strong increase from 2000-01 to 2010-11 can be observed, mainly within some central wards of GL, such as Roehampton and Putney Heath and Woolwich Riverside, including Brunel being on the GL border; having the strongest IC increases of over 31%. Bloomsbury, Chaucer and Cathedrals have the highest IC values in 2000-01 of 35.4%, 34.9% and 34.3% respectively, whilst in 2010-11, the highest IC values are found in Millwall, Cathedrals and Grange with 59.4%, 56.9% and 56.6% respectively. The figures show that most wards in GL are well connected and that connectivity has increased over time. Two wards on the other hand, experienced a decrease in the IC; in Bread Street Castle and Aldgate Billingsgate, the IC fell from 8.3% and 4.9%, to 0% in 2010-11, making these the only wards with no connectivity in 2010-11. It is perhaps surprising to observe that these two wards are very central and yet show 0% connectivity; both are relatively small wards and might have experienced a major change of residential space into commercial space.



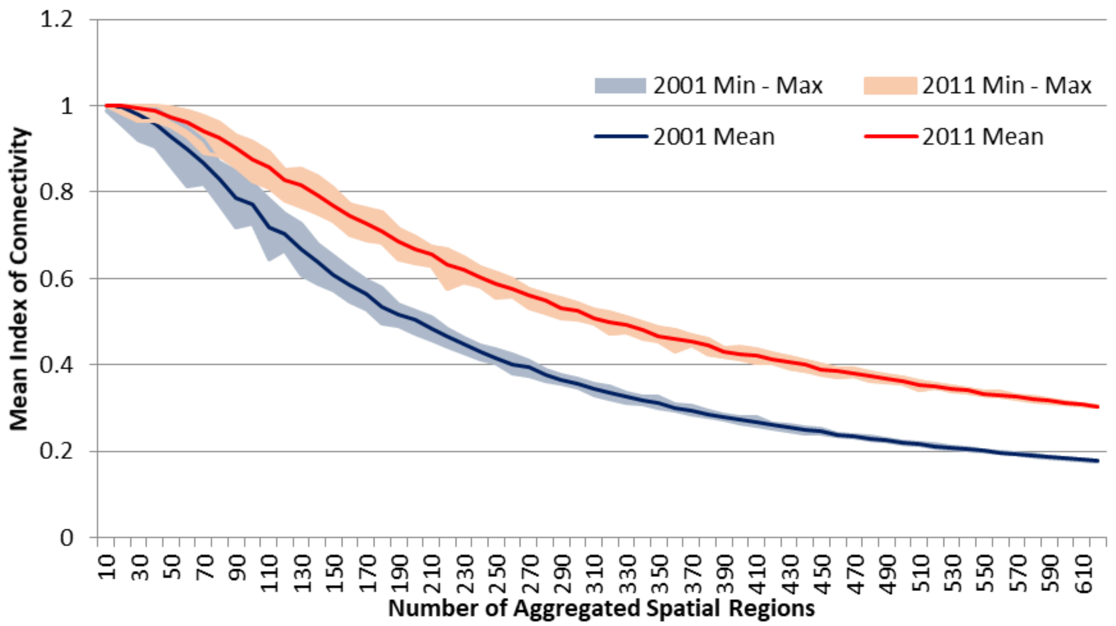
a. 2000-01

b. 2010-11

Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.26: Net migration connectivity index by ward in Greater London, all ages, 2000-01 and 2010-11

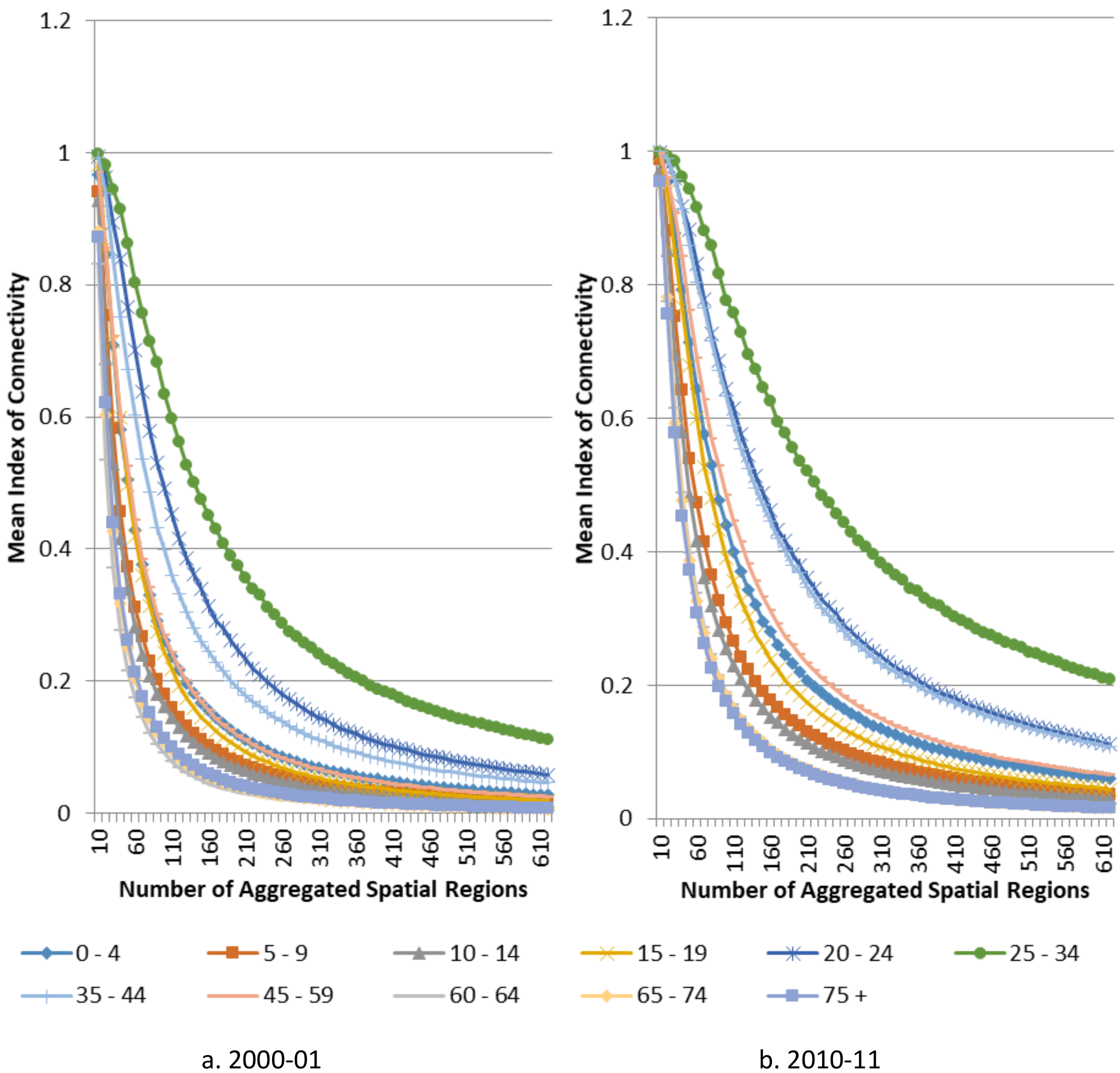
Figure 7.27 shows the IC values for all ages in 2000-01 and 2010-11 by scale. The results show that as the zones get smaller, the IC decreases. At a fully aggregated scale level of 10 ASRs, the IC is at 100% and starts decreasing immediately after 10 ASRs in 2000-01 whereas in 2010-11 the IC starts to decrease after 40 ASRs. In 2010-11, a higher IC of 30.4% can be observed at 620 ASRs, which has shown to be an increase from 17.7% at 620 ASRs in 2000-01. A zonation effect can also be observed at larger scales, and get smaller as the scale increases.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.27: Mean connectivity index, Greater London, all ages, 2000-01 and 2010-11

When analysing the different age groups, the graph in Figure 7.28 shows that the age-group trajectories are comparable with the all age trajectory, with curves having different degrees of concavity according to their values at the smallest scale (620 BSUs). The 25-34 year olds have a trajectory with the highest connectivity and least scale effect whereas the 60-64, 65-74 and 75+ age groups show the lowest connectivity but largest scale effects. Connectivity is also consistently higher in 2010-11 across all age groups, as all age group have a higher IC at 620 ASRs in 2010-11 (7.28b) compared to 2000-01 (7.28a). Similar to the observation made in Chapter 6 at LAD level for the UK, at ward level for GL, the IC is increasing over time, and as the population moves shorter distances, zones appear to be more connected than before. Connectivity is increasing for short-distance moves due to a potential desire for upgrading the home without having to change work, maintaining the same social circle as well as keeping kids within the same school zone. Also with GL improving its public transport by creating a more efficient transport system using the underground and buses (Guo and Wilson, 2011), it may not be necessary to relocate further distances to access new amenities or to be open to new opportunities.



Source: Estimates based on data from 2001 and 2011 Censuses

Figure 7.28: Mean connectivity Index, by age group, Greater London, 2000-01 and 2010-11

Table 7.8 shows the total scale and zonation effects of index of connectivity by age groups for 2000-01 and 2010-11. The total scale effect show the same patterns as observed in previous figures with the total age group having a much smaller scale effect than each individual age group. The decrease of the total scale effect is also defined in this table with the 45-59 age group having the strongest decrease over time. The elderly age groups, 60-64, 65-74 and 75+, have the strongest scale effect in both time periods whilst the 25-34 age groups of the smallest total scale effect.

The total zonation effect has also decreased from 2000-01 to 2010-11 for most age groups, with the 75+ age groups experiencing the steepest decrease. The 15-19, 20-24, 35-44 and 45-59 age groups experienced an increase with the 20-24 age group having the highest total zonation effect in 2010-11.

Table 7.8: Total scale and zonation effects of index of connectivity, by age groups, 2000-01 and 2010-11

	Total scale effect	Total zonation effect	Total scale effect	Total zonation effect
	2000-01		2010-11	
0 - 4	3.41	3.74	2.71	3.72
5 - 9	3.82	4.07	3.16	3.96
10 - 14	3.96	4.20	3.30	4.00
15 - 19	3.78	3.84	3.01	3.86
20 - 24	2.76	*4.87*	2.14	*5.11*
25 - 34	2.14	*5.21*	1.54	*4.97*
35 - 44	2.98	3.93	2.17	4.09
45 - 59	3.50	3.70	2.64	3.85
60 - 64	*4.75*	3.78	*3.93*	3.62
65 - 74	*4.56*	3.78	*3.88*	3.61
75 +	*4.43*	4.12	*3.89*	3.89
Total	1.70	4.55	1.18	4.10

Source: Estimates based on data from 2001 and 2011 Censuses

7.6 Conclusion

This chapter has explained how London's population has changed between 2001 and 2011 as a context for the migration analysis, with an increase in population by 12.3% overall. Whilst the population growth is highest in a number of wards to the east of central London, a lower growth in the peripheral areas of outer London, particularly in the south and east was observed. This chapter has also reported results for multiple indicators: the crude migration intensity, the migration effectiveness index and the aggregate net migration rate and their respective scale and zonation effects, showing a CMI and ANMR increase and MEI decrease.

A strong MEI was identified in both time periods but has diminished slightly in 2010-11. The analysis of the scale and zonation effects of migration within GL shows that the CMI and the ANMR rates are scale sensitive, whereas the MEI tends to be less scale dependent. These results conform with the LAD analysis conducted in Chapter 5.

As well as these indicators, this chapter has explored distance migrated, distance decay and ward connectivity within Greater London. The results have shown that while the all-age propensity to migrate within London increased between 2000-01 and 2010-11, the distance over which migrants moved declined but ward connectivity increased, and that the in and out-migration distance has decreased over time.

The chapter has shown how the scale effects by age group have changed from 2000-01 to 2010-11 for all the selected indicators as summarised in Table 7.9. A positive sign shows that there has been an increase between both time periods and negative sign indicates a decrease. Some key observations here are the increases in the index of connectivity across all the age groups and with the CMI increasing for the majority of age groups, with the 15-19 having the most significant increase over time. Other indicators such as the MEI have mostly decreased across all the age groups over time except for the 20-24, 25-34 and 65-74 year olds, whilst the 75+ age group remained the same. Similar to the ANMR where all the age groups experienced a decrease apart from the 10-24, 20-24, 25-34 and 65-74 age groups. Also the family and mature workers age groups have shown an increase in the mean migration distance, the total MMD has decreased over time, indicating that although the rate of migration is increasing, migrants are moving shorter distances than they used to.

Table 7.9: Scale effect change for different indicators from 2000-01 to 2010-11, by age group, Greater London

<table>
<tr><th></th><th></th><th>CMI</th><th>MEI</th><th>ANMR</th><th>MMD</th><th>Beta</th><th>MAD</th><th>IC</th></tr>
<tr><td rowspan="3">Family</td><td>0 - 4</td><td>-</td><td>-</td><td>-</td><td rowspan="3">+</td><td rowspan="3">+</td><td rowspan="3">-</td><td>+</td></tr>
<tr><td>5 - 9</td><td>-</td><td>-</td><td>-</td><td>+</td></tr>
<tr><td>10 - 14</td><td>+</td><td>-</td><td>+</td><td>+</td></tr>
<tr><td rowspan="2">Students and young workers</td><td>15 - 19</td><td>+</td><td>-</td><td>-</td><td rowspan="2">-</td><td rowspan="2">+</td><td rowspan="2">-</td><td>+</td></tr>
<tr><td>20 - 24</td><td>+</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td rowspan="2">Family</td><td>25 - 34</td><td>+</td><td>+</td><td>+</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">-</td><td>+</td></tr>
<tr><td>35 - 44</td><td>-</td><td>-</td><td>-</td><td>+</td></tr>
<tr><td>Mature workers</td><td>45 - 59</td><td>-</td><td>-</td><td>-</td><td>+</td><td>-</td><td>-</td><td>+</td></tr>
<tr><td rowspan="3">Retired</td><td>60 - 64</td><td>-</td><td>-</td><td>-</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td><td>+</td></tr>
<tr><td>65 - 74</td><td>+</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td>75 +</td><td>+</td><td>=</td><td>-</td><td>+</td></tr>
<tr><td colspan="2">All</td><td>+</td><td>-</td><td>+</td><td>-</td><td>-</td><td>-</td><td>+</td></tr>
</table>

Source: Estimates based on data from 2001 and 2011 Censuses

Table 7.10 shows the how the zonation effect has changed by age group from 2000-01 to 2010-11. The IC shows an increase in the zonation effect across all age groups over time. The CMI has also increased across all age groups with the exception of the five age groups 0-4, 5-9, 35-44, 45-59 and 60-64. The MEI and the ANMR show also show an increase over time for most age groups except for the 0-4, 35-44 and 60-64 age groups. The zonation effect for the MMD and MAD have also increased over time except for the family age group, who have experienced a decrease from 2000-01 to 2010-11. Lastly, the zonation effect for the beta value has increased for the students and young workers and for the mature workers, whilst the family and retired age groups decreased.

Table 7.10: Zonation effect change for different indicators from 2000-01 to 2010-11 by age group, Greater London

		CMI	MEI	ANMR	MMD	Beta	MAD	IC
Family	0 - 4	-	-	-	-	-	-	+
	5 - 9	-	+	+				+
	10 - 14	+	+	+				+
Students and young workers	15 - 19	+	+	+	+	+	+	+
	20 - 24	+	+	+				+
Family	25 - 34	+	+	+	-	-	-	+
	35 - 44	-	-	-				+
Mature workers	45 - 59	-	+	+	+	+	+	+
Retired	60 - 64	-	-	-	+	-	+	+
	65 - 74	+	+	+				+
	75 +	+	+	+				+
Total		+	+	+	+	-	-	+

Source: Estimates based on data from 2001 and 2011 Censuses

The changes shown in Table 7.9 signifies that in terms of migration intensity, net migration rate and connectivity, the scale effect has become more important over the inter-censal decade, signifying how crucial it is to use the correct scale level as results will vary and could be misrepresented. Changes in Table 7.10 have shown that all indicators, with the exception of Beta and MAD, have increasingly become less predictive as the data aggregates, suggesting low scale levels would allow a better representation of the true data.

This chapter brings an end to the reporting of results in this thesis and is followed by a final chapter containing the overall conclusions and final discussions.

Chapter 8: Conclusions

8.1 Introduction

The primary aim of this thesis was to investigate the effects of the two MAUP components, scale and aggregation, on selected indicators of internal migration intensity, pattern and impact in the United Kingdom (UK) using data from the last two censuses of population in 2001 and 2011. This investigation was designed to provide a better understanding of the sensitivity of quantitative measures of internal migration behaviour to geographical scale and area configuration, but it also to provide an opportunity to examine the characteristics of migration in the two single-year pre-census periods and the changes that have taken place in the UK over the inter-censal decade, a comparison that had not been undertaken hitherto. The availability of all-age and age group origin-destination migration flows from the census for consistent sets of 'basic spatial units' has allowed analyses to investigate levels and patterns of migration indicators across a whole country (using local authorities in the UK as BSUs) and within a selected region (using wards in Greater London as BSUs) and to quantify the MAUP effects of scale and zonation in each case.

This chapter begins in section 8.2 by summarising the main results and presenting the key conclusions of the thesis according to the five objectives outlined in Chapter 1. Thereafter, section 8.3 provides an assessment of the software system, the IMAGE Studio, which has been the tool used to compute the indicators at different scales and to generate extensive sets of results. Some suggestions for further research are offered in section 8.4 before a final conclusion is included to complete the thesis.

8.2 Summary of findings and conclusions

To realise the above primary aim, five key objectives were proposed in Chapter 1. In this section, the research and main findings associated each of the objectives are considered in turn in order to demonstrate what has been achieved in summary form.

1. **Undertake a review of the definition of, theory associated with, and previous research on internal migration behaviour in order to understand the context in which the research is conducted and recognise the gaps that the research is trying to fill.**

This objective was met in Chapter 2, where it was recognised that defining internal migration is not necessarily straightforward, that internal migration theory dates back to the nineteenth century, and that there is a wealth of previous empirical research on internal migration, much of which has been conducted by geographers, each of whom has typically used a spatial system of interest dictated by the availability of data for undertaking their statistical or model-based analyses of internal migration.

It was recognised that the definition of what constitutes internal migration is not straightforward, given the propensity of some researchers to use the concept of residential mobility to distinguish shorter-distance internal migration (where a change of job may not take place alongside a change of location) from longer-distance migration (where a job change is much more likely). This thesis has followed the ONS definition of internal migration which includes anyone who has moved to a new address in the year prior to the census, regardless of how far they have moved or the reasons for the move. The analyses reported in the thesis are primarily focused on internal migration flows between local authority districts (LADs) at BSU level, but the use of wards in Greater London enables a closer examination of residential mobility in one region.

There is a noticeable lack of work focused on the volume of migration and the reasons for migration (Lee, 1966). A review of previous studies reveals that researchers have used a wide variety of spatial scales to analyse internal migration, many of which are determined by the availability of data for specific sets of zones, such as census migration data for regions, local authorities or wards or NHS patient re-registration movement data for Family Health Service Areas (FHSAs). In some cases, other researchers have developed their own more functional regionalisations, such as the labour market areas or city regions or constructed zone types based of geodemographic classification methods. The use of different spatial scales, defined through a process of aggregation of BSUs was only proposed relatively recently by the IMAGE project and the data collected in this project together with the papers that have been published from the project relate primarily to cross-national comparative analyses of all-age origin-destination migration matrices. This thesis is therefore novel in investigating how different migration indicators change according spatial scale and zone configuration using more disaggregated age group data as well as all-age flows for one country and for one region of that country. The reason for examining MAUP effects for one region was to enable the analysis of indicators to begin from a much smaller set of BSUs (wards of Greater London) and therefore include a larger proportion of the total migration taking place than that between local authorities (boroughs in Greater London). The use of ward to ward flows at national level would have been problematic because of the problem of matrix sparsity. Whilst analysis of the MAUP effects has been the key focus, the review indicated no previous studies comparing internal migration in the UK based on data from the last two censuses. After making adjustments for consistency, the thesis reports the results from the first analysis of change in internal migration between 2000-01 and 2010-11 based on census data.

2. **Explain the underlying MAUP, the statistical and model-based indicators used to compare migration and the methodology by which the IMAGE Studio computes these indicators and their summaries at different scales and zone configurations. These explanations will provide the methodological foundations for the thesis and the basis on which to build interpretation of the results.**

Geographical boundary data, migration flow data and associated populations at risk were prepared and input to the IMAGE Studio, before being subsequently aggregated and processed by the software to obtain global migration indicators for aggregate spatial regions (ASRs) at different spatial scales as well local migration indicators at the BSU scale. The aggregation procedure, an adaptation of Openshaw's initial random aggregation wave algorithm (Openshaw, 1977), was explained in detail in Chapter 3. The selection of a suitable step size and number of iterations for use in computations and age group comparisons throughout the analysis was crucial, recognising that repeating this type of analysis for each age group is both time consuming and unlikely to generate further insights of significance. This experiment, the results of which are reported in Chapter 5, suggests that 10 was an appropriate step size, since reducing the step size below 10 added considerably to the amount of time and increasing the step size above 10 caused a loss of detail in the results. The results of the experiment also suggested that 50 iterations at each step was realistic; the sum of the range values for all the selected indicators showed the least variation with 50 iterations. Thus, the results reported are all based on the use of the mean and range values of the indicators based on a step size of 10 with 50 configurations at each scale.

Local migration indicators were used to create maps in order to have a geographical representation of the data at the BSU scale, while bar charts and line graphs were used to visualise migration indicators for ASRs. Visualizing ASRs at different spatial scales proved to be infeasible because different configurations of BSUs were created at each scale with no optimum zonation being defined, and consequently line graphs were used for identifying the scale and zonation effects of an indicator.

Three related indicators were selected to measure intensity (CMI) and impact (MEI and ANMR) and three more indicators were selected to measure distance (MMD and beta) and connectivity (IOC). These indicators were selected as representing key dimensions of migration (Bell *et al.*, 2001). The algebraic forms of the first three indicators were explained in Chapter 5 where it was shown that the main indicator of impact, the ANMR, is equivalent to the product of the intensity of migration in the system (CMI) and the effectiveness of migration (MEI) in moving people around the spatial system. This relationship, enabling an assessment of the relative importance of intensity and effectiveness in explaining aggregate net migration, was used to compare migration behaviour by age group in Chapter 4.

The measurement of migration distances using the straight lines between the centroids of zones at BSU level and as the average of distances between BSU centroids at ASR level, was explained in Chapter 3 whereas the derivation of the beta parameter using a doubly constrained spatial interaction model (SIM) was outlined in detail in Chapter 6, together with the mean absolute deviation, the statistic used to measure model goodness-of-fit, i.e., the difference between the flows predicted by the SIM and the observed flows in the two census periods. Migration between districts result in levels of connectivity between different areas and a simple index of connectivity for use at different spatial scales and zone configurations was explained in Chapter 6.

3. **Review the data sets available for analysis of internal migration in the UK, make appropriate selections of the origin-destination data sets to be used given the constraints on computer-processing time and adjust the chosen sets so as to ensure consistent measurements for temporal comparison. The rationale for the choice of data at a scale appropriate to fulfil objectives 4-6 is based on data availability and suitability but also on practical constraints imposed by limited resources.**

It was considered necessary to undertake a comprehensive review of the internal migration data available from different sources in order to offer a clear justification for the selection of the data that were used within this thesis. Census data are reliable; cover the national territory; are available in disaggregated form; do not have the limitations of NHSCR data; and are produced for geographical units that are reasonably consistent between censuses.

In addition to understanding the range of available migration indicators and different approaches for zone aggregation, the analysis had to be limited to certain data sets because of the constraints imposed by the time available for running the IMAGE Studio multiple times and the storage space required when generating large files containing different boundary sets and their associated attributes. Given the variation in migration propensities and patterns that occur during the life course, the decision was made to use migration matrices disaggregated by age. The census provides origin-destination flow matrices for 11 age groups but one of the issues confronted in the modelling analysis is that it is necessary to avoid sparsely populated matrices. Thus, it proved necessary for certain analyses to aggregate the data into four age groups broadly representing key stages in the life cycle to overcome the sparsity issue. The sparsity issue gets worse for data disaggregated by other variables such as ethnicity and tenure, for example, creating problems for national analysis, i.e., some of the matrices for different subgroups of migration have cells that contain mostly zeros.

It was also recognised that when it comes to making comparisons of census migration between two different time periods, 2000-01 and 2010-11, it is essential to take into account the changes that have been made to the way in which the migration data are counted and the geographical boundaries of the zones within and between which people migrate. The necessary changes to boundary changes had to be addressed in order to have comparable data. In fact, the problem of boundary incompatibility turned out to be relatively trivial, with only a handful of changes in LAD and ward boundaries requiring attention between the two periods. However, during this process, one important problem was identified, that of the exclusion of those migrants with origins unknown in 2000-01; consequently, a new methodology for estimating these flows and adding them in was developed in Chapter 3. This methodology estimates the origins of those people who should not have been identified as having an unknown origin address in the 2001 Census returns so as to compile complete sets of migration flows for the UK for 11 age groups which are comparable to equivalent data for 2010-11.

4. **Analyse and visualise the characteristics of all-age and age-group internal migration taking place between local authority districts as the 'basic spatial units' selected for the whole of the UK in order to understand the spatial patterns which the migration indicators are quantifying and the changes that have taken place between the two census periods.**

The results of the analyses at BSU level for the UK have shown a number of trends in all-age migration between 2000-01 and 2010-11, some of which confirm results reported elsewhere and some of which are new. The census data indicate that although more people were migrating in the latter period, the all-age migration rate decreased for both longer-distance migration between LADs and shorter-distance migration within LADs. Moreover, the data suggest that the average distance over which migration takes place between LADs has declined significantly. These results confirm trends from other data for the UK (e.g., Champion and Shuttleworth, 2016b; Lomax and Stillwell, 2017) and contribute to the debate on whether people are becoming less mobile in more developed countries across the world (Champion et al., 2017). These changes may be due to demographic restructuring due to the increased ageing of the population or to a range of determinants that are affecting migration behaviour such as technological change or increasing rootedness (Cooke, 2011).

The results for all-age migration between LADs also suggest that net migration is becoming less influential in redistributing the population between different places; declines in the overall migration effectiveness index and the aggregate net migration rate became apparent whilst the frictional effect of distance measured by the SIM beta parameter increased, and LADs became more connected by migration. Explanations of these changes are related to a decline in the process of counterurbanisation during the 2000s with diminishing net migration losses from the main metropolitan areas and gains in more rural areas (Lomax and Stillwell, 2015) and a fall in the willingness to move over longer distances due to a range of factors relating to household structure and both the labour and housing markets.

The spatial patterns of different 'global' migration indicators and the changes taking place between the two periods are determined by the characteristics of migration of different age groups whose 'local' behaviour, as documented in Chapter 2, is explained by various factors, usually associated with phases in the life cycle. The results at BSU level for the UK different age groups have shown that the 20-24 age group exhibits the highest migration intensities in both censuses; this is the labour force peak of the model migration rate schedule proposed by Rogers and Castro (1981) and identified also by Dennett and Stillwell (2010) using 2001 Census data. The pattern of all-age net migration losses from more urban areas and gains in non-urban areas mentioned above was shown to have been maintained in 2010-11 but different age groups were responsible for the reduction in its intensity. A sixfold classification was used to summarize how the patterns of net migration change differed between the four broad age groups, with the 15-24 year olds standing out as having a pattern of increasing net losses in rural areas, the reverse of that shown by the family age group. The patterns of change for mature workers and retired age groups were characterised by reducing net losses from the central core of the UK and increasing net gains in the peripheral areas, potentially to take advantage of the coastline as they go into retirement and are therefore not bound to a specific location for work. The analysis of migration effectiveness suggested that the impact of migration on redistributing the population increased between the two periods for those in the student and young worker age group but decreased in other age groups, since relocating for Universities or new job opportunities is on the rise (Swinney and Williams, 2016). The positive correlation between in-migration and out-migration rates increased between 2000-01 and 2010-11 for the aggregate rates and, most significantly, for the mature workers age groups, which could be affected by the UKs increasing aging population.

Finally, there are clear variations in the distance, decay and connectivity indicators for the various age groups which comprise the aggregate flows. The results obtained in Chapter 6 have demonstrated that distance is a key variable in influencing people on how far they are willing to move and incorporating a measurement of distance decay into a migration model is crucial. Migration distance has decreased between 2000-01 and 2010-11, whilst the connectivity index has increased for the same time period. Which means that in the UK, the population moves shorter distances but places are more connected by migration in 2010-11 than they were in 2000-01. With the 25-34 age group being the most connected in 2010-11, supposedly because they are the most agile work force and may have more opportunities to move after graduate school or for work. The calibrated beta values indicate that the retired and mature workers age groups were the most affected by migration distance, whilst the family and student and young workers were less affected. These results demonstrate that the older members of the population tend to be more reluctant to move over further distances.

5. **Use the IMAGE Studio to identify the effects that scale and zone configuration have on selected migration indicators for different age groups when progressively aggregating the basic spatial units the across the whole of the UK. The purpose of this analysis is to examine parameter stability across different scales and zone systems and identify changes between two time periods.**

This objective is at the heart of the thesis since the literature review in Chapter 2 concludes that most analyses prior to the IMAGE project used data relating to one particular configuration of zones at one or two spatial scales and no analyses have been undertaken of variation in indicators of age-specific migration according to the scale (the number or size of zones) and the zonation (the configuration of zones), the so-called MAUP effects. The analyses reported are underpinned by the theoretical principle proposed by Tobler (1970, p.236) that "everything is usually related to all else but those which are near to each other are more related when compared to those that are further away". In the context of internal migration, this translates into gravity theory in which spatial interaction is proportional to the sizes of the origin and destination and inversely proportional to the distance between them. We would therefore expect to observe variations in migration indicators as the size and shape of spatial units changes. The analyses reported in Chapters 5 and 6 have attempted to identify and quantify these relationships for the UK as a whole in the two study periods using data for all-ages and for age groups.

The IMAGE Studio was used to investigate the effects of scale and zonation on each selected indicators with aggregation performed in scale steps of 10 from 10 to 400 ASRs with 50 iterations at each scale. Variation in the mean values of the different configurations at each scale provided an indication of the scale effect whereas the range between the maximum and minimum values at each scale provided a measure of zonation.

The main conclusion is that the six migration indicators selected for this research vary across scale and by zonation in different ways, showing different degrees of linearity and/or scale and zonation dependence. Generally speaking, for all ages and age groups, crude migration intensity and mean migration distance vary according to Tobler's law, i.e., migration intensity falls as the number of zones in the system reduces or the size of the zones increases, whereas the distance travelled increases. This makes sense since, as the zones get larger and larger, more and more migrants will be excluded from the ASRs and the distances those remaining inter-ASR migrants travel will get longer. However, this relationship is not linear; both intensity and distance indicators are more affected by scale as the number of ASRs gets smaller, particularly below around 100 units. Moreover, the zonation effect for both these indicators appears to vary relatively little by scale; the range of values from different configurations of zones is larger when there are smaller numbers of zones but not by very much. In contrast to the characteristics of these schedules, migration effectiveness and the beta parameter both show much less variation by scale but much greater variation across different zonations as the number of ASRs drops. This conclusion implies that at whatever spatial scale migration is analysed, the impact of net migration measured by the effectiveness index and the frictional effect of distance on migration are likely to be much the same but may vary more according to the zonation when the numbers of ASRs get smaller. These results confirm findings reported elsewhere that used total or all-age migration (Bell et al., 2015; Stillwell, et al., 2016). The two remaining indicators are the aggregate net migration rate and the index of connectivity. In the former case, the indicator is a function of both migration intensity and effectiveness (equation 5.2) and consequently its relationship with scale and zonation falls between that of the crude migration intensity and migration effectiveness index whilst the index of connectivity shows a much more linear form, with system connectivity reaching 100% at around 30 ASRs.

It was recognised that, although graphic visualisations of the scale and zonation effects proved helpful for understanding the variation apparent for each indicator, they did not provide a summary measure that allowed us to compare the scale effects for different time periods, for example. A 'total scale effect' was therefore introduced as a numeric summary by adding the percentage change of the mean values of each indicator between each scale step. The total scale effects shown in Table 8.1 summarise the results and show that the effect of scale on crude migration intensity (CMI), on the migration effectiveness index (MEI), the aggregate net migration rate (ANMR), and the mean migration distance (MMD) all increased between 2000-01 and 2010-11. Table 8.1 also shows a 'total zonation effect' which was calculated by adding together the difference between the minimum and maximum values at each scale step. Here again, the results show increases in the zonation effects between the two periods for each of the indicators.

Table 8.1: Summary of total scale and zonation effects for some indicators for the UK in 2000-01 and 2010-11

	Total scale effect (%)		Total zonation effect (%)	
	2000-01	2010-11	2000-01	2010-11
CMI	0.74	0.77	5.85	6.22
MEI	0.14	0.34	23.23	25.03
ANMR	0.87	1.1	0.76	0.82
Mean MD	0.84	0.91	2.45	2.71

Source: Estimates based on data from 2001 and 2011 Censuses

Whilst these conclusions are based on general observations drawn from the results of the analyses of all-age internal migration, it is clear that there are some significant variations, and in some instances, anomalies, when the scale and zonation effects for same set of indicators are computed for specific age groups. For example, the 15-19 age group has shown to have a different shape of the MEI and ANMR schedules in both time periods (Figures 5.9 and 5.10), compared to all other age groups, demonstrating that scale is only an important consideration for 15-19 year olds, with an increased MEI and ANMR scale effect from 2000-01 to 2010-11. This age group contains the students who migrate to their places of higher or further education and those spatial pattern of net migration is almost the reverse of that of other age groups, as shown in Chapter 4.

The relationship between CMI and MEI for all age groups are represented with the INMI (as shown in Figure 5.13), have demonstrated that the 15-19 year olds exhibit the highest net migration impact, driven by above average MEI and CMI slope relative to the average. This age group consist of a higher MEI ratio than CMI slope ratio, and the MEI ratio has become more significant over the decade; whereas the 20-24 and 25-34 age groups have the highest CMI but a low MEI.

The analysis of the scale and zonation effects of migration within the UK shown in Chapter 5, has demonstrated that the CMI and the ANMR rates are scale sensitive, in contrasts to the MEI which tends to be less scale dependent, except for the 15-19 age group, which is an extremely active age group, moving across the UK. A distinct scale effect for MEI for 15-19 age group occurred because, in contrast with other age groups, as the scale changes to fewer ASRs, the ratio of net migration to total migration reduces significantly.

6. **Undertake analyses of the scale and zonation effects, as well as the spatial patterns of age-specific migration for one region (Greater London) that is part of the UK in order to identify the relationships between scale and selected indicators of internal migration in this region and make comparisons with internal migration in the country as a whole.**

Previous analyses using the IMAGE Studio, both reported in this thesis (Chapter 4-6) and in the literature, have been undertaken at the national scale with relatively large spatial units as BSUs. In the UK, the use of LADs is appropriate at the national level since matrix sparsity becomes increasingly apparent with smaller spatial units. The aim of the research reported in Chapter 7 was to investigate migration taking place within one region of the UK but with BSUs that were considerably smaller than LADs. In selecting census wards of Greater London (GL), inter-ward migration matrices contained a much higher proportion of shorter-distance residential moves and the problem of sparsity was much less evident than in other regions of the UK.

Initial analyses of the six selected migration indicators at the BSU level indicated distinctive patterns of migration intensity, impact and distance moved within GL as well as changes in a city that experienced a 12.3% increase in population between 2001 and 2011. All-age migration intensities measured using turnover rates have a distinct core (Inner London) - periphery (Outer London) pattern and unlike the national trend of decline, migration rates both between and within wards of GL increased during the decade. The explanation for this may stem from the behaviour of people in a vibrant capital city with a buoyant labour market (despite the financial crisis during the period) but it may also be due to the housing market; house prices in GL are significantly higher than elsewhere in the country, increasing disproportionately and causing problems for first-time home buyers in particular and pushing increasing numbers of people into private renting, a sector which has always been associated with higher mobility levels (e.g. Krumm, 1984; Hamnett, 1991; Boyle, 1993; Boyle, 1998). The core-periphery patterns of local migration intensity are most evident for the family age groups which also have the highest CMI and the most distinct pattern of migration impact. Migration effectiveness and net migration rates show the general pattern of deconcentration of households from wards in Inner London to those in Outer London. Interestingly though, it is the older age groups (60+) that have the largest MEI values in both periods. The global indicators of MEI and ANMR for GL both decline, following the national trend, as does the MMD for inter-ward flows, which in GL drops from 5.56km to 5.23km, a decline of 6% compared to that of 12% in the inter-LAD mean migration distance for the UK as a whole. Ward connectivity also follows the national trend by increasing at BSU level from around 18% to 35%, with another distinctive geographical pattern of higher connectivity in more central areas and lower connectivity further away from the GL core.

The IMAGE Studio was used to investigate the effects of scale and zonation on each of the selected indicators with aggregation performed in scale steps of 10 from 10 to 620 ASRs with 50 iterations at each scale. The analysis of the scale and zonation effects of migration within GL shows that the mean CMI and mean MMD are scale sensitive and are very similar in shape to the national inter-LAD trajectories and with relatively small zonation effects, although the mean CMI is higher in 2010-11 than in 2000-01 for the GL case study. The MEI appears to be much less scale dependent but with smaller numbers of ASRs (less than around 130 spatial units), the MEI rises rather than falling slightly as it does with the national data and as the zonation effect expands; migration effectiveness in both periods is at its highest at the scale of 10 ASRs. The MEI at these smaller scales is not sufficient to influence the ANMR trajectory, which continues to decline in a manner similar to that observed from the national data. The fact that the MEI rises when the number of ASRs gets smaller shows that there has been an effect of population redistribution (Rees et al., 2016). The frictional effect of distance measured by the beta value shows more scale independence but the schedules for the two time periods are not parallel; there is a switch over as scale gets larger with beta parameter being slightly higher in 2000-01 than 2010-11 with smaller numbers of ASRs. As with the MEI, the beta value increases as the ASRs get larger, unlike the beta for the national data which declines. The trajectory of the global connectivity index for GL, however, is similar to the national schedule, showing relatively linear scale dependence.

The total scale effects shown in Table 8.2 summarise the results and show that the effect of scale on CMI and ANMR has increased between 2000-01 and 2010-11 whilst effects on the MEI decreased. The total effect is largest for the ANMR. The ‘total zonation effect’ also shown in Table 8.2, shows that the MEI has a strong zonation effect in 2000-01 that increases in 2010-11, whereas the ANMR has a weak zonation effect in 2000-01 that also increases in 2010-11. Similar to the LAD at national level, the total zonation effect for GL has increased for all three indicators. Even though the trends are similar, some of the differences between national level and GL consist of differences in the volume of some indicators, e.g., in 2010-11 the MEI at national level has a total zonation effect of 25.03 compared to 5.50 for GL.

In terms of the MMD, the total scale effect dropped slightly, whilst the total zonation effect increased over time; this signifies that the scale size has a lesser impact on MMD but has become less predictable. The total scale effect of the mean migration distance in GL for both time periods, shows negative values, which are a product of the way the total scale effect was calculated. The total zonation effect for the mean migration distance shows an increase from 2000-01 to 2010-11, which is similar at the national level.

Table 8.2: Summary of total scale and zonation effects for some indicators for Greater London in 2000-01 and 2010-11

	Total scale effect (%)		Total zonation effect (%)	
	2000-01	2010-11	2000-01	2010-11
CMI	0.73	0.77	1.38	1.51
MEI	0.38	0.28	5.05	5.50
ANMR	0.66	0.80	5.00	5.57
Mean MD	-0.65	-0.64	5.64	5.78

Source: Estimates based on data from 2001 and 2011 Censuses

These conclusions have shown the all-age internal migration observations from Chapter 7, but these results have also experienced some differences in the scale and zonation effects when disaggregated into specific age groups. Some of these key observations were that for the CMI, all age groups experienced an increase in their respective scale effects, but the 15-19 age groups stood out, since they showed the highest and most significant increase from 2000-01 to 2010-11, which is consistent with the results at national level. Whilst the total scale effect for the MEI decreased for most age groups, the 20-24, 25-34 and 65-74 age groups increased, having the 25-34 age group showing the biggest increase from 2000-01 to 2010-11, indicating that this age group had the strong population redistribution in GL. Which is similar to the ANMR where all the age groups experienced a decrease apart from the 10-24, 20-24, 25-34 and 65-74 age groups. All age groups show similar patterns for the MMD to that of the all age group, with a decrease in the MMD as the scales become smaller. Although the family and mature workers age groups have shown an increase in the mean migration distance, the total MMD has decreased over time, indicating that although the rate of migration is increasing, migrants are moving shorter distances than they used to.

In terms of the zonation effect, the CMI has increased across all age groups with the exception of the five age groups 0-4, 5-9, 35-44, 45-59 and 60-64. The variation in MEI due to the zonal configuration at each scale has become more important and demonstrated and increase for most age groups except for the 0-4, 35-44 and 60-64 age groups. The total zonation effect for the ANMR has also increased for all age groups over time, with the exception of the 0-4 and 60-64 age groups who have experienced a decrease. The zonation effect for the MMD have also increased over time except for the family age group, who have experienced a decrease from 2000-01 to 2010-11.

8.3 Evaluation of the IMAGE Studio

The IMAGE Studio is the only software currently available that enables spatial aggregation of BSUs to create new spatial systems for which indicators can be computed. Each of the subsytems in the software is discrete and all the computations are stored in directories created automatically, so it is possible to create data for a set of different spatial scales and compute indicators, such as the CMI, MEI and ANMR, or run the SIM for the different zonal systems created previously in order to quantify the frictional effect of distance. An extensive user manual is available and provides useful insights, but use of the system involves a steep learning curve and some trial and error. The IMAGE Studio is therefore a powerful software suite for aggregating large data sets of BSUs into different configurations, enabling the user to compute migration indicators for sets of ASRs at different spatial scales. However, during the course of this thesis some limitations of the software were encountered which are reported in this section, together with some suggestions for improvement.

The IMAGE Studio was designed initially for analysis of internal migration taking place within a single nation. In this thesis, the software has been use to explore the scale and zonation effects of migration within one region, that of Greater London, as well as for the migration within the UK as a whole. It became evident that, for single region analysis, the software does not allow the flexibility of having a 'rest of the country' region, which could be held constant throughout the BSU aggregation processing. This limitation means that flows across the border of one region to adjacent regions and beyond are excluded. These maybe sizeable and therefore a significant volume of migration into and out of the selected region's zones, particularly those closer to the boundary with other regions is not included. Having a 'rest of the country' zone option would be helpful for including these flows and providing a more comprehensive approach to making comparisons across different regions.

The implications of these results link to further research and how the IMAGE Studio might be improved. In terms of practical use, i.e., how a local authority might make use of the IMAGE Studio in preparing population estimates and projections. The results for GL suggest that just using inter-ward flows within London would exclude quite a significant proportion of flows affecting estimates/projections. Therefore, a local authority would probably want to estimate/project at a ward or even smaller scale and would need to include the movements into and out of either the rest of the UK and the rest of the world (or flows in from zones defined as being adjacent LADs and other LADs in the UK) in order to close the system. This would necessitate modification of the data preparation system in IMAGE Studio to indicate 'rest of the system zones' and then modification of the aggregation code to hold 'rest of the system' zones constant throughout the aggregation process. It would also require data inputs that included flows into and out of wards in the LAD from elsewhere as well as an inter-ward matrix.

Another issue identified in the modelling analysis in Chapters 6 and 7 is that it is necessary to avoid sparsely populated matrices in order to calibrate spatial interaction models and derive optimum distance decay parameters. As explained previously, it became necessary to aggregate the data into four broad life-cycle age groups to overcome the sparsity issue. While running each of the age group data sets with the SIM in the IMAGE Studio, an error occurred for certain age groups because the balancing factors in the SIM were not converging and therefore a beta value was not being calibrated and the model was unable to predict a flow matrix. It became apparent that one cause of the problem was an excess of zero flows in the matrix. SIMs are designed to model flows rather than non-interaction and there are limits on the ability of the model to calibrate when the number of zones is large and the matrix is relatively sparsely populated. The workaround for this problem was to aggregate matrices until there were sufficient non-zero cells in the matrix for the SIM to calibrate the distance decay parameter. Another approach to this problem might have been to add a constant value (say, 5 or 10) to the flow in each cell of the matrix, thus eliminating the sparsity problem and allowing the model calibration to occur. Adding this constant value is a workaround for the Iterative Proportional Fitting (IPF) methodology (Lomax and Norman, 2016). Time constraints did not permit further experimentation with this approach to understand the sensitivity of results to the value of the added constant. This is a further reason why analysis of migration flows disaggregated by other variables such as ethnicity and tenure, for example, creates problems for national analysis.

As well as these limitations, there are three other issues that might be considered as ways of enhancing the IMAGE Studio. First, there is no in-built mechanism to enable the indicators to be mapped at BSU level or for any higher level aggregation, despite the fact that all 'geographies' are saved by the system and could be retrieved for mapping indicators if required. A mapping facility might be added or developed relatively easily.

Second, is there a better way of outputting the results by scale step? The IMAGE Studio creates a large amount of data in CSV files for each output data style (e.g., mean, minimum and maximum) including numerous columns in each file for all available indicators. The outcome is a large amount of files containing a lot of data. In this thesis, Excel was used to collect and manipulate the results. These 'data' need to be manipulated in the right format in order to provide useful insights and to create comprehensible graphs. Many formulae were used in Excel to collect all the required data and to group them in the right location for this process to work. This was repeated for each time the IMAGE Studio was run to create data, e.g., for all different age groups and time series. It would be advantageous to have this process simplified or automated to facilitate the data processing given the large quantities of data generated by the software.

Third, only a doubly constrained SIM model is available for calibration at the moment; it would be valuable to extend the model framework to include other variants (singly constrained and unconstrained versions) of the SIM family (Dennett, 2010), as well as versions enabling origin-specific or destination-specific decay parameters to be calibrated (Stillwell, 1978). Moreover, the inclusion of deterministic models (e.g., based statistical regression) would be valuable in order to address cause and effect although models of this nature would require the availability of further sets of explanatory variables for the system of interest under study. However, population data are input and can aggregated from BSU level – so regression analysis could be automated that looks for example at the relationship between net migration rates and population density. Moreover, data on average population size of spatial units can be generated at each scale by simply dividing the national population by the number of ASRs. This enables graphs to be drawn that show mean indicator values by average population size, thus allowing a clearer understanding of the relationship between migration indicators and population density. Courgeau (1992) showed the linear relationship that occurs when CMI is plotted against logged values of population density at different scales and linear regression can be used to predict total migration intensities (Bell *et al.,* 2015).

Following on from this, the final point is that there is the potential to use the IMAGE Studio to predict migration in the future at any spatial scale or zone configuration. This would require further development of the modelling framework and additional data for the projection period on which to base any projection.

8.4 Future research

This thesis has reported many results, for several indicators, different age groups, two time periods and different geographical scales within the UK. This research can be expanded in multiple ways. First of all, scale and zonation effects associated with other sets of census migration data for the UK can be explored. The data review in Chapter 3 indicated quite a long list of variables used to disaggregate migration: economic activity, industry of employment, household composition, qualifications, time since last worked, approximated social grade, number of people living in households, age by sex and resident type, economic activity by sex and limiting long-term illness, sex and occupation by employment status and hours worked and also sex and age by distance travelled to work, age of household reference person (HRP) by sex and marital status (headship), schoolchildren and students in full-time education living away from home in term-time by age, general health and limiting long-term illness and occupancy rating by age and also shared/unshared dwelling and central heating and occupancy rating by religion of household reference person. Whilst each of these variables might provide different insights, one crucial key limitation is that all these sets of the census data may be subject to the sparsity problem identified earlier, where many of the matrices might have too many zeros and will limit their use, at least when it comes to modelling. A solution would be either aggregation of the data or the addition of a constant to the data, but as mentioned previously, this would need further research to define which constant was most suitable for the selected data.

The results of the 2021 Census will become available in due course and further time comparison will become possible to see what more recent changes within the UK have occurred and to obtain a more up-to-date picture. Apart from censuses, others sources are available from which data can be extracted for further investigation. The use of other data sets, such as patient re-registration data and data from the World Bank, would be very useful to confirm results from census data, but also provide an annual time series of scale and zonation effects. Furthermore, NHS patient registration data on an annual basis would provide a more up-to-date picture of change.

The use of other migration indicators might offer further insights into the sensitivity of internal migration to zone size and shape. For example, an index of spatial inequality might be used to measures the difference between the observed flows in the migration matrix and an expected flow distribution. The expected distribution may take different forms but one standard is that the total flows out of any single zone will be distributed equally to all other zones in the system. The extreme value of the index would be where all the flows out of one zone end up in one of the other zones in the system.

As mentioned previously, the IMAGE Studio can be developed further to include the option of running data for one region but closing the system by adding an 'elsewhere in the UK' region. This new option will allow further research on the scale and zonation effect to be examined and to be compared across different regions.

Lastly, further research can be carried out using the IMAGE Studio with data disaggregated by age or other variables that might be available to compare what is happening in the UK with other countries in north-west Europe.

8.5 Final conclusion

In the context of internal migration in the UK, the results reported in this thesis have demonstrated that migration indicators will vary according to the spatial scale and the zone configuration that is used to measure these indicators. This thesis therefore underlines the necessity for population geography researchers to remain sensitive to the spatial systems they use to study spatial phenomena and recognize the limitations as well as the benefits of macro data sets prepared and published by governmental or non-governmental institutions in terms of understanding internal migration behaviour and dynamics.

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