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# Modeling The Role of Freedom of Movement of Workers in Shaping Migration Patterns in the EU+: the Case of Poland

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**Abstract**

We developed a hierarchical Bayesian model to quantify international migration in 31 European countries from 2002 to 2022. The approach consistently addresses data quality issues, harmonizes migration definitions, and merges different data sources. We then used the model outcomes to assess the impact of freedom of movement and labor market access in destination countries. Our primary focus is on Poland, a key country among the A-8 countries that joined the EU in 2004. The evidence suggests that the main emigration flows from Poland shifted from Germany to the UK and other countries following Poland's 2004 EU accession. However, in 2011, the pattern reversed when Germany opened its labor market to A-8 country workers, resulting in a significant increase in immigration. As we refine our analyses, we expect to be able to provide more details about the role of migration policy on European migration dynamics.

## 1 Introduction

### Free Movement of Workers After 2004 EU Enlargement

Freedom of movement for workers is a core principle of the European Union (EU) included in Article 45 of the Treaty on the Functioning of the European Union. This principle grants EU citizens the following rights: (1) seek employment in another EU country, (2) work in that country without requiring a work permit, (3) reside there for employment purposes, (4) stay even after their employment ends, and (5) enjoy equal treatment with nationals regarding employment access, working conditions, and social and tax benefits [13; 10].

In May 2004, the European Union experienced its largest expansion, with ten new Member States joining, including eight from the former Eastern Bloc (Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia), along with Cyprus and Malta. See Appendix A for details.

Freedom of movement significantly accelerated migration from these new EU countries to Western Europe and contributed to return migration in later years. However, official migration data suffer from inconsistent definitions, incomplete records, and varying quality. While official sources provide migration-related information, they are not designed for precise measurement, leading to inconsistent figures. To improve our understanding of international migration flows, we address these data limitations within a Bayesian statistical framework, integrating multiple data sources to enhance the accuracy of our estimates.

In this paper, we present preliminary results from Bayesian migration models for 31 EU and EFTA countries, covering the period from 2002 to 2022. We focus particularly on migration flows from Eastern European countries that joined the EU in 2004 and later, with a specific emphasis on flows from Poland. Our analysis examines different models of freedom of movement for workers, including their predictions and counterfactual scenarios, assessing the impact of the presence or absence of freedom of movement on migration flows.

## 2 Data Sources and their quality

In this paper, we utilize administrative migration flow data, which can be obtained from various sources, including official statistics provided by National Statistical Institutes, organizations such as the UN, and Eurostat. Additionally, historical data used in previous models, which is no longer available from other sources, is also considered. For a comprehensive list of sources, please see our Shiny app, HMigD I App [6].

Administrative data encompasses population or migration registers, border crossing data, foreign resident permits, and estimates based on censuses or other surveys. Comparing administrative data across different countries presents several challenges. First, countries may use varying duration criteria to define international migrants, leading to discrepancies in migrant identification. Second, undercounting may occur if individuals do not register upon immigration or fail to deregister when emigrating. Third, coverage bias in data collection processes may exclude specific population segments, such as national return migrants or foreigners who are not counted in the official immigration and emigration counts, respectively. Additionally, certain subpopulations, including asylum seekers, nomad populations, military personnel, and homeless individuals, as well as some geographic areas, may not be included in the migration data. Finally, accuracy issues in data collection can lead to random errors during registration or deregistration [6; 16].

## 3 Methods

We develop a hierarchical Bayesian model (JAGS, R software) to estimate the latent bilateral migration flows, denoted as $Y_{ijt}$, from country $i$ to country $j$ in year $t$. This estimation is conditioned on the definition of long-term migration, which requires relocation followed by a minimum stay of 12 months. To address inconsistencies among countries and data sources, we incorporate a measurement error model. Additionally, we tackle data incompleteness using a predictive model to estimate missing data and capture time trends. Our proposed statistical model builds upon and extends methodologies previously developed by [18; 19; 23; 7]. See Appendix B for details.

## 4 Preliminary Results

The Figure 1 presents migration data from Poland to Germany, representing one of the most significant migration flows in Europe. Polish data suffers from substantial undercounting issues, which stem from both poor data quality and the permanent definition of stay. Conversely, German data tends to overcount due to the absence or very short definition of the duration of stay. The mdels address data quality issues and duration of stay definitions effectively, and integrate both emigration and immigration data provided by Poland and Germany. The second higher peak in migration flows is related to freddom of movement of workers that was granted by Germany in 1 May 2011.

Our models reveal a dynamic shift in the destination preferences of Polish emigrants over time (Figure 2). Prior to Poland's accession to the EU in May 2004, the majority of emigration flows were directed towards Germany. However, since 2004, we observed a significant shift in destination preferences. The share of emigrants heading to Germany decreased, making way for increased emigration to the United Kingdom, Italy, Ireland, Norway, France, and several other countries. These nations, upon opening their labor markets to Polish and other A-8 nationals, became attractive destinations.

A significant turning point occurred in May 2011 when Germany granted freedom of movement to A8 citizens. This policy change quickly altered the distribution of Polish emigrants' destinations. However, the proportion of Polish emigrants moving to Germany never returned to its pre-2004 levels.

In recent years, the increase in emigration flows from Poland to other countries has been primarily driven by rising flows to Spain and Denmark (not shown). Conversely, both the share and number of flows to the UK have decreased. It is speculated that this decline may be partially attributed to the effects of Brexit (effective from February 1, 2020), which ended the freedom of movement of workers between the UK and the EU-27 on December 31, 2020 [12].

The Figure 3 shows the effect of freedom of movement on predicted migration flows to EU-15 and EFTA countries. The blue lines represent the effect of freedom of movement according to the basic

model (Eq. 2 in appendix), where the proportional impact on migration flows from all Eastern European countries that joined the EU in 2004 and later is considered the same. The difference between the black and blue curves indicates the additive effect size. We found this effect to be substantial, especially when freedom of movement was granted in a single year rather than gradually, as in Norway's case. However, even for Norway, the difference becomes substantial from 2007 onwards.

The red line in the figure shows the counterfactual prediction for the model where the effect of freedom of movement has two separate parameters: one for the A8 countries and another for countries that joined later, including Bulgaria, Romania, and Croatia (Eq. 3 in appendix). Again, the effect is very apparent; however, for the A8 countries, it is consistently smaller than when all countries are treated the same (red versus blue lines). Indeed, if we look at migration flows from Romania, which represents the second group of countries to the EU-15 and EFTA, we see that this effect is significantly larger (see figure 4 in appendix).

The wider confidence interval for the UK estimates results from the low accuracy of the data (passenger survey) provided by the Office for National Statistics. Both Romania and Poland supply poor-quality data, but this is compensated by high-quality data from Germany, the Netherlands, and Norway.

## 5 Summary and Conclusions

We developed a hierarchical Bayesian model to estimate latent international migration flows among 31 European countries from 2002 to 2022, using data from administrative sources. Our model builds upon previous Bayesian models that separately handled administrative flow data by integrating these approaches into a unified framework [19; 23]. The primary objective is to estimate the true relocation rate [18], which is then used to predict the true latent migration flows based on the criterion of defining a long-term migration event as having a minimum duration of 12 months.

The model comprises two main components: a measurement error model and a predictive model. The measurement error model harmonizes data from different sources and accounts for biases and inconsistencies. The predictive model addresses missing data through smooth functions of time and random effects, while incorporating a "shock" migration variable, such as the freedom of movement of workers, to capture rapid changes in migration flows that smooth models might not detect.

Our approach introduces several innovations. We demonstrate that despite the incompleteness and inconsistencies of data sources like population registers and household surveys, integrating these diverse sources can effectively estimate international migration flows among European countries. The inconsistencies stem from varying definitions of long-term migration, undercounting biases, population coverage, data collection accuracy, and sampling design issues. Our model addresses these challenges by accounting for data inconsistencies and biases with a special focus on time changes, which is a novel aspect compared to the IMEM [19] and QuantMig [1] approaches.

Indeed, this model is capable of incorporating various data sources and includes auxiliary data, such as metadata, to assess data quality by converting this information into probability statements in the form of prior distributions for the parameters. A notable feature of our method is its ability to dynamically adjust the classification of undercounting and accuracy over time. Specifically, we use a data-driven methodology to categorize undercounting, as formulated by [6].

Our analysis revealed dynamic shifts in Polish emigration patterns over the years, likely influenced by various factors including EU accession, the granting of freedom of movement, and economic events. Prior to Poland's EU accession in 2004, Germany was the primary destination for emigrants. However, during post-accession period, we observed a redistribution of emigration to other European countries, particularly the United Kingdom, Italy, Ireland, Norway, and France. The granting of freedom of movement to A-8 workers by Germany in 2011 was a significant turning point, which led to increased emigration to Germany, returning to the pre-accession patterns. Indeed, these turning points highlight the impact of EU policy changes on migration trends. Our models effectively captured the effect of these policy changes while older model seemed to face problems due to more general approach to modeling the freedom of movement variable (see comparison of IMEM and QuntMig results via our Shiny app, Dańko 5).

These are early findings, but they show promise to quantify the impact of policy changes on

migration flows in Europe. As we continue to work and develop our analyses we expect to be able to expand the results and related insights, which will include also other predictive models.

Our research contributes to a deeper understanding of European migration dynamics and the role of policy changes in shaping emigration patterns. Our Bayesian model, capable of handling data inconsistencies and limited availability, offers a robust tool for estimating migration flows and can support policymakers and researchers in analyzing and anticipating migration trends in Europe.

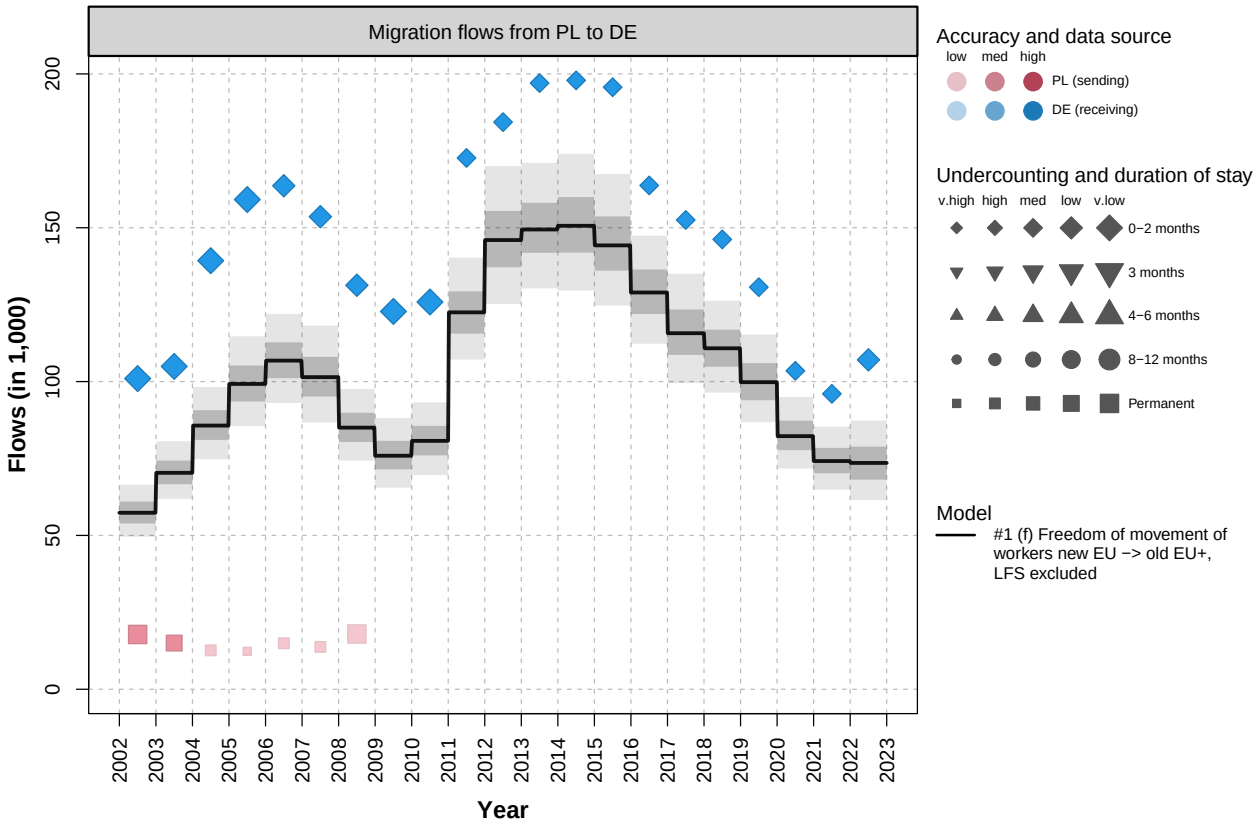


Figure 1: Model-predicted flows from Poland to Germany for the basic model (Eq. 2) and underlying data quality. The legend on the right side of the panel plot shows data quality codes using transparency (accuracy), size (undercounting), and shape (duration of stay). Two types of credibility intervals are shown 50% and 95%

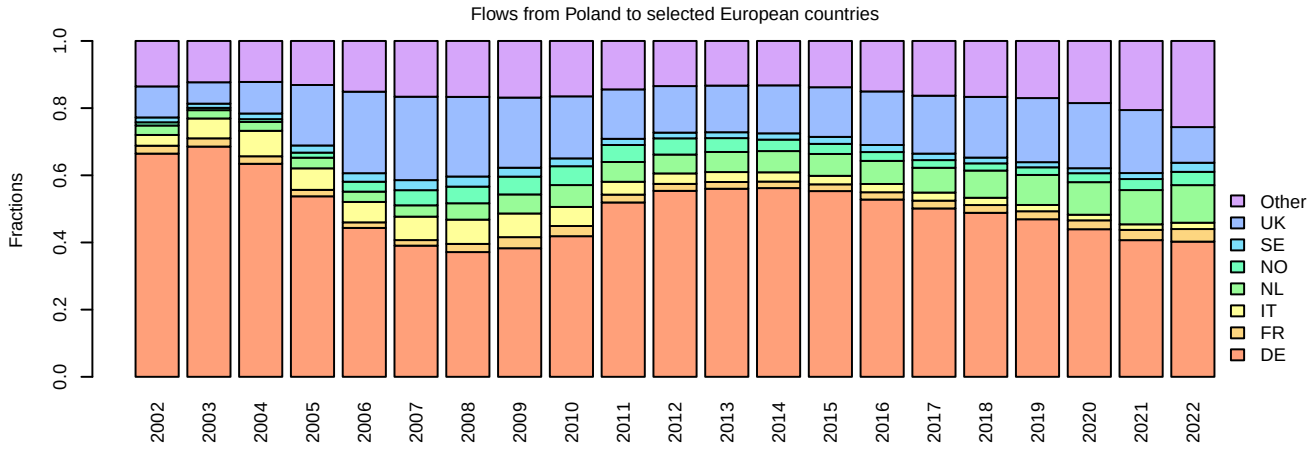


Figure 2: Fraction of migration flows from Poland to different European countries.

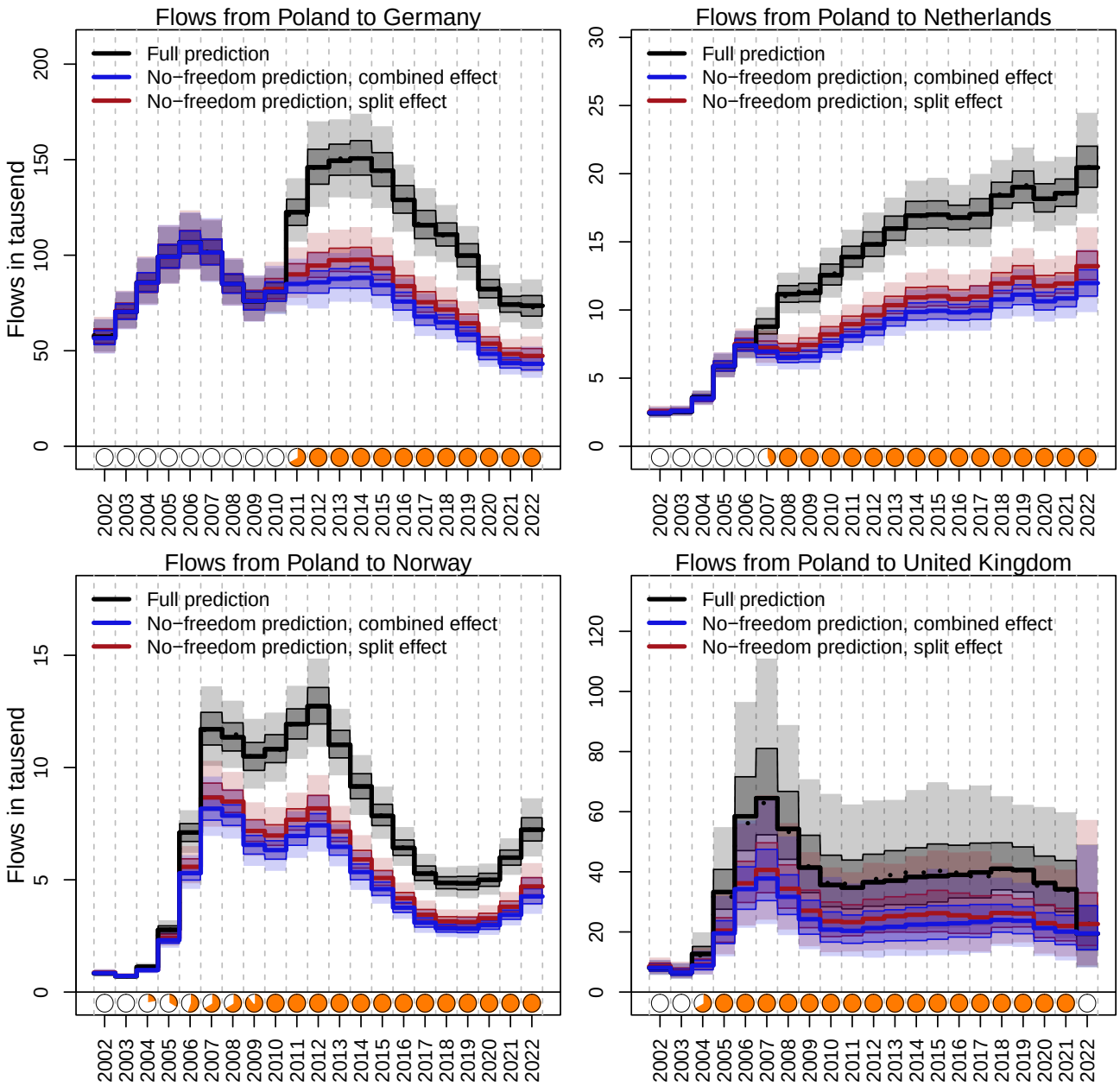


Figure 3: Predicted migration flows from Poland to selected countries. Two models are considered: the basic model (Eq. 2), which assumes the same effect of freedom of movement for all countries (A8, RO, BG, and HR), and the split model (Eq. 3), which distinguishes between the A8 countries that joined the EU in 2004 and the countries that joined later, including BG, RO, and HR. The black line represents the full prediction, while the blue lines show counterfactual predictions assuming that freedom of movement for workers never occurred in the basic model. The red line indicates the counterfactual predictions for the split effect model. The circles at the bottom represent the freedom of movement. The more filled a circle is, the more complete the freedom of movement of workers.

# 6 Appendix

## A Detailed description of the granting of freedom of movement in Europe since 2004

In May 2004, the European Union witnessed its largest-ever expansion. Ten new Member States joined, including eight nations (A-8) from the former Eastern Bloc: Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia. Cyprus and Malta also became part of the union. In 2004, disparities in unemployment rates and salaries were persisting among member states, leading individuals from regions with lower wages to seek employment in more prosperous countries. This expansion raised concerns about the potential for unrestricted labor migration from the A-8 countries, which could have posed significant challenges to the labor markets of the EU-15 countries, as well as non-EU European Economic Area (EEA) and European Free Trade Association (EFTA) countries such as Iceland, Liechtenstein, Norway, and Switzerland. To address these concerns, a transitional period of seven years (2+3+2) was established to gradually open their borders to workers from the new member countries [10; 14; 15].

Sweden, and in practice also the United Kingdom and Ireland, opened their labor markets from day one [8; 9]. Unlike Sweden, other Nordic countries, namely Denmark, Finland, Iceland, and Norway, introduced transitional solutions for the movement of workers from the A-8 in 2004 [15; 9]. Although Norway is not part of the EU, it is associated with it through the EEA and has adopted the rules of the single market like every other EU member state. Despite transitional arrangements for enlargement in 2004, Norway was generally perceived as quite open in its approach compared to other Nordic countries. This was because there was no minimum wage in Norway, general tariffs were not yet in force, and the preliminary condition for granting permits was full-time employment at the Norwegian salary level [15]. Denmark also slightly relaxed its rules in the first years after its accession in 2004 and allowed pre-approval of companies with collective wage agreements [9].

Although 70 percent of migrants from the A-8 chose Ireland and the United Kingdom[3], it's worth noting that in the years 2004-2006, over two-thirds of work permits among Scandinavian countries were granted to Norway, of which two-thirds of Norwegian work permits were issued to Polish citizens [15; 8]. It's also important to mention that a significant portion of the permits were for short-term employment. The number of all permits increased over the following years. While permits issued in 2005 represented only 0.4 percent of the total Nordic labor force, permits issued in Norway in 2006 most likely exceeded 2 percent of the labor force [8]. In Iceland, this percentage was much higher, placing these countries alongside Ireland in terms of labor migration from the A-8 [8].

Finland, Iceland, Greece, Portugal, and Spain abolished the transitional arrangements on 1 May 2006, and Italy followed suit on 27 July of the same year. The Netherlands (with prior limit of 22k workers per year) and Luxembourg repealed these rules in 2007 (on May 1 and November 1, respectively), and France on July 1, 2008. Belgium, Denmark, and Norway maintained restrictions or partial restrictions until the end of the second phase of transitional period, i.e. until May 1, 2009. The last countries to repeal restrictions, using the complete transitional period (May 1, 2011), were Austria, Germany, and Switzerland. However, Switzerland reintroduced restrictions for A-8 countries from May 1, 2012, to April 30, 2014 [21; 22; 2; 3; 4].

In 2001, visa restrictions for citizens of A-8 countries intending to travel to the EU-15 were removed for stays of no more than three months in all [20; 14]. Therefore, labor mobility occurred de facto well before the official accession of the A-8 countries to the European Union and obviously, ahead of the conclusion of the transition periods. This can be observed in the UK Worker Registration System that monitors migrants after the enlargement. During the first six months after the enlargement on May 1, 2004, approximately 30 percent of applications to the program were submitted by workers who had already established residence in the UK prior to the enlargement [14]. Additionally, for some of these countries, students, researchers, and, more rarely, self-employed and service providers were exempt from the restrictions.

# B Detailed methods

## B.1 Measurement error model

The specification of the measurement error model varies depending on the data sources to account for their unique characteristics and limitations. We assume that the number of observed migration events, denoted as $y_{ijt}^{(k)}$ for data source $k$, follows a Poisson distribution with parameter $\lambda_{ijt}^{(k)}$. Here, $k$ can take one of three values: (i) $k = IR$ represents immigration from administrative sources based on the country of previous residence and (ii) $k = ER$ represents emigration from administrative sources based on the country of next residence The parameters $\lambda_{ijt}^{(k)}$ are modeled as follows:

$$\begin{aligned} \log \lambda_{ijt}^{IR} &\sim \mathcal{N}\left(\log R_{ijt} - \mu_{*,j,t} + d_j^m + \delta_{ijt} + \log \upsilon_{jt}^{IR} - \log\left(1 + \exp(-\kappa_j^{IR})\right), \tau_{jt}^{IR}\right), \\ \log \lambda_{ijt}^{ER} &\sim \mathcal{N}\left(\log R_{ijt} - \mu_{*,j,t} + d_j^m + \delta_{ijt} \log \upsilon_{it}^{ER} - \log\left(1 + \exp(-\kappa_i^{ER})\right), \tau_{it}^{ER}\right). \end{aligned} \tag{1}$$

Here, $R_{ijt}$ represents the number of relocations, where a relocation is considered a migration event if a person remains in country $j$ for at least the minimum duration of stay $d_m^{(j)}$. $\mu_{ijt}$ denotes the true relocation rate and $\mu_{*,j,t} = \sum_{i;i\neq j} \mu_{jit}$.

The factor $d_j^m$ is expressed in years, and can be equal to 0 (as there is no time limit, each relocation is considered a migration), 0.083 years (1 month), 0.25 years (3 months), 0.333 (4 months), 0.5 years (6 months), 0.667 (8 months), 1 year (12 months - the reference period adopted in the EU), or 5 years (for permanent residence) [17].

The duration of stay is parameterized using $\delta$ parameter and includes 5 categories: "no time limit$\delta_1$ if the criterion is "no time limit" or lower than 3 months, $\delta_2$ if the criterion is 3 months, $\delta_3$ if the criterion is 4-6 months, 0 if the criterion is 8-12 months, and $\delta_4$ if the criterion is "permanent residence" (five years).

To account data quality biases, we classify countries into groups based on their undercounting $\upsilon$ (five groups), coverage bias $\kappa$ (two groups), and and accuracy $\tau$ defined as random error in data sources (three categories).

## B.2 Predictive model

We use a predictive migration model to estimate the latent number of relocations ($R_{ijt}$) across multiple data sources. In the most basic model, the number of relocations $R_{ijt}$ is log-normally distributed and defined as:

$$\log R_{ijt} \sim \mathcal{N}\Big(\beta_1 + \beta_2 A_{ijt} I_{i,j}^{E\to W} + \sum_{k=1}^{12} b_{k,i,j} Z_{t,k} + \gamma_{ij}, \omega_R\Big), \tag{2}$$

- $\beta_1$ is an intercept
- $A_{ijt}$ is an indicator variable representing freedom of movement for workers from country $i$ to $j$ in year $t$. The indicator can take fractional values if freedom of workers was granted after January 1st or if the restrictions were gradually relaxed (e.g., Norway).
- $\beta_2 A_{ijt} I_{i,j}^{E\to W}$ accounts for specific flow patterns, namely flows from new European countries (A-8, BG, RO, HR) to old European countries (EU-15, CH, IS, and NO).
- $\beta_3 A_{ji(t-1)} I_{i,j}^{W\to E}$ accounts for specific flow patterns, including returning flows from old EU countries to new EU countries.
- $I_{i,j}^{E\to W}$ is indicator for flow directions from new European countries (A-8, BG, RO, HR) to old European countries (EU-15, CH, IS, and NO).
- $\gamma_{ij}$ represents corridor-specific random intercepts.
- Cubic B-splines ($b_{k,i,j} Z_{t,k}$) model temporal effects, where $Z$ is a B-spline basis.

We also consider more complex models. In the model presented below, we divide the freedom of movement effect into two distinct components. The first component, $\beta_2 A_{ijt} I^{A8\to W} i, j$, captures the effect of freedom of movement for workers migrating from A8 countries to EU-15 and EFTA countries. The second component, $\beta_3 Ajit I_{i,j}^{BRC\to W}$, represents the effect for flows from Eastern European countries that joined the EU later—specifically Bulgaria (BG), Romania (RO), and Croatia (HR)—to these same countries.

$$\log R_{ijt} \sim \mathcal{N}\Big(\beta_1 + \beta_2 A_{ijt} I_{i,j}^{A8\to W} + \beta_3 A_{jit} I_{i,j}^{BRC\to W} + \sum_{k=1}^{12} b_{k,i,j} Z_{t,k} + \gamma_{ij}, \omega_R\Big), \tag{3}$$

In both models, we assign prior distributions to the coefficients and precision parameters to reflect our assumptions and uncertainties about these parameters.

- For the model coefficients ($\beta$) related to the intercept and the effect of freedom of movement, we use a heavy-tailed Student's $t$ distribution with 3 degrees of freedom, denoted as $t_3(0, 2.5)$. This choice allows for greater flexibility and robustness to outliers, indicating a prior belief centered around 0 with a moderate scale of 2.5 [11].
- The spline coefficients $b_{k,i,j}$, which capture temporal effects, are modeled using a normal distribution centered around a baseline coefficient $b_k^0$ with precision $\omega_b$. The baseline coefficients $b_k^0$ themselves follow a normal distribution with a mean of 0 and precision $\omega_b^0$. Both $\omega_b$ and $\omega_b^0$ are assigned weakly informative Gamma priors $\Gamma(0.1, 0.1)$.
- The corridor-specific random intercepts $\gamma_{ij}$ are also modeled with a normal distribution centered at 0, with precision $\omega_\gamma$. The precision $\omega_\gamma$ is assigned a assigned weakly informative Gamma prior $\Gamma(0.1, 0.1)$.
- Finally, $\omega_R$ is the precision parameter of the log-normal distribution of the relocation counts, and it is given a weakly informative prior to reflect limited prior knowledge about its value.

This predictive model allows us to estimate relocations consistently across data sources and account for various migration dynamics. The true migration flows, conditional on a minimum duration of stay of 12 months, are obtained as $Y_{ijt} = R_{ijt} \exp(-\mu_{*,j,t} d_j^m)$ [7].

# C Supplementary figure

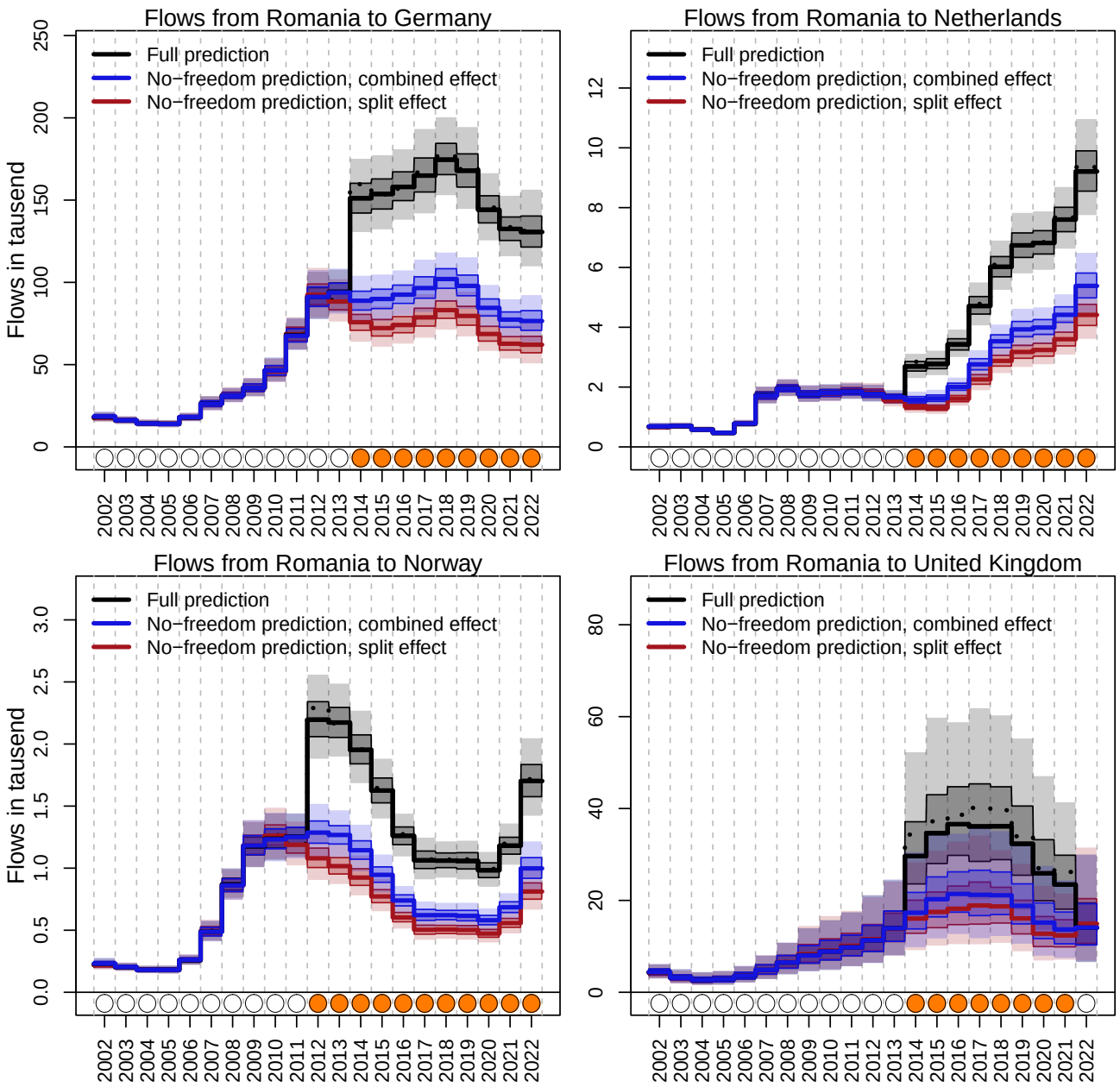


Figure 4: Predicted migration flows from Romania to selected countries. The description is analogous to that in Figure 3.

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