

Integrating macro- and micro-level approaches in the explanation of population change

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Demographers study population change across time and place, and traditionally they place a strong emphasis on a long-range view of population change. This paper builds on current reflections on how to structure the study of population change and proposes a two-stage perspective. The first stage, discovery, focuses on the production of novel evidence at the population level. The second stage, explanation, develops accounts of demographic change and tests how the action and interaction of individuals generate what is discovered in the first stage. This explanatory stage also provides the foundation for the prediction of demographic change. The transformation of micro-level actions and interactions into macro-level population outcomes is identified as a key challenge for the second stage. Specific instances of research are discussed.

Keywords: demographic research; theory; life course; micro–macro; discovery; explanation

Introduction

Demographers study population change across time and place, and traditionally they place a strong emphasis on a long-range view of population change. In this paper, I address two questions about the strategy of studying this phenomenon. First, should the study of population change be anchored solidly at the macro level of populations as located in time and place? Second, should we consider the micro level of individual actions and interaction that bring about demographic change to be outside the core realm of demography? Building on current and past reflections, on methodological arguments, and on actual practice in population studies, I argue for a positive answer to the first question and for a negative answer to the second. More precisely, I propose that the scientific study of human populations and their change comprise two essential and complementary stages: discovery and explanation. Methodologically, and for clarity of exposition, I treat the discovery of demographic facts and their explanation as discrete stages. The two stages, of course, should be seen as interacting iteratively.

The first stage of demographic inquiry should be aimed at producing solid evidence on population trends and patterns, as well as their associations across time and space. In this, the *discovery* stage,

the production of demographic evidence is grounded in formal demographic measurement, which at times might require spatial or temporal statistical modelling, or both. ‘Discovering’ population trends and patterns is a macro-level challenge, albeit ultimately based on the collection of micro-level data.

Informed by evidence produced in the first stage, the second stage in demographic inquiry should be aimed at explaining population change and predicting its future development. For this second, *explanation*, stage, a micro-level ‘life-course’ theoretical and empirical framework is essential in order to explain what has been discovered. The use of the term ‘explanation’ here relies chiefly on the generative approach to social science advocated by Epstein (2006). Explaining population change means recognizing the fact that human actions and interactions, embedded in a macro-level context, are driving demographic events. In turn, these actions and interactions are driving population change at the macro level. The key challenge for the explanation stage is the aggregation of micro-level outcomes up to the macro level of population change—that is, the recognition that explaining population change cannot be confined to micro-level outcomes but requires an understanding of the mechanisms through which the aggregation of micro-level behaviour shapes macro-level population change.

In this view of the study of population change, both stages are considered as highly legitimate, complementary, and valued parts of demographic research. A single piece of research will normally focus on either the discovery or the explanation stage. However, research directed towards a broad understanding of population change, including (but not limited to) long-term population change, must unavoidably take both stages into account to produce comprehensive scientific knowledge. These efforts are demanding because they require an integrative view at macro and micro levels of analysis, with command of traditional demographic methods, the life-course approach, and formal and simulation models. This integration should however be seen as the goal that guides research and training in the study of population change, and fully justifies the definition of demography as the scientific study of (human) populations and their change.

Is demography abandoning its ‘core’? And, if yes, is that really harmful?

In an important manuscript, never formally published, Ron Lee (2001) discusses the evolution of demographic research during recent decades. In particular, Lee argues that along with the rise of what he calls ‘micro demography’, demography itself is abandoning its ‘core’. Defining the core of an area of study is a challenging issue—and no doubt scholars who have had a huge influence in shaping the area, as Lee has, are among the best placed to formulate such a definition. In particular, Lee’s central thesis is that ‘Key issues are macro demographic’, examples being the relationship between population growth and economic development, and the consequences of population change for the environment. Similarly, in an earlier reflection on the state of population theory 150 years after the death of Malthus, Roger Schofield and David Coleman (1986) identified the core of the subject matter of demography as being the ‘mathematical theory which deals with statics and dynamics of population; vital rates in relation to the age structure, dynamics, growth and their perturbations, and all the techniques of measurement, analysis and substitution that follow’ (p. 5).

The emphasis on measurement as the core of demography is paramount in one of the key textbooks in demography produced in the new millennium. Preston, Heuveline, and Guillot introduced their book by maintaining that it ‘attempts to impart an understanding of the behaviour of human populations by describing carefully the basic measures,

models, and observational procedures devised by generations of demographers’ (p. xiv). In other words, demography is what demographers do, as we should say from a sociology of science perspective. Thus, the book by Preston et al. (2001) is deliberately emphasizing the core technical tradition that extends from the life table onwards. In contrast, Le Bras’s (2008) non-orthodox textbook comes much closer to the general view of demography that I am proposing here.

Lee’s fears that demography is abandoning its core are not isolated. In an influential article, Ní Bhrolcháin and Dyson (2007) state that ‘[t]he current prominence of individual-level analysis has tended to displace and distort approaches to aggregate phenomena, with a resulting blight on causal explanation at higher levels’ (p. 1). Dyson and Ní Bhrolcháin go further in taking as their point of departure Herbert Smith’s (2003) advice that demographers should not ‘blindly cede our population-based perspective in service to the micro-foundations’ (p. 467) of statistics and econometrics, concluding that ‘We believe that aggregate phenomena and demographic change through time should be at the heart of demography, and therefore represent a central object of causal investigation in the discipline’ (Ní Bhrolcháin and Dyson 2007, p. 1). In a similar vein, Geoffrey McNicoll (1992) sees ‘little excitement’ in micro-level social demography and claims that ‘More ambitious work on what could be called the Malthusian program—concerned with demographic regimes rather than individual behavior—remains [...] sporadic and noncumulative’—thus limiting the policy relevance of an important part of demographic research.

Why have these scholars felt that the primacy of this macro-demographic core is threatened by micro-level approaches? Lee argues that the rise of ‘micro demography’ can be explained by three key developments: the growing availability of survey data; the development of new or better statistical methods for analysing such data; the increase in computing power and opportunities for data storage. Moreover, Lee argues, demography has been influenced by the development of micro-level economic theory, shaped in particular by the works of economists such as Becker, Mincer, Heckman, and Willis (see, in particular, Becker 1976).

Are demographers who ‘cede’ their population-based perspective to micro-foundations, to use Smith’s words, soldiers in a Trojan horse that threatens the discipline? Not in my opinion. On the contrary, it is the outright rejection of micro-level analysis that potentially threatens the existence of

demography as an independent discipline. Indeed, some of the analytical tools that ‘micro demography’ now uses are derived from seminal ideas that originated within the discipline, such as the regression approach to life tables pioneered by Cox (1972). Limiting the core to the traditional macro-level approach ‘devised by generations of demographers’ in an explicit counter-position vis-à-vis the peripheral, micro-level life-course approach would, in my view, be a grievous error. Nevertheless, a framework needs to be put in place to delineate useful directions. In line with another idea proposed by Ní Bhrolcháin and Dyson (2007), that is, of a double nature of demography, with ‘powerful descriptive potential’ on the one side and ‘a long history of causal analysis’ on the other, I argue that the enlargement of a measurement core that is focused on macro-demographic issues is not harmful if a broader, two-stage, view of demography is adopted. The perspective adopted here borrows in particular from the view of sociology depicted by John Goldthorpe (2007, 2015) and James Coleman (1986, 1990), and recently systematized within the so-called ‘analytical sociology’ programme (Hedström and Bearman 2009). However, in contrast to Goldthorpe’s micro-based sociology, rational action theory is not necessarily seen as the ‘default’ approach to the study of population change. My proposed perspective also draws on the interdisciplinary paradigm that has become known as the ‘life-course’ paradigm (e.g., Giele and Elder 1998).

Here, in brief, is the line of reasoning we shall follow. In the definition of key demographic issues, one should agree with Lee—if one wants to study population change, the key issues need to be defined as ‘macro demographic’. The first stage of demographic inquiry, discovery, should remain what Schofield and Coleman, Lee, Preston, and others see as the ‘core’ of demography. It should comprise the measurement, using appropriate formal methods and with the usual obsessive concern over data quality, of population change, that is, demographic processes and their association over time and space. This measurement may entail the use of a series of summary measures of fertility, mortality, and migration (e.g., the total fertility rate, life expectancy, migration rates), or more complex distributional measures (e.g., a series of age-specific rates, life tables or population counts, age–period–cohort analyses) and their associations. Examples of established associations that have been very important discoveries include the links between mortality and fertility decline (Ní Bhrolcháin and Dyson 2007). Advances in formal modelling of population

dynamics at the macro level also constitute discoveries. In other words, demographers should keep the mathematical and statistical description of how the world works, that is, of how population changes, at the centre of their scientific research. Inasmuch as this form of description contributes to cumulative knowledge on population change, it becomes the discovery of demographic facts. However, it would be a mistake to stop at this stage, or to restrict the core of demography to the macro level. While discoveries should be highly valued, they also need to be seen as the starting point, or as the target phenomena to be explained in the second stage. We should note here that ‘discovery’ has been a central concept in the epistemological debate since at least Popper (1959) and Reichenbach (1938), although the use of the term has been debated and seen as ambiguous at times (see, in particular, Hoyningen-Huene 1987).

In the second stage, an explanation of how population change comes about has to be rooted in models of the action and interaction of individuals, couples, and families, as embedded in their macro-level context. Discoveries provide the empirical *target* for the second stage—usually a ‘puzzle’ for explanation, in the shape of a set or pattern of demographic data. The idea of the ‘life course’ is that demographic trajectories are shaped by life events (from birth to death), and the timing of these life events is influenced by the historical, political, and cultural context, the development of individuals, and their relationships with significant others (‘linked lives’) (Giele and Elder 1998; Mayer 2009). The life-course perspective is useful in informing this second stage, together with theories on prospective decision-making approaches that have informed recent comparative demographic surveys such as the Generations and Gender Survey (Vikat et al. 2007). Biological (including genetic and epigenetic) and evolutionary ideas can also contribute significantly to the explanation (Hobcraft 2006; Sear 2015, this issue). The use of a life-course foundation for demographic research has been advocated previously (e.g., van Wissen and Dykstra 1999; Hobcraft 2006). Courgeau (2012) has argued for a multilevel probability-based approach to the study of population issues (see also Courgeau and Franck 2007).

For this second stage to be complete and fruitful, it needs to specify how macro-level population patterns re-emerge from the action and interaction of individual life courses. The need for explicit micro-level foundations is certainly not new in demography—for instance, Davis (1963), in his

‘theory of change and response’, emphasized the need to motivate through individual behaviours the long-term population changes that were of interest to him. Here, we propose this second stage to be built according to the ‘social mechanisms’ approach of Hedström and Swedberg (1998), based on James Coleman’s work (see, e.g., Coleman 1986, 1990). In the social mechanisms approach, the explanation of macro-level social change entails three parts (which we can see as constituting the key components of our second stage). First, *situational mechanisms* are the ways through which the macro level is seen as affecting individual outcomes (e.g., how mortality decline in a society affects individual fertility choices). Second, *action-formation mechanisms* are the ways through which inter-individual processes (over time) affect individual outcomes (e.g., how past fertility choices affect current fertility choices). Third, *transformational mechanisms* are the ways through which, via the aggregation of individual outcomes or the interaction among individuals, macro-level outcomes are generated. Figure 1 provides a graphical summary of the proposed framework, including both stages.

Situational mechanisms have implicitly been invoked in analyses that make use of multilevel models of demographic behaviour, in which a micro-level outcome (such as the timing of demographic events or the prevalence of demographically relevant behaviour among individuals or couples) is studied as a function of macro-level factors (Entwisle et al. 1984, 1986; Entwisle 2007). Action-formation mechanisms have implicitly been invoked in life-course analyses of demographic behaviour, in which micro-level outcomes are studied as a function of the past history of individuals (embedded in a macro context), and in event-history analysis (Hobcraft and Murphy 1986; Courgeau and Lelièvre 1992), generalized to outcomes that are more general than the timing of events as life-course analysis (Billari 2003).

Of course, the fact that population researchers might focus on micro-level, individual outcomes is precisely what is criticized by scholars who see the macro as the ‘core’ (although John Hobcraft (2006, 2007) has argued for going *below* the micro level of individuals, ‘under the skin’). A focus on transformational mechanisms is therefore essential if one wants to move fully from the discovery stage of demographic research and close the feedback by inferring an explanation of population change, one that will allow further ‘discoveries’. Only an account of how aggregation takes place, that is, of how the micro shapes the macro can close the explanatory circle. In the social sciences, the debate on aggregation has mostly been important within economics, with the widespread use of representative agents in building macro-economic theories (Lucas 1976) and their critics (Kirman 1992). If one privileges analytical (i.e., mathematical) tractability in the micro-to-macro link, models based on representative agents are particularly useful, while heterogeneous agents are more challenging because they are much less tractable. Given that transformational mechanisms represent the key challenge in the development of demography’s capacity to integrate macro and micro processes in the study of population change, the remainder of this paper will deal with instances of the successful application of these mechanisms.

Transformational (micro→macro) mechanisms in demography

Mortality

The formidable improvement in survival triggered by the demographic transition and its aftermath has contributed to a renewed interest in the determinants of age patterns of mortality and their changes over time. In this area, the study of mortality and longevity through the lens of ‘frailty’ is an important example

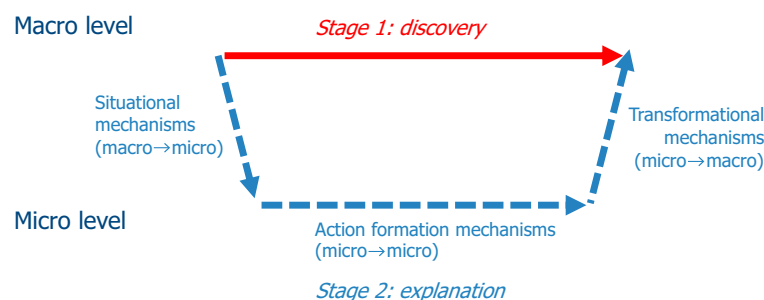


Figure 1 The two-stage view of demography (adapted from Hedström and Swedberg 1998 and the original diagram by Coleman 1986)

of how the discovery of a population-level target—data on age patterns of mortality—can be generated using transformational mechanisms that aggregate the findings of a model founded at the micro level.

For scholars interested in mortality decline in advanced societies, the discovery stage provided, in addition to a general picture of the evolution of survival, some puzzles. One such puzzle was the decreasing rate of increase of mortality at old and ‘oldest-old’ ages. While a Gompertz-type of ageing mechanism, that is, an exponential increase in the risk of dying by age, seemed a plausible assumption, the key advance in research on this issue was the recognition of the limits of the assumption. It was plausible enough at the *micro* level of the individual, but when scholars looked at the *macro* level of the population (or more precisely of the cohort), additional assumptions were needed in order to reconcile what I have described as the discovery and explanation stages of research. In a seminal and particularly influential paper, Vaupel et al. (1979) criticized the methods of research then prevailing on two counts: their overestimation of current life expectancy and of potential gains from policy interventions affecting health, and their underestimation of rates of individual ageing, the extent of past improvements in life expectancy, and differences across populations.

The idea of Vaupel et al.—one of those ideas that appear as simple only after someone else has had it—is to start from the micro level of the individual, or rather of a *statistical individual*. This is an abstract and fictitious creature whose experience can be described through probability theory (Courgeau 2012) combined with a probabilistic interpretation of the same life table that has constituted a key tool for core demography for some centuries (Hoem and Funck Jensen 1982). In the model of Vaupel et al., for each individual the ‘force’ of mortality μ , that is, the instantaneous risk of dying at age x , is seen as a function of the individual’s observed population group, i , her or his exact age x at time t , and her or his unobserved ‘frailty’ z , that is, the individual-specific chance of dying, $\mu = \mu_i(x, t, z)$. After some algebraic transformations (and the assumption that frailty enters as a multiplicative factor), the age-, group-, and period-specific average force of mortality can be shown to be the product of individual-specific forces of mortality and the average frailty of individuals who remain alive at age x :

$$\bar{\mu} = \mu_i(x, t) \times \bar{z}. \quad (1)$$

Because individuals with high values of z , that is, high frailty, tend to die earlier, the average frailty of the

surviving cohort will decline with age. In other words, even if micro-level forces of mortality increase exponentially with age according to Gompertz’s intuition, when frailty is heterogeneously distributed, the macro-level force of mortality will increase at a less than exponential pace. The puzzle posed by the macro-level discovery is then solved. This is also an instance where research proceeds by going ‘under the skin’ and below the level of single individuals to explain variation across individuals in frailty and in the ‘rate of ageing’, that is, in the pace of increase in mortality with age (Vaupel 2010). The explanation stage therefore provides the target for further interdisciplinary explanatory research. The profound impact of this result (a similar formal result was derived earlier by an actuary, William Perks (1932)) is such that Vaupel et al.’s paper is, currently, the second most cited article ever published by the journal *Demography* (search performed on Thomson Reuters’ ‘Web of Science’, 2 March 2014).

In a sense, one could see this development as an equivalent of the ‘Lucas critique’ in economics, because it showed that in order to understand—and forecast—population change, as measured through the change in age patterns of mortality, it is essential to understand the micro-level basis of the change and how micro-level outcomes become population-level outcomes. It is not by chance that, later, pitfalls in the long-term forecasting of limits to life expectancy have been the target of Vaupel’s work with Jim Oeppen (Oeppen and Vaupel 2002).

Outside demography, frailty has become a standard tool in the formulation of survival/event-history analysis models, that is, models in which the timing of events is the outcome, and where a regression model for a life table (Cox 1972) might allow for frailty as a means of summarizing unobserved factors. Within (formal) demography, micro-level frailty has become readily part of the standard toolkit (Keyfitz and Caswell 2005, Chap. 19), without provoking adverse reactions among those who see research at the macro level as the core of the discipline. Perhaps the reason for the welcoming approach to what is essentially a micro-level study of population is that, under plausible assumptions, macro-level age patterns arise formally as an aggregation, via averaging, of micro-level age patterns. The priority of analytical tractability in demography is clear for Lee (2001): ‘Formal demography provides the analytic link between individuals at the micro level and populations at the macro level. Sometimes a simulation can serve the same purpose, with less effort, but the proper design and validation of a simulation also requires formal demography. While simulations definitely have a

useful place in research and analysis, their shortcomings are well known, most notably that they do not provide insight' (p. 4).

Migration and spatial mobility

The idea that simulations do not provide insight for demography is at variance with experience in neighbouring disciplines, such as epidemiology and ecology (e.g., Grimm and Railsback 2005; Longini et al. 2005). The precision of simulation models, a feature that has been described as central for demographic theory by Tom Burch (1996, 2003), allows the use of simulation in transformational mechanisms in a way that is homothetic to the use of analytical models. We therefore now move to instances in which micro-level simulations are used to derive insights about macro-level population outcomes, that is, as aggregation tools in transformational mechanisms. The need for analytical tractability—which is very welcome when suitable—should not limit the use of behavioural models based on micro-analysis. They are especially important for research on migration, mobility, and family and fertility, where demographic events are a clearer and a more direct outcome of *agents* and their decision-making. Micro-based simulation, also known as individual- or agent-based simulation, provides a crucial toolkit for the study of population change as it emerges from 'the bottom up' (Billari and Prskawetz 2003; Gilbert and Troitzsch 2005; Epstein 2006; Silverman et al. 2013). We start discussing this approach with the study of population movement and another pioneering example.

Thomas Schelling (1971) developed a model to explain, in a way based on micro-analysis, segregation patterns in cities as the macro-level target. Seen as the archetypal example of an insightful agent-based model, it is described by Gilbert and Troitzsch (2005) in their introductory textbook. Schelling's (1971) aim was to study spatial mobility as the outcome of micro-level discriminatory behaviour 'reflecting an awareness, conscious or unconscious, of sex or age or religion or color or whatever the basis of segregation is, an awareness that influences decisions on where to live, whom to sit by, what occupation to join or to avoid, whom to play with or whom to talk to' (p. 144). In particular, he was interested in 'tipping', that is, in the change in the ethnic composition of a neighbourhood.

In Schelling's model, at the micro level agents have a 'tolerance' schedule that depends on a threshold. The individual agent does not tolerate living in an area where he or she is a member of a minority if the minority is too scarcely represented in the area.

Going below the tolerance thresholds will trigger the spatial mobility of individuals. Individual-level moves will, in turn, determine the spatial redistribution of the whole population. The key result is that, even with relatively low values of the threshold, the macro-level outcome will be complete segregation. The original model is abstract and based on the broad observation of segregation. The fact that it provides sufficient insight has been confirmed by subsequent empirical tests of micro-based 'tolerance schedules' that have been implemented within demography and beyond, and that have been reported in a flourishing literature. Later studies have shown that, even when Schelling's initial micro-level assumption is not fully supported by evidence, the transformational mechanisms can be seen to work in a way that follows the initial intuition (Clark 1991; Bruch and Mare 2006), although their applicability to large cities has been disputed (Singh et al. 2009).

Moving to a broader spatial scale, simulation models have so far been much less used to explain international migration, but some recent and promising studies have tackled the issue (Heiland 2003; Kniveton et al. 2011), and Willekens (2012, 2013) has advocated a wider use of simulation models in this area. Although the adequate definition of empirical macro-level targets appears to be a central challenge for international migration, prospects for research in this area are definitely promising.

Family and fertility

Demographic micro-simulations of conception and birth were developed as early as the mid-1960s by Sheps and Hyrenius (see Coale and Trussell 1996). Since then, micro-simulation models have been used to study the long-term consequences at the population level of specific mortality and fertility rates for kinship. For these studies it is important to keep track of kin relations for each individual in order to derive aggregate kinship measures (e.g., Wachter 1997; Tomassini and Wolf 2000; Murphy 2004, 2011; Zagheni 2011). Usually, the results from the discovery stage of demographic inquiry in these studies (e.g., sets of age-specific rates) are used as probabilistic inputs in simulation models to generate macro-level outcomes and population forecasts. Agents' decision-making in these models is in the background and quantities that are not available at the time of analysis are usually the outcome of the second stage. An example is the use of micro-simulation for demographic forecasting (Booth 2006).

In the two-stage view of research on population change, the focus is on cases in which a behavioural model is built at the micro level, and aggregation is the main challenge. One such case is research on family formation, which has been growing as a privileged field of application in agent-based computational demography (Billari and Prskawetz 2003). In particular, age patterns of marriage have been the macro-level target of models of union formation based on micro-level analysis (Billari 2000; Todd and Billari 2003; Todd et al. 2005; Billari et al. 2007; Bijak et al. 2013). The approach to generating the macro-level target is similar to that adopted by Vaupel et al. for mortality. Given the challenges of analytical tractability of marriage as a matching process, simulation models are particularly appropriate.

It is well known that the age-specific pattern of marriage rates (or more generally, union formation) rates is non-monotonic, with usually a quicker increase over age, followed by a slower decrease. This pattern has often been investigated using ‘pure’ macro-demographic models, such as the Coale–McNeil model (Coale and McNeil 1972), which has been extensively used and is considered to be one of the key examples of the ‘demographic model’ (Coale and Trussell 1996). In agent-based models of marriage, the pattern of age-specific marriage rates is used as a target, and models are built in which agents search for partners, following mechanisms derived from psychological evidence on search heuristics or from the study of social networks. When search heuristics are the micro-level mechanism, Todd et al. (2005) have shown that heterogeneity in a baseline parameter at the individual level is a key ingredient required for the reproduction of age patterns that match the empirical target qualitatively. In their case, the duration of the ‘learning’ period in which agents gather information but do not marry is heterogeneously distributed. The capacity of individual heterogeneity in the duration of marriage search to account for aggregate-level patterns resembles the finding on mortality patterns using the notion of frailty. Diffusion and social interactions underlie the agent-based ‘wedding ring’ model of marriage (Billari et al. 2007), which was loosely inspired by the macro-demographic model developed earlier by Hernes (1972).

In recent studies of fertility, standard indicators over time or space or both have been used as targets for the second stage of analysis. Social interaction models of fertility decisions have been used to model agents’ decision-making, with simulations used to transform micro- into macro-level outcomes

(Aparicio Diaz et al. 2011; Fent et al. 2013; González-Bailón and Murphy 2013).

Discussion

In this paper I have argued that a two-stage process is essential for the comprehensive study of population change. In the first, discovery stage, novel evidence should be gathered on trends over time and space in demographic components, their mutual relationships, and their associations with other factors. This discovery stage is macro-oriented (even if data originate from individual-level sources) and corresponds to what several scholars insist is the ‘core’ of demography. In the second stage, an explanatory account based on mechanisms at the micro level should be built and tested, to show how population change arises from individual behaviour and interactions between individuals. The need for this form of methodological individualism in demography has been advocated earlier, for instance, by Kingsley Davis (1963), and its importance is recognized in mainstream economics and certain areas of sociology and evolutionary biology. Nevertheless, among the social sciences, demographic research is unique in the importance it accords to the discovery stage, and for the demographic facts that it provides as crucial empirical foundations for the other social sciences (Xie 2000).

If one accepts this two-stage perspective, there are implications for demographic research in general. The scientific study of population change should value both stages, and treat research in each of them as ‘core’ demography. A complete research programme on population change, however, cannot be limited to the macro or micro level only. The two-stage perspective also has implications for the training of researchers. Scholars of population change need to be versed in the methods required for both stages. Particular research and training efforts are needed to improve understanding of the micro-to-macro transition in the explanation stage. We have discussed examples of this transition that deal with it by analytical modelling or by simulation—demographers should be equipped to use both.

The way of studying population change advocated here requires of its practitioners the ability to deal with a number of disciplines that provide behavioural models, such as (but not limited to) economics and sociology, psychology and biology. Also required is skill in the use of mathematical, statistical, and simulation models. The study of population change is not easy. Nevertheless, it remains fascinating and, in my view, worth the substantial efforts its successful study entails.

Notes

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- 2 This paper benefited from comments, criticisms, and suggestions from participants to the workshop ‘Population—the long view’ and from other colleagues, in particular David Coleman, Anette Fasang, John Goldthorpe, Ridhi Kashyap, John Simons, James W. Vaupel, Emilio Zagheni, and three anonymous reviewers.

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