

# Contents

## Part I Introduction

- 1 Introduction and Background** . . . . . 3
  - 1.1 Migration Forecasting as a Research Problem . . . . . 3
    - 1.1.1 Role of International Migration and Its Forecasts . . . . . 3
    - 1.1.2 Problems with Errors in Migration Forecasting . . . . . 5
  - 1.2 Aim and Structure of the Book . . . . . 6
    - 1.2.1 Aim and Scope . . . . . 6
    - 1.2.2 Structure of the Book . . . . . 7
  - 1.3 Terminology and Symbols . . . . . 10
    - 1.3.1 Basic Terms Used in the Study . . . . . 10
    - 1.3.2 Mathematical Notation . . . . . 11
    - 1.3.3 Bibliographical Notation . . . . . 12
- 2 Preliminaries** . . . . . 15
  - 2.1 Definitions and Measurement of International Migration . . . . . 15
    - 2.1.1 Data Sources and Definitions . . . . . 15
    - 2.1.2 Quality and Comparability of Migration Data . . . . . 16
    - 2.1.3 Ways of Dealing with Deficient Statistics . . . . . 17
  - 2.2 Uncertainty, Subjectivity and Judgement in Population and Migration Forecasting . . . . . 20
    - 2.2.1 Uncertainty in Demographic and Migration Forecasting . . . . . 23
    - 2.2.2 Subjectivity and Judgement in Population and Migration Predictions . . . . . 26
  - 2.3 Bayesian Inference in Statistics: Introductory Notes . . . . . 27
    - 2.3.1 The Bayesian Paradigm . . . . . 27
    - 2.3.2 Decision-Theory, Empirical and Orthodox Approaches . . . . . 29
    - 2.3.3 Bayesian Interval Estimation and Forecasting . . . . . 31

2.4	Markov Chain Monte Carlo (MCMC) Simulations . . . . .	32
2.4.1	Numerical Solutions to Bayesian Problems: General Remarks . . . . .	32
2.4.2	Simulation of Posterior Distributions Using Gibbs Sampling . . . . .	33

## Part II Explaining and Forecasting Migration

<b>3</b>	<b>Explaining Migration: Brief Overview of Selected Theories . . . . .</b>	<b>37</b>
3.1	Different Theoretical Perspectives on Migration Flows . . . . .	37
3.1.1	Sociological Theories . . . . .	37
3.1.2	Macroeconomic Theories . . . . .	40
3.1.3	Microeconomic Theories . . . . .	43
3.1.4	Geographical Theories . . . . .	45
3.1.5	Unifying Perspectives . . . . .	46
3.2	Theory in Migration Forecasting: A Global Outlook . . . . .	47
3.2.1	Migration Theories: General Remarks . . . . .	47
3.2.2	Use of Theories for Migration Predictions . . . . .	50
<b>4</b>	<b>Forecasting Migration: Selected Models and Methods . . . . .</b>	<b>53</b>
4.1	Deterministic Methods of Predicting Migration . . . . .	53
4.1.1	Judgemental Migration Scenarios . . . . .	53
4.1.2	The Delphi Method and Surveys Among Experts . . . . .	55
4.1.3	'Migration Potential' Assessment Surveys . . . . .	56
4.1.4	Macro-Level Mathematical Models in Demography . . . . .	58
4.1.5	Demo-Economic Modelling Attempts . . . . .	60
4.2	Probabilistic Migration Forecasts: Assessing Uncertainty . . . . .	61
4.2.1	Markovian and Related Models of Aggregate Population Flows . . . . .	61
4.2.2	Micro-Level Methods: Event-History Analysis and Ethnosurvey . . . . .	64
4.2.3	Selected Attempts to Bridge the Micro and Macro Perspectives . . . . .	67
4.2.4	Econometric Forecasts of International Migration . . . . .	68
4.2.5	Limitations of Econometric Models . . . . .	72
4.2.6	Stochastic Forecasts of Migration Time Series . . . . .	74
4.3	Bayesian Approach in Migration Studies and Demography . . . . .	77
4.3.1	Bayesian Models and Forecasts of Population Flows . . . . .	77
4.3.2	Bayesian Methods in Demography: A Concise Survey . . . . .	78
4.4	From Migration Theories to Model-Based Forecasting . . . . .	79
4.4.1	Migration Forecasting Methods and Models: State of the Art and Typology . . . . .	79

4.4.2	Deterministic Character of Many Existing Predictions . . . . .	81
4.4.3	Notes on Including Theory in Population and Migration Forecasts . . . . .	82
4.4.4	Implications for the Current and Future Studies . . . . .	84

### **Part III Examples of Bayesian Migration Predictions**

<b>5</b>	<b>Bayesian Model Selection and Forecast Averaging . . . . .</b>	<b>91</b>
5.1	Selection and Averaging Problems: Simple Stochastic Processes . . . . .	91
5.1.1	Methodological Foundations of Bayesian Model Selection . . . . .	91
5.1.2	Bayesian Forecast Averaging (Inference Pooling) . . . . .	93
5.1.3	Empirical Application: Specification of Forecasting Models . . . . .	95
5.1.4	Computations: The Carlin–Chib Algorithm . . . . .	97
5.2	Simple Time Series Forecasts: Individual and Averaged . . . . .	98
5.2.1	Estimation of the Models and Calculation of Their Posterior Probabilities . . . . .	98
5.2.2	Predictions Based on the Formally-Selected and Averaged Stochastic Processes . . . . .	106
5.2.3	Interpretation of Forecasts and the Comparison of <i>Ex-Post</i> Errors for 2005–2007 . . . . .	113
<b>6</b>	<b>Bayesian VAR Modelling ‘from General to Specific’ . . . . .</b>	<b>117</b>
6.1	VAR Processes and Lindley’s Tests for Restrictions . . . . .	117
6.1.1	Selection of Predictors in Econometric Models: Rationale for the VAR Modelling . . . . .	117
6.1.2	VAR Models and the ‘from General to Specific’ Approach . . . . .	118
6.1.3	Inference on the Impact of Additional Variables on Migration . . . . .	121
6.2	Example: Migration Forecasts from General and Reduced VARs . . . . .	123
6.2.1	Applying the Reduction Approach: Model Specification, Estimation, and Testing . . . . .	123
6.2.2	Results of Forecasts from the General VAR and Marginal AR Models . . . . .	129
6.2.3	‘From General to Specific’ Modelling: Discussion of the Outcomes . . . . .	134
<b>7</b>	<b>Selected Approaches to Discontinuities in Trends . . . . .</b>	<b>137</b>
7.1	From Deterministic Analogies to Stochastic Volatility . . . . .	137
7.1.1	The Simplest Options: Dummy Variables and Forecasting by Analogy . . . . .	137

7.1.2	Models with Changing Conditional Variance ARCH, GARCH, Stochastic Volatility . . . . .	139
7.2	Example: Forecasts from Models with Discontinuities . . . . .	140
7.2.1	Application to Polish-German Flows: Models with Analogy to Iberian Migration . . . . .	140
7.2.2	Models with Changing Conditional Variance: Model Selection for AR(1) Extensions . . . . .	144
7.2.3	Predictions Prepared with Models Acknowledging Discontinuity in Trends . . . . .	147
<b>8</b>	<b>Evaluation of Presented Forecasts of European Migration . . . . .</b>	<b>153</b>
8.1	Robustness of Forecasts Against Certain Changes In Priors . . . . .	153
8.1.1	Role of Sensitivity Analysis in the Bayesian Approach: Basic Remarks . . . . .	153
8.1.2	Robustness of Forecasts Yielded by Selected Models . . . . .	155
8.1.3	Discussion and Tentative Conclusions . . . . .	160
8.2	Comparison of Selected Bayesian and Frequentist Forecasts . . . . .	161
8.2.1	General Remarks on <i>Ex-Ante</i> and <i>Ex-Post</i> Prediction Errors . . . . .	161
8.2.2	Likelihood-Based Estimation and Model Selection Framework . . . . .	162
8.2.3	Selected Bayesian and Frequentist Migration Forecasts for 2000–2007 . . . . .	165
8.2.4	Comparison of <i>Ex-Ante</i> and <i>Ex-Post</i> Errors for Various Predictions . . . . .	169
<b>9</b>	<b>Bayesian Computing in Practice . . . . .</b>	<b>175</b>
9.1	A Short Survey of Available Bayesian Software . . . . .	175
9.1.1	R programming Language . . . . .	175
9.1.2	Octave . . . . .	176
9.1.3	BUGS . . . . .	177
9.2	Bayesian Computation in WinBUGS . . . . .	177
9.2.1	Model and Data Specification . . . . .	177
9.2.2	Model Compilation, Initialisation and Updating . . . . .	179
9.2.3	Convergence Diagnostics and Inference . . . . .	180
9.3	Example of Bayesian Computation in R Language . . . . .	181
9.3.1	Forecasting Migration Using R . . . . .	181
9.3.2	The Model of Immigration Flows . . . . .	181
9.3.3	Sampling . . . . .	183
9.3.4	Carlin–Chib Model Selection Procedure . . . . .	189
9.4	Conclusions . . . . .	195

## **Part IV Perspectives of Forecast Makers and Users**

<b>10</b>	<b>Extensions and Limitations of Migration Forecasts</b> . . . . .	199
10.1	Data, Theories and Judgement: Towards a Synthesis? . . . . .	199
10.1.1	Theory in an Atheoretical Setting: Prior Distributions in Multivariate Models . . . . .	199
10.1.2	Data Versus Judgement: Elicitation of Expert Knowledge . . . . .	202
10.2	Controlling Plausibility of Outcomes in Demographic Models . . . . .	205
10.2.1	Combining Deterministic Population Models with Stochastic Forecasts . . . . .	205
10.2.2	The Bayesian Melding Approach: Outline and Discussion . . . . .	207
10.3	Imperfect Knowledge Forecasting of Migration and Population . . . . .	208
10.3.1	Micro-level Foundations in Macro-level Forecasting . . . . .	208
10.3.2	The Imperfect Knowledge Paradigm: Quantitative Versus Qualitative Predictions . . . . .	209
10.4	Implications for Forecast-Makers and Future Research Agenda . . . . .	211
10.4.1	Limitations of Predictability and Plausible Horizon of Non-stationary Forecasts . . . . .	211
10.4.2	Forecasting Migration and Population: Proposal for a Research Agenda . . . . .	214
<b>11</b>	<b>Dealing with Uncertain Forecasts: A Policy Perspective</b> . . . . .	217
11.1	Preliminaries of the Decision Analysis: A Bayesian Perspective . . . . .	217
11.1.1	Background: Selected Insights into Decisions and Attitudes Towards Uncertainty . . . . .	217
11.1.2	Estimation and Prediction in the Bayesian Decision Framework . . . . .	220
11.1.3	Bayesian Decision Analysis: Some Stylised Examples . . . . .	223
11.1.4	Possible Extensions of the Decision Framework . . . . .	226
11.2	Limitations of Uses of Migration and Population Predictions . . . . .	228
11.2.1	Alternatives to the Use of Optimal Forecasts . . . . .	228
11.2.2	Which Questions Can the Forecasts Answer? . . . . .	231
11.2.3	Towards Interactive Demographic Forecasting? . . . . .	232

**Part V Conclusion**

<b>12 Summary and Conclusion: Beyond Migration Forecasting . . . . .</b>	<b>237</b>
12.1 Summary of the Key Findings . . . . .	237
12.1.1 Bayesian Model Selection and Forecast Averaging . . . . .	237
12.1.2 Vector Autoregression Models and Their Reduction . . . . .	238
12.1.3 Models Acknowledging Discontinuity in Trends . . . . .	239
12.1.4 Sensitivity of the Results to Changes in Priors . . . . .	240
12.1.5 <i>Ex-ante</i> and <i>Ex-post</i> Comparison of Forecasts: Implications for Users . . . . .	240
12.1.6 General Conclusions . . . . .	242
12.2 Bayesian Forecasts in the Population Forecasting Debates . . . . .	243
12.2.1 Bayesian Methods in Perspective: Uncertainty, Judgement and Occam's Razor . . . . .	243
12.2.2 Migration Forecasting as a Continuous Process . . . . .	244
12.2.3 From Point Predictions to Decision Support: In Need of a Paradigm Shift? . . . . .	247
12.3 A Possible Future of Migration and Its Forecasts . . . . .	248
<b>Annex A Empirical Illustrations: Data Sources and Preparation . . . . .</b>	<b>251</b>
Migration Flows . . . . .	251
Population Stocks . . . . .	251
Economic Variables . . . . .	255
<b>Annex B WinBUGS Code Used in the Forecasting Examples . . . . .</b>	<b>257</b>
<b>Annex C Selected Results of Presented Migration Forecasts . . . . .</b>	<b>263</b>
<b>References . . . . .</b>	<b>275</b>
<b>Author Index . . . . .</b>	<b>295</b>
<b>Subject Index . . . . .</b>	<b>301</b>