Chapter 1
Introduction

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People in Time and Space

Demography's task is to document, analyse and theorize population dynamics, the ways in which spatially defined populations grow, shrink or redistribute themselves over time. Historical demographers, in particular, strive to model population processes that spread across space and unfold over time, and this volume explores innovative ways in which demographers are doing so. The eight chapters that follow utilize newly available sources of historical data and implement novel methods to assess the role of time and space and their intersection in core demographic, historical and sociological theories. The theories, methods and substantive findings presented here also offer models and insights of value to demographers more broadly; space and time are critical elements in all population studies, as important for scholars attempting to understand current populations, or to make projections into the future, as for those focusing on the past.

Spatial and temporal analysis feels fresh and current, yet has a long history in the social sciences. As Voss (2007) points out, spatio-temporally explicit research agendas predate contemporary interest in all of the core topics of population research. Perhaps the most widely recognized and iconic example of the value of spatial and temporal analysis was provided by John Snow during the 1854 London cholera epidemic. His map of cholera deaths revealed clustering around the Broad Street water pump, supporting his theory that cholera was spread through the contamination of water (Snow, 1855). In another example, the dramatic maps published by the U.S. Census Bureau about population change prior to the 1890 census informed Frederick Jackson Turner's famous declaration that the American frontier had closed (Turner, 1893).

Demographers, too, have long considered space and time simultaneously. At the very beginning of modern population studies in the nineteenth century, analysts revealed that population processes operate through time in a spatial context. The

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demographic transition, a major trope in contemporary and historical population analysis since the 1940s (see, for example, Davis (1945)), has benefited from attention devoted to the pace and location of change. Nowhere is the mix of the spatial and temporal clearer than in the Princeton European Fertility Project, whose capstone volume (Coale & Watkins, 1986) relies on the geography of population processes to tell the story of changing fertility. Indeed, the notion of diffusion of fertility regulation continues to be salient even years after the publication of the Coale and Watkins summation (Watkins & Danzi, 1995; Chapter 2 by Haines and Hacker, this volume).

Nonetheless, social scientists' interest in 'putting people into place' (Entwisle, 2007) – their attention to how social processes are embedded within temporal and spatial contexts – has grown dramatically in recent years, from both theoretical and applied empirical perspectives. In social theory, the roles of time and space are changing. The practice of equating variation over space with temporal progress along a universal trajectory has been denounced by sociologists, geographers and historians (Thornton, 2001, 2005; Massey, 2005; McClintock, 1995) as what Thornton (2001, 2005) critically calls 'reading history sideways'. Scholars now recognize the necessity of analysing space and time together, both because these dimensions are inextricable from one another and because neither can be reduced to the other. Such theoretical notions as 'social interaction', 'social capital', 'diffusion and contagion' and 'spatial mismatch', for example, require explicit specification in spatial and temporal terms.

Likewise, the quest for analytic models of space-time dependence is not new, but social scientists continue to seek ways to overcome the inherent limit condition to any proper solution, that 'clarity in one dimension demands restriction in the other' (Knox, 1964). Elegant and powerful methods of quantifying the proximity of events in space and time have been available since well before the advent of the geographic information systems that breathed new life into spatial social science. Signature examples, resulting from efforts to define epidemicity, are found in the two-by-two cross-classification of nearness (or not) in time and in space proposed by John Knox (1964) and its generalization to a covariance measure for continuous distributions of nearness by Nathan Mantel (1967). These measures of space-time association, in turn, owe a debt to the still earlier successes of statisticians who developed the two-dimensional spatial analogues to univariate descriptive statistics known now as 'centrographic statistics' (cf. Lefever, 1926; Furfey, 1927).

Why, then, does the interest in space-time analysis remain fresh and why have the measures just described not found broader application? The answer appears to lie in the conceptual and empirical divide between research questions that ask where and when did an event occur versus those that ask whether the quantity of something is systematically related to the quantity that is near in space and prior in time. The former correspond to point patterns, which were the subject of centrographic statistics and the associational measures proposed by Knox and Mantel. When quantity, rather than occurrence, frames the research question, the measurement of dependence, or autocorrelation, is readily resolved in either time (e.g. Durbin & Watson, 1950, 1951) or space (e.g. Moran, 1950; Geary, 1954), but our ability to separate

and quantify both simultaneously is almost always challenged by too little information, a problem known in econometrics as 'underidentification'. The problem is that we measure spatial dependence by the contemporary coincidence of quantity similarity with locational similarity. This 'coincidence in values-locations' is therefore already defined in temporal terms: it is not only an instant coincidence, but also the product of what happened in the past and what has subsequently spread through geographic space (Anselin, 2001a). Identification of true spatial dependence and true temporal dependence (and the separation of the two) therefore requires additional leverage. The authors of the following chapters find this leverage in a variety of ways: by introducing a time-lag in the spatial dependence term, by adapting the point pattern approach to achieve insight into questions about quantitative changes in locations over time or by gaining clarity over the spatial dimension by restricting the temporal dimension.

Such methodological advances have given historical demographers a rich new set of tools with which to re-examine received ideas and pose new questions. This volume is the result of an effort to assess recent contributions and advances, and to demonstrate how valuable this new research will be for re-imagining historical and contemporary questions. The eight chapters published here were among a larger group of papers presented at the Workshop on Space and Time organized by the International Union for the Scientific Study of Population in Minneapolis, MN, October 31–November 1, 2006 at the Minnesota Population Center (MPC) of the University of Minnesota. The workshop was sponsored by the MPC, the Committee on Historical Demography of the International Union for the Scientific Study of Population and the Inter-university Consortium for Political and Social Research (ICPSR). Three of the editors of this volume, along with Steven Ruggles of the MPC, served as scientific committee members and conveners.

The selections included in this volume cover a variety of core demographic topics and explore population change from the eighteenth to the twentieth century in the United States, Latin America, Europe and the Islamic world. The first three chapters examine mortality and fertility in the framework of demographic transition theory, and are followed by three works on migration. The volume concludes with two chapters demonstrating the broader sociological application of spatially and temporally explicit concepts and methods. The new data, innovative methods and substantive results reported here demonstrate valuable recent advances in spatio-temporal approaches to historical demographic research and suggest their striking potential for the future. This introduction begins by examining the theoretical bases on which the chapters are written. We emphasize the long-standing importance of the issues that the authors consider, arguing that the fundamental contribution of these papers is their development of new ways to analyse phenomena that have been at the heart of population studies for a long time. Our second section discusses the innovative data used in the chapters and the ways that such data have recently become available. In the third section we focus on the methods implemented by the authors to analyse their data and to answer their questions. The wide variety of methods presented in this volume illustrates the many new directions in which studies of space and time will reach in coming years. Finally, we turn to substantive

findings, presenting each chapter in turn and exploring the ways they come together to provide new lenses through which to view space and time in historical population studies.

Theoretical Bases

The papers in this volume describe, test and challenge a range of theoretical formulations that are well established in demographic scholarship and, in so doing, demonstrate the power of these new approaches to historical populations. One of the most important accomplishments of the work represented by these chapters is their ability to bring new light to well-established theory by expanding upon or combining existing approaches. Some add spatial elements to traditionally temporal theories; others add temporal elements to traditionally spatial theories.

At the heart of demography – especially studies of the redistribution of population or changes in rates and determinants of population growth – is the notion of spatial diffusion: people and their demographic behaviours move through space at a regular pace over time. This core theory explicitly or implicitly animates all of the work presented in this volume. Spatial diffusion suggests that people and patterns of demographic change can flow across space in different ways, as waves spilling over barriers or discrete nodes in dense social networks, modifying other patterns of behaviour they encounter. The space over which people, ideas and behaviours diffuse is neither empty nor inert (Massey, 2005): people spread over uneven terrain that may already be inhabited; ideas spread among people who may hold competing beliefs; new norms and behaviours spread across societies that may be more or less able to support them. Diffusion is an explicitly spatial process, but also occurs over time. The social, economic, political and cultural factors that shape it also exist in and change over time. At any given moment, however, diffusion processes are identified and assessed through the location and measurement of patterns of spatial clustering.

The concept of diffusion can add a spatial element to traditionally temporal theories, such as the demographic transition. This theory posits universal change over time, from a high-mortality/high-fertility equilibrium to a low-mortality/low-fertility equilibrium. Scholars associated with the Princeton European Fertility Project began to explore spatial dimensions of the demographic transition when structural factors failed to fully explain fertility decline (Coale & Watkins, 1986). Diffusion suggests that, rather than making independent appearances in various locales when certain socio-economic thresholds are reached, end-state behaviours may start in one or more locations and then spread gradually across space and through time, reaching places that are farther away later in time. If that were the case, and there were few barriers, it would be easy to predict when in time that end-state behaviour would reach a given location. Three of the following chapters complicate this view by applying the concept of diffusion to the study of transitions between demographic regimes. They contribute to both demographic transition and spatial diffusion theory by asking whether demographic outcomes tend to spread

from person to person (Schmertmann, Potter and Assunção); by exploring structural factors that may have impeded or accelerated the spatial diffusion of demographic practices (Haines and Hacker); and by situating demographic behaviour in political and ideological – in addition to geographical – space (Guend).

Classic theories of migration explicitly involve diffusion over and concentration in space: on the one hand, the dispersion of people from more to less densely settled areas (Turner, 1893); on the other, the attraction of people to established centres of population (Ravenstein, 1885). Although time often remains implicit in theories of migration, this dimension is critical, both because the movement of individuals and populations occurs over time and because migration is thought to undergo secular increase and acceleration as a result of modernization and industrialization (Lee, 1966). The three chapters in this volume dealing with migration bring time to the foreground and offer historically contextualized ways to study and theorize migration and the resulting diffusion and clustering of population in space. The authors of these chapters add an explicit temporal dimension to theories of migration by assessing barriers to the diffusion of historical populations (Darlu, Brunet and Barbero); by assessing the ways in which distance and its meaning change over time in a modernizing and nationalizing context (Ekamper, Van Poppel and Mandemakers); and by examining the effects of the environmental, economic and social features of space on the temporality and shape of population diffusion (Gutmann, Deane and Witkowski).

Social scientists typically aspire to produce ‘timeless’ and ‘placeless’ theories and inferences that can be generalized across location and era (Griffin, 1992), while historians seek to demonstrate the contingency of social processes by contextualizing them in time and place. The chapters in this volume unite the two approaches; by analysing the role of time and place in social processes, our contributors seek to further develop well-established social theories. These approaches have also proven useful for scholars working outside the core demographic themes of mortality, fertility and migration. The final chapters test propositions about urban growth in specific U.S. cities at various points in the twentieth century (Beveridge) and ask how spatial patterns of social inequality change with the dominant regime in a colonial setting (Curtis). The work presented in this volume goes well beyond the application of general social theories to particular times and places. The authors, instead, ask how time and space function within demographic and social theories, while taking seriously the ways in which ideational change can confound the simplicity of diffusion, and while paying close attention to the role of social, economic and political structures in advancing or impeding change over time and diffusion over space. The tension between the smooth spread of people and concepts and the existence of barriers to diffusion give life to the work in the book.

Data for Analyses

In a masterful survey of the renewed interest in spatial demography, Voss (2007) emphasizes the changing role of data at different units of analysis in the transformation of demographic research. He points out that, since the 1970s,

individual-level data have become increasingly available while high-performance computing environments have offered improved ways to analyse them. Together, these developments have engendered extremely valuable research. However, these individual-level data are not as well-suited to spatial analysis as the aggregate-level data that formed the basis for most earlier demographic analysis. Only in the last decade have new approaches to aggregated data and newly constructed data sets significantly improved researchers' ability to analyse the role of space and time in determining demographic change in the past. Producing these data sets is often a straightforward matter of transcribing the contents of books of census results that have been published in great quantity over the past two centuries. In other instances, utility is added by merging or matching data from multiple sources, as Gutmann (2005a, 2005b) has done for the population and agriculture of the Great Plains or as Haines (2004) has done for the counties of the United States. Projects to produce improved and more useful data sets by harmonizing previously-separate raw data sources usually focus on the counties of the U.S. and its territories and have been undertaken at the University of Minnesota, Colgate University, the University of Wisconsin and ICPSR at the University of Michigan. These improved data are supplemented by increasingly useful information about the location of the spatial units whose attributes are represented in the data and by the new and sometimes reconfigured analytical methods that we describe in the next section of this Introduction.

In addition to some of the improved or newly available data sets created for the United States and its territories, contributors to this volume make effective use of spatially referenced population and mortality data for microregions of Brazil and national level data for Muslim countries. They have also found creative ways to exploit individual-level data: for example, surnames are extremely valuable in linking the geographic origins and destinations of migrants, while marriage documents provide an extremely rich way to show how patterns of migration changed over time in concert with deep-seated transformations in society, economy, political life and infrastructure. These data, when combined with new ways of thinking about underlying theory, facilitate the use of emerging methods to study important demographic issues. A large fraction of the aggregate- and individual-level data utilized in this volume is now available through the University of Minnesota's National Historical GIS repository (http://www.nhgis.org) and IPUMS-International (https://international.ipums.org/international/). These collections also include data at other spatial scales, including census tract data and an extremely accurate and useful set of digital geographical data that locate political and administrative units in coordinate space.

Innovative Methods

Although historical demography has been applauded as one of the few fields of historical research that has recognized and embraced the utility of traditional multivariate techniques (Griffin & van der Linden, 1999), it is not hard to

recognize how differences in overt disciplinary objectives have constrained intellectual progress. Social scientists typically work hard to escape the spatial and temporal constraints of their studies. By definition and intent, most do not seriously ground either the theories they use or the analyses they perform in the local (temporal and spatial) contexts of the data-generating processes they study. On the other hand, most historians, including social historians, are typically indifferent to the conventions of formal social science, particularly those calling for the development and application of codified theory and the use of formal inferential techniques and methodologies. A profound skepticism about the power of formal social science to elucidate historical processes has made historians reluctant to concern themselves with methodological advances in the social sciences and to explore how emerging techniques can be fruitfully applied to historical research (Griffin & van der Linden, 1999: pp. 3–8). Given the interest of social historians in 'localizing' social processes, this is an unfortunate aversion. Recently, however, innovative approaches to historical theorizing give reason to believe that thinking of events in the past as parts of a process moving through time and across space is becoming more commonplace. A new consensus recognizes that events occurring at a given point in time are affected by earlier events, and that events occurring in one location are affected by similar events in a neighbouring area. Although the traditional methodological paradigm assumes the independence of analytic units, this new consensus tells us that interdependence (temporal and spatial autocorrelation) is the rule, requiring an explicit modelling of two-way or multi-way interactions over space.

In recent years, rapid advances in the technology of spatial data handling – such as geographic information systems, software for spatial data analysis and the explosion in available geo-coded data – have created the infrastructure for geographical analysis to become part of the standard technical toolbox of historical demographers. Our intent in publishing this collection of essays is to demonstrate the utility and promise of explicit attention to space-time dependencies in historical inquiry. Although the cases addressed by our contributors are significant on their own terms and are of clear relevance to historical demographers, the purpose of this collection is to display in an accessible manner when, why and how the application of various formal methods generates deeper, more satisfying explanations and interpretations of historical processes. To this end, the common denominator of our eight essays is their use of distribution maps, which are the natural graphical representation of geographic data.

Maps are the oldest coordinate graphs, dating back to ancient Egypt. All maps are 'distribution maps' in the sense that it is impossible to represent relative geographical location without showing the distribution of something (Robinson & Sale, 1969). Statistical maps, which illustrate the geographic distribution of quantities or of events, are substantially newer, but are still among the earliest statistical graphs. The fundamental objective of qualitative distribution maps is to present the relative geographical location of spatially rendered phenomena. Statistical maps typically graph the distribution of a variable at one point in time, but can also illustrate the distribution of change in a variable between two points in time, or can be arrayed in temporal sequence, elegantly summarizing both spatial and temporal variation. Our

contributors repeatedly show how heuristically useful these most simple maps can be through the presentation of temporal sequences of maps as evidence (or counter evidence) of space-time interaction.

The most common statistical map is the choropleth map, which uses colour or shading to represent relative quantities that are tied to enumeration districts on the ground. Alternatively, the graduated symbol map employs differentially sized symbols to identify levels of a given variable at specific locations. The graduated circle is one of the oldest of the quantitative point symbols used for statistical representation. By quantifying the relative magnitude in point locations, these maps efficiently identify geographic outliers and represent temporal stability or change. Both types of maps improve upon tabular statistics, which are very convenient for many purposes, but array data alphabetically rather than geographically. It is hard to imagine an alternative to these statistical maps that could be more universally intuitive or informative for comparing magnitudes in various places. The majority of our contributors employ this method of visualization.

The visual inspection of distribution maps, however, has long been recognized by cartographers as unreliable in terms of detecting spatial clusters and patterns in the data. Human perception tends to be biased towards finding patterns, even in spatially random data. It is by now widely accepted that the map as a visualization device cannot be left to unconstrained human interpretation and needs to be augmented with tools to formally assess pattern and structure. Many of our contributors therefore apply exploratory spatial data analysis (ESDA) and its space-time extension, exploratory space-time data analysis (ESTDA). ESDA is a subset of exploratory data analysis (EDA) that focuses on the distinguishing characteristics of spatial data and, specifically, on spatial autocorrelation and spatial heterogeneity (Anselin, 1994). The point of departure in ESDA is the same as in EDA, namely to use descriptive and graphical statistical tools to discover patterns in data and suggest hypotheses while imposing as little prior structure as possible (Tukey, 1977). More specifically, ESDA is a collection of techniques to describe and visualize spatial distributions, identify atypical locations or spatial outliers, discover patterns of spatial association, clusters or hot spots and suggest spatial regimes or other forms of spatial heterogeneity. Central to this endeavour is the notion of spatial autocorrelation or spatial association (Cliff & Ord, 1981; Upton & Fingleton, 1985).

The most popular statistic of global spatial autocorrelation is undoubtedly Moran's *I*. Moran's *I* is simply the spatial analogue of a correlation coefficient; it summarizes the strength and direction of neighbouring values of a variable, *Y*. If we imagine a scatter plot created by the bivariate distribution of the value of *Y* in each locale paired with the average value of its neighbours, we can identify the form of spatial association affecting each locale according to its position in each of the four quadrants of the scatter plot: higher than average value of *Y* whose neighbours are also higher than average (the upper right quadrant), lower than average value of *Y* paired with neighbours whose average value is also lower than average (the lower left quadrant), higher than average value of *Y* whose neighbours are lower than average (the lower right quadrant) and lower than average value of *Y* whose neighbours are higher than average (the upper left quadrant). This scatter plot is a

'local indicator of spatial association', or LISA (Anselin, 1995). When mapped, it effectively diagnoses the location and form of spatial clusters. It is also useful to consider the bivariate LISA as a simple extension of the univariate LISA. Whereas the numerator of the univariate LISA gives the covariation of the (standardized) value of a variable, *Y*, at a given locale with the average value of that locale's neighbours, the numerator of the bivariate LISA gives the covariation of the (standardized) value of *Y* at a given locale with the average of neighbouring values of another variable, *X*. Another popular global statistic of spatial association is Getis and Ord's *G*. Because *G* only measures overall spatial clustering in the high-high and low-low quadrants described above, its interpretation is restricted to positive spatial autocorrelation. Specifically, if *G* is larger than its expected value, then the overall distribution of *Y* shows a preponderance of high-valued clusters. A prevalence of low-valued clusters is indicated when *G* is smaller than its expected value (Getis & Ord, 1992).

The modes of spatial analysis described so far, from distribution maps to measures of spatial association, have been facilitated by recent advances in geographic information systems technology, which map data onto the spatial locations they describe. Locating data in space, however, can impose temporal constraints on analysis, and measures of spatial autocorrelation typically capture patterns only at one point in time. The contributors to this volume, therefore, draw on innovative methods of statistically assessing the temporal dimension of spatial association in a variable of interest. For example, an effective extension of ESDA is found when the local statistic is converted into an estimator of first-order space-time dependence by combining the (spatial) distribution of *X* at time *t* with the spatially lagged distribution of *X* at time *t-1* (Chasco & López, 2004). In this instance, the LISA gives the covariation between *X* at a given locale at a given period in time with the average neighbouring *X* at a previous period in time.

Many of our contributors use these global and local statistics to formally assess patterns of geographic dispersion. However, ESDA/ESDTA as such is not an end in itself. Rather, the visualization and quantification of spatial and temporal regularity provide our contributors with a rigorous basis for model specification and hypothesis testing. For example, in accordance with Anselin, Bera, Florax and Yoon (1996), Moran's *I* will quantify evidence of residual spatial dependence in regression models and then help adjudicate evidence in support of spatial-lag vs. spatial-error model specifications. When spatial dependence is produced by the existence of a spatial interaction, spatial spillovers or spatial hierarchies in the endogenous variable of a spatial regression model, the spatial-lag is a viable solution (Anselin, 2001b). In space-time regression models, this simultaneous model of spatial dependence is problematic if our core research interest is in trying to answer questions that require separation of spatial and temporal dependencies.

Many of our contributors solve this problem by purging the regression models of correlated error through the direct incorporation of the sources of temporal or spatial dependence as independent variables. Evidence of autocorrelation in the residuals of a regression model may indicate that the model specification is incomplete – that relevant explanatory variables are missing. Thus, the inclusion of these omitted variables would fully explain – or eliminate – the autocorrelation. The following

chapters demonstrate the wide choice of additional variables available to analysts. In some instances, the expanded model results from the incorporation of spatially or temporally lagged *X*s (or both), or by utilizing trend surface models, which incorporate spatial dependence via the spherical coordinate system of longitude and latitude. Trend surface and, more generally, spatial expansion models spatially detrend by regressing an outcome on location and possibly second-order and multiplicative functions of location. However, spatial expansion and spatial-temporal-lags are naïve in the sense that they offer no clear theoretical underpinning for the data generating process. Accordingly, the truly enduring contribution to social theory is often found in concluding speculation upon those additional explanatory variables.

Outline of Chapters and Their Valuable Findings

Most demographic processes are by definition both spatial and temporal. They interest us because they occur at some place and across space, and they occur at some time and over time. The originality and strength of the chapters in this book come from the authors' ability to find new ways to understand the spatial and temporal in historical demographic research. Because many analysts believe that changes in behaviours are largely a result of changes in ideas that have to be communicated from individual to individual, it makes sense to think that demographic and socio-economic change will follow spatial patterns of communication. Understanding the importance of diffusion, and the ways that our authors look at it, gives us a unifying frame for thinking about their findings and the ways that those findings come together in a series of new conclusions about the role of space and time in historical demographic research.

The first two chapters assess the extent to which the diffusion of ideas and behaviours contributed to the two interlocking elements of the demographic transition: mortality decline and fertility decline. Focusing on sustained reduction in child mortality as a signal of the onset of the demographic transition in Brazil's microregions, **Schmertmann, Potter and Assunção** employ the language of contagion, suggesting that behaviours leading to low mortality rates may have spread from person to person through space. A diffusion process of this type would lead to spatio-temporal clustering of mortality rates that cannot be explained by variables measuring socio-economic conditions and the provision of sanitary and health services. The authors, therefore, adopt and adapt a model originating in epidemiology, John Knox's (1964) cross-classification of space-time interaction. Generalizing this test to proportional hazards models allows the authors to test the null hypothesis that mortality decline was independent of its spatial and temporal context, while controlling for relevant structural and ideational covariates. Schmertmann, Potter and Assunção then use their model to predict the timing of the mortality transition and assess the possible clustering of Brazilian microregions that experienced mortality change earlier than expected, which could indicate the interpersonal transmission of low-mortality behaviours over space. That is their hypothesis for the early transition in Rio Grande do Sul, located near low-mortality Uruguay. In the north,

however, where low population density and great distances make the prospect of cultural transmission of ideas unlikely, the same factors may have served as barriers to the transmission of illness. Like so many of the chapters in this volume, their research provides important answers, but also identifies significant research to be done in the future.

Turning to the spatial diffusion of fertility decline, **Haines and Hacker** take as a starting point the readily observable east-west gradient from low to high fertility levels in the United States between 1800 and 1860, which they illustrate with a time series of quantile maps of county level child–woman ratios. They proceed by contrasting and combining a spatial diffusion model with other theoretical approaches, many well established in the literature (Carter, Ransom, & Sutch, 2004). The authors, testing a wide variety of covariates while controlling for region, use these models to assess structural and ideational reasons why couples might have chosen to lower their fertility earlier than they would have done simply because the new idea 'arrived.' By effectively using Getis and Ord's *G* statistic to draw the conclusion that significant spatial clustering shifted from the low fertility counties to high fertility counties over the course of the antebellum period, Haines and Hacker show that high fertility followed the expanding western frontier, while low fertility regions were clustered near urban centres. At the same time, they demonstrate that ideational factors like the proportion of 'individualist' religious denominations and structural factors like higher literacy and better transportation connections mediated the uniform east-west progression of low to high child–woman ratios, accelerating change beyond the level predicted by an east-west spatial diffusion. Their work hints at complex simultaneous processes of fertility rise and decline, mediated by culture, transportation networks and geographic distance.

The next chapter takes a different approach to uncovering patterns of fertility change. **Guend** identifies neighbours in social, cultural and political 'space' and then determines whether proximity along these axes corresponds better to fertility outcomes than geographic proximity does. He focuses on the temporality of fertility decline in predominantly Muslim countries – a region of the world designated by other studies as lagging in the fertility transition as a result of religious barriers to behavioural change. Guend locates spatial, political and cultural regimes in the temporal transition of fertility of Muslim populations by mapping fertility outcomes and by applying hierarchical cluster analysis to the national-level proximate determinants of fertility, to national socio-economic characteristics and to indicators of a country's commitment to development and modernization. Countries are defined as neighbours by their similarity in multivariate space, and the strength of each set of determinants of Muslim fertility decline is revealed by the temporal trajectory of total fertility rates in each of the analytically defined groups. Guend concludes that, at the national scale, spatial diffusion models have less to contribute to the decline of fertility in the Muslim world than other theoretical approaches. He reveals that fertility decline is governed by the interaction between the intellectual traditions of individual countries and their adoption of – or failure to adopt – programmes of reform and development. Guend argues that these dynamic and often state-led movements of social change promote the transformation of demographic

behaviour and are linked to, but not isomorphic with, economic, political and educational improvement. This chapter suggests that, while ideas may spread easily from person to person or province to province within a country, political borders and cultural and intellectual traditions may present strong barriers to diffusion. Diffusion still matters, but it is primarily the diffusion of ideas across conceptual space rather than geographical space.

The concern then turns to migration, which is the ideal spatial and temporal population process, one where we expect people to move through space over time, and where we should be able to see diffusion and spillover processes at work. The authors of the next three chapters utilize unusual data sources to track the origins and destinations of migrants in the period before systematic information about migration was collected and implement innovative methods to explicitly explore the time-dependence of spatial migration processes. **Darlu, Brunet and Barbero** assess migration patterns by following the distribution of surnames in the Savoy region of south-eastern France during the eighteenth through the mid-twentieth centuries. Their work is based on the solid knowledge that in many populations a new surname in a community reflects the arrival of a new individual or a new family; the extent of turnover of surnames therefore reflects the quantity of migration while the surnames themselves indicate where the migrants may have originated. Region- and period-specific origin/destination scaled association models allow the authors to map the distribution of kinship ties over space and time, revealing patterns in the geography and temporality of migration. Darlu, Brunet and Barbero find that surname exchanges are stronger between communes in the same sub-region than between those in different sub-regions, supporting basic diffusion processes for migration in which movement within the region is preferred. The authors also document exceptions to these patterns, demonstrating that some circumstances made people more likely to cross regional boundaries than to stay within their region. This was so in two cases, one where physical barriers made it more difficult to move within a region than to move outside, and a second where growing cities had a large demand for immigrants. These examples suggest that the physical and social characteristics of space influence the ways people move across it.

Ekamper, Van Poppel and Mandemakers focus on the social nature of space, analysing changes in the geographical distance between the birthplaces of marriage partners to assess the effects on migration of nineteenth-century processes of modernization and nationalization in the Netherlands. They illustrate migration patterns with regional- and period-specific graduated symbol maps that quantify the relative magnitude of the distance from grooms' places of birth to their places of marriage in each of five provinces over four periods spanning the years 1812–1922. After this descriptive prelude, the authors specify municipality-specific pooled cross-sectional regressions predicting the distance between groom and bride. Residual diagnostics detect evidence of spatial dependence unaccounted for by other covariates, allowing for the adjudication of evidence in support of spatial-lag or spatial-error model specifications. Ekamper, van Poppel and Mandemakers find patterns of marital migration very different than those that would appear in a world of spatial diffusion unconstrained by social, technological and cultural barriers. In the early part

of the period, traditional modes of transportation limited migration distances, but less so for people with higher occupational status than for those with lower status, such as agricultural workers and farmers. This social differential in marital migration eroded over time, as social mobility increased and as national transportation and communication networks improved. These nationalizing processes diminished cultural barriers between the south and north of the Netherlands, leading to more marriage across this distance, but also strengthened the barriers imposed by national boundaries with Belgium and Germany. Through this analysis, the authors demonstrate that explicit attention to spatio-temporal patterns can offer new ways to test and validate established social and historical theories.

The chapter by **Gutmann, Deane and Witkowski** turns to the role of the physical and social characteristics of space in the settlement of the Great Plains of the United States from 1880 to 1940. Specifically, they test the generally held view that most westward migration in the U.S. gradually spread across the country as settlers in search of a farm or ranch moved from land that was already occupied to land that had not yet been claimed by the ambitious and growing European-origin population. The authors draw on earlier research indicating that the process of spatial and temporal diffusion was shaped in significant ways by other environmental, economic and social factors. Populations grew more rapidly in places where natural resources (e.g. high quality land, climate suitable for agriculture, mineral deposits) offered more potential for economic growth, suggesting that spatial diffusion theory and economic development theory work together and can be measured and tested using space-time approaches.

Gutmann, Deane and Witkowski offer their initial evidence in the form of quantile maps that display spatial variation in population density and in important environmental covariates (precipitation, temperature and elevation) across the U.S. Great Plains. Formal analysis draws on a series of nested proportional hazards models for repeated events, beginning with simple trend surface models – which incorporate spatial dependence via the spherical coordinate system of longitude and latitude – and building toward a full specification of physical environment and agricultural and industrial ecologies. Results provide strong evidence in support of east-to-west (longitude) dependencies in the temporal process of frontier settlement, but also confirm the kinds of results that others in this volume have achieved: agricultural characteristics – temperature, precipitation and elevation – shaped the diffusion process, while other economic factors, like the early development of industry and mining, caused migrants to jump over otherwise attractive agricultural areas and settle first in those regions closest to the new forms of opportunity. These findings complicate the story of east-west population movement, suggesting that prior conditions are important and offering new ways to formally specify and closely measure them.

Some of the same questions about prior conditions and the non-contiguous or 'leap-frogging' nature of spatial change are raised in the last two chapters. **Beveridge**'s examination of population growth in major U.S. cities tests predictions about the patterns of diffusion within urban areas generated by three schools of urban sociology, each named for the city whose experience it describes: Chicago

(development in concentric rings away from the central business district), Los Angeles (dispersed, low-density, multi-centred development) and New York (continued concentrated development in the centre city). While most of the studies of population movement examined in this volume (and many of those published elsewhere) utilize a national, regional or sub-regional scale of analysis, Beveridge increases the spatial resolution to that of the census tract (a sub-metropolitan spatial unit used in the U.S. since the early twentieth century). Chloropleth maps of neighbourhood population density and density change over the twentieth century provide initial support for Beveridge's contention that the spatial patterning of urban neighbourhood growth in Chicago, Los Angeles and New York was varied enough to support three different 'schools'. Formal inference from global and local levels of spatial autocorrelation in the decadal per cent change in population over the course of the twentieth century for the three core cities and for several other large U.S. cities reveals a pattern of outward growth – as predicted by the Chicago school – during a city's early years, but also demonstrates that growth in later periods was much more complicated, confirming the conclusion that urban growth does not follow a single trajectory. Beveridge therefore suggests that social theory, though aspiring to generalizability across time and place, bears traces of the historical and geographical contexts in which it is formed. He also proposes further research into the spatial patterning of urban growth, using tract-level data on racial, ethnic and socio-economic status to explore how these distinctions mapped onto urban space.

This call to analyse change over time in spatial patterns of social inequality is taken up in the final chapter, where **Curtis** examines space-time dependencies in racial literacy differentials across Puerto Rican *municipios* after the U.S. takeover of the island (and the attendant economic restructuring) at the turn of the twentieth century. While most of the chapters in this volume emphasize diffusion processes by which populations, ideas or demographic changes spread over time and through space, this chapter is more concerned with understanding the spatial nature of socio-economic structures over time. Curtis asks whether Puerto Rico's agricultural geography and the social dimensions of production of different crops created a spatial pattern in literacy rates (a proxy for socio-economic status), and how changes in that pattern were shaped over time by prior conditions. To this end, she incorporates time and space covariates into a longitudinal growth model to assess the effects of initial conditions, change over time and spatial proximity on her outcome of interest. In addition to her conventional use of univariate and bivariate ESDA, Curtis embraces the direct assessment of space-time dependence using the methods of ESTDA. She quantifies first-order space-time dependence by combining the (spatial) distribution of literacy at time t with the spatially lagged distribution of literacy at time $t\text{-}1$. In doing so, her LISA give the covariation between literacy at a given locale at a given period in time with the average neighbouring literacy at a previous period in time. Curtis ultimately finds support for her equalizing hypothesis – that U.S. investment in Puerto Rican sugar production involved the provision of infrastructural improvements that diminished racial inequality, as proxied by literacy rates. However, she reveals that the spatial distribution of agricultural production

doesn't tell the whole story, as spatial patterns in racial composition, both initially and over time, also affect the diffusion of racial equality.

The works presented in this volume explore processes of diffusion – whether of population, demographic behaviour, or other characteristics distributed over populations – as they articulate with core social and demographic theories in specific historical locales. Using creative approaches to newly available data, our contributors assess how historical instances of diffusion compare to theoretical predictions and measure the forces that accelerate or retard spatial diffusion, or that transform, divert or halt it completely. In so doing, they offer us new comparative insights into processes of modernization and cultural change and how they are manifest in time and space. Whether they examine long-lived nations and civilizations or relatively new colonial societies, all authors point to or acknowledge the manner in which population dynamics are conditioned by spatial and temporal patterning in modern times.

Taken together, the papers illustrate hierarchies of interaction, in which urban places are a key element and social stratification another layer that can be explored, that condition both the temporal and the spatial processes of change. The diffusion of change is complicated by this hierarchy and by its uneven nature. On the surface, the hierarchy is often a question of the scale of measurement. Clearly, in the Netherlands, when the story is taken to the individual level, we see how the spatial process is shaped by social class. But the hierarchy also exists at other scales and is manifest in the disruptive effects of urbanization and modernization in each of the societies examined here. All of this reminds us of the potential for this work and the need in future work to think in terms of multiple levels of analysis and nested social change.

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