Parsimonious Stochastic Forecasting of International and Internal Migration on the NUTS-3 level – An Outlook of Regional Depopulation Trends in Germany

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Introduction

Causes and consequences of demographic trends are likely to exhibit a distinct regional component. These may be influenced by regional heterogeneity in mobility, health services, shopping opportunities, housing, labor, and education (Zhang and Bryant, 2020). Moreover, regional attractiveness (Skirbekk et al., 2007), such as cities' architecture, landscape, or climatic differences may lead to discrepancies in the demographics of different regions in larger countries (Eberhardt et al., 2014). Vice versa, the future demographic structure is of high importance for regional planning in infrastructure, labor market needs, supply with childcare, and schools, among others (Wilson, 2015, Zhang and Bryant, 2020). Moreover, the future need for healthcare due to population aging (Vanella et al., 2020b) or future demand for housing depends on the future population structure as well (Gløersen et al., 2016, Vanella et al., 2020a). Therefore, regional population forecasts are of high importance.

Out of the three demographic components fertility, mortality, and migration, the latter is the one that shapes regions the strongest in the short term (Deschermeier, 2011), as fertility and mortality trends are of stronger long-term importance (Vanella et al., 2020a). This can have a significant impact on the population structure, particularly for smaller regions, where emigration can change the population size and structure significantly

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(Deschermeier, 2011, Zhang and Bryant, 2020). Migration shows higher stochasticity as it is more sensitive toward acute events such as crises. International crises impact international migration flows heavily (Vanella and Deschermeier, 2018), which subsequently lead to further internal migration flows. For instance, the correlation coefficient between annual international immigration to Germany for the years 1994 to 2018 and the one year delayed emigration of the German districts (i.e. migration over district borders in 1995-2019) amounts to 94.8% (GENESIS-Online, 2021, Statistische Ämter des Bundes und der Länder, 2021a).

Internal migration is subject to frequent discussion in local studies, as economically weaker regions often suffer persistent net emigration, especially among more educated and skilled sub-populations (Fratesi and Percoco, 2013). This leads to the depopulation of said regions. A significant share of the younger population leaves their regions of origin, which is followed by an echo effect as the population in the reproductive age is missing eventually. Therefore, birth numbers will be small as well, which will accelerate the depopulation trends. Thus, it is of high importance to characterize future developments in internal migration to enact policies aimed at either counteracting regional depopulation or, as an alternative, mitigate the expected developments by changing, for example, infrastructural supply according to the future diminishing demand in the respective regions (Iwanow and Gutting, 2020, Krüger, 2020).

Migration projections on the NUTS-3 level are regularly done deterministically by the estimation of migration rates (e.g., Maretzke et al., 2021). However, deterministic approaches have major limitations, as they do not reflect future uncertainty but only present a rather small number of realistic scenarios, which have a statistical probability to take place close to zero (Keilman et al., 2002). Therefore, the quantification of prediction intervals instead of point forecasts is preferable, as they allow us to quantify ranges of outcomes of our migration statistics by probabilities (Vanella and Deschermeier, 2018). This is especially crucial in planning on the regional level, where migration is associated with higher uncertainty and may have crucial implications for future development, as Deschermeier (2011) has shown.

Materials and Methods

We use small-area data on emigration from and immigration to the NUTS-3 regions in Germany (*Kreise* or *Districts*) for the period 1995-2019, which is publically available online by the German federal statistical office and the statistical offices of the federal states (Statistische Ämter des Bundes und der Länder, 2021b). First, we evaluate five different model approaches regarding their ex-post standardized mean absolute percentage error, performing backtest forecasts for the years 2009-2019 in Germany, based on the data of 1995-2008, and assuming no knowledge of migration trends after that period. Before we develop the stochastic model, we compare the model alternatives deterministically as described. For the model identified as having the best forecast performance, we derive a stochastic forecast until the year 2040.

According to our backtest, a simple random walk model performed best in predicting migration on the district level and by age group in comparison to more complex principal component-based approaches, and that models based on (pseudo) migration rates tend to perform better than models based on migration flows. Here, we assume the first differences of the log-(pseudo) migration rate time series to follow a multivariate Gaussian distribution with a null vector as means and a covariance matrix according to the empirical covariance matrix of the first differences time series. Using Monte Carlo simulation, we then compute 1,000 trajectories of the future development of the (pseudo) migration rates for all age groups and districts.

Preliminary Results

Among children, depopulation based on migration[5] over the forecast horizon is highly unlikely for the vast majority of German districts. Only some major and less family-friendly cities, such as Berlin, face a high probability to depopulate in that age group which may be explained by a higher tendency of families to populate neighboring districts on the one hand and a lack of affordable room for living for young families on the other hand. The model includes effects such as displacement among different age groups as a

[5] Which does not rule out depopulation because of low fertility.

consequence of overburdened local real estate markets indirectly as derived from the historical data. Among the study age population, regional effects will become obvious with large depopulation for most districts against growth in the cities with large universities. This is partially balanced by depopulation in the labor age group in these regions, whereas other districts without or only with minor universities but with intact labor markets are improbable to depopulate in the labor age groups. Finally, we can expect depopulation among the pension age group in the larger cities, as migration to surrounding areas will pose a serious option for those.

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