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ORIGINAL RESEARCH

Gravity Models for Global Migration Flows: A Predictive Evaluation

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Abstract
This study introduces a comprehensive econometric framework based on gravity equations and designed to forecast migrant flows between countries. The model's theoretical underpinnings are validated through empirical data, and we show that the model has better out-of-sample predictive ability than alternative global models. We explore the quantitative effects of various socioeconomic, demographic, and geographic factors on migration and illustrate its use to obtain scenario-driven projections of bilateral migration, assessing the potential contributions of migration to population and GDP dynamics in Germany and Portugal for the period 2021–2025. Our projection results highlight the critical role of immigration in sustaining population levels and economic growth, particularly in the context of ageing populations and decreasing fertility rates across Europe.

Keywords Migration · Gravity model · Economic growth · Forecasting

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Introduction

The world is undergoing unprecedented changes in its age structure, fertility and mortality (Mason, 2022). On the one hand, certain countries around the world, from Japan and South Korea to Italy and a lot of Eastern Europe, are experiencing population decline (Bricker & Ibbitson, 2019). According to Vollset et al. (2020, p. 1285), 23 countries including Spain, Japan and Thailand are forecast to undergo population declines larger than 50% between 2017 and 2100. Among richer countries, the issue is not simply one of declining populations, but also of ageing. Currently, the working-age population accounts for more than 65% of the world population, outnumbering the older age group (65 +) by almost seven times (UNDESA, 2019). However, the ratio of the working-age population to the older population is expected to fall to 5.5 by the year 2030, altering fundamental aspects of society such as labour force participation (Baker et al., 2005). Moreover, a declining and ageing population increases the burden on the capacity of public services (Lubitz, 2003), finances (Bloom, 2015), as well as social and family support networks (Prince, 2015).

In countries facing ageing and declining populations, migration can reduce old-age dependency ratios, and other factors, such as a higher labour force participation of women and better educated individuals, may help curve these demographic impacts (Lee, 2014). To investigate the magnitude of the effect of international mobility and design evidence-based migration policy, policy makers need accurate estimates of current migration and reliable forecasts of their future change, as well as credible predictions of their effects on economic growth.

In this contribution, we provide an approach to provide bilateral international migration flow predictions based on gravity models for short-term projection (5 years ahead). We augment the standard gravity model of migration by including additional social and economic variables known to impact migration and assess the forecasting accuracy of different specifications making use of out-of-sample predictive validation. We exemplify the usefulness of estimated gravity models by creating migration forecasts and comparing them to ‘zero immigration’ scenarios for population and gross domestic product (GDP) in Germany and Portugal. The choice of Germany and Portugal is justified as they exhibit low fertility rates and increasing inflows of migrants in recent years. In addition, reliable input data is available for both nations and their governments hold a rather stable position towards migration, which makes it easier to create credible projections of expected future developments.

The central underlying assumption of gravity models for international mobility is that migration flows between two countries are proportional to their size, i.e., to their total population and inversely proportional to the geodesic distance between them, which acts as a proxy for transportation costs (see (Ramos, 2016), for example). In addition to their intuitive appeal, gravity models can be augmented in a flexible manner with additional potential socioeconomic determinants of migration activity, such as GDP per capita, the relative size of the middle class, the ratio of the working-age population to children and elderly, fertility rates and the size of the existing stock of migrants of a given origin in a destination country. Moreover, gravity models also have a solid theoretical foundation in the random utility maximization (RUM) model. The RUM model is an economic framework that explores why individuals choose to migrate by considering their preferences and perceived benefits and costs of different locations. Such a framework posits that individuals select the migration destination that maximizes their overall satisfaction, leading to the calculation of choice probabilities based on the total utility of their action.

The use of gravity models in the context of migration goes back to Ravenstein (1885), who identifies gravity-like properties of international migration in the context of the United Kingdom, as well as Zipf (1946) who applies a gravity approach to analyse U.S. intercity migration. Another example of a migration analysis based on the gravity approach is given by Karemera (2000), that puts forward a gravity model of international migration for North America and identifies the population size of origin countries and the income of destination economies as two significant determinants of mobility to the region. Cohen (2008) also ground their approach on a gravity model and propose a generalized linear model based only on geographic and demographic independent variables. Kim and Cohen (2010) analyse the determinants of international migration flows to and from industrialized countries based on panel data and a gravity model specification that uses demographic, geographic and socioeconomic explanatory variables. Another example of panel data used in a gravity model of migration is Mayda (2010), who focuses on the determinants of migration inflows into 14 OECD countries. In particular, this study analyses the effect of income in countries of origin and destination on migration flows.

Traditionally, forecasts of migration flows have been based on relatively simple extrapolation exercises for past data, expert opinion, or the existing correlations between migration and economic or demographic data (Disney, 2015). While accurate knowledge of actual and projected migration flows is central to planning and implementing policy instruments, migration can be affected by many social, economic, and political drivers, making forecasting exercises difficult. Assessing the predictive performance of different methodological approaches to create forecasts of bilateral migration flows appears thus particularly important when selecting statistical models for migration flows (Aslany et al., 2021; Disney, 2015). Azose and Raftery (2015), who compare the performance of Bayesian probabilistic projections, persistence models, and gravity models of migration based on out-of-sample validation, find that their Bayesian hierarchical model outperforms an approach based on a gravity model as described in Cohen (2012). As opposed to our analysis, Azose and Raftery (2015) focus on country-level net migration instead of bilateral flows, and aim at creating projections over a long time horizon.

Building on Azose and Raftery (2015) and other studies, Sardoschau (2020) collects and visualizes migration predictions developed by several leading experts in the field of migration modelling. Focusing on relatively long-term forecasts of net migration flows, they compare the performance of gravity models to that of structural and Bayesian specifications. Their analysis shows that gravity models perform slightly worse regarding the theoretical foundation, transparency of assumptions, and predictive power than structural models, but have lower data requirements. In contrast, when comparing gravity models to Bayesian models, they find that gravity models have slightly higher data requirements but a more robust theoretical foundation and a similar level of transparency in the underlying assumptions. An important recent critique of gravity models comes from Beyer et al. (2022), who question the explanatory power of gravity models for variation in migration flows over time for pairs of countries. In particular, the analysis in Beyer et al. (2022) concludes that while gravity models describe spatial patterns of international migration very well, they do not capture temporal dynamics better than averages of historical flows.

The aim of this paper is to rigorously evaluate the predictive ability of gravity models of migration for bilateral flows using a forecasting exercise and comparing the predictive ability of gravity specifications with those of averages of the historical flows (in the spirit of Beyer et al. 2022). We assess the demographic, geographical, and socioeconomic factors that appear empirically relevant to explaining and forecasting migration patterns. Our results indicate that the best predictive performance is delivered by econometric models for migration which in addition to the standard gravity variables incorporate information about diaspora, demographic factors and labour market outcomes. We exemplify the use of these models to create projections of the future contribution of migration to population and GDP dynamics.

The remainder of this paper is organized as follows, In Sect. 2, we describe our input data, our specification of the gravity model and the other statistical methods that we use for a comparison. Section 3 presents the results and Sect. 4 concludes.

Gravity Models of Migration: Specifications and Data

In the framework of gravity models, migration flows between countries are linked to their respective size and the distance between them (as a proxy of mobility costs). Such a relationship implies an underlying data generating process that links migration flows from origin country i to destination countries j in period t ($m_{i,j,t}$) to the size, measured by total population, of origin and destination countries ($S_{i,t}$ and $S_{j,t}$ respectively) and the geodesic distance that separates them ($d_{i,j}$),

$$m_{i,j,t} = c\, \frac{S_{i,t}^{\beta} S_{j,t}^{\gamma}}{d_{i,j}^{\delta}}\, \epsilon_{i,j,t}, \tag{1}$$

where $\epsilon_{i,j,t}$ is a stochastic error term, and c represents a scaling constant. The theoretical basis of such a specification is motivated by migration decisions based on their potential gains to expected utility (see for instance Ortega & Peri, 2013). Additional push and pull factors of origin and destination countries that are assumed to influence migrants' decisions can be incorporated to Eq. (1). Besides the standard gravity model, we also estimate specifications that include (a) socioeconomic factors such as GDP per capita and the relative size of the middle class to capture economic incentives that act as pull and push factors for migration, as well as the ratio of the working-age population (15–64) to the total population and unemployment rates as proxies for labour market needs; (b) demographic characteristics such as fertility rates and the share of people with at least secondary education; (c) diaspora variables measuring the existing number of migrants of a given origin in the destination country and the flow of migrants in the last period (i.e., with a five-year lag); and (d) dummy variables indicating whether origin and destination countries share a common border or a common (official) language.

Summarizing these additional origin-specific variables in the vector $\mathbf{Z}_{i,t}$, the destination-specific variables in $\mathbf{Z}_{j,t}$ and the bilateral factors in $\mathbf{X}_{i,j,t}$, and using a linear model in (natural) logs, the specifications we use in our forecasting exercise are nested in the model given by

$$\log m_{i,j,t} = \log c + \beta \log S_{i,t} + \gamma \log S_{j,t} - \delta \log d_{ij} + \mathbf{Z}_{i,t}\boldsymbol{\theta} + \mathbf{Z}_{j,t}\boldsymbol{\phi} + \mathbf{X}_{i,j,t}\boldsymbol{\eta} + \mu_{i,j,t}, \tag{2}$$

where the vectors $\boldsymbol{\theta}$, $\boldsymbol{\phi}$ and $\boldsymbol{\eta}$ summarize the effect of the variables in $\mathbf{Z}_{i,t}$, $\mathbf{Z}_{j,t}$ and $\mathbf{X}_{i,j,t}$, respectively, and $\mu_{i,j,t} = \log \epsilon_{i,j,t}$ is assumed to fulfil the assumptions of the standard linear regression models.

To measure the predictive power of the proposed gravity model, we assess the quality of the forecasts produced by the specification in a pseudo-out-of-sample predictive analysis exercise and benchmark the forecasts from several specifications of the form given by equation (2) with other simpler heuristic models: (i) the naive approach to use migration in the last observation period as prediction for the following periods (*random walk* model); (ii) use the historical average for each given origin and destination country as a prediction (*historical mean* model); and (iii) a simple autoregressive model, where the forecasts are obtained from a model that projects the (cross-sectional) flows on their lagged values and bilateral origin–destination fixed effects as explanatory covariates.

The bilateral migration flow data required to estimate the gravity specifications is sourced from Abel and Cohen (2019), who provide information for 200 countries of the world in 5-year intervals ranging from 1990 to 2020. Specifically, we use their results based on a closed demographic accounting system and a minimization approach to estimate the missing bilateral migration flows. For the set of independent covariates in the gravity models, we employ data from several sources. Information on national GDP per capita is sourced from the World Economic Outlook from the International Monetary Fund (2022) and data on population from the UNDESA (2019) World Population Prospects (WPP) dataset. Data on migrant stocks are obtained from the United Nations Department of Economic and Social Affairs UNDESA (2020). For each five-year interval of migration flow data, we use migrant stock data referring to the beginning of the corresponding period. We also employ a (5 years) lag of the bilateral migration flows as an additional covariate. Information on the share of people of working age (15–64) in the total population is also sourced from the United Nation's WPP dataset. The share of persons with post-secondary education and fertility rates are obtained from Wittgenstein Centre (2018). Data on the share of the middle class (defined as households spending $11–110 per day per person in 2011 purchasing power parity, or PPP) in the general population are obtained from the World Data Lab (2022), World Data Pro. Finally, information on unemployment is sourced from International Labour Organization (2022). Our final data set contains (bilateral) information on 177 origin and destination countries. Information on some variables is missing for particular country pairs and periods. The final unbalanced panel data set contains 116,460 observations, and we utilize the balanced sub-panel containing 113,700 observations composed of 28,425 country pairs and four five-year periods starting in 2000.[1]

Results

Estimates

We consider four different specifications of the form given by Eq. (2), that differ in the number and nature of the regressors included as controls in the model. The variables included in each of the specifications estimated can be found in Table (1). The estimation results for the parameters of the models are presented in Table 2. The first column shows the estimates corresponding to a basic gravity model which only includes population, GDP per capita, distance, as well as period fixed effects as covariates (GM-SMALL). In the second column, we present the results of the estimated effects for the extended specification which includes the full set of explanatory variables introduced in the section above (GM-LARGE). The estimates presented in the third column correspond to a model that, in addition to the additional variables, also includes origin and destination country fixed effects (GM-LARGE-FE). In column 4, we consider a model including the interaction of these fixed effects, that is, bilateral origin–destination fixed effects (GM-LARGE-BFE). Note that all time invariant variables are perfectly colinear to those bilateral origin–destination fixed effects and are therefore excluded for the estimation of the GM-LARGE-BFE model.

The intuitive theoretical relationships implied by the simple gravity model are qualitatively validated in the data. The variables that capture country size have effect estimates which are statistically significant and have a positive sign, whereas distance appears negatively related to migration flows. The sign of the effect of these variables is not affected by the inclusion of additional covariates, but the magnitude of the parameter estimates decreases. When controlling for origin and destination specific fixed effects the parameter estimates of population and GDP per capital remain significant indicating that those variables provides information about country-specific outflows and inflows exceeding the mean values. The intuitive direction of the effects predicted by the standard gravity model of migration are validated by the cross-sectional variation of migration flows in our dataset. Once the variation across country pairs is controlled for, the estimated parameters obtained by exploiting variation over time present are clearly different from those in the models without fixed effects. The parameter estimate of population in the destination country is negative in the model including country-specific fixed effects, suggesting that while countries with large populations tend to experience larger migration flows,

[1] All the data and codes required to replicate the analysis can be found at https://github.com/jakobZellmann/Gravity-Models-for-Global-Migration-Flows-A-Predictive-Evaluation.

Table 1 Overview of regressors included in each gravity specification

Regressors	GM-SMALL	GM-LARGE	GM-LARGE-FE	GM-LARGE-BFE
Population, origin (log)	•	•	•	•
Population, destination (log)	•	•	•	•
GDP per capita, origin (log)	•	•	•	•
GDP per capita, destination (log)	•	•	•	•
Distance (log)	•	•	•	
Contiguity	•	•	•	
Common official language	•	•	•	
Bilateral migration flows, lagged (log)		•	•	•
Migration Stocks, (log)		•	•	•
Ratio of working-age population, origin (log)		•	•	•
Ratio of working-age population, destination (log)		•	•	•
Share of mid-class, origin (log)		•	•	•
Share of mid-class, destination (log)		•	•	•
Share of post-secondary education, origin (log)		•	•	•
Share of post-secondary education, destination (log)		•	•	•
Unemployment rate, origin (log)		•	•	•
Unemployment rate, destination (log)		•	•	•
Fertility rate, origin (log)		•	•	•
Fertility rate, destination (log)		•	•	•
Period fixed effects	•	•	•	•
Country fixed effects, origin			•	
Country fixed effects, destination			•	
Country fixed effects, bilateral				•

population changes tend to correlate negatively with changes in migration flows on average, after controlling for the other factors included in the model. The same interpretation explains the estimated negative effect of GDP per capita in origin countries on migration flows, and similar results are obtained for the model that includes bilateral fixed effects. The significant effect of lagged migration flows and the effects of the migration stock variables suggest an important role of persistence effects of migration and diaspora networks as determinants of future migration flows.

We find additional significant effects from several socioeconomic and demographic covariates included in the specification. The share of persons with secondary or higher education in the origin country has a positive and sizeable effect on migration flows, especially when controlling for fixed effects. Furthermore, the ratio of working age population to total population in the origin (destination) country

Table 2 Full sample estimates: gravity models

	Dependent variable: Bilateral migration flow (log)			
	(GM-SMALL)	(GM-LARGE)	(GM-LARGE-FE)	(GM-LARGE-BFE)
Population, origin (log)	0.366***	0.085***	0.975***	0.913***
	(0.004)	(0.003)	(0.064)	(0.051)
Population, destination (log)	0.315***	0.069***	− 1.299***	− 1.053***
	(0.004)	(0.003)	(0.064)	(0.051)
GDP per capita, origin (log)	0.145***	0.104***	− 0.355***	− 0.265***
	(0.005)	(0.009)	(0.044)	(0.036)
GDP per capita, destination (log)	0.832***	0.210***	0.236***	0.176***
	(0.005)	(0.009)	(0.044)	(0.036)
Distance (log)	− 0.561***	− 0.079***	− 0.125***	0.007
	(0.008)	(0.006)	(0.007)	(0.005)
Contiguity	2.223***	0.048	0.218***	
	(0.051)	(0.038)	(0.037)	
Common Language	0.923***	0.120***	0.188***	
	(0.019)	(0.014)	(0.015)	
Bilateral migration flows, lagged (log)		0.421***	0.311***	− 0.124***
		(0.003)	(0.003)	(0.003)
Migration stock (log)		0.286***	0.302***	− 0.058***
		(0.002)	(0.003)	(0.012)
Ratio of working-age population, origin (log)		0.508***	− 0.579***	− 2.798***
		(0.111)	(0.225)	(0.192)
Ratio of working-age population, destination (log)		− 1.634***	1.569***	2.410***
		(0.114)	(0.225)	(0.193)
Share of mid-class, origin (log)		− 0.049***	−0.040***	− 0.035***
		(0.006)	(0.013)	(0.011)

Table 2 (continued)

	Dependent variable: Bilateral migration flow (log)			
	(GM-SMALL)	(GM-LARGE)	(GM-LARGE-FE)	(GM-LARGE-BFE)
Share of mid-class, destination (log)	− 0.037***	−0.030**	− 0.029**	
		(0.006)	(0.013)	(0.011)
Share of post-secondary education, origin (log)		0.344***	6.408***	7.899***
		(0.103)	(0.528)	(0.392)
Share of post-secondary education, destination (log)		1.146***	−2.599***	−2.288***
		(0.105)	(0.529)	(0.395)
Unemployment rate %, origin (log)		−0.065***	0.023	0.028
		(0.006)	(0.018)	(0.026)
Unemployment rate %, destination (log)		0.034***	0.054***	0.054***
		(0.006)	(0.018)	(0.016)
Fertility rate, origin (log)		0.271***	0.807***	
		(0.026)	(0.071)	
Fertility rate, destination (log)		− 0.313***	− 0.488***	
		(0.026)	(0.071)	
Period fixed effects	Yes	Yes	Yes	Yes
Country fixed effects, origin	No	No	Yes	No
Country fixed effects, destination	No	No	Yes	No
Country fixed effects, bilateral	No	No	No	Yes
Observations	113,700	113,700	113,700	113,700
R^2	0.330	0.649	0.691	0.822
Adjusted R^2	0.330	0.648	0.690	0.763
Residual Std. Error	2.165 (df = 113,689)	1.569 (df = 113,677)	1.472 (df = 113,341)	1.286 (df = 85,252)

Table 2 (continued)

	Dependent variable: Bilateral migration flow (log)			
	(GM-SMALL)	(GM-LARGE)	(GM-LARGE-FE)	(GM-LARGE-BFE)
F statistic	5,723.179*** (df = 10; 116,449)	9,764.606*** (df = 22; 116,437)	695.355*** (df = 374; 116,085)	13.857*** (df = 85,252; 28,447)

positively (negatively) influences the magnitude of migration flows between pairs of economies. However, controlling for country-specific fixed effects reverses the direction of these results, thus indicating that the effect of this variable in the specification given by GM-LARGE is mostly driven by cross-country variation, as opposed to variation over time. Similarly, we find that high fertility origin countries tend to have higher emigration, whereas high fertility rate in destination countries tend to reduce immigration flows. These results still hold when controlling for country-specific fixed effects, but change direction when controlling for bilateral origin–destination fixed effect, indicating that the effects implied by cross-sectional variation and those implied by time variation can be very different.

Out-of-sample Prediction Validation

To assess the predictive power of the gravity models for migration, we estimate our gravity specifications using data for the period 1995 to 2015, use the estimated models to obtain forecasts for 2015–2020 and compare the predictive ability of our models with that of heuristic methods based on random walk specifications, historical averages of migration flows and simple autoregressive models. We obtain different measures of prediction accuracy: (i) the root mean square forecast error (RMSE), as a measure of discrepancy between realized and predicted values, (ii) the mean directional accuracy (MDA), which measures the share of correctly predicted changes in migration flows (based on predicted increase/decrease) and (iii) the estimated coefficients of a linear regression model where the realized migration flow values are regressed on an intercept and the predicted values (where rational predictions would correspond to an intercept of zero and a slope of unity in this regression model).

Scatterplots of predicted and realized values in the out-of-sample period for all models are presented in Fig. 1, and the results of the prediction exercise can be found in Table 3. Figure 1 depicts the scatterplot of realized and predicted values together with the 45 degree line (which would imply compatibility with rational forecasts) and the corresponding regression line. Deviations between these lines are informative of biases in the forecasts. We find that the large gravity model without country-fixed effects (GM-LARGE) performs best in means of RMSE. It is closely followed by the model including country and destination fixed effects (GM-LARGE-FE) and the historical averages. The relatively poor prediction results from both GM-LARGE-FE and GM-LARGE-BFE suggest that models including bilateral and country fixed effects may tend to overfit the existing migration flow data.

The results presented are robust in respect to the estimation method for the migration flow data. In particular, we find that the results obtained for the migration flow data used remain similar if the migration flow estimates obtained by the pseudo-Bayesian approach in Abel and Cohen (2019) are used. In addition, we also entertained models based on Poisson and negative binomial regression, to account for the count nature of migration flows and the excess of zero observations.[2] The predictive

[2] It can be seen in Fig. 1 that zero bilateral migration flows significantly alter the predictive ability of the models employed.

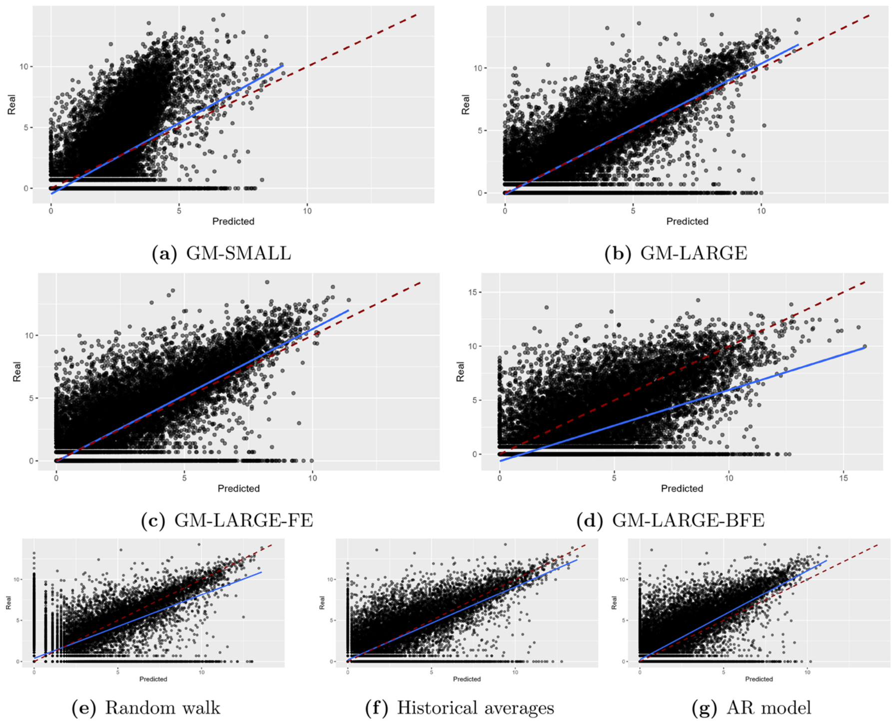


Fig. 1 Predicted vs realized values of log level migration flows. The solid blue line represents the regression line of (linearly) regression the realized on the predicted values. The 45°-line is depicted in red and dashed

ability of these specifications was significantly worse than that of our log-linearized models.[3]

Measuring the Effects of Migration on GDP: An Illustrative Example

The predictive ability of gravity models can be exploited to support evidence-based policies, not only through the use of best-practice migration forecasts, but also by providing the basis for the creation of (counterfactual) projections of population and GDP based on scenarios concerning migration flows. In this section, we provide a simple illustrative example of such a scenario-driven projection exercise, in which we provide a first (lower bound) approximation of the potential contribution of migration to population and GDP dynamics in Germany and Portugal over the period 2021–2025.

For this purpose, we combine migration forecasts from the GM-LARGE model with population projection from the WPP dataset and GDP data from the IMF.

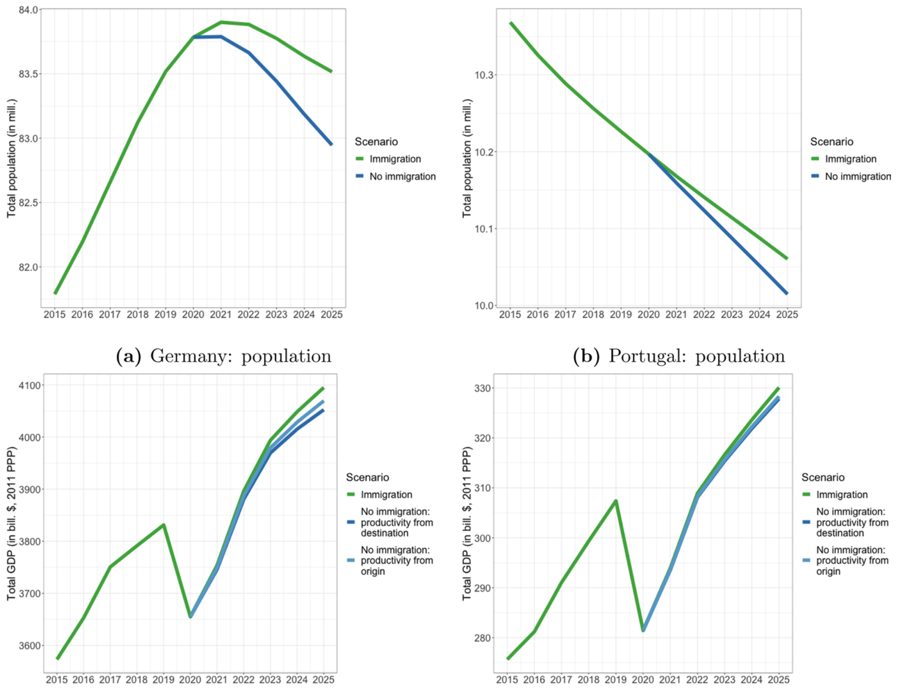
[3] Results based on different migration flow estimates and Poisson and negative binomial models can be obtained at https://github.com/jakobZellmann/Gravity-Models-for-Global-Migration-Flows-A-Predictive-Evaluation.

Table 3 Out-of-sample validation results (2015–2020)

	RMSE	MDA	Inter	Slope
Level of log migration				
GM-SMALL	2.181	0.853	− 0.469	1.166
GM-LARGE	1.506	0.879	− 0.099	1.045
GM-LARGE-FE	1.536	0.869	− 0.044	1.055
GM-LARGE-BFE	2.938	0.831	− 0.642	0.659
Random walk	1.849	0.782	0.392	0.772
Historical averages	1.617	0.877	0.203	0.889
AR model	1.680	0.876	0.234	1.082
Changes of log migration				
GM-SMALL	1.111	0.589	− 0.052	0.426
GM-LARGE	0.877	0.661	− 0.021	1.208
GM-LARGE-FE	0.912	0.632	− 0.022	1.052
GM-LARGE-BFE	1.809	0.526	− 0.193	0.153
Random walk	1.066	0.388	− 0.095	–
Historical averages	0.930	0.655	− 0.031	0.823
AR model	0.948	0.653	0.133	0.823

We subtract the projected number of persons migrating to Germany and Portugal from 2021 to 2025 implied by our model forecasts from the population projections from a scenario with migration (that is, by the population projections in the WPP data). This projection exercise is thus aimed at measuring the population that would live in these two countries if no immigration took place over the the next years. As compared to a scenario without emigration and immigration, we choose this design in order to minimize the uncertainty around future population changes created by migration flows. Eliminating emigration from the scenario would imply employing additional estimates of bilateral migration flows between Portugal and Germany (as origin nations) and all other countries of the world. These estimates would add to the uncertainty of the immigration figures and would make our projections less credible.

Given that our model contains explanatory variables measured at the beginning of the period when the migration flows take place, we can use the latest available data point in order to create the projections of bilateral migration flows for all country pairs in the period 2015–2025. Figure 2 presents the two scenarios (benchmark from the WPP projections and scenario without immigration) for the total population in Germany and Portugal. The benchmark projection shows that the total population of Germany and Portugal is expected to decrease in the coming years, a trend which is further amplified in the scenarios without immigration. Should immigration to Germany and Portugal have come to a halt in 2020, we would see a sharp drop in population numbers in both countries of destination, with the no-immigration scenario in Germany implying around half a million less inhabitants by 2025 and the one for Portugal around 50,000 less. In addition to this alternative scenario for population trends, we also analyse how migration projections can be used to provide first approximations of the effect of human



(a) Germany: population

(b) Portugal: population

(c) Germany: GDP

(d) Portugal: GDP

Fig. 2 Projected total population and GDP with and without immigration: Germany and Portugal

mobility effect on economic growth in receiving countries. To quantify the productivity of migrants, we use GDP growth projections from the IMF and create three scenarios where we assign migrants (a) the average labour productivity corresponding to their country of origin or (b) that of the recipient economy. Summing up the monetary value added to the economy by each individual migrant (as measured by their assumed labour productivity), we are able to assess how GDP in Germany and Portugal would be affected by migration flows in the different scenarios designs. Figure 2 presents this gap in the two scenarios entertained, together with benchmark GDP forecasts from the IMF. Assigning the average productivity of the country of destination to each migrant, in 2025 Germany would already lose over 42 billion dollars of GDP (in 2011 PPP), corresponding to over 1% of its total annual GDP. Assuming that each migrant's productivity corresponds to that of workers in their country of origin would lead to slightly lower losses for Germany, while for Portugal the two scenarios regarding migrant productivity would lead to very similar drops in GDP growth. In relative terms, the fall in GDP implied by the projection scenarios without immigration is larger than that in population, so qualitatively the results for GDP translate to GDP per capita figures in terms of the relative ordering of the scenarios presented.

Such simple exercises based on conditional projections from the gravity model for migration illustrate how our gravity specifications can contribute to an evidence-based debate on migration policy and on the economic effects of migration. It should be noted that, by abstracting from spillovers related to market innovation activities or entrepreneurship, for instance, our exercise can be thought of as providing a lower bound estimate of the effects of migration on economic growth.

Conclusion

This paper estimates global gravity models aimed at forecasting migrant flows between countries and exemplifies their use as a tool to inform economic policy by combining migration projections with current IMF economic growth forecasts to calculate potential GDP losses to the German and Portuguese economies in a scenario without immigration. To assess the validity of this gravity model approach, we perform an out-of-sample prediction exercise and compare different measures of forecasting accuracy, comparing the results of four different specifications of a gravity model to those of three heuristic models. This validation exercise shows that a gravity model including some socioeconomic pull and push factors without country fixed effects performs best in every measure of prediction quality. In addition to projecting expected migration flows, we also provide a simple estimate of how the population and GDP of Germany and Portugal might develop in a no immigration scenario. For this purpose, we combine our migration forecasts with population projections and GDP forecasts.

The modelling framework put forward in our analysis can be particularly useful for the design of evidence-based migration policy instruments, in particular in the context of current discussions in the European political arena. The development of statistical tools to inform policy about issues related to the regulation of asylum requests and the allocation of immigrants across EU economies would require different methods that account for the particular nature of such forced migration flows. On the other hand, our modelling tools could be helpful to create a scientific basis to frame the current discussion on the competition for skilled workers in the global market in ageing societies. To deepen the insights gained by our modelling tool, it would be desirable for further research to perform a more in-depth analysis of the productivity of migrants and the corresponding effects migration may have on economic growth via entrepreneurship, investment in human or physical capital. In this respect, data limitations are currently a binding constraint to the advancement of the research agenda.

Our simple illustration of the use of such models to quantify the economic effects of migration serves as a proof=of=concept example that would need to be further improved to account for additional factors. For longer-term forecasts, it would be useful to extend this relatively simple approach and consider a wider range of determinants that might influence the effect that immigrants have on the population of their country of destination. Age structure, fertility and mortality differentials between migrants and the rest of the population, for instance, would need to be investigated in order to create credible population projections under different scenarios for long time horizons. Focusing only on the next four to five years, we abstract from these effects in the projections provided in this contribution.

Information on the age, sex and education structure of migrants, as well as their allocation in specific economic sectors, would need to be incorporated to refine the assumptions concerning the productivity of migrants and thus GDP projections.

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