Modelling international migration by means of stochastic evolution

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International migration is a complex human phenomenon with multi-faceted determinants that make it difficult to identify precise mechanisms. In addition, the lack of consistent high-resolution data poses another dimension of uncertainty. Nevertheless, there is a need for self-consistent, dynamic models of international migration, since climate change is considered to have an impact on migration [1, 2] and well-founded projections are essential for developing adaptation and mitigation strategies. Here, we present a new model for international migration forecasts that is based on discrete time stochastic evolution. This approach combines the strengths of proper population flow accounting in terms of evolution equations while incorporating determinants of migration in stochastic parameters. More precisely, we combine the deterministic element of evolution equations with non-deterministic effects for those variables that are typically difficult to assess or to measure. Apart from direct migration flows between origin and destination countries we discuss the effect of assimilation, transit migration and return migration. Consequently, the model contains not only dynamics at different time scales but also geographical, economic, demographic, social, and political dependencies. As a proof of concept, we study model systems and compare to the commonly used Gravity Model [3, 4] pointing at crucial differences between the two formalisms. The importance of time dynamics for future projections is highlighted and possible pathways for including Climate Change effects are presented.

International migration flows are influenced by a multitude of demographic, economic, social, political, and environmental factors [5]. Investigating the effect of climate change on migration patterns over time requires models that can account not only for climate change itself, but also for other important drivers of migration which might themselves be altered by climate change, or might modulate climate effects on migration. Existing population-level models of interna-

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tional migration vary in the degree of determinism reflecting the assumptions about the underlying migration mechanism. On the one side of the spectrum, for instance, there are autoregressive models that are solely based on reported data without assumed knowledge on dependencies of variables (e.g. Ref. [6, 7]). On the other side, we find approaches that motivate a specific functional form for equations predicting migration rates (e.g. Ref. [8]). While the latter methods are prone to introducing biases and are less flexible for future scenarios, the purely data-driven models offer no easy interpretation of migration mechanisms. In addition, the paucity of consistent, long-term and high-resolution migration data poses another challenge for any modeling approach.

Here, we present a new model for international migration forecasts that is based on discrete time stochastic evolution. This approach combines the strengths of proper population flow accounting in terms of evolution equations while incorporating determinants of migration in stochastic parameters. More precisely, we combine the deterministic element of evolution equations with stochastic effects for those variables that are typically difficult to assess or to measure. Therefore, our approach offers a high degree of flexibility and allows for further extensions with respect to the stochastic component.

Specifically, we describe the change in population of country i between time steps t_{n+1} and t_n by

$$\begin{aligned}
&P_i(t_{n+1}) - P_i(t_n) \\
=&P_i(t_n) \cdot c_i(t_n) && (1)\\
&- M_i(t_n) \cdot (1 + c_i(t_n)) && (2)\\
&+ \sum_{m=-\infty}^{n-1} \sum_{l} \left(R_{li}(t_n; t_m) + A_{li}(t_n; t_m)\right) \cdot \left(1 + \tilde{c}_{il}(t_n, t_m)\right), && (3)
\end{aligned}$$

where the first contribution (1) accounts for death and birth rates c_i in country i. The second contribution in population change (2) is attributed to out-migration M_i with the additional effect of c_i. Lastly in (3), return migration $R_{li}(t_n; t_m)$ from people in country l back to country i, that were residing in l since t_m, give a positive change in population in country i. Additionally, we treat assimilation $A_{li}(t_n; t_m)$ from people of a diaspora of origin country l that were residing in i since t_m as another contribution. Both, return migration and assimilation, are re-scaled by an interpolated population change rate $\tilde{c}_{il}(t_n, t_m)$ that respects the residence time in the destination country. These additional flows ((2) and (3)) reflect different dynamics and are therefore treated separately in our model. Note that the explicit dependency on t_m introduces a different time scale to the dynamics of the system.

In contrast to the deterministic evolution equation describing population, we use a stochastic approach for migration and assimilation flows, i.e. we sample these from probability distribution functions (pdf). The multi-variate dependencies on these flows are incorporated in the parameters of the pdfs, e.g. mean, variance, or scaling, which are determined by means of regression analysis.

Combining these two aspects in our population modelling we arrive at a self-consistent treatment of flows and population sizes. Moreover, the stochastic modeling not only takes account of uncertainties in the reported migration data but also assumed multi-variate dependencies on migration and assimilation flows which makes it a powerful tool for future migration scenarios.

References

[1] D. Wesselbaum and A. Aburn, “Gone with the wind: international migration”, Global and Planetary Change **178**, 96–109 (2019).

[2] D. J. Kaczan and J. Orgill-Meyer, “The impact of climate change on migration: a synthesis of recent empirical insights”, Climatic Change **158**, 281–300 (2020).

[3] M. Beine, S. Bertoli, and J. Fernández-Huertas Moraga, “A practitioners’ guide to gravity models of international migration”, The World Economy **39**, 496–512 (2016).

[4] R. M. Beyer, J. Schewe, and H. Lotze-Campen, “Gravity models do not explain, and cannot predict, international migration dynamics”, Humanities and Social Sciences Communications **9**, 56 (2022).

[5] R. Black, W. N. Adger, N. W. Arnell, S. Dercon, A. Geddes, and D. Thomas, “The effect of environmental change on human migration”, Global Environmental Change **21, Supple**, 3–11 (2011).

[6] J. Bijak and A. Wisniowski, *Forecasting international migration in europe: a bayesian view*, The Springer Series on Demographic Methods and Population Analysis (Springer Netherlands, 2010).

[7] J. J. Azose, H. Ševčíková, and A. E. Raftery, “Probabilistic population projections with migration uncertainty”, Proceedings of the National Academy of Sciences **113**, 6460–6465 (2016).

[8] F. Docquier, “Long-term trends in international migration: lessons from macroeconomic model”, Economics and Business Review **4**, 3–15 (2018).