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Jakub Bijak

Forecasting International Migration in Europe: A Bayesian View

(with contribution by Arkadiusz Wiśniowski)

Springer

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To my Kasia

– JKB

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[1] See, for example, W. Bijak (1990) – I am especially grateful for mini-lectures on subjective probability around the time of publishing that paper.

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Part I
Introduction

Chapter 1
Introduction and Background

The current book is devoted to known (although seldom used by demographers) Bayesian statistical methods, applied in one of the most under-researched areas of population forecasting; that is, predictions of international migration. The study aims to keep up to date with the methodological state-of-the-art migration forecasting by presenting a thorough review of methods, while at the same time advocating for the use of the stochastic approach within the Bayesian framework, which allows for a formal incorporation of expert judgement. The current, introductory chapter presents the background, aims, scope and structure of the book, as well as terminological and notational conventions.

1.1 Migration Forecasting as a Research Problem

1.1.1 Role of International Migration and Its Forecasts

Migration, and in particular international migration, is one of the key factors that are anticipated to be increasingly influential in shaping population dynamics in the coming decades. This is especially important in the more developed regions of the world, such as Europe, which are already facing zero or negative natural population growth (e.g., van der Gaag & van Wissen, 1999; Kupiszewski, 2002b). Furthermore, the impact of migration is not limited to demography. Migration also affects many other areas of social life, including economy and labour relations, politics and culture; and, *vice versa*, is also influenced by them. All these effects are nowadays gaining in importance, as migratory processes in a globalising world are becoming more and more dynamic and complex (King, 2002).[1]

One of the links between migration, demography and other social processes is the impact of migration on age structures of populations (United Nations, 2000) and labour force resources (Bijak, Kupiszewska, Kupiszewski, Saczuk, & Kicinger, 2007). These relationships indirectly influence labour markets, social

[1] For a summary of issues related to globalisation and mobility, see e.g. the *World Migration Report* (IOM, 2008).

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security systems, health expenditures, fiscal balance and national savings, as well as other macroeconomic indicators (Roseveare, Leibniz, Fore, & Wurzel, 1996). With respect to the labour market adjustments through migration, it is worth stressing that they affect the economies of both sending and receiving countries. Movements of unskilled workers on one hand and highly-trained professionals on the other are a way to reduce structural labour market imbalances: surpluses at source and deficits at destination. In turn, with respect to the social aspects of migration, an increasingly important issue is the integration of immigrants into the host society. Besides, migration can also influence other areas of social life, like for example education systems.

Given the impact of migration on various areas of life, there is an increasing need for more accurate forecasts of population movements, especially at the international level. This matter is however very delicate, not least because migration is the most complex and most difficult to predict component of population change, bearing high levels of forecast errors (NRC, 2000; Kupiszewski, 2002b). This is due to several factors. Firstly, migration data on which the predictions are based are inconsistent, incomplete and generally low quality. Secondly, migration is extremely sensitive to government actions and other political factors, which themselves are difficult to forecast (NRC, 2000, pp. 177–182). With respect to the latter, of special importance is crisis migration, which generates high waves of refugees, asylum seekers and displaced persons. Some late twentieth century examples of crisis migration flows include conflicts in the former Yugoslavia, Rwanda and Chechnya, to name but a few (UNHCR, 2000). Such tragic events and their demographic consequences are very difficult to predict, both in terms of timing of their occurrence, as well as of their magnitude.

All these factors contribute to the very high ex-post errors of migration forecasts. A comprehensive overview of different projections and forecasts made in various European countries has been provided by Salt and Singleton (1995), who showed that errors in the relative magnitude about 100% were not unusual, with the extremities reaching as much as 1,350%. In some cases even the dominant direction of flows between two countries was erroneously predicted, with a notable example of the recent migration history of Ireland.

Nevertheless, given the increasing impact of international migrations, a need for accurate, high-quality forecasts of population flows is becoming more and more significant despite high error levels. On one hand, migration forecasts themselves are of interest for the policy makers from a purely operational point of view, concentrating on the numbers of migrants and the impact of migration for example on labour markets. On the other hand, such predictions constitute an important and inevitable part of population forecasts in general, which are crucial for many aspects of socio-economic planning. For this reason, many issues related to population forecasting apply directly to international migration predictions. However, as remarked by Duchêne and Wanner (1999, p. 6), it should be noted that demographic forecasts are not exclusively aimed at predicting the future as such, but rather, more importantly, at providing necessary input to the political decision making process. Improving forecasts can contribute to better policy decisions, which in turn may

have significant consequences for the societies. Clearly, the consequences do not need to be limited to their economic dimension (Ahlburg, Lutz, & Vaupel, 1998, p. 192).

1.1.2 Problems with Errors in Migration Forecasting

Some level of migration forecasting error is always inevitable, as any inference about the future is made under uncertainty: an issue which is further elaborated on Chapter 2. Nevertheless, as noted by Dawid (1984, p. 278), 'one of the major purposes of statistical analysis is to make forecasts about the future [and] to offer suitable measures of uncertainty associated with unknown events or quantities'. Along similar lines, Robert (2001, p. 2) suggested that adding the uncertainty component allows for more meaningful interpretations of the phenomena under study, not being limited to their explanations *ex post*.

There have been several suggestions about possible ways to improve the accuracy of migration and population forecasts. For example, de Beer (1990b) proposed to examine average migration over several years rather than yearly values. Ahlburg (1995) and Smith (1997), following Armstrong (1985), advocated the benefits from combining (averaging) forecasts in order to reduce their errors. Gjaltema (2001) discussed the advantages of rule-based forecasting, originally developed by Collopy and Armstrong (1992). As an alternative, Sanderson (1998) suggested considering causal relationships between various socio-economic variables and the elements of population change, including international migration. As a prerequisite, the quality of migration statistics, on which the forecasts are based, needs to be enhanced.

In a sample study of some European and North American countries it has been shown that naive forecasts of zero or constant migration flows would usually generate higher prediction errors than forecasts with more sophisticated assumptions (NRC, 2000, pp. 318–325). Moreover, as suggested by Rees, Kupiszewski, Eyre, Wilson, and Durham (1999), methodological advancements in migration forecasting have already led to some declines in the ex-post prediction errors. However, there seem to be inherent limits to the predictability of migration. As argued by several authors from the domain of forecasting, adding more complexity to the models beyond a certain point need not lead to further error reductions (e.g., Makridakis & Hibon, 2000; Orrell, 2007). All these issues together constitute a rationale for the current book, which aims to contribute to the methodology and philosophy of migration forecasting, whilst clearly showing its inherent limitations.

Already over half a century ago, Hajnal (1955) in his seminal paper noted that predictions of future populations are doomed to be uncertain, and the only mitigating factor in that respect is the inertia of demographic processes and the information already embodied in the age structure of the population. He identified the main success of demographic forecasting in the survival analysis of pre-existing cohorts (that is, in mortality predictions), whereas fertility and especially migration have to be seen as much less predictable. As to the development of more accurate methods of forecasting, Hajnal (1955) was utterly skeptical. Nonetheless, he acknowledged

that there will most likely be a continuous demand for forecast from their users, for various reasons related to policy making and planning. This perspective is shared throughout the book.

From this point of view, regardless of whether there is still space for further error reductions in population and migration forecasting, there is definitely scope for developing a more robust methodology of making predictions. Given the imperfect data, such a methodology would have to allow for combining statistical information on past trends with expert judgement on migratory processes in order to obtain a plausible model with credible assumptions. Notably, there have already been several attempts to combine both sources of information; for example within a framework of 'expert-based population forecasting,' developed under the auspices of the World Population Program of the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria (Lutz, Sanderson, & Scherbov, 1996, 1998, 2000, 2004). As an alternative, this book proposes to apply the mechanisms of Bayesian statistical inference, for the reasons set forth in Chapter 2.

1.2 Aim and Structure of the Book

1.2.1 Aim and Scope

The aim of the book is to evaluate the existing methods of forecasting international migration and to propose an alternative methodological framework, which would acknowledge the presence of uncertainty and enable the inclusion of judgemental knowledge in the models. Such forecasts, with all caveats concerning their inherent limitations, would ultimately serve as information input for decision making. The solution proposed in this book, following the suggestions of Willekens (1994, pp. 26–30), is to employ the methods and tools of Bayesian statistics, where combining the subjective prior knowledge with statistical information constitutes a natural way of inference. In order to make the book more accessible for broader readership, no prior knowledge of Bayesian statistics is assumed. In that respect, the book offers a brief primer both in the philosophy of Bayesian inference and also in some practical computational issues.

There exists a wide variety of approaches to international migration forecasting. Since migration is a very complex and multi-dimensional phenomenon, its models and predictions stem from various scientific disciplines: demography, geography, economics, statistics, sociology and political science. Some existing attempts to forecasting even involve application of advanced methods of theoretical physics. This book also provides a discussion of various methods, with an overview of migration theories and their possible role in setting the forecast assumptions.

As an empirical illustration, the book presents Bayesian forecasts of migration flows between Germany and three selected European countries: Italy, Poland and Switzerland. In terms of geography, the analysis focuses on countries being important migration sources or destinations of intra-European flows. Also the statistical information for these flows is available and relatively complete. A detailed

discussion of data issues, focusing on the selected countries, is presented in Chapter 2. The empirical analysis is based on historical migration data limited to the period 1985–2004, in order to emulate forecasting uncertainty at the onset of a different regime of European migration after the 2004 enlargement of the European Union (EU). The forecast horizon is mid-term, spanning the years 2005–2015. The proposed Bayesian migration forecasting models are compared with their counterparts based on the traditional (frequentist, sampling-theory)[2] statistical approach, with respect to their theoretical characteristics and *ex-post* prediction errors.

Speaking of European migration, the scope of the presented illustrations is obviously incomplete in geographic terms. The main reason for this is the currently limited availability of data conforming to a uniform definition of migration for all flows under study. Hopefully, the recent Regulation of the European Parliament and the Council[3] will contribute to enhancing the statistical knowledge base of migration within the European Union. Promisingly, the Regulation allows sound modelling techniques to be used to estimate the missing data and to ensure the comparability of the data according to one common definition.

As more and better macro-level data on migration flows become available in Europe in the future, attempts can be made to answer many additional research questions, such as those related to population flows following the successive EU enlargements, and to country-specific gross migration inflows and outflows in Europe. Alternatively, with better data, relationships between various origins or destinations of migration can be also examined, which would allow testing the hypothesis about complementary versus substituting character of different directions of flows. However, as good-quality comparable data are a clear prerequisite of all such analyses, the projects aiming at establishing a sound methodology for their estimation should be given priority in the European migration research agenda in the coming years, if various forecasting methods are to be of real use in demographic and policy-oriented research at the EU level.

1.2.2 Structure of the Book

The book is structured in five parts, altogether comprising twelve chapters.

Part I contains the basic introductory information. The current introduction (Chapter 1) starts with background information concerning the study, defining its rationale, aims and scope. Subsequently, terminology and symbols applied in the text are introduced. In Chapter 2, four issues are briefly addressed, setting the scene for the further discussion. These are: problems with migration data, general

[2]Despite the subtle differences, in the current book, the terms 'traditional', 'frequentist' and 'sampling theory' will be used interchangeably to denote the statistical paradigm based on the works of R. A. Fisher, K. Pearson and J. Spława-Neyman (see Chapter 2). 'Sampling theory' in this case refers to the general idea of inference based on the sample data rather than being limited, for example, to representative sampling from finite populations.

[3]*Regulation of the European Parliament and Council No. 862/2007 from 11 July 2007 on the Community Statistics on Migration and International Protection*, Official Journal OJ L 199/23.

issues concerning uncertainty, subjectivity and expert judgement in migration and population forecasting, the Bayesian paradigm in statistical inference, and finally the numerical algorithms used in Bayesian analysis, based on the example of the Markov chain Monte Carlo simulations. More detailed information on Bayesian computations in practice is also presented in Chapter 9, in Part IV.

Part II of the book discusses the existing framework for explaining and forecasting international migration. First of all, in Chapter 3, a brief outline of selected international migration theories is given, with a discussion of their applicability in prediction-making. Then, in Chapter 4, the most important models and methods used in migration forecasting are presented as a practical alternative to theory-based forecasting. The overview follows the distinction between the deterministic and probabilistic paradigms in scientific research. The methods in the former category include migration scenarios, surveys, Delphi methods, and mathematical models of population flows. The probabilistic methods encompass econometric models of migration and stochastic forecasts of migration time series. A few existing Bayesian examples of demographic applications are also listed. The chapter concludes with a typology, comparison and evaluation of the presented methods of migration modelling from the perspective of forecasting applications.

Part III of the book contains several suggestions for developing migration forecasting models within the Bayesian approach. The propositions focus on three groups of methods, described in subsequent chapters and illustrated with forecasts of migration flows among four selected European countries. Thus, Chapter 5 is devoted to the Bayesian model selection and forecast averaging based on the posterior odds criterion, applied here for simple stochastic processes. In Chapter 6, the approach 'from general to specific' is presented in the context of vector autoregression (VAR) models. Such models have the potential to include theoretical information on relations between migration and its likely determinants. In turn, Chapter 7 explores, among others, the Bayesian hierarchical modelling in an attempt to accommodate for the possible discontinuity in migration trends. Of interest are models based on historical analogies and solutions involving non-constant conditional variance. Subsequently, Chapter 8 includes basic remarks on the robustness of forecasts against selected changes in the prior distributions. In addition, a slightly more thorough analysis of both *ex-ante* and *ex-post* empirical performance is offered for selected Bayesian forecasts and their traditional equivalents. Finally, computational issues related to the Bayesian approach are addressed from a practical point of view in Chapter 9, contributed by Arkadiusz Wiśniowski, whereby a short survey of available Bayesian software is presented. This overview is followed by a description of WinBUGS, an environment specifically devoted to Bayesian analysis. Additionally, simple examples of Bayesian computations in the R language are provided. R is very flexible, comprehensive free software designed for statistical analysis, recently gaining in popularity among demographers.

Part IV of the book offers a general discussion of forecasts and the associated uncertainty from the perspective of population forecasters and forecast users,

usually, political decision makers. The discussion is largely based on the selected recent literature on forecasting and decision analysis, while providing some basic examples directly pertaining to migration and population studies. Thus, Chapter 10 is predominantly concerned with the theory-based forecasting and the use of migration predictions in the models of population dynamics. As an example of methods, which allow controlling the plausibility of outcomes in such models, the Bayesian melding approach is discussed. Moreover, the issue of microfoundations of forecasts is addressed from the point of view of the notion of 'imperfect knowledge', being a contemporary response in the theory of economics to the empirical failures of the mainstream forecasting. The chapter concludes by sketching a possible research agenda for the future. In a policy-oriented Chapter 11, in turn, a brief introduction to the decision analysis is presented, including a primer in its Bayesian version. A stylised Bayesian decision analysis based on migration forecasts is also presented, aimed to derive optimal decisions under various preferences of the decision makers. At the end, the chapter aims at providing the forecast users with some indications as to which policy questions can be answered by migration forecasts, and how.

Finally, Part V consists of Chapter 12, featuring a summary of the findings and the most important conclusions from the study. Together with a brief synopsis of the main results, some recommendations for future research in international migration forecasting are addressed. The discussion includes selected implications for the forecasters and forecast users (decision makers). The book concludes by putting the obtained results in the context of theoretical debate on population forecasting, with focus on uncertainty issues, the use of expert judgement, and the dilemma of simplicity versus complexity of forecasting models.

The study is accompanied by three Annexes containing graphs and tables, both with the input for the analysis and the empirical illustrations. Annex A contains an inventory of sources, time series of observations and a brief description of methods used to prepare and harmonise the data. Annex B provides the listing of WinBUGS programme code used to calculate Bayesian forecasts presented in Chapters 5–8. The empirical illustrations of the analysis – predictions of population flows between the countries under study – are subsequently dealt with in more detail in Annex C, extending the empirical material offered in the subsequent chapters of Part III.

The book can be read in a variety of ways. Nevertheless, several sequences of chapters are particularly recommended for different readership. A policy-oriented reader, likely to be less interested in technicalities and theorising, might like to gain a general insight into the problems listed in Part IV, preceded by the introduction in Chapters 1 and 2, and with the results of the research summarised in general terms in Chapter 12. A theory-oriented reader can skip the whole of Part III containing modelling and technical details. Finally, the whole book can be of potential interest – at least that is the hope of the author – to demographers, and in particular to statistical demographers (for relevant definitions, see Alho & Spencer, 2005, p. 3), as well as to postgraduate students of demography and migration.

1.3 Terminology and Symbols

1.3.1 Basic Terms Used in the Study

Terminology used in this book generally follows the established conventions in demography. Therefore, *migration* is a form of spatial mobility, understood as

> the movement of people across a specified boundary for the purpose of establishing a new or semi-permanent residence; divided into international migration (migration between countries) and internal migration (migration within a country).[4]

Throughout the book, the term *migration* generally depicts *international migration*, unless explicitly noted otherwise. A *(crude) migration rate* is an intensity measure of migration risk, obtained by dividing the overall number of migrants by the size of *population at risk* – all persons who potentially may experience migration in a given period. Such intensity measures of risk are usually referred to in demography as the *occurrence-exposure rates* (e.g., Rees & Willekens, 1986). A convenient estimate of the population at risk for a given year is the mid-year population, calculated either as the population size on 30 June or as an average of the stocks at the beginning and at the end of the year. Importantly, rates should not be confused with probabilities of experiencing demographic events, such as migration, within a specific timeframe. Probabilities measure, on a scale between zero and one, how likely is it that something can be expected to happen (see Chapter 2 for more details).

An important distinction concerns the possible ways of inference about the future characteristics of demographic phenomena. Thus, a population *projection* usually refers to 'computation of future changes in population numbers, given certain assumptions about future trends in the rates of fertility, mortality, and migration'.[5] The projection is thus directly conditional on the assumptions, which is the reason why in most cases several *scenarios* of a projection are prepared, conventionally baseline, high and low. However, the popularity of population 'projections' among national and international statistical agencies, and individual researchers can raise suspicions that they are in fact perceived as something more than merely the hypothetical paths of development conditional on the assumptions. Indeed, as noted by Booth (2004, p. 10), 'demography appears to be alone among disciplines in its insistence that its projections are somehow not forecasts of the future'. As an alternative, some demographers prefer to use the label 'projection' for computations of future population trajectories assuming constant age-specific fertility, mortality and migration rates (Rogers & Willekens, 1978, p. 62).

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[4]The Population Reference Bureau (PRB) Glossary of Population Terms (www.prb.org/Content/NavigationMenu /PRB/PRB_Library/Glossary2/Glossary.htm, accessed on 25 May 2005). Despite of the fact of crossing national boundaries, other criteria to distinguish various types of migration flows can be set, for example, by type of change in the place of residence, duration, distance, or socio-demographic characteristics of migrants (Paradysz, 2006, p. 232).

[5]The Population Reference Bureau (PRB) Glossary of Population Terms (*idem*).

Following Keilman (1990, p. 7) a *forecast* is unconditional, as a result of the process, in which 'based on current scientific insights, a forecaster gives his best guess of what the future population will be'.[6] Further, Keilman distinguishes between forecast, which is 'based on relatively poorly developed behavioural theories', and *prediction*, 'based on a calculation with an explicit model or a verified theory' (*idem*, p. 8). However, contemporarily this difference becomes less clear with respect to some modern forecasting techniques, for the reasons that will be further explored in discussing the vector autoregressive model features in Chapter 6. For this reason, throughout the book the terms *forecast* and *prediction* will be used interchangeably. It is also worth noting that although all quoted definitions refer to population projections or forecasts in general, they can be easily adopted for the specific needs of a study of international migration.

Another distinction that needs to be made is the one between *knowledge* and *judgement*. Although, especially with respect to the former one, many competing definitions exist, in the current study *knowledge* is understood as 'the fact or condition of knowing something with familiarity gained through experience or association; [. . .] of having information or of being learned'. Respectively, *judgement* is defined as 'a proposition stating something believed or asserted'.[7] According to these descriptions, judgement is an external expression of a piece of knowledge possessed by a researcher, and hence can be directly used, for example, to form assumptions about future patterns of the phenomenon under study.

Finally, as far as the properties of (stochastic) processes are concerned, *stationarity* refers to exhibiting the same features at different points in time. In a stronger sense, this is usually defined as generating observations from the same probability distributions, and in a weaker sense, to time-independence of the autocovariance function of the process (cf. Granger & Morris, 1976).

1.3.2 Mathematical Notation

Similarly to the terminological framework, also the mathematical notation generally follows the established conventions. In the formulae, symbols for variables and functions are typed in italics, while for vectors, matrices and sets – in boldface. With respect to the latter, the most common is $\mathbf{R}$ – set of real numbers. Probability notation follows the usual convention: $p(A)$ denotes the probability of an event A, and $p(A|B)$ – conditional probability of A given B; the same rationale applies to

[6] With respect to the dispute on making population 'forecasts' or 'projection', Keyfitz (1972, p. 363) observed that 'a demographer makes a projection, and his reader uses it as a forecast' (after: Ahlburg & Land, 1992, p. 290).

[7] Both citations after the Merriam-Webster Online Dictionary (www.m-w.com, accessed on 25 April 2006). 'Knowledge' can be alternatively defined for example as 'acquaintance with or understanding of a science, art, or technique; the fact or condition of being aware of something; the range of one's information or understanding; the circumstance or condition of apprehending truth or fact through reasoning; the sum of what is known: the body of truth, information, and principles acquired by mankind' (*idem*).