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Towards causal forecasting of international migration

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Abstract

International migration is difficult to predict because of uncertainties. The identification of sources of uncertainty and the measurement and modelling of uncertainties are necessary, but they are not sufficient. Uncertainties should be reduced by accounting for the heterogeneity of migrants, the reasons why some people leave their country while most stay, and the causal mechanisms that lead to those choices. International migration takes place within a context of globalisation, technological change, growing interest in migration governance, and the emergence of a migration industry. Young people are more likely than older people to respond to these contextual factors, as they are better informed, have greater self-efficacy, and are more likely to have a social network abroad than previous generations. My aim in this paper is to present ideas for the causal forecasting of migration. Wolfgang Lutz's demographic theory of socioeconomic change is a good point of departure. The cohort-replacement mechanism, which is central to Lutz's theory, is extended to account for cohort heterogeneity, life-cycle transitions, and learning. I close the paper by concluding that the time has come to explore the causal mechanisms underlying migration, and to make optimal use of that knowledge to improve migration forecasts.

1 Introduction

In 2015, approximately 244 million people, or 3.4% of the world's population, were living in a country other than their country of birth (United Nations Department of Economic and Social Affairs, Population Division 2016). While less than 1% of the

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world's population emigrate in a given year (Abel and Sander 2014), the share of people who express a desire to emigrate is much larger. A worldwide Gallup survey conducted in 2005 found that 14% of the world's population aged 15+ (630 million people) would like to move permanently to another country if they had a chance to do so, but that only 3% had started making preparations to leave (Esipova et al. 2011). Thus, while many people express a desire to leave their country, very few actually make such a move.

Forecasting international migration is a huge challenge. According to Bijak and Wiśniowski (2010, 793), international migration is difficult to predict for the following reasons:

a. There is no comprehensive migration theory. The existing theories on migration are partial, addressing only certain aspects of a hugely complex phenomenon.
b. A coherent and harmonised definition of migration across countries and time does not exist, and standardised procedures for measuring migration are lacking.
c. Data on migration are missing, incomplete, or defective. For example, a time series of observations typically includes a few time points only. Moreover, the existing data are not comparable across countries, and the existing information on the causal mechanisms that trigger migration flows is rudimentary.
d. The processes governing migration are inherently random, and are susceptible to factors that are difficult to predict. In addition, a wide range of actors can help to shape international migration flows.

The classical approach to international migration forecasting is to identify regularities in migration trends and to use that knowledge to forecast migration. That approach produces reliable forecasts if the future is a continuation of the past. Forecasters emphasise the need to quantify uncertainties (using probability theory) and to reduce uncertainties by combining data from different sources, including expert judgments on trends. Wolfgang Lutz and colleagues were among the first to introduce expert judgments (Lutz et al. 1998; Lutz and Goldstein 2004) and to quantify the underlying narrative in argument-based scenarios (Lutz and Scherbov 2003). In recent years, the Bayesian approach has become the leading paradigm in probabilistic forecasting (see, e.g., Bijak (2011); Bijak and Wiśniowski (2010); Azose and Raftery (2015); Billari et al. (2014); Disney et al. (2015); Bijak et al. (2016)). It offers a coherent framework for combining data from different sources, and for assessing the multiple uncertainties in forecasting.

Collecting expert knowledge on modelling and prediction is a first step towards developing a knowledge-based forecasting approach. While commenting on population forecasting in general, Keyfitz (1982) expressed scepticism that more demographic knowledge could improve forecasts because the theories of population growth were developed to *explain* population change, not to support forecasting. A decade and a half later, Sanderson expressed optimism when he wrote: "Yes, knowledge can improve forecasts" (Sanderson 1998, 88). Sanderson observed

that in the forecasting models he had reviewed, knowledge was incorporated as statistical associations between the time series of the demographic variables to be predicted and the time series of the factors that are known to influence these variables. This *prediction by association* approach makes no reference to the behaviours of individuals, families, and institutions. Keyfitz (1982, 747) noted that this approach circumvents the need for causal understanding. He envisaged a behavioural approach to forecasting in which causal mechanisms are incorporated into forecasting models (Keyfitz 1982, 747). A similar argument was made more recently by Bijak (2015), who asserted that the relatively weak theoretical foundations of demography, and especially the lack of theoretical micro-foundations, make forecasts more uncertain. Mechanism-based forecasting and the predictive validity of demographic theories have occupied demographers ever since Keyfitz asked the question: "Can knowledge improve forecasts?" (for an overview, see Willekens (1992) and Booth (2006)). Progress in mechanism-based forecasting has been slow because (a) the theories were developed to explain, not to predict; and (b) the existing projection models are ill-suited to incorporating causal mechanisms. That situation is changing with the emergence in demography of behavioural theories and actor-based or agent-based models.

My purpose in this paper is to contribute to the development of a projection model that incorporates the causal mechanisms of migration. The presentation of such a model, which requires the operationalisation of the mechanisms in mathematical equations, is beyond the scope of this paper. These mechanisms operate at multiple levels (micro, meso, and macro), and involve a multitude of actors, from individuals to international organisations. These actors operate within institutional and historical contexts. At the highest level, migration is embedded in mega-trends, including globalisation, demographic change, technological change, socio-cultural and political shifts, and climate change (see, e.g., Castles (2010)). The diversity of the actors and the factors that contribute to these trends increases the degree of uncertainty and makes it difficult to produce reliable migration forecasts, particularly during periods of discontinuity.

The paper is structured as follows. In Section 2, I explain why international migration is difficult to predict. The complexity of migration is attributed to (a) the multiplicity of reasons for migration and of the types of migration that result from these diverse motivations; (b) the multiplicity of factors that influence the migration decision-making process; (c) the multiplicity of actors and actions that encourage or facilitate, or discourage or constrain, migration; (d) the politicisation and securitisation of migration; and (e) the absence of harmonised definitions and standardised measurements of migration. I present the main features of the migration forecasting model in Section 3. The point of departure is Wolfgang Lutz's (2012) theory of demographic metabolism, which posits that cohort replacement is the central mechanism of demographic and social change. According to this theory, each new cohort provides an opportunity for social transformation because young people are more likely than older people to adopt new technologies and values. For instance, successive cohorts are increasingly mobile-minded and less nationally

oriented (see Striessnig and Lutz (2016)). Providing a detailed description of the model and an assessment of the predictive performance of the model relative to existing migration forecasting models is beyond the scope of this paper. For an operationalisation of some of the mechanisms covered in this paper, the reader is referred to Klabunde et al. (2017). In Section 4, I present my conclusions.

2 Why is international migration forecasting so difficult?

Migration is difficult to predict for the following reasons:

a. There are many motives for migration.
b. Migration is sometimes hard to distinguish from other forms of mobility.
c. A wide range of actors influence migration.
d. Migration is being politicised and securitised.
e. Migration is difficult to measure.

I discuss each of these reasons in this section. Because they introduce major uncertainties, these issues should be considered in migration forecasting. In addition, these challenges should be studied further to identify key processes that can be modelled and incorporated into existing models as mechanisms that help shape international migration.

2.1 Multiple motives for migration

Migration is a possible response to the drive to meet two universal basic needs: security and proximity. The need for security is more than simply the need for safety or the absence of threat. For people to feel secure, they require access to food, water, shelter, income, and health care. They also need access to education, which in turn creates the human capital required to secure access to food and other basic necessities. People's security needs further extend to protection from sudden major losses. To obtain such protection, people must have access to risk management tools, particularly tools for diversifying and sharing risk. People may also migrate to be close to jobs, schools, and other opportunities that are not available at home, but that exist or are perceived to exist elsewhere. Migration is not an end in itself, but a means to an end: i.e., migration is instrumental for gaining access to jobs and other income-generating activities, schools, health facilities, and safety and security.

The reasons for migration, and how these motivations vary over the life course, have been studied extensively (see, e.g., Castles et al. (2014)). But the reasons for migration are changing. Two reasons for migration that have become increasingly important in recent years are gang violence and food insecurity. Gang violence has become a major push factor in Central America's 'Northern Triangle' (El Salvador,

Guatemala, and Honduras) (Cantor and Serna 2017).[1] According to a recent study by the UN World Food Programme, food insecurity resulting from climate change, military conflict, population growth, and cash crop dependencies is becoming a push factor worldwide (World Food Programme 2017). Migration is a risk management strategy in situations in which other risk management tools are non-existent. For instance, families may see the migration of one or more family members as a way to diversify sources of income and to create safety valves that can be activated to escape threats that may arise in the future (Stark 1991).

People also migrate to be close to loved ones (proximity). Marriage migration and family reunification are examples of migration in response to proximity needs.

The reasons for migration are diverse, and tend to change over the life course. Thus, migration forecasts need to account for these shifts in the reasons for migration, including over the life course. De Beer (2008) made a strong argument for distinguishing between the main types of migrants and reasons for migration in migration forecasting; asserting that at a minimum, forecasts should differentiate between labour migration, family-related migration, and asylum-seeking. De Beer also advocated differentiating between nationals and foreigners because members of these groups have very different propensities to migrate across national borders. According to De Beer, the number of migrant categories that should be created and the reasons for migration that should be distinguished depend on the purpose of the forecast. For example, different migrant categories may be identified depending on whether the purpose of the forecast is projecting population or providing information to policy-makers. Migrants may have multiple motives, or may be more likely to report the motive they believe increases their chances of (im)migrating successfully (Kusa 2015). Migrants' motives for moving may also vary depending on their living conditions; and certain living conditions may influence some motives more than other. For instance, in order to anticipate the impact of climate change on migration, it is essential to assess the likely impact of climate change on migration motives (The Government Office for Science 2011).

Gaining insight into migration motives can improve forecasts, but it cannot explain why most people who want to emigrate do not actually leave their home country. Answering this question would require us to gain a better understanding of the migration decision-making process, which is often complex and lengthy. A wide range of variables and actors influence the decision to migrate, such as the availability of resources and the existence of a support network. Moreover, even the people who ultimately leave their home country may find that they are unable to settle in the country of their choice, and need to stay in a transit country.

[1] Gang members include US immigrants who joined gangs in US cities, like Los Angeles, and were later deported.

2.2 Multiple forms of mobility

Migration is often not necessary to meet the basic needs of security and proximity. Opportunities to undertake frequent short-term stays abroad and/or to use communication technology may reduce the desire to migrate. As travel and border crossing have become easier, many people are participating in activities and social networks in different countries, and are traveling frequently or periodically. These transnationals, as they are called, identify with groups in different countries. They may have multiple identities, and some have multiple citizenships. There are different kinds of transnationals, including expatriates, people with residences and/or jobs in multiple countries, and irregular migrants.

Some people relocate to gain access to services and opportunities, while others try to gain access without relocating. The growth of telework, crowdsourcing, outsourcing, and the gig economy are developments that are changing the traditional link between physical presence and job access. The availability of distance learning means that people no longer need to migrate to get access to education. Trends in migration and other forms of geographical mobility cannot be understood or predicted without reference to the type of access being pursued, or to the roles of the intermediaries (migration brokers, smugglers, etc.) who facilitate access (Alpes 2017).

Long-term relocation and short-term relocation are part of a continuum encompassing different types of mobility with varying durations of stay. As a result of technological change and reductions in travel costs, people are much more mobile today than they were in the past (Zelinsky 1971). Migration, or a permanent change in a person's usual residence, is an extreme form of mobility that is increasingly being replaced by short-term relocations. Individuals and governments often prefer a sequence of short-term relocations to a long-term relocation, but when repeat migrations (circular migration) are made difficult, people are likely to settle for a long-term relocation (Massey and Pren 2012; Czaika and de Haas 2013). The traditional definition of migration as a relocation for an extended period of time (more than 12 months), which was introduced by the United Nations in 1998 to enhance the international comparability of migration statistics (United Nations 1998), is becoming outdated. Meanwhile, the duration of stay (actual and intended) is becoming increasingly important.

2.3 Multiple actors

To be successful, an emigrant requires support from a wide range of individuals and institutions. These actors may be informal or formal; public or private; and based in the country of origin, of transit, or of destination. The decision to emigrate is often made not by an isolated individual, but by families and households (Stark 1991). Some of these actors might inhibit migration (Massey et al. 1993). People with a wealth of social capital are likely to get informal support, whereas people

with sufficient financial means may be able to purchase support or a permanent residence permit.[2] Migration is much more likely if the prospective migrant has a support infrastructure in place, even if using the infrastructure is very costly. The most obvious type of social infrastructure migrants can tap into is offered by family and friends in the countries of origin, transit, and destination. Migration leads to the development of transnational social networks that can in turn trigger and channel new migration flows. In labour-exporting countries, such as the Philippines and Bangladesh, governments offer assistance for migration.

In addition to these informal and public support systems, a migration industry has emerged to support or discourage migrants in the origin, transit, and destination countries; to implement policies, including border controls; to transfer remittances; and to help migrants integrate into the country of destination. Castles et al. (2014, 235) has described the migration industry as a broad spectrum of individuals and institutions who have an interest in migration or earn their livelihood by organising migratory movements. Such actors include travel agents, labour recruiters, brokers, interpreters, immigration lawyers, money transfer agencies, border control agencies, and human smugglers. These actors may, for example, (i) facilitate migration; (ii) assist migrants before departure, during travel, and/or at arrival; (iii) assist governments in managing border security by verifying (biometrically or otherwise) the identities of individuals at border crossings, or by detaining and deporting people who are not authorised to cross the border or stay in the country; or (iv) assist immigrants in transmitting remittances. The authors argued that over time, the migration industry could become the primary motivating force in migratory movements, which would make migration very difficult to control and forecast (see also Gammeltoft-Hansen and Nyberg Sorensen (2013); Cranston et al. (2017)). These actors may pursue different goals, including goals that reflect an individual's ideology or self-interest. Although the roles of such actors have been addressed in the literature, they are largely missing from migration theory (Massey 2015). Europol has estimated that 90% of the more than one million migrants who reached the European Union in 2015 used facilitation services, mostly provided by migrant smugglers (Europol and Interpol 2016).[3] According to Europol and Interpol, most smuggling networks are loosely coordinated along a given route, and manage activities locally through personal contacts and opportunistic low-level facilitators. This observation is consistent with reports from journalists and scientists who have investigated network operations. Research has shown that smugglers are not always involved in organised crime, but sometimes belong to the migrants' own

[2] In the US, the EB-5 visa allows applicants to obtain a US green card and permanent residency through an investment that results in at least 10 full-time jobs for US workers for at least two years. Several European countries offer residency and even citizenship in exchange for investment, including investment in residential properties (http://www.eb5investors.com/european-investment-immigration and http://www.eb5investors.com/eb5-basics/international-immigrant-investor-programs)

[3] Globally, the criminal migration industry is worth US$35 billion a year (Horwood and Reitano 2016).

social networks and local communities. Users of these operations have reported that law enforcement officers, border guards, and state officials are also involved in smuggling (see, e.g., Kingsley (2016); Crawley et al. (2016)). Smuggling arises from a mismatch between global migration intentions and opportunities for legal immigration. Van Liempt (2016, 6) asserted that there are only few smuggling cases in which it has been proven that organised crime was involved, and concluded that "[t]hese policies of blaming smugglers divert attention away from the fact that smuggling is first of all a reaction to the militarisation of border controls, not the cause of irregular migration" (Van Liempt 2016, 7). For a recent review of research on migrant smuggling, see Sanchez (2017), who argued that "the processes leading to clandestine or irregular migration are not merely the domain of criminal groups. Rather, they also involve a series of complex mechanisms of protection . . . as attempts to reduce the vulnerabilities known to be inherent to clandestine journeys" (Sanchez 2017, 10).

Migration is difficult to predict without understanding the many individual and institutional actors that influence and shape international migration flows.

2.4 Politicisation and securitisation

In destination countries, two perspectives on migration dominate the public debate, and may have far-reaching consequences for the future of migration. The first perspective emphasises the contributions of immigration to economic growth and a sustainable welfare state, and thus describes migration as an opportunity. The second perspective sees immigration as a threat to the national identity, safety, social cohesion and the nation state.

International migration is tied to the concept of the nation state, and that concept is evolving. A government's views on immigration will depend to a large extent on its views on the nation state. The concept of the nation state originated in 1648 with the Peace Treaty of Westphalia (Germany). The Treaty ended the European wars of religion (the Thirty Years' War, 1618-1648, between the Habsburgs and their Catholic allies and the Protestants and their allies; and the Eighty Years' War, 1568-1648, between Spain and the Dutch Republic). The Treaty established a system of political order in Europe based on the concept of co-existing sovereign nation states. As European influence spread across the globe, the concept of sovereign states became central to the prevailing world order. The concept is upheld in the UN Charter. Countries did not control immigration until relatively recently. The British Empire introduced immigration control with the Aliens Act of 1905. The United States introduced immigration control with the Chinese Exclusion Act of 1882.

The concept of nation states legitimates the limitations national governments place on human mobility, both arrivals and departures. Global and transnational forces limit the ability of national governments to enact migration policies and to control migration flows (Sager 2016). The recent growth of transnational networks and multiple citizenship has challenged the sovereignty of nation states (Betts 2011),

and that challenge helps explain the unease some people feel about immigration. That feeling becomes stronger when in the sending and the receiving countries controversies arise about the dual loyalty of transnationals who identify with both the country of origin and the country of residence, or about the diaspora engagement policies of some sending countries. In several nation states, people have expressed considerable doubt about the government's ability to control migration flows because of (a) the implications of international agreements (e.g., Schengen; ASEAN countries seeking a single-visa policy similar to that of the Schengen countries; the 1951 Refugee Convention and the 1967 Protocol); (b) the limited effectiveness of authentication and authorisation schemes intended to prevent illegal entries and stays; and (c) threats made by sending and transit countries to use mass migration as an instrument to persuade target countries to change their policies or make concessions (Greenhill 2010, 2016). In response to these developments, many people have come to perceive immigration as a threat to their national sovereignty and national security (securitisation of immigration). These perceptions have major consequences for international agreements. For instance, in 2017 the United Kingdom decided to withdraw from the European Union (Brexit) in 2019, largely in order to 'regain control over immigration'. Several countries responded to the inflow of refugees in 2015 by replacing the long-term humanitarian protections guaranteed by the 1951 Refugee Convention with temporary protections under the 1949 Geneva Convention.

2.5 Migration measurement

The main source of migration data is the population census. Some countries (mostly in Europe) also have population registers. In addition, some countries use sample surveys (border surveys, labour force surveys, household surveys) to measure migration (for an overview, see Willekens et al. 2017b). There is no universal and harmonised definition of migration that all countries in the world use, and there is no standardised measurement of migration. To make census data on migration globally comparable, the United Nations (1998) introduced in 1998 the concepts of long-term migrant (12 months or more) and short-term migrant (between three and 12 months). Only a few countries have adopted the UN definitions of migration. In Europe, the UN definition of long-term migrant was officially adopted in the EU Regulation 862 of 2007. In 2009, the Member States started to publish migration data that are consistent with the UN definition.

The population census and sample surveys usually measure immigration by comparing each respondent's country of current residence and country of residence at some previous point in time, usually at his or her date of birth or at a date one or five years prior to the census. The census does not yield data on emigration. Emigration can be measured by cross-classifying immigration data for all countries of the world. Since such data are not available, the measurement of emigration is considerably more challenging than the measurement of immigration (Dumont and

Lemaitre 2005). Countries with a population register usually rely on administrative data to measure immigration and emigration. A register system requires individuals to report immigration and emigration. When people leave the country without deregistering, emigrants are undercounted and net migration is overestimated. In some countries, such as Poland, residents who migrate to another country do not need to deregister unless they intend to stay abroad permanently. In the 2002–2007 period, Poland registered an annual average of 22,306 emigrants to the 18 EU and EFTA countries considered by de Beer et al. (2010); whereas the destination countries registered a total of 217,977 immigrants from Poland. The 2011 census revealed that 1.9 million residents of Poland (5% of the population) had been living abroad for more than three months (Wiśniowski 2017).

3 Response: demographic metabolism and causal forecasting of migration

In this section, I augment the cohort replacement mechanism, which is the central causal mechanism in Wolfgang Lutz's theory of socioeconomic change, with other mechanisms that should be considered in mechanism-based migration forecasting. The extension accounts for (a) the heterogeneity of cohorts and (b) the changes in personal attributes over the individual life course. Lutz acknowledged these mechanisms (see, e.g., Lutz (2012, 283)), but did not elaborate on them. To accommodate the extensions, the cohort-component model is modified in three directions. First, cohort biographies are replaced by individual biographies. Second, it is assumed that individuals have agency; i.e., the capacity to make choices and to act accordingly. Choices are outcomes of decision processes, which are cognitive processes that vary individually (Willekens et al. 2017a). Third, it is assumed that individual actors are influenced by other actors: e.g., members of the actors' social networks, individual brokers/intermediaries, and private and public institutions and organisations. To accommodate the diversity of actors, individuals are replaced by actors (agents). Actors interact with other actors. These interactions lead to the transmission of resources, information, values, and norms. In turn, these interactions result in a social diffusion mechanism causing social change.

Any model of these actions and interactions is fully consistent with Lutz's theory of socioeconomic change and with the cohort-component model. The cohort-component model, which describes the cohort-replacement mechanism, is the most common demographic forecasting model. The model describes individual mechanisms (e.g., decision processes) and social mechanisms (e.g., social influence and social diffusion).

3.1 Demographic metabolism: from cohorts to individuals

A population changes because the personal attributes of its members change from one generation to the next, and over the life course of each individual (Lutz

2012, 283). A few attributes are fixed (e.g., sex, date, and country of birth), but most change during the life course (e.g., level of education, level of income, and family composition). When personal attributes are fixed at a young age, personal characteristics remain stable throughout the life course, and social change is caused entirely by new cohorts replacing old cohorts (cohort effects). In that case, the cohort-component model is sufficient to predict social change.[4] According to the theory of demographic metabolism, cohorts are "heterogeneous in measurable ways while their characteristics are persistent along cohort lines" (Lutz 2012, 285–286).

Personal attributes influence the propensity to migrate. When attributes are fixed over a lifetime, changes occur when new cohorts replace old cohorts. In such cases, understanding the cohort replacement mechanism is sufficient to assess the impact of personal attributes on migration. Since most personal attributes change during the life course, their effects on migration change. The ages at which these attributes change need to be predicted to determine their effects on migration. For instance, getting married, having a child, and securing a stable job tend to reduce an individual's propensity to migrate. The effects of these events on migration are larger if they occur early in life, when the propensity to migrate is high. While individual differences between cohort members and personal attributes that change in the life course cannot be easily accommodated in population-based models, such as the cohort-component model, they can be easily accommodated in individual-based models (Railsback and Grimm 2012) and micro-simulation models (see Billari and Prskawetz (2003); Willekens (2011); Bélanger and Sabourin (2017)). Individual-based models extend the concept of cohort biography introduced by Ryder (1965, 847). Cohort replacement remains the key driver of change, but cohort members differ and their personal attributes are not stable throughout the life course.

Linking population-based models, such as the cohort-component model and individual-based models, was previously proposed by Keyfitz and Caswell (2005). They observed that formal demographic models provide the framework within which micro-level individual phenomena can be interpreted; concluding that the vital rates and other parameters of demographic models "are, in the end, properties of individuals" (Keyfitz and Caswell 2005, 511). The authors called for new models that relate the vital rates to their determinants "through often complicated causal pathways" (Keyfitz and Caswell 2005, 512). Thus, Keyfitz and Caswell were calling for models that describe causal mechanisms.

To predict cohort biographies *and* individual biographies, multistate models are generally used. They describe the life course in terms of states and transitions between states (Willekens 2005).

[4] Striessnig and Lutz (2016, 310) found strong cohort effects in national and regional (European) identities even during periods of major change, which confirms the predictive power of cohort replacement even during turbulent times.

3.2 Causal forecasting: focus on mechanisms

The call for *causal forecasting* is not new. For many years, scholars have voiced concerns that demographic forecasting models disregard substantive scientific knowledge on the drivers of mortality, fertility, and migration; and on the mechanisms linking drivers and outcomes (Keyfitz 1982; Willekens 1992; Sanderson 1998; de Beer 2000; Bijak 2011, 82ff; Lutz and Goldstein 2004, 3; Wilson and Rees 2005; Booth 2006). According to Herbert Simon, "Without a knowledge of these mechanisms, we cannot predict how variables will co-vary when the structure of the system under study is altered, either experimentally or by changes in the world around us" (Simon 1979, 79). Simon's statement, which applies to both causal analysis and forecasting, is as important today as it was in 1979.

The first call for causal forecasting was probably made by Euler in 1760 (Euler 1970 (1760)). He was the first to establish the causal mechanism that links population structure and the components of change (fertility and mortality). He also distinguished between cohorts in population projections. Euler's work was rediscovered by Sharpe and Lotka (1911), which led to the development of the stable population theory. The cohort-component model and the Lotka equation, which describes a trajectory of births in terms of surviving women, are causal models. They describe the mechanism linking drivers (fertility and mortality) and output (population and births).

Causal models are generative models; they describe the mechanisms through which causes operate and generate effects (see Russo (2009, 19 and 160)). Interest in causal modelling has increased significantly in recent years, as exemplified by the rise of generative social science (Epstein 2007) and analytical sociology (Hedström and Ylikoski 2010; Goldthorpe 2016); and by the growing interest in the micro-level underpinnings of demographic phenomena at the population level (Billari 2015; Courgeau et al. 2017). Sanderson (1998, 88) has advocated the formulation of causal forecasts (Sanderson 1998, 88), while Booth (2006) has called for the development of theory-informed forecasts. The models Sanderson and Booth have described are not causal or generative models in the sense that they represent the mechanisms that generate phenomena at the population level; they are regression models that describe statistical associations between population change and socioeconomic determinants.

Three causal mechanisms should be considered in migration forecasting. The first is the cohort replacement mechanism. The second is the cognitive process of decision-making, with the outcome being the decision to migrate (by country of destination) or the decision to stay. The decision-making process consists of multiple stages. Each stage lasts a certain amount of time to allow the individual to accumulate the information necessary to proceed to the next stage. During each stage, conditions may change or events may occur that cause the individual to reassess the benefits and the costs of migration. A decision to migrate does not automatically lead to a migration event, because intervening factors (e.g., a lack of resources) and actors (e.g., a border control agency) may prevent the person from

implementing his or her choice and taking the desired action. In several existing models of migration, migration decision-making is implemented (for a review, see Klabunde and Willekens (2016)). Most models are based on relatively simple behavioural theories (decision theories or action theories). Klabunde et al. (2017) and Willekens (2017) recently used the theory of planned behaviour (Fishbein and Ajzen 2010) to model the migration decision-making process. For a discussion of decision mechanisms and decision theories in the context of individual-based generative models, see Willekens et al. (2017a).

The third causal mechanism that should be considered in migration forecasting is the mechanism that generates and governs interactions between actors and the diffusion processes that may result. Encounters may be random, but whether they result in some type of bonding (ties) depends on individual decision-making processes (Prskawetz 2017). Interactions usually involve the transmission of information (communication) and a transaction (exchange of goods and services). Communication and exchange are easier when the actors are close (geographically) or are similar (socially and/or culturally). Interactions may trigger a diffusion process. Diffusion mechanisms should be considered when seeking to determine the macro-level (population-level) effects of micro-level actions and interactions (Billari 2015; Casterline 2001; Caswell and John 1992; Klüsener et al. 2017).

Actors that influence migration operate at different levels of aggregation, from the individual to the international level (e.g., International Organisation for Migration and UNHCR). Causal models need to incorporate mechanisms at different levels that interact with processes at other levels. Therefore, a causal model is necessarily a multilevel model (Billari 2015; Courgeau et al. 2017). Warnke et al. (2017) proposed a new computer language that facilitates the multilevel causal modelling of demographic phenomena. They applied the language in implementing the computer model of international migration developed by Klabunde et al. (2017).

3.3 Towards a causal forecasting model

A causal forecasting model of migration should, at minimum, have the following characteristics:

1. The model should be an individual-based or micro-demographic model.
2. The actors (agents) should be individuals and institutions/organisations.
3. The actors should have multiple attributes. Changes in attributes imply transitions between states. The traditional cohort-component model distinguishes three transitions only: childbirth, migration, and death. The multistate cohort-component model considers additional attributes and transitions.
4. The actors should have life histories that are operationalised as sequences of states and transitions between states.
5. The individuals should be members of a birth cohort. Cohorts are heterogeneous. The cohort biography should be obtained by aggregating individual life histories, while accounting for the influence on individual life

histories of interactions between the individual and other individuals and institutions.

6. The life courses of identical individuals should differ stochastically. Caswell (2009) called the random difference between individuals *individual stochasticity*. This type of difference should be distinguished from *individual heterogeneity*, which reflects differences in latent or unobserved attributes.
7. The life course of an individual should consist of multiple careers, one for each time-varying attribute. Each career is a sequence of states and transitions between states. In the fertility career, a state represents parity. In the migration career, a state represents a country of residence. Different dependencies between careers may be distinguished (Willekens 1991; Blossfeld 2009).
8. A career should be modelled as an outcome of a stochastic process; more specifically, as a continuous-time Markov process. The parameters should be transition rates. Courgeau (2012, 197 and 253) referred to a group of individuals whose life courses are described by the same probability model as the life course of a *statistical individual*. The life courses should differ only stochastically.
9. Two approaches should be distinguished to determine (in the stochastic process model) the occurrence and the timing of migration and other events in the individual life course. The first approach uses transition rates estimated from empirical data. Transition rates are estimated by relating event counts to the population at risk, weighted by the duration of exposure (Aalen et al. 2008; Willekens 2014). The estimates are maximum-likelihood estimates. The second approach does not use transition rates, but transition rules. These rules are more or less complex heuristics based on decision/action theories and theories of social interaction and diffusion.
10. Time matters. Time should be a continuous variable, and two time scales should be distinguished: age to mark the location of transitions in the individual life course, and calendar time to mark the location of transitions in historical time. Calendar time may be used to account for the historical context early in life and its effect on the life course (cohort effect).
11. In principle, all of the variables in the forecasting model are random. Their values follow probability distributions. The distributions are usually based on a combination of beliefs and empirical evidence. For combining beliefs and evidence, the Bayesian approach is the most appropriate (Azose and Raftery 2015; Bijak 2011). This approach also provides a way of formalising the process of learning; i.e., of updating beliefs in light of new evidence.
12. The forecasting model should acknowledge the different sources of uncertainty, including the model specification, measurement, parameter estimation, heuristics, and exogenous variables used (see, e.g., Bijak (2011, 23ff)).

4 Conclusion

Migration forecasting is extremely difficult because of the diversity of reasons for migration, the possibility that migration will be substituted by other forms of mobility, the multiplicity of actors influencing migration, the politicisation and securitisation of migration, and the conceptual and measurement issues surrounding migration. Most models of migration in use today identify patterns in time series of migration data (usually net migration), and use that knowledge to project migration. However, future migration patterns are likely to be quite different from those in the past because of the challenges mentioned above, and in light of ongoing social transformations, technological changes, and demographic changes. In this paper, I have argued for the use of causal forecasting, which emphasises the causal mechanisms that generate migration. The starting point of this approach is the demographic theory of socioeconomic change proposed by Wolfgang Lutz (2012). While cohort replacement is an important facilitator of change, cohorts are not homogeneous, and personal attributes do not remain fixed throughout the life course. To accommodate these shifts, cohort biographies are replaced by individual biographies of the members of a cohort. By focusing on individual biographies, the interaction between migration and other demographic events in the life course can be modelled relatively easily. In addition, interactions between individuals and between individuals and institutions can be incorporated into the model.

Individual life histories are modelled as continuous-time Markov processes, like in the modelling of cohort biographies. To accommodate the actors who affect migration and to model their influence on potential migrants, the parameters of the Markov model (transition rates) are replaced by individual decision rules or behavioural rules. If these rules are based on migration theory, they can provide a vehicle for the integration of theoretical insights into migration forecasting models. The resulting model is a causal forecasting model that is rooted in Lutz's demographic theory of socioeconomic change, but that extends the existing theory, which operates at the macro (cohort) level, to construct a new theory, which combines the macro level and the individual level. The full specification of a causal forecasting model is beyond the scope of this paper. Several characteristics of such a model have been listed. The ultimate model is an actor-based or agent-based model with multiple levels, in which individuals have agency and make decisions in a stochastic environment, and in which other individuals and institutions influence individual decisions and actions.

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