

On the Determinants of Global Bilateral Migration Flows*

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Abstract

We present a method aimed at estimating global bilateral migration flows and assessing their determinants. We employ that fact that available net migration figures for a country are (nonlinear) aggregates of migration flows from and to all other countries of the world in order to construct a statistical model that links the determinants of (unobserved) migration flows to total net migration. Using simple specifications based on the gravity model for international migration, we find that migration flows can be explained by standard gravity model variables such as GDP differences, distance or bilateral population. The usefulness of such models is exemplified by combining estimated specifications with population and GDP projections in order to assess quantitatively the expected changes in migration flows to Europe in the coming decades.

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1 Introduction

In 1990, there were approximately 150 million international migrants in the world, a figure that increased by more than 40% in the following two decades. Currently, about 214 million people worldwide live outside the country where they were born, a number that represents roughly 3.1% of total population (see United Nations (2011)).

The lack of availability of global databases for bilateral migration flows is an important barrier to the understanding of the causes and consequences of international migration. While the OECD's International Migration Database (OECD, 2012) provides data on bilateral immigration flows, the information is limited to migration to a relatively small group of industrialized economies. Docquier and Marfouk (2006) present a data set of bilateral migration stocks by educational attainment for over 170 countries in 1990 and 2000, which researchers have used to construct migration flows as differences between stocks at these two points in time (see for example Beine, Docquier, and Ozden (2011)). The problems involved in using differences in migration stocks as a proxy of migration flows can be important and are often acknowledged in the empirical studies performing such an approximation. Mortality and return migration distort the quality of such a variable as a measurement of migration flows and thus the assessment of the dynamics of newcomers based on the difference in the stock of migrants can lead to seriously flawed inference.

Common approaches in the empirical literature aimed at modelling bilateral migration flows and assessing their determinants are extended *gravity models*. Gravity models relate flows of goods or factors between two countries to their attractive mass and to the distance between them. Although originally introduced to model trade flows between two countries (Tinbergen, 1962), the gravity specification also provides a useful tool to model international migration flows. Ravenstein (1885, 1889), in his early assessment of the determinants of migration, states as part of his *Laws of Migration* that “*the bulk of migrants ought to travel short distances only*” and that an “*increase in the means of locomotion and a development of manufactures and commerce have led to an increase of migration*”, thereby implicitly formulating the gravity model for migration. The first empirical application of the gravity model to explain migration flows between two countries is attributed to Vanderkamp (1977), who explained the logarithm of bilateral migration flows by the distance between the countries and their bilateral size, measured by the population of the source and destination countries.

More recent studies build upon the basic gravity model and focus on further determinants of migration flows beyond geographical distance and aggregate measures of economic mass Vanderkamp (1977); Karemera, Oguledo, and Davis (2000); Clark, Hatton, and Williamson (2007); Pedersen, Pytlikova, and Smith (2008); Ortega and Peri (2009); Kim and Cohen (2010); Beine, Docquier, and Ozden (2011); Grogger and Hanson (2011) or Ortega and Peri (2013) are recent examples of this branch of empirical research. Data availability tends to limit these studies on the determinants of bilateral migration to cases where the recipient country is an advanced OECD economy, thus explicitly ignoring South-South migration in their analysis. Bakewell (2009) shows that, depending on how the *South* is defined, between 33% and 45% of global migration can be categorized as South-South migration. To the extent

that the determinants of South-South migration may differ from those of migration flows to industrialized economies, these studies may only have limited applicability to other world regions.

In this study we propose a new method to study the empirical determinants of worldwide bilateral migration flows using net migration data, which are available for practically all countries in the world. By assuming that (log) bilateral migration flows can be described by a simple gravity model, we construct econometric specifications based on net migration, which can therefore be thought of as a nonlinear aggregation of (unobserved) bilateral flows. These, in turn, are functions of observed explanatory variables. Such a modelling strategy allows us to estimate the effects of the various determinants of bilateral migration and eventually construct estimates of bilateral migration flows as the corresponding fitted values. In addition, our approach presents a natural framework to obtain projections of bilateral migration flows that can be used to assess future trends in labour mobility and to improve existing population projection exercises.

Our work is related to recent developments in the estimation and modelling of bilateral migration flows. Abel (2013), building on Abel (2010), estimates bilateral migration flows for 195 countries based on place of birth data. This is done by deriving migration flows from sequential stock migration data in the framework of spatial interaction specifications. Although conceptually the approach in Abel (2013) shares some similarities with our method, we depart from this group of contributions by exploiting the nonlinear nature of the linkage between log bilateral migration (the variable we aim to model) and net migration (the variable we actually observe).

The paper is organized as follows. In section 2, the statistical modelling framework and the estimation strategy are presented. In order to assess the quality of the parameter estimates using our proposed method, a small-scale simulation study is also performed in this section. Section 3 presents the estimates of a representative model and section 4 provides a projection exercise where future changes in migration flows to Europe are assessed based on population and GDP projections. Finally, section 5 concludes.

2 Modelling nonlinearly aggregated bilateral migration flows

2.1 The econometric setting: From bilateral flows to net migration

Since gravity models tend to be specified in log-linear form, obtaining coefficient estimates for the model using aggregated net migration rates implies that the econometric specification used is a nonlinear function of the underlying parameters. We start by assuming that (log) bilateral migration flows can be represented by the model

$$m_{ij} = \log M_{ij} = X_{ij}\beta + u_{ij}, \quad (1)$$

where M_{ij} denotes migration from country j to country i , X_{ij} is a $1 \times k$ vector of determinants of bilateral migration, β is a $k \times 1$ vector of parameters to be estimated and u_{ij} is an error term assumed independent, identically distributed and homoskedastic with variance σ^2 . Bilateral flows are not observed, but data for n countries exist on net migration (N_i), which is given the difference of migration flows to country i from all other countries and migration out of country i to all other countries,

$$N_i = M_{i*} - M_{*i} = \sum_{j \neq i} M_{ij} - \sum_{j \neq i} M_{ji} = \sum_{j \neq i} \exp m_{ij} - \sum_{j \neq i} \exp m_{ji}. \quad (2)$$

The model for our observed data can thus be written in matrix form as

$$\mathbf{N} = \mathbf{S} \exp(\mathbf{m}) = \mathbf{S} \exp(\mathbf{X}\beta + \mathbf{u}), \quad (3)$$

where \mathbf{N} is an n -dimensional column vector of net migration observations, \mathbf{X} is an $(n-1)^2 \times k$ matrix of observations on the bilateral explanatory variables, \mathbf{S} is an $n \times (n-1)^2$ matrix which selects the corresponding bilateral migration flows, aggregates them for each country and creates the net migration figures and $\exp(\mathbf{v})$ denote the element-by-element exponent of vector \mathbf{v} . Assuming that \mathbf{m} is ordered by recipient country, a typical row k of \mathbf{S} has elements equal to 1 in columns $(n-1)(k-1)+1$ to $(n-1)(k-1)+(n-1)$ and -1 in columns $k+k(n-1)$, $k+(k+1)(n-1)$, ... for elements in positions beyond $k(n-1)$ and in columns $k-1+k(n-1)$, ... $k-1+(k+1)(n-1)$ for elements prior to $(k-1)(n-1)$. This implies that the matrix \mathbf{S} is given by $\mathbf{S} = (\mathbf{I}_n \otimes \iota_{n-1}) - \mathbf{B}$, where \mathbf{B} is an $n(n-1)^2$ matrix composed by $n-1$ column blocks of matrices whose structure corresponds to augmenting the matrix $-\mathbf{I}_{n-1}$ by one row of zeros in position b for each block $b = 1, \dots, n-1$.

While the model for the bilateral migration flows is linear in parameters, the aggregation of the flows which yields the net migration flows implies a nonlinear link between \mathbf{N} and β . Therefore, we cannot estimate our model with least squares and rely on nonlinear maximum likelihood methods to estimate β . Proietti (2006) proposes an iterative algorithm which allows to estimate models specified on disaggregated data using aggregated data.¹ The algorithm focuses on the Taylor approximation around some trial value of the vector of disaggregated variables.² This method can be shown to be equivalent to quasi-maximum likelihood estimation, which is the approach we take for our application.

A simple approach to the estimation of model (3) starts by ignoring the nonlinearity in the error term and estimating β based on a specification where the disturbance is defined at the level of the aggregated variable (N_i) instead of at the bilateral level,

$$\mathbf{N} = \mathbf{S} \exp(\mathbf{X}\beta) + \eta, \quad (4)$$

¹In a simplified setup, Proietti (2006) considers a standard linear model $y = \alpha + X\beta + \epsilon$ where α is the intercept, X is a known $N^2 \times k$ matrix of explanatory variables, y a N^2 vector of unknown responses and $\epsilon \sim N(0, \sigma^2 I)$. The vector y is not observed but a non-linear aggregation $Y = \sum_{j=1}^N f(y)$ is, where $f(\cdot)$ is a twice differentiable function. Y and y can be linked through an aggregation matrix $A = I_N \otimes \iota_N$, so that $Y = Af(y) = (I_N \otimes \iota_N)f(y)$.

²Badinger and Crespo Cuaresma (2012) use a similar approach to estimate bilateral trade flows.

which allows to estimate β using nonlinear least squares or pseudo maximum likelihood methods. Assuming independence, normality and homoskedasticity for the disturbance term, the likelihood of the model can be written as

$$L(\beta, \sigma_\eta | \mathbf{N}) = \prod_{i=1}^n f(N_i | \beta, \sigma_\eta), \quad (5)$$

with the corresponding log-likelihood function

$$\ell(\beta, \sigma_\eta | \mathbf{N}) = \sum_{i=1}^n \ln f(N_i | \boldsymbol{\theta}). \quad (6)$$

Assuming normality of the errors, we can write the log-likelihood function as

$$\begin{aligned} \ell(\beta, \sigma_\eta | \mathbf{N}) &= \sum_{i=1}^n \ln \left[\frac{1}{\sigma_\eta \sqrt{2\pi}} \exp \frac{\eta_i^2}{2\sigma_\eta^2} \right] \\ &= -n \ln \sigma_\eta - n \ln(\sqrt{2\pi}) + \frac{\sum_{i=1}^n \left(N_i - \sum_{j \neq i} \exp(X_{ij}\beta) + \sum_{j \neq i} \exp(X_{ji}\beta) \right)^2}{2\sigma_\eta^2} = \\ &= -n \ln \sigma_\eta - n \ln(\sqrt{2\pi}) + \frac{1}{2\sigma_\eta^2} (\mathbf{N} - \mathbf{S} \exp(\mathbf{X}\beta))' (\mathbf{N} - \mathbf{S} \exp(\mathbf{X}\beta)), \quad (7) \end{aligned}$$

which can be maximized using standard optimization methods.

2.2 Maximum likelihood estimation of the net migration model: Simulation results

In a first step we evaluate the method proposed using simulated data. We obtain 9900 observations of simulated log migration flows m_{ij} , which are generated by the process

$$m_{ij} = 1 + .1x_{1,ij} + 0.5x_{2,ij} - 0.5x_{3,ij} + u_{ij}, \quad (8)$$

where the observations for x_1 , x_2 and x_3 are drawn from standard normal distributions. The noise term, u_{ij} , is assumed normally distributed with mean zero and variance σ_u^2 . In different simulation settings we draw errors with variances which lead to signal-to-noise ratios corresponding to R^2 values which range from 0.95 to 0.7. The simulated values of m_{ij} are aggregated as in equation 1 to obtain 100 observations of simulated net migration flows N_{ij} . We use these 100 net migration observations to obtain estimates of the parameters in the model following the maximum likelihood method sketched in section 2. This exercise is repeated 1000 times for different noise-to-ratio levels. Table 1 presents the mean and root mean square error (RMSE) of the estimated coefficients for each one of the settings (which correspond to R^2 values of 0.95, 0.9, 0.85, 0.8, 0.75 and 0.7).

The results indicate that the method works well for noise levels which correspond to R^2 values above. Since net migration is defined estimated as a differences of

Table 1 – Simulation results for different levels of noise

	$R =$	0.95	0.90	0.85	0.80	0.75	0.70
$\beta_0(1.0)$	RMSE	0.082	0.121	0.156	0.215	8.922	12.748
	Mean	1.01	1.02	1.02	1.04	0.65	0.11
$\beta_1(.1)$	RMSE	0.017	0.027	0.036	0.041	0.083	0.970
	Mean	0.10	0.10	0.10	0.10	0.10	0.06
$\beta_2(-.5)$	RMSE	0.027	0.039	0.050	0.067	0.863	1.970
	Mean	-0.50	-0.50	-0.50	-0.51	-0.55	-0.63
$\beta_3(.5)$	RMSE	0.026	0.039	0.050	0.066	1.659	2.180
	Mean	0.50	0.50	0.51	0.51	0.57	0.64

nonlinear functions of the parameters, the identification of the intercept is weak, leading to less satisfactory estimates for the constant term even for an R^2 of 0.8, while the estimates of the slope parameter present better properties throughout the simulation settings. The empirical literature on the estimation of gravity models for migration flows using (fragmentary) bilateral data tends to report high explanatory power even in parsimoniously parameterized specifications, which makes us believe that the method proposed should work acceptably well in this setting.

3 Empirical analysis: Assessing migration flow determinants

We present a simple econometric model that should serve as an application of the model to highlight the usefulness of the approach. In particular, we construct a specification for bilateral migration flows where the respective flow depends on the distance between the two countries, their relative income per capita, their combined size and other geographical and cultural aspects which are summarized in a dummy variable measuring geographical contiguity, another one identifying common colonial history, 21 world-region dummies for the destination country and 21 world-region dummies for the source country.

Net migration flows, as well as GDP and population data are sourced from the World Bank’s World Development Indicators. Net migration is evaluated at the period 2000-2005 and measures the total number of immigrants less the number of emigrants and it represents the net total of immigrants of a given country over this period. The net migration estimates are based on a number of national sources and when no official source of net migration is available, it is calculated by the difference between total population growth and natural increase in a country for a given period.³ GDP as well as population corresponds to the year 2000. Data on

³Notice that the “quality” of each data point is thus not necessarily the same. Exploiting the existing information on the quality of observations to develop a weighting scheme that can be embedded in the estimation method is a potentially fruitful avenue of further research but outside the scope of this contribution.

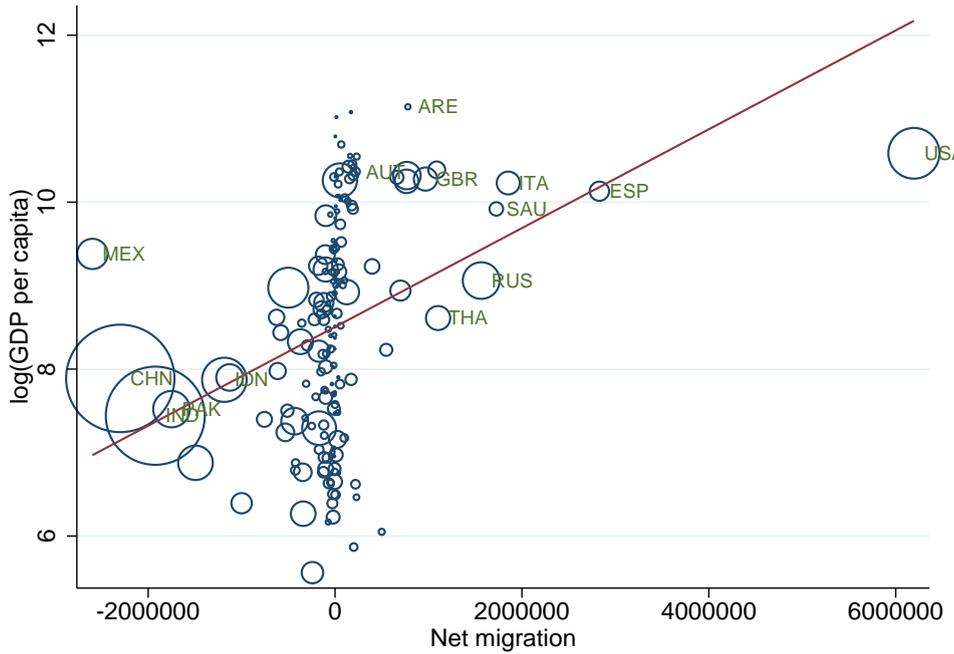


Figure 1 – Net migration flows vs. income per capita (size of the bubbles represents population size)

common official language, common borders, colonial history and bilateral distance corresponding to a country pair are obtained from the CEPII Gravity Dataset (Head, Mayer, and Ries, 2010). Dummy variables representing world regions are based on the United Nations Statistics Division’s geographical sub-regions classification. The dataset contains information for 172 countries.

The relationship between net migration flows, GDP per capita and population at the country level is displayed in Figure 1. The scatterplot links net migration to income per capita and the size of the bubbles in the figure is proportional to the population of each country. The figure shows that the absolute values of net migration flows are higher for countries that are larger in terms of population. Countries with relatively high GDP per capita are associated with positive net migration flows, indicating that income acts as a pull factor for migration.

Table 2 shows the results of the nonlinear maximum likelihood estimation sketched in section 2 for the specification described above. The results suggest that the core variables of the gravity model such as the ratio of per capita GDP of destination and source country, the product of the populations of both countries, the distance between the countries as well as colonial relationships and contiguity are important determinants of global bilateral migration flows, although the income variable does not appear significant. The estimated coefficients support the predictions of the standard gravity model and in addition provide new quantitative insights to the determinants of bilateral migration flows. Geographical contiguity increases the flow between countries on average by approximately 137% while migration flows between pairs of countries having a common colonial history tend to be more than the double of those without colonial links, keeping all other variables constant.

As a cross-validation check, we compute the net migration flows implied by our

Table 2 – Maximum Likelihood estimation results

	Coefficient	Std. Error	p-value
Constant	3.563	1.4468	0.0138
Log distance	-0.344	0.0839	0.0000
Ratio per capita GDPs	0.002	0.0027	0.3823
Product of log(populations)	0.037	0.0005	0.0000
Contiguity	1.367	0.1274	0.0000
Common colonial history	2.184	0.0651	0.0000
Observations	29584		

Nonlinear maximum likelihood estimation based on net migration as a dependent variable in the model given by (3). The model includes 21 destination and 21 source region dummy variables, whose parameter estimates are not shown in the table. Net migration corresponds to the period 2000-2005, while the explanatory variables are evaluated in the year 2000.

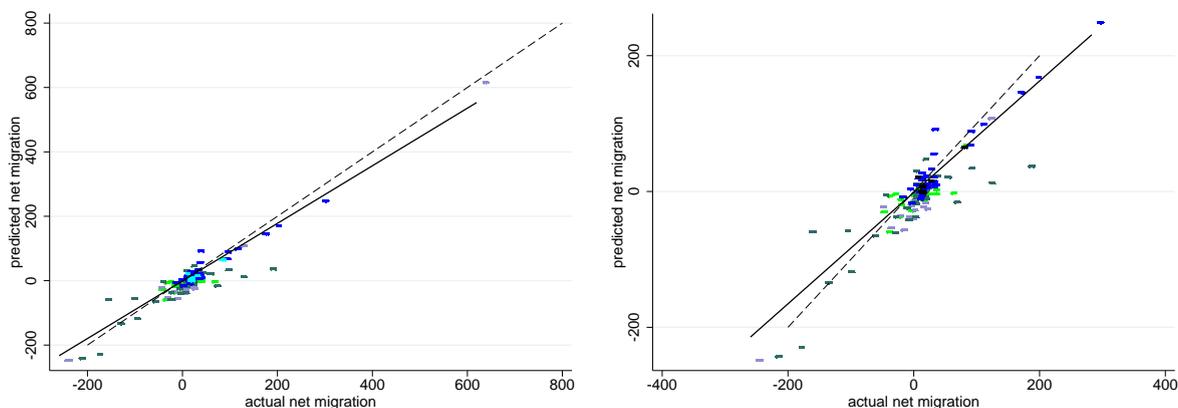


Figure 2 – Actual vs. predicted net migration flows, full sample (left panel) and full sample excluding United States (right panel)

model estimates for 2000-2005 and compare them to the actual data existing. Figure 2 plots actual versus estimated net migration rates for each country. The left panel of Figure 2 shows net migration flows for all countries and the right panel excludes the United States, as immigration to the United States is significantly higher than to any other country. Comparing the least squares fit (solid line) to the 45-degree line (dotted line) shows that the net migration figures implied by our model estimates are very much in line with actual net migration flows. The slope parameter estimate of the line is not significantly different from unity and estimated with a high degree of precision (the standard deviation of the estimate is 0.002).

4 Projecting migration flows to Europe: An illustration

The elasticities provided by the estimates obtained can be used to obtain projections of migration flows using assumptions on global population and income dynamics. As an illustration of this type of analysis, we carry out a simple migration projection exercise for the period 2010-2050, where we concentrate on the migration trends to Europe.

We combine the parameter estimates presented in Table 2 with population and GDP projections for most countries of the world which have been recently developed in the framework of the Intergovernmental Panel for Climate Change (IPCC) by Lutz and K.C. (2013) (for population) and Crespo Cuaresma (2013) (for GDP). Projections for the IPCC are constructed around five narrative scenarios which correspond to different challenges in terms of mitigation and adaptation to climate change. These scenarios are dubbed *Shared Socioeconomic Pathways* (Kriegler, O'Neill, Hallegatte, Kram, Lempert, Moss, and Wilbanks, 2013). We obtain projections of population and GDP for the Shared Socioeconomic Pathway which depicts the “middle-of-the-road” scenario, and as such is neither too optimistic nor too pessimistic concerning fertility reduction in developing economies and income convergence dynamics at the global level. Such a projection scenario provides a realistic benchmark to assess the changes in migration flows to Europe in the coming decades.

Using the projected population and GDP paths for all countries of the world obtained by the methods put forward by Lutz and K.C. (2013) and Crespo Cuaresma (2013), we compute the changes in migration flows to EU-15 countries for the period 2010-2050. We concentrate in the EU-15 group in order to explicitly address also the change in migration flows from Eastern Europe, which has been a prominent component of migration within Europe in the last decades. Figure 3 depicts the projected changes in migration flows towards Europe for the period 2010-2050 against the current GDP per capita levels of the source countries. Such a graphical representation informs us about the expected change in the profile of migrants to Europe by country of origin over the coming decades.

The results in Figure 3 suggest that the projected demographic and economic developments at the global level are expected to increase migration flows to Europe in the next 35 years. The relative increase in migration flows by source country, however, is expected to be heterogeneous. Migration flows from Central and Eastern European countries to EU-15 economies are expected to remain roughly constant over the coming 35 years. The U-shaped relation between current income levels and expected increase in migration flows points towards a changing source country composition of immigrants, as in particular migrants from countries with currently low income levels are expected to significantly increase their share in total migration to Europe. The income convergence trends embodied in the GDP projections used for the middle-of-the-road scenario of the Shared Socioeconomic Pathways is a

This type of projection exercise can serve to inform policy makers in recipient countries of disaggregated migration trends and provide signals about, for example, changes in the skill profiles of immigrants.

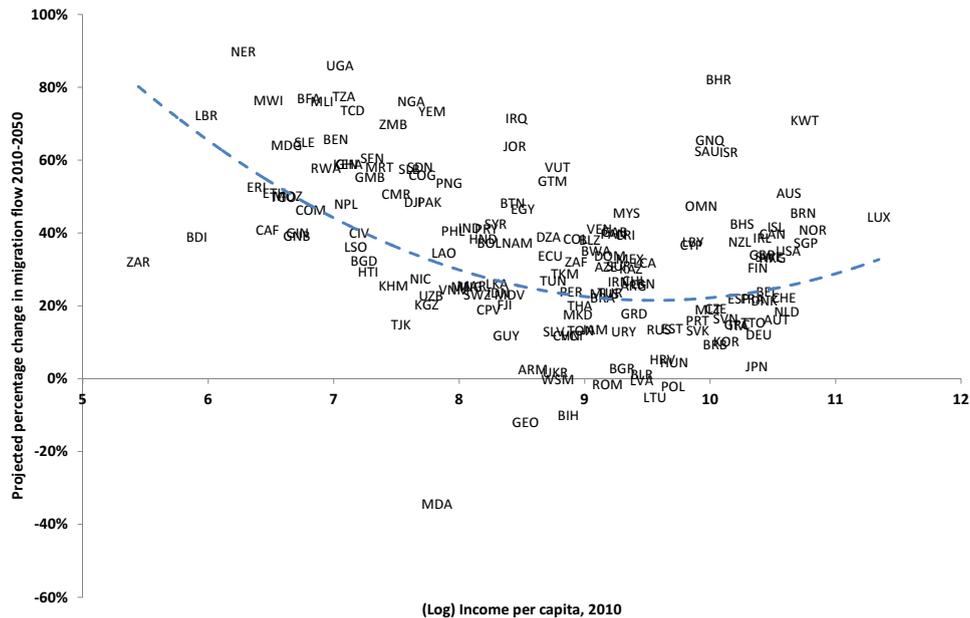


Figure 3 – Projected change in migration to EU15

5 Conclusions and paths of further research

A large body of literature is devoted to understanding the causes of bilateral migration flows. The majority of the empirical studies focus on North-South, North-North or South-North migration, as available data sets only cover immigration flows for receiving industrialized countries. We propose a method that allows to assess global migration flows using the fact that available net migration rates are nonlinear aggregates of bilateral migration flows. We show that a simple quasi-maximum likelihood method performs well for underlying bilateral specifications with relatively good explanatory power for migration flows. Modelling the bilateral migration flows with the aid of simple gravity models and linking them to the net migration flows allows estimating the response of bilateral migration flows to changes in the explanatory variables.

Using a simple projection exercise for bilateral migration flows to Europe based on a realistic scenario for population and income dynamics, we exemplify how the method can be used to monitor future trends in migration and inform policy makers of changes in the composition of migrants by country of origin.

The specification used in the analysis has an illustrative character and can be extended further to account for parameter heterogeneity across world regions. The maximum likelihood estimation framework allows for a natural extension to Bayesian estimation methods, which in addition should allow for a straightforward (albeit arguably computationally expensive) assessment of model uncertainty. This avenue of research is already being carried out by the authors.

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