Future Directions in Spatial Demography

STUART SWEENEY
Department of Geography
University of California, Santa Barbara
Email: sweeney@geog.ucsb.edu

I am keenly interested in spatial demography and have been particularly focused more recently on many of the same issues that will be addressed in the meeting. A new population center was established at UCSB this year and my role in the new center is as the area director for Spatial Demography and Migration. A basic starting point for considering prospects for growth, challenges, and future directions in spatial demography is to establish what is meant when the words “spatial” and “demography” are stuck together. My definition for the area focus in the center is as follows:

The spatial demography research area . . . focuses on place-dependence, relative location, and interaction to gain insights into population level processes and individual-or household behavior. One intellectual thread within this tradition is multiregional mathematical demography. These models extend life tables to study the spatial and temporal evolution of multiple regional populations that are connected by age-specific migration flows. They have had a particularly strong impact in applied demography and forecasting because migration is usually the dominant component of change in subnational populations. The core insights of multiregional demography can be linked to individual-level behavior through the life course perspective and multistate hazard models. At a more general level, there has been increasing interest in accounting for space and place in individual-and household-level studies. This has been driven, in part, by the rapid diffusion and adoption of spatial “tools” and methodologies such as GIS and spatial econometrics.

I would be interested to know whether others would agree or disagree with my definition. In my view, there is already a cohesive approach to spatial demography in the realm of formal mathematical demography that emerged in the mid-1960s (for example Rogers 1967) and by the mid-1970s had coalesced into textbook-length treatments of the topic (Rogers 1975, Rees and Wilson 1977). Indeed the Rees and Wilson text is titled, “Spatial Population Analysis” but the general approach is usual termed multiregional demography and it generalizes to any population subjected to increments and decrements (multistate life tables). There is a second realm of spatial demography that has emerged in conjunction with an emphasis on individual (or household) behavior where spatial technologies (GIS, GPS, remote sensing) and spatial statistics (spatial econometrics and MRF-style spatially correlated errors in mixed models) have served to extend and refine what would otherwise be aspatial analyses. This second realm is equally deserving of the label spatial demography but it is less cohesive and less integrated with some of the core theory and measurement constructs of demography. There are certainly frontiers in both realms but there are also some clear barriers that I think currently limit the applicability of spatial technologies/methods in the second realm.
Concepts and Measures
Demography is different from other social sciences in that the primary mechanism that binds it together as a field of study is the object of analysis, rather than a theoretical perspective on human or social behavior. It is also different in that historically the objects of analysis have been so few in number; the bulk of demographic analysis has focused on fertility and mortality, with migration running a distant third. Any theory base can be used to study why individuals change their residence, have longer or shorter spacing between children, etc. The core and unique theory base to demography has tended to focus on concepts and measures.

Events, exposure, and age-period-cohort (APC) are elements at the core of demographic measurement. Demography is the study of demographic events which include the core forces of population change (birth, death, and migration) but also any other events that can influence one of those processes. If we want to understand variation in events, or describe the process generating the events, basic measurement theory requires that we focus on the population that is at-risk of experiencing the event, thus exposure. APC, and the Lexis diagram, is a primary measurement and data architecture framework for achieving precise measures and meaning in aligning events with exposure. This framework is particularly dominant in formal demography. Multiregional demography is simply a logical extension of the framework to allow for multiple interacting populations. Since the extension is entirely logically consistent, the integration of the spatial component is complete.

Formal demography is obsessively focused on precise measurement and description of demographic processes, but it typically stops short of explanation. Attempts to explain why groups (perhaps regions) or individuals differ in their demographic behavior have focused on regression-type frameworks. Even those frameworks, however, share the same measure framework with formal demography. Survival analysis (hazard models) based on time-to-event data are also attuned to correctly characterizing the timing of events and the duration of exposure. These models are workhorses in building demographic theories of individual behavior because they allow for the inclusion of covariates and because they can be linked directly back to survival analysis based on life tables.

Frontiers and issues in individual-level analysis
One of the most direct ways that spatial technologies/methods have impacted individual level analysis is in placing individuals in context. GIS is a perfect tool for data integration across different scales and it has certainly contributed to better, and more creative, covariates that might be difficult or impossible to create otherwise. In this category I am also including the use of remote sensing imagery and its manipulation in GIS to extract covariates.

One problem in using GIS as a mechanism to create covariates is that detailed spatial cross-sections are unlikely to align correctly with notions of exposure. In most cases the covariates will only be able to measure very near-term influences. For any long-term exposure measure—such as those that would be appropriate in studying chronic diseases—the utility of GIS is likely limited. In general, I think there needs to be more attention given to the timing of measures in GIS layers relative to the timing of events being studied. Data collection based on mobile
computing devices may have some ability to generate better exposure methods for near-term influences. For long-term exposure the best approach would be to build off of detailed residential and work histories.

There is relatively little work (that I am aware of) that accounts for spatially correlated errors in survival analysis and event history models. The only approaches I know of are mixed effects models where individuals are nested in zones and the zonal errors are partitioned into spatially-structured and random components. I am not sure how widely these models have been adopted in demography.

**Frontiers and issues in aggregate-level analysis**

Spatial analytic tools would seem to have a natural affinity with formal demography in its focus on ecological analysis. I think there is fundamental dissonance in the way that processes are conceived and in data architecture. While there is a rich tradition of conceptualizing space-time paths in Geography, the dominant framework in standard GIS representations is cross-sectional. There is also no ability to access and represent interaction among regions (except for standalone tools such as Tobler’s flowmapper). To bridge this gap would require retooling GIS data architecture to fit the framework used in demography. A step in that direction already exists in Serge Rey’s STARS (Space-Time Analysis of Regional Systems) software but it would also require further tweaks. Somewhere I have a proposal that Serge and I started to write that would make this extension.

Similarly, the basic spatial lag and spatial error models from spatial econometrics are not easily linked into the core analytic framework of demography. The problem resolved by cross-sectional spatial econometric models is that we only observe a single realization of the underlying spatial (-temporal) process. I know that there are many papers that have applied spatial econometric methods to summary indicators (e.g., Total Fertility Rate, Crude Death Rate, etc.) measured on regions along with covariates. But this is a decoupled two-step analysis. There is more work that could be done to integrate the well-defined process theories from demography (and multiregional demography) with underlying specification choices in spatial econometric models.

The frontiers in multiregional demographic analysis are primarily focused on its use in population forecasting. Three areas that have been the focus of recent work include model-based estimates of directional migration flows (especially for international data), incorporating uncertainty into forecasts, and the use of multiregional methods in small area analysis.

**Training**

One of basic challenges to training is that inclusion of spatial dependence or interaction into statistical or mathematical models only makes sense pedagogically after a foundation in more basic (non-spatial) methods has been established. In 2009 I offered a graduate-level Spatial Demography class and in a 10-week quarter it was challenging to provide the foundation and then engage students in spatial content in a meaningful way. In that class I started with standard content from formal demography—single- and multiple-decrement life tables—then on to
increment-decrement tables using the specific instance of multiregional life table analysis. The
next section focused on event history theory and the connection between hazard models
estimated from data on individual event histories (single events, multiple events, and multiple
recurrent events) and how the resulting model predictions are link back to the probabilities in life
tables. This left relatively little time for covering applications of spatial econometrics in
demography.

The obvious solution to the time constraints imposed by a single quarter (or semester) is to
have a series of courses that provide sufficient coverage of foundational material before
providing “advanced” spatial training. This approach requires that there is sufficient critical mass
both in terms of instructional capacity and interests among students. I can only think of a few
universities where both conditions are satisfied.