Central European Forum For Migration Research

Środkowoeuropejskie Forum Badań Migracyjnych

CEFMR Working Paper 10/2005

A REVISION OF THE TRADITIONAL MULTIREGIONAL MODEL TO BETTER CAPTURE INTERNATIONAL MIGRATION: THE MULTIPOLES MODEL AND ITS APPLICATION

Dorota Kupiszewska and Marek Kupiszewski

Central European Forum for Migration Research (CEFMR) is a research partnership of the Foundation for Population, Migration and Environment, Institute of Geography and Spatial Organization of the Polish Academy of Sciences and the International Organization for Migration

International Organization For Migration

Foundation for Population, Migration and Environment

Institute of Geography and Spatial Organisation, Polish Academy of Sciences

ul. Twarda 51/55, 00-818 Warsaw, Poland
tel. +48 22 697 88 34, fax +48 22 697 88 43
e-mail: cefmr@cefmr.pan.pl
Internet: www.cefmr.pan.pl

CEFMR Working Paper
10/2005

A REVISION OF THE TRADITIONAL MULTIREGIONAL MODEL TO BETTER CAPTURE INTERNATIONAL MIGRATION: THE MULTIPOLES MODEL AND ITS APPLICATION

Dorota Kupiszewska and Marek Kupiszewski**

* Central European Forum for Migration Research in Warsaw

Abstract: It has been established that existing models of population dynamics, including multiregional ones, do not allow for a neat inclusion of international migration into the process of modelling population change. They are not adapted to simultaneous modelling of the populations of many countries and, at the same time, to modelling regional populations in these countries. MULTIPOLES (MULTIstate POpulation model for multiLEvel Systems), a multiregional multilevel model of population dynamics addresses this problem by simultaneously forecasting population change in countries and regions, taking account of international migration between modelled countries, as well as from outside the system. A forecast of the elderly population in Central Europe illustrates an application of the model. A comparison of the average ex-post error of this forecast with those of the 1985 and 1990 Eurostat forecasts for a 10-year period shows that the forecast conducted with the MULTIPOLES model performed better than the two Eurostat forecasts.

Keywords: Population forecasting, population projections, migration, Europe

Paper prepared for the *Workshop on the Estimation of International Migration in Europe: Issues, Models, and Assessment*, Southampton, United Kingdom, 28–30 September 2005

Editor
ul. Twarda 51/55, 00-818 Warsaw, Poland
tel. +48 22 697 88 34, fax +48 22 697 88 43
e-mail: cefmr@cefmr.pan.pl
Internet: www.cefmr.pan.pl

ISSN 1732-0631
ISBN 83-921915-9-5

CONTENTS

Acknowledgements

The support of the Nuffield Foundation which funded M. Kupiszewski's Social Science Research Fellowship and subsequent grants from the Royal Society, the British Academy and the School of Geography of the University of Leeds are kindly acknowledged. We are grateful to our employers: School of Geography of the University of Leeds, Institute of Geography and Spatial Organization of the Polish Academy of Sciences and International Organization for Migration for their support. Research on mortality patterns was kindly sponsored by the Research Support Scheme of the OSI/HESP grant No: 214/1997. Professor Philip Rees encouraged us to construct the model and was always ready to offer his very valuable advice and support. Krystyna and Piotr Kupiszewski have improved Authors' English. Responsibility for all errors and mistakes lies solely with us.

Such a data-intensive project would be impossible to complete without the extensive help of researchers from many countries. The following people have helped us to obtain data: Brigitte Baccaïni, Anna Branicka, Hansjörg Bucher, Zdenek Čermák, Dušan Drbohlav, Jürgen Dorbritz, Bogusław Grużewski, Tomas Frejka, Anne Herm, Charlotte Höhn, Vlado Ira, Kalev Katus, Zoltán Kovács, Tomáš Kučera, Alexander Kucuk, Miroslav Macura, Steffen Maretzke, France Meslé, Franco Millich, Elżbieta Mścichowska, Lucyna Nowak, Bohdan Nowak, Ewa Tabeau, Mathias Siedhoff, Grzegorz Węcławowicz.

1. Multinational population projections and forecasts in Europe

Multinational population projections and forecasts may be conducted in a variety of ways. One option is to run a simple projection or forecast for large supranational units, such as political or economic groupings of states or continents. A recent example of such an approach was offered by Lutz, Sanderson and Scherbov (1996, 2004). However, this sort of projection/forecast does not give any detail at the level of individual states, not to mention a subnational level. They are therefore a valuable tool for thinking about the development of humanity, but unsuitable for taking any policy decisions, which, in order to make sense, have to be geographically-specific.

Another strategy is the one adopted by the United Nations, which prepares one of the best known population projections, published biannually in the *World Population Prospects* (the 2004 revision (UN 2005) being the most recent at the time of writing this paper). The UN projections cover the entire world on a country by country basis and the results are aggregated to 21 world regions. The UN uses a cohort component model for an entire country, and assumptions on fertility, mortality and net international migration. The methodology is a basic one, but the only possible, given the number of countries the UN has to cover. Certainly one of the most difficult problems is the estimation of input parameters for less developed countries, which lack sophisticated and therefore expensive population statistics. Wars and the political uncertainty in many parts of the world make data collection even more painstaking. A detailed analysis of problems concerning the preparation of the UN projections can be found in Keilman (2001).

There is a number of other organisations that produce multinational population projections and forecasts on a national level, for example the US Census Bureau (Johnson, 1999) and the World Bank (Vu, Bos 1992, World Bank 2005). Recently, two scenario-based population projections were prepared for all the European countries by a Dutch team of researchers (de Beer, van Wiessen 1999). Their book is an outstanding example of a well based on theoretical research and careful scenario setting for all the components of population dynamics.

The projections and forecasts mentioned above do not look at the regional dimension of population processes and therefore have a limited attraction for decision makers, spatial planners and geographers, who are more interested in population processes in smaller spatial units. Notable efforts to produce regional projections for the member states of the European Union, European Free Trade Area and the candidate countries have been made by the European Commission and Eurostat, the Statistical Office of the European Union. There have been five rounds of population projections of the entire European Union on a subnational (NUTS – 2) level. The first two covered twelve EU member states in 1980 and 1985 and spanned 30 years, till 2010 (NEI 1986) and 2015 (NEI 1990). An advantage over the projections conducted by individual countries was that the EC projections were based on a uniform methodology, the same starting year and a unified set of assumptions. The Netherlands Economic Institute (NEI) model was a top-down one, with regional populations being derived from the national population. National projections applied a cohort component female-dominant model with fixed fertility and mortality rates.

The NEI model was a major step forward at the time of its construction. There was, however, plenty of room for improvement. The main shortcoming of the NEI model was that it was data-availability-driven. The handling of fertility and mortality was quite simple. International migration was either neglected or taken into account only for Germany and Ireland. The scenario-setting capability of the model was limited to mortality and fertility only, which was a major shortcoming given the role that migration plays in European population dynamics. For these reasons the NEI model was later modified. The new version improved the handling of international migration and had scenario capabilities built in (NEI 1994). The geographical scope was also extended from EC12 to EC12 and EFTA. The projection went up to 2020 and has been used in the preparation of the Fifth Periodic Reports.

Eurostat has been busy improving projection techniques. The research on mortality forecasting (Tabeau et al 1997), fertility forecasting (de Jong 1997), internal (van der Gaag, van Imhoff, van Wissen 1997) and international (de Jong and Visser 1997) migration scenarios has been completed and the results have been incorporated into the next generation of models used for the 1995 round of population projections and forecasting. An external revision of Eurostat's achievements in population projections (Rees et al. 1999) suggested some further improvements and changes to the model existing at the time. The description of the methodology of the 2005 round of Eurostat forecasts has not been published at the time of writing of this paper, however, the engine used for the projection was the LIPRO model and, as far as we know, no significant changes have been introduced.

What differs Eurostat's projections and forecasts from those prepared by other organizations is the level of spatial detail: Eurostat is the only institution which prepares its forecasts and projections on a subnational, national and supranational level, the supranational level being a simple summation of national results. Such a solution was reasonable when international migration, the component that links national populations, was negligible. In recent decades one of the key issues in population forecasting is how to handle the development of populations in regions which have intense international migration interactions with other regions. In the late 1980s and early 1990s, massive international migration in Europe forced researchers and forecasters to think of the populations of one state not as isolated entities but as subpopulations of a larger system with interactions (international migration) between the elements of the system. This new approach was triggered by at least three factors: (i) Massive international migration flows existing at the time, which changed the dynamics of national and regional populations in a very significant way; (ii) European nations face rapid, often region-specific ageing, and some decision makers perceive international migration as a remedy; (iii) Political changes, in particular the process of the expansion of the European

Union, have given a political weight to the need for integrated approaches to population modelling.

The first to create a model capable of simultaneous handling of internal and international migration for supranational populations was Philip Rees with colleagues (Rees, Stillwell, Convey 1992), who constructed a population projection model called ECPOP, for the then European Community member states. The model was a female-dominant multiregional multilevel model with migration being handled on three levels:

- Level 1 - interregional, intrastate migration (input data: origin – destination – age – sex migration matrices for each country);
- Level 2 - international migration between countries (input data: origin-destination interstate matrix);
- Level 3 - international migration from the Rest of the world (input data: net migration by country).

The age dimension of migration data has been reconstructed using the Rogers-Castro model for age dependent intensity of migration.

The ECPOP model allows to set scenarios for all classes of migration as well as for mortality and fertility. Initially, it was used for population projections in EU regions on the NUTS level 1. At this stage the model generated national and subnational projections separately and their results were inconsistent. In its refined version (Rees 1996a) a bottom-up approach was implemented, removing the inconsistency problem. The model was used for the population projection of NUTS level 2 regions. In many ways, Rees' model is a major improvement in population projection practice. From the methodological point of view, it represents an implementation of the state of the art in population projections theory, as developed by Rees' and Rogers' schools. It allows for a coherent and unified treatment of supranational but regionally disaggregated populations, developing Rogers' concepts applied earlier for multiregional models.

Rees' model gave us the idea for the development of the MULTIPOLES model to be used to study the population development of Central and Eastern European countries. The preparation of supranational population projections consisted of three main tasks: the design of a population projection model, the construction of data sets as required by the model (in practice the model has to take data availability into account), and the generation of scenarios for population projections and forecasts. In the next section a detailed mathematical definition of the model is offered, while Section 3 deals with the other two issues and presents an application of the model.

2. The MULTIPOLES model: the MULTIstate POpulation model for multiLEvel Systems

The construction of the model and its application for population forecasts and projections included the following steps:

I. Construction of the mathematical model and software that implements the model.

- Identification of input and output variables of the model.
- Defining the notation for the model's variables.
- Formulating accounting and projection equations.
- Defining the methodology for estimating rates of demographic events.
- Defining the way forecast assumptions will be introduced into the model.
- Writing computer software.

II. Implementation of the model for a specific population system.

- Defining the population system.
- Collection of the data.
- Preparation of the input files.

III. Application of the model for solving specific research and planning problems.

- Formulation of the assumption on the components of population change.
- Preparation of files defining the assumptions according to software requirements.
- Estimation of demographic rates and running the model.
- Analysis and assessment of the results.

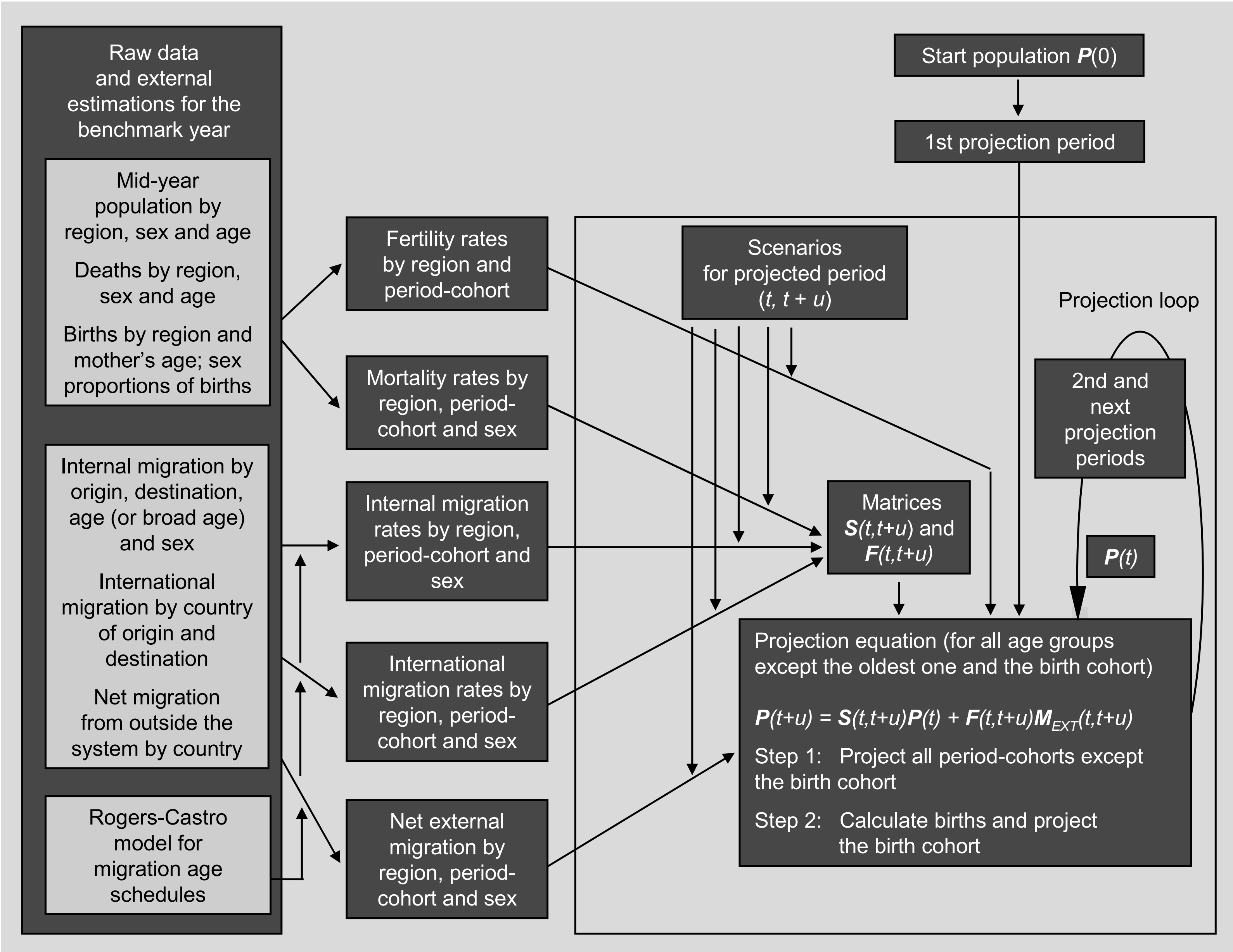
Below we focus on the first step of the forecast preparation, namely the construction of the mathematical model.

The MULTIPOLES is a cohort-component female-dominated, multilevel multiregional supranational model of population dynamics. It may be used for forecasts, projections and simulations. The population is disaggregated into sexes and eighteen five-year age groups, i.e. nineteen projection cohorts, with the cohort number zero being the birth cohort and the cohort 85+ being the last one. Geographically, the population is disaggregated into countries and regions. The model is based on movement type population accounts. The rates appearing in the accounts are defined as the number of events (deaths, migration or births) in a projection period divided by the population at risk, assumed to be equal to the mid-year population or calculated as an arithmetic average of the population of the projection cohort at the beginning and at the end of the projection period. Migration is handled on three levels, as in the ECPOP model:

- interregional intranational migration within each country;
- interregional international migration within the system;
- net migration from the Rest of the world to each country within the system.

The structure of the MULTIPOLES model is presented in Figure 1.

Figure 1. The structure of the MULTIPOLES multiregional multinational population projection model.



2.1. Specification of the population system and notation

Each region is identified by a pair of indices (*is,ir*), where *is* denotes the number of a country and *ir* the number of a region in this country. Such notation guarantees an elasticity of the model and possibility to redefine both the number of countries modelled as well as the number of regions in each country easily. When we refer to events occurring in age group *a* over period (*t,t+u*), we have in mind the period-cohort measurement plan (see Figure 2), that is the events concerning persons at the age (*a,a+u*) at time *t* which took place over period (*t,t+u*).

In the formulas, the following notation has been used (see also Figure 2):

u	– span of the age groups and the length of a projection/forecast step;
t	– time;
g	– sex (f – female, m – male);
a	– age group (covering persons at the age from *a* to *a+u* years);
00	– birth cohort;
A+	– the oldest, open ended age group, covering persons of age *A* or more;
ir, jr	– region;
is, js	– country;
ns	– number of countries in the system;
nr(*is*)	– number of regions in country *is*;
nrtot	– total number of regions.

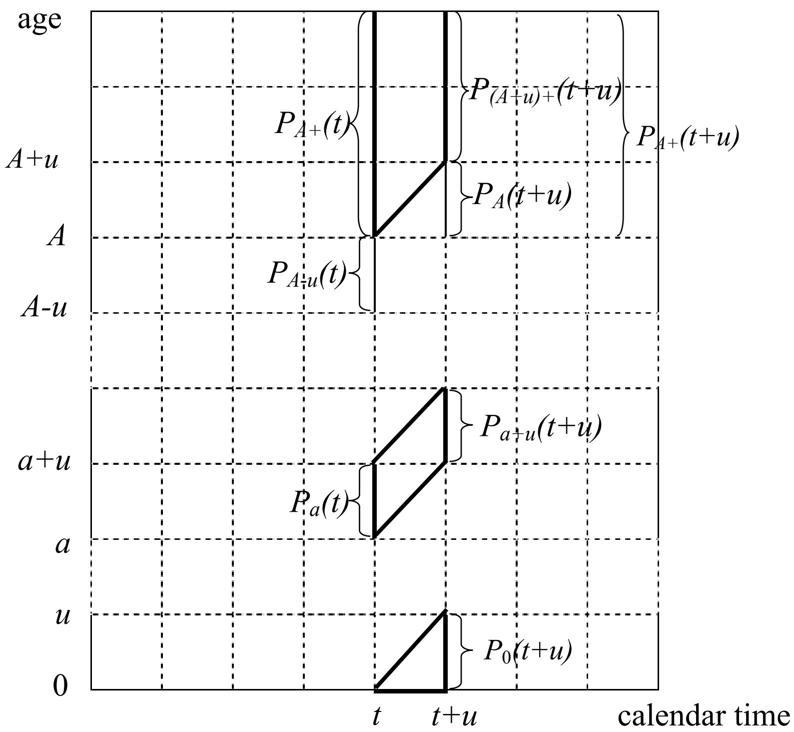
Stock variables:

$P_a^{(is,ir)}(t)$	–	Population in age group *a* in region *ir* in country *is* at time *t*, that means at the beginning of a projection step.
$P_a^{(is,ir)}(t+u)$	–	Population in age group *a* in region *ir* in country *is* at time *t+u*, that means at the end of a projection step.

Event variables:

$B^{(is,ir)}(t,t+u)$	–	Births in region *ir* in country *is* over period (*t,t+u*);
$D_a^{(is,ir)}(t,t+u)$	–	Deaths in age group *a* in region *ir* in country *is* over period (*t,t+u*);
$M_{IRa}^{(is,ir)(is,jr)}(t,t+u)$	–	Interregional migration from region *ir* to region *jr* in country *is* in age group *a* over period (*t,t+u*) (subscript IR denotes internal migration);
$M_{ISa}^{(is,ir)(js,jr)}(t,t+u)$	–	International migration from region *ir* in country *is* to region *jr* in country *js* in age group *a* over period (*t,t+u*) (subscript IS denotes internal migration);
$M_{EXTa}^{(is,ir)}(t,t+u)$	–	Net migration from the Rest of the world in region *ir* in country *is* at age group *a* over period (*t,t+u*).

Figure 2. Lexis diagram illustrating the notation used in the MULTIPOLES model.



Source: own elaboration.

The migration system in the MULTIPOLES model is presented in Table 1. In the table, the rows refer to the source regions and the columns to the destination regions. In accord with the adopted notation, each region is identified by a pair of indices, the first denoting the number of a country, the second denoting the number of a region within the country. In addition, there is a separate region „the Rest of the world" with which the exchange of international migrants takes place. This region is not a part of the modelled population system, but it is an external source or destination of migrants. No information on population, fertility or mortality in this region is collected or modelled.

In an ideal world we should have a full „region to region" matrix of international flows. Such data do not exist and countries struggle to deliver even the data on country to country migration. In consequence, other existing models are more parsimonious as far as the demand for data on international migration is concerned.

In Table 1, all cells representing migration flows for which data are needed in the MULTIPOLES model have been shaded or marked with the letter **m**. So far in the applications of the model, the data for the shaded cells have been taken directly from the observed flows, while the figures for the cells marked with the letter **m** had to be estimated or modelled. The empty cells in Table 1 correspond to intraregional migration, not considered in the model.

Table 1. The migration system in the MULTIPOLES model.

		Destination country											
		1				*is*				*ns*			
		Destination region			Total	Destination region			Total	Destination region			Total
Country	Region of origin	1,1	1,*ir*	1,*nr*(1)		*is*,1	*is*,*ir*	*is*,*nr*(*is*)		*ns*,1	*ns*,*ir*	*ns*,*nr*(*ns*)	
1	1,1				s	**m**	**m**	**m**	s	**m**	**m**	**m**	s
	1,*ir*				s	**m**	**m**	**m**	s	**m**	**m**	**m**	s
	1,*nr*(1)				s	**m**	**m**	**m**	s	**m**	**m**	**m**	s
	Total	s	s	s	s	s	s	s		s	s	s	
is	*is*,1	**m**	**m**	**m**	s				s	**m**	**m**	**m**	s
	is,*ir*	**m**	**m**	**m**	s				s	**m**	**m**	**m**	s
	is,*nr*(*is*)	**m**	**m**	**m**	s				s	**m**	**m**	**m**	s
	Total	s	s	s		s	s	s	s	s	s	s	
ns	*ns*,1	**m**	**m**	**m**	s	**m**	**m**	**m**	s				s
	ns,*ir*	**m**	**m**	**m**	s	**m**	**m**	**m**	s				s
	ns,*nr*(*ns*)	**m**	**m**	**m**	s	**m**	**m**	**m**	s				s
	Total	s	s	s		s	s	s		s	s	s	s
Net international migration from the Rest of the world		**m**	**m**	**m**		**m**	**m**	**m**		**m**	**m**	**m**	

(shading)	Observed internal migration
(shading)	Observed international migration between modelled countries
(shading)	Observed net migration from the Rest of the world
m	Modelled international migration
	Migration not taken into account in the model
s	Values obtained through summation

Note: In the table, a simplified notation has been used.

Source: Own elaboration.

A comparison of Table 1 with the relevant tables in Rees et al. (1999) shows that the information on international migration used in the NEI models and the model used in the 1995-2025 Eurostat forecast is very limited and constrained to the net migration in each country. The MULTIPOLES model is much more demanding, as a full matrix of flows between modelled countries is needed as well as the net migration from the Rest of the world to each country.

2.2. Accounting equations of the model

In this section we present accounting equations for the birth cohort, for the oldest age group and for the remaining age groups. Stocks and the measurement plan for demographic events are illustrated in Figure 2. For the sake of simplicity, the gender index has been omitted in the equations that are identical for both sexes. In the formulas defining birth rates and number of births, the gender index has been specified explicitly.

2.2.1. Accounting equations for age groups a = 0, u, … , A-u

The population accounting equation for region *ir* in country *is*, for each sex and all age groups except 00 and *A*+, may be formulated as follows:

$$P_{a+u}^{(is,ir)}(t+u) = P_a^{(is,ir)}(t) - D_a^{(is,ir)}(t,t+u) +$$
$$- \sum_{jr\neq ir} M_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u) - \sum_{js\neq is} \sum_{jr} M_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u) +$$
$$+ \sum_{jr\neq ir} M_{\mathrm{IR}a}^{(is,jr)(is,ir)}(t,t+u) + \sum_{js\neq is} \sum_{jr} M_{\mathrm{IS}a}^{(js,jr)(is,ir)}(t,t+u) + M_{\mathrm{EXT}a}^{(is,ir)}(t,t+u).$$

The components of change in the above formula may be expressed in terms of occurrence-exposure rates. Using the convention proposed by Rees (1973) we will define them as the number of events divided by the population at risk. Let us denote:

$d_a^{(is,ir)}(t,t+u)$ – Death rate in region *ir* of country *is* in age group *a* over period $(t,t+u)$;

$m_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u)$ – Out-migration rate from region *ir* to region *jr* of country *is* in age group *a* over period $(t,t+u)$;

$m_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u)$ – Emigration rate from region *ir* in country *is* to region *jr* of country *is* in age group *a* over period $(t,t+u)$.

The rates are expressed with the formulas:

$$d_a^{(is,ir)}(t,t+u) = \frac{D_a^{(is,ir)}(t,t+u)}{0.5(P_a^{(is,ir)}(t) + P_{a+u}^{(is,ir)}(t+u))};$$

$$m_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u) = \frac{M_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u)}{0.5(P_a^{(is,ir)}(t) + P_{a+u}^{(is,ir)}(t+u))};$$

$$m_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u) = \frac{M_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u)}{0.5(P_a^{(is,ir)}(t) + P_{a+u}^{(is,ir)}(t+u))}.$$

Consequently:

$$\begin{aligned} P_a^{(is,ir)}(t+u) = P_a^{(is,ir)}(t) - 0.5\, d_a^{(is,ir)}(t,t+u)\, [P_a^{(is,ir)}(t) + P_{a+u}^{(is,ir)}(t+u)] +\\ - 0.5 \textstyle\sum_{jr\neq ir} m_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u)\, [P_a^{(is,ir)}(t) + P_{a+u}^{(is,ir)}(t+u)] +\\ - 0.5 \textstyle\sum_{js\neq is} \sum_{jr} m_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u)\, [P_a^{(is,ir)}(t) + P_{a+u}^{(is,ir)}(t+u)] +\\ + 0.5 \textstyle\sum_{jr\neq ir} m_{\mathrm{IR}a}^{(is,jr)(is,ir)}(t,t+u)\, [P_a^{(is,jr)}(t) + P_{a+u}^{(is,jr)}(t+u)] +\\ + 0.5 \textstyle\sum_{js\neq is} \sum_{jr} m_{\mathrm{IS}a}^{(js,jr)(is,ir)}(t,t+u)\, [P_a^{(js,jr)}(t) + P_{a+u}^{(js,jr)}(t+u)] +\\ + M_{\mathrm{EXT}a}^{(is,ir)}(t,t+u). \end{aligned}$$

Using matrix notation, the accounting equation may be formulated as follows:

$$\boldsymbol{P}_{a+u}(t+u) = \boldsymbol{P}_a(t) - 0.5\boldsymbol{M}_a(t,\, t+u)[\boldsymbol{P}_a(t) + \boldsymbol{P}_{a+u}(t+u)] + \boldsymbol{M}_{EXTa}(t,\, t+u),$$

where $\boldsymbol{P}_a(t)$ is a column vector of regional stocks of population at age group a at time t, $\boldsymbol{M}_a(t,t+u)$ is a matrix dependent on death rates $d_a^{(is,ir)}(t,t+u)$, out-migration rates $m_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u)$ and on emigration rates $m_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u)$. The vector $\boldsymbol{M}_{\mathrm{EXT}a}(t,t+u)$ contains net migration from the Rest of the world, expressed as absolute numbers rather than rates.

The structure of the matrices and vectors introduced above is as follows. The vector $\boldsymbol{P}_a$ shows the distribution of population in age group a, by country and region:

$$\boldsymbol{P}_a = [P_a^{(1,1)}, \ldots, P_a^{(1,nr(1))}, \ldots, P_a^{(is,1)}, \ldots, P_a^{(is,ir)}, \ldots, P_a^{(is,nr(is))}, \ldots, P_a^{(ns,1)}, \ldots, P_a^{(ns,nr(ns))}]^{\mathrm{T}}.$$

This vector comprises $nrtot = \sum_{is} nr(is)$ elements.

The matrix $\boldsymbol{M}_a(t,t+u)$ is a square matrix consisting of $nrtot*nrtot$ elements. The diagonal elements of the matrix $\boldsymbol{M}_a(t,t+u)$, i.e. the elements meeting the conditions $is = js$ and $ir = jr$, are defined as follows:

$$M_a^{(is,ir)(is,ir)}(t,t+u) = d_a^{(is,ir)}(t,t+u) + \textstyle\sum_{jr} m_{\mathrm{IR}a}^{(is,ir)(is,jr)}(t,t+u) + \sum_{js}\sum_{jr} m_{\mathrm{IS}a}^{(is,ir)(js,jr)}(t,t+u).$$

The non-diagonal elements have the form:

$$M_a^{(is,ir)(is,jr)}(t,t+u) = -m_{\mathrm{IR}a}^{(is,jr)(is,ir)}(t,t+u) \text{ for } ir \neq jr;$$
$$M_a^{(is,ir)(js,jr)}(t,t+u) = -m_{\mathrm{IS}a}^{(js,jr)(is,ir)}(t,t+u) \text{ for } is \neq js.$$

The diagonal elements depict the decrease of population in a region due to mortality and emigration to the other regions of the country and to the other countries. The non-diagonal elements represent the inflow of population to a given region from the other regions of the country and from abroad. The submatrix of the matrix $\boldsymbol{M}_a(t,t+u)$ which meets the condition $is=js$, is shown in Table 2. The entire matrix is presented in Table 3. For the sake of simplicity the age and time indices have been omitted in Table 2 and Table 3.

After solving the accounting equation for $\boldsymbol{P}_{a+u}(t+u)$, we obtain:

$$\boldsymbol{P}_{a+u}(t+u) = [\mathbf{I} + 0.5\boldsymbol{M}_a(t,t+u)]^{-1}[\mathbf{I} - 0.5\boldsymbol{M}_a(t,t+u)]\,\boldsymbol{P}_a(t) + \\ + [\mathbf{I} + 0.5\boldsymbol{M}_a(t,t+u)]^{-1}\boldsymbol{M}_{\mathrm{EXT}a}(t,t+u)$$

where **I** is the identity matrix.

Table 2. The submatrix of the matrix ***M*** meeting the condition is = js.

Country		*is*				
	Region	1	…	*ir*	…	*nr*(*is*)
	1	$d^{(1,1)} + \sum_{jr} m_{\mathrm{IR}}{}^{(1,1)(is,jr)} + \sum_{js} \sum_{jr} m_{\mathrm{IS}}{}^{(1,1)(js,jr)}$		$-m_{\mathrm{IR}}{}^{(is,ir)(is,1)}$	…	$-m_{\mathrm{IR}}{}^{(is,nr(is))(is,1)}$
	⋮		⋱			⋮
is	*ir*	$-m_{\mathrm{IR}}{}^{(is,1)(is,ir)}$	⋱	$d^{(is,ir)} + \sum_{jr} m_{\mathrm{IR}}{}^{(is,ir)(is,jr)} + \sum_{js} \sum_{jr} m_{\mathrm{IS}}{}^{(is,ir)(js,jr)}$	⋱	$-m_{\mathrm{IR}}{}^{(is,nr(is))(is,ir)}$
	⋮	⋮			⋱	
	nr(*is*)	$-m_{\mathrm{IR}}{}^{(is,1)(is,nr(is))}$	…	$-m_{\mathrm{IR}}{}^{(is,ir)(is,nr(is))}$		$d^{(is,nr(is))} + \sum_{jr} m_{\mathrm{IR}}{}^{(is,nr(is))(is,jr)} + \sum_{js} \sum_{jr} m_{\mathrm{IS}}{}^{(is,nr(is))(js,jr)}$

Source: Own elaboration

Table 3. The matrix ***M***.

Country	Region	1					…	is					…	ns				
	Region	1	…	*jr*	…	*nr*(1)		1	…	*jr*	…	*nr*(*is*)		1	..	*jr*	…	*nr*(*ns*)
1	1	$M^{(1,1)(1,1)}$		$-m_{IR}^{(1,jr)(1,1)}$	…	$-m_{IR}^{(1,nr(1))(1,1)}$		$-m_{IS}^{(is,1)(1,1)}$	…	$-m_{IS}^{(is,jr)(1,1)}$	…	$-m_{IS}^{(is,nr(is))(1,1)}$	…	$-m_{IS}^{(ns,1)(1,1)}$	..	$-m_{IS}^{(ns,jr)(1,1)}$	…	$-m_{IS}^{(ns,nr(ns))(1,1)}$
	:		⋱			:		:		:		:		:		:		:
	ir	$-m_{IR}^{(1,1)(1,ir)}$		$M^{(1,jr)(1,jr)}$		$-m_{IR}^{(1,nr(1))(1,ir)}$		$-m_{IS}^{(is,1)(1,ir)}$	…	$-m_{IS}^{(is,jr)(1,ir)}$	…	$-m_{IS}^{(is,nr(is))(1,ir)}$	…	$-m_{IS}^{(ns,1)(1,ir)}$	..	$-m_{IS}^{(ns,jr)(1,ir)}$	…	$-m_{IS}^{(ns,nr(ns))(1,ir)}$
	:	:			⋱			:		:		:		:		:		:
	nr(1)	$-m_{IR}^{(1,1)(1,nr(1))}$	…	$-m_{IR}^{(1,jr)(1,nr(1))}$		$M^{(1,nr(1))(1,nr(1))}$		$-m_{IS}^{(is,1)(1,nr(1))}$	…	$-m_{IS}^{(is,jr)(1,nr(1))}$	…	$-m_{IS}^{(is,nr(is))(1,nr(1))}$	…	$-m_{IS}^{(ns,1)(1,nr(1))}$	..	$-m_{IS}^{(ns,jr)(1,nr(1))}$	…	$-m_{IS}^{(ns,nr(ns))(1,nr(1))}$
:							⋱							:		:		:
is	1	$-m_{IS}^{(1,1)(is,1)}$	…	$-m_{IS}^{(1,jr)(is,1)}$	…	$-m_{IS}^{(1,nr(1))(is,1)}$		$M^{(is,1)(is,1)}$		$-m_{IR}^{(is,jr)(is,1)}$	…	$-m_{IR}^{(is,nr(is))(is,1)}$		$-m_{IS}^{(ns,1)(is,1)}$	..	$-m_{IS}^{(ns,jr)(is,1)}$	…	$-m_{IS}^{(ns,nr(ns))(is,1)}$
	:	:		:		:			⋱			:		:		:		:
	ir	$-m_{IS}^{(1,1)(is,ir)}$	…	$-m_{IS}^{(1,jr)(is,ir)}$	…	$-m_{IS}^{(1,nr(1))(is,ir)}$		$-m_{IR}^{(is,1)(is,ir)}$		$M^{(is,ir)(is,jr)}$		$-m_{IR}^{(is,nr(is))(is,ir)}$		$-m_{IS}^{(ns,1)(is,ir)}$	..	$-m_{IS}^{(ns,jr)(is,ir)}$	…	$-m_{IS}^{(ns,nr(ns))(is,ir)}$
	:	:		:		:		:		:	⋱			:		:		:
	nr(*is*)	$-m_{IS}^{(1,1)(is,nr(is))}$	…	$-m_{IS}^{(1,jr)(is,nr(is))}$	…	$-m_{IS}^{(1,nr(1))(is,nr(is))}$		$-m_{IR}^{(is,1)(is,nr(is))}$	…	$-m_{IR}^{(is,jr)(is,nr(is))}$		$M^{(is,nr(is))(is,nr(is))}$		$-m_{IS}^{(ns,1)(is,nr(is))}$	..	$-m_{IS}^{(ns,jr)(is,nr(is))}$	…	$-m_{IS}^{(ns,nr(ns))(is,nr(is))}$
:		:		:		:							⋱					
ns	1	$-m_{IS}^{(1,1)(ns,1)}$	…	$-m_{IS}^{(1,jr)(ns,1)}$	…	$-m_{IS}^{(1,nr(1))(ns,1)}$	…	$-m_{IS}^{(is,1)(ns,1)}$	…	$-m_{IS}^{(is,jr)(ns,1)}$	…	$-m_{IS}^{(is,nr(is))(ns,1)}$		$M^{(ns,1)(ns,1)}$		$-m_{IR}^{(ns,jr)(ns,1)}$	…	$-m_{IR}^{(ns,nr(ns))(ns,1)}$
	:	:		:		:		:		:		:			⋱			:
	ir	$-m_{IS}^{(1,1)(ns,ir)}$	…	$-m_{IS}^{(1,jr)(ns,ir)}$	…	$-m_{IS}^{(1,nr(1))(ns,ir)}$	…	$-m_{IS}^{(is,1)(ns,ir)}$	…	$-m_{IS}^{(is,jr)(ns,ir)}$	…	$-m_{IS}^{(is,nr(is))(ns,ir)}$		$-m_{IR}^{(ns,1)(ns,ir)}$		$M^{(ns,ir)(ns,jr)}$		$-m_{IR}^{(ns,nr(ns))(ns,ir)}$
	:	:		:		:		:		:		:		:			⋱	
	nr(*ns*)	$-m_{IS}^{(1,1)(ns,nr(ns))}$	…	$-m_{IS}^{(1,jr)(ns,nr(ns))}$	…	$-m_{IS}^{(1,nr(1))(ns,nr(ns))}$	…	$-m_{IS}^{(is,1)(ns,nr(ns))}$	…	$-m_{IS}^{(is,jr)(ns,nr(ns))}$	…	$-m_{IS}^{(is,nr(is))(ns,nr(ns))}$		$-m_{IR}^{(ns,1)(ns,nr(ns))}$	..	$-m_{IR}^{(ns,jr)(ns,nr(ns))}$		$M^{(ns,nr(ns)(ns,nr(ns)}$

Source: Own elaboration

2.2.2. Accounting equations for the birth cohort

Age group 00, the birth cohort, comprises children born during the current step of the projection. The accounting equation for this age group has the form:

$$P_0^{(is,ir)}(t+u) = B^{(is,ir)}(t,t+u) - D_{00}^{(is,ir)}(t,t+u) +$$
$$- \sum_{jr\neq ir} M_{\mathrm{IR00}}^{(is,ir)(is,jr)}(t,t+u) - \sum_{js\neq is}\sum_{jr} M_{\mathrm{IS00}}^{(is,ir)(js,jr)}(t,t+u) +$$
$$+ \sum_{jr\neq ir} M_{\mathrm{IR00}}^{(is,jr)(is,ir)}(t,t+u) + \sum_{js\neq is}\sum_{jr} M_{\mathrm{IS00}}^{(js,jr)(is,ir)}(t,t+u) +$$
$$+ M_{\mathrm{EXT00}}^{(is,ir)}(t,t+u).$$

As before, we express this equation in terms of occurrence-exposure rates. The population at risk is estimated as the average number of babies born over the period from t till $(t+u)$, that is $0.5(0 + P_0^{(is,ir)}(t+u))$. Death and emigration rates for the birth cohort are therefore:

$$d_{00}^{(is,ir)}(t,t+u) = \frac{D_{00}^{(is,ir)}(t,t+u)}{0.5P_0^{(is,ir)}(t+u)};$$

$$m_{\mathrm{IR00}}^{(is,ir)(is,jr)}(t,t+u) = \frac{M_{\mathrm{IR00}}^{(is,ir)(is,jr)}(t,t+u)}{0.5P_0^{(is,ir)}(t+u)};$$

$$m_{\mathrm{IS00}}^{(is,ir)(js,jr)}(t,t+u) = \frac{M_{\mathrm{IS00}}^{(is,ir)(js,jr)}(t,t+u)}{0.5P_0^{(is,ir)}(t+u)}.$$

Using matrix notation we arrive at the following accounting equation:

$$\boldsymbol{P}_0(t+u) = \boldsymbol{B}(t,t+u) - 0.5\boldsymbol{M}_{00}(t,t+u)\boldsymbol{P}_0(t+u) + \boldsymbol{M}_{\mathrm{EXT00}}(t,t+u),$$

where $\boldsymbol{B}(t,t+u)$ is a column vector of births of babies of a given sex by region over the period $(t,t+u)$ and the matrix $\boldsymbol{M}_{00}$ has the form shown in Table 3. Transforming the above formula we finally get:

$$\boldsymbol{P}_0(t+u) = [\mathbf{I} + 0.5\boldsymbol{M}_{00}(t,\ t+u)]^{-1}[\boldsymbol{B}(t,t+u) + \boldsymbol{M}_{\mathrm{EXT00}}(t,\ t+u)].$$

In order to use the above equation in a population dynamics model we have to specify how the birth vector $\boldsymbol{B}(t,t+u)$ is calculated. Let us use the following notation:

$b_a^{(is,ir)}(t,t+u)$	–	Fertility rate for females in age group a in region ir in country is over period $(t,t+u)$;
$B_a^{(is,ir)}(t,t+u)$	–	Number of children born to females in age group a in region ir in country is over period $(t,t+u)$;

f_g^{is} – Proportion of newborn children in country *is* who are of sex *g* (it is assumed that this ratio is identical in all regions of a country).

Fertility rate $b_a^{(is,ir)}(t,t+u)$ is defined by the formula:

$$b_a^{(is,ir)}(t,t+u) = \frac{B_a^{(is,ir)}(t,t+u)}{0.5(P_{a\mathrm{f}}^{(is,ir)}(t) + P_{(a+u)\mathrm{f}}^{(is,ir)}(t+u))}.$$

Let us note that the denominator in the above equation refers to the female population, hence the index f, whereas the children born are of both sexes. The number of newborn children of sex g in region *ir* of country *is* over period (*t,t*+*u*) is:

$$B_g^{(is,ir)}(t,t+u) = 0.5 f_g^{is} \sum_a b_a^{(is,ir)}(t,t+u)[P_{a\mathrm{f}}^{(is,ir)}(t) + P_{(a+u)\mathrm{f}}^{(is,ir)}(t+u)],$$

where the sum goes through all fertile age groups.

2.2.3. Accounting equations for the oldest age group (A+)

Accounting equations for the oldest age group can be obtained taking into account (see Figure 2) that:

$$\boldsymbol{P}_{A+}(t+u) = \boldsymbol{P}_{(A+u)+}(t+u) + \boldsymbol{P}_A(t+u).$$

Proceeding as before we will obtain:

$$\begin{aligned}\boldsymbol{P}_{A+}(t+u) = {} & [\mathbf{I} + 0.5\boldsymbol{M}_{A+}(t,t+u)]^{-1}[\mathbf{I} - 0.5\boldsymbol{M}_{A+}(t,t+u)]\,\boldsymbol{P}_{A+}(t) + \\ & + [\mathbf{I} + 0.5\boldsymbol{M}_{A+}(t,t+u)]^{-1}\boldsymbol{M}_{\mathrm{EXT}A+}(t,t+u) + \\ & + [\mathbf{I} + 0.5\boldsymbol{M}_{A-u}(t,t+u)]^{-1}[\mathbf{I} - 0.5\boldsymbol{M}_{A-u}(t,t+u)]\,\boldsymbol{P}_{A-u}(t) + \\ & + [\mathbf{I} + 0.5\boldsymbol{M}_{A-u}(t,t+u)]^{-1}\boldsymbol{M}_{\mathrm{EXT}(A-u)}(t,t+u)\end{aligned}$$

2.3. Projection equations

Let

$$\boldsymbol{S}_a(t,t+u) = [\mathbf{I} + 0.5\boldsymbol{M}_a(t,t+u)]^{-1}[\mathbf{I} - 0.5\boldsymbol{M}_a(t,t+u)]$$

and

$$\boldsymbol{F}_a(t,t+u) = [\mathbf{I} + 0.5\boldsymbol{M}_a(t,t+u)]^{-1},$$

where *a* = 00, 0, *u*, … , *A*-*u*, *A*+.

Taking into account the formulas derived in the previous sections we get:

$$
\begin{aligned}
&\boldsymbol{P}_0(t+u) = \boldsymbol{F}_{00}(t,t+u)[\boldsymbol{B}(t,t+u) + \boldsymbol{M}_{\mathrm{EXT00}}(t,t+u)],\\
&\boldsymbol{P}_{a+u}(t+u) = \boldsymbol{S}_a(t,t+u)\boldsymbol{P}_a(t) + \boldsymbol{F}_a(t,t+u)\boldsymbol{M}_{\mathrm{EXT}a}(t,t+u),\\
&\boldsymbol{P}_{A+}(t+u) = \boldsymbol{S}_{A+}(t,t+u)\boldsymbol{P}_{A+}(t) + \boldsymbol{F}_{A+}(t,t+u)\boldsymbol{M}_{\mathrm{EXT}A+}(t,t+u) +\\
&\qquad + \boldsymbol{S}_{A-u}(t,t+u)\boldsymbol{P}_{A-u}(t) + \boldsymbol{F}_{A-u}(t,t+u)\boldsymbol{M}_{\mathrm{EXT}(A-u)}(t,t+u).
\end{aligned}
$$

These equations are used for population projections in the MULTIPOLES model.

The matrix $\boldsymbol{S}$ may be interpreted as the matrix of survival coefficients for the population present in the system at time *t,* whereas $\boldsymbol{F}$ as the matrix of survival coefficients for the population which joined the system through births or immigration from the Rest of the world in projection period $(t,t+u)$.

These equations are analogous to those derived by Willekens and Drewe (1984) for multiregional population projections of a single country. The MULTIPOLES model is therefore a generalization of the multiregional movement-type projection model to the multilevel migration case. The key difference between the models is the way in which the matrices $\boldsymbol{S}$ and $\boldsymbol{F}$ are calculated and the meaning of the vector $\boldsymbol{M}_{\mathrm{EXT}}$. In Willekens and Drewe's model, the matrices $\boldsymbol{S}$ and $\boldsymbol{F}$ are calculated based on the region-specific death rates, direction-specific out-migration rates and region-specific international emigration rates. The vector $\boldsymbol{M}_{\mathrm{EXT}}$ covers total international immigration. In the MULTIPOLES model, the vector $\boldsymbol{M}_{\mathrm{EXT}}$ contains net international migration from the countries not belonging to the modelled system, whereas the matrices $\boldsymbol{S}$ and $\boldsymbol{F}$ are calculated based on the region-specific death rates, the direction-specific out-migration rates and the direction-specific rates of emigration for international migration flows within the system. This mechanism allows for a more complete treatment of international migration in the MULTIPOLES model, assuming the availability of the data.

3. An application of the MULTIPOLES model – a forecast of the elderly population in Central and Eastern Europe

The MULTIPOLES model has been tested in a variety of applications: for a projection of population in Central and Eastern Europe (Kupiszewski and Kupiszewska, 1997), for forecasting elderly population in Central and Eastern Europe (Kupiszewski and Kupiszewska, 1999), for forecasting the labour force supply in Central and Eastern Europe (Kupiszewski 2001), for assessing the impact of international migration on the development of the regional populations in Central and Eastern Europe (Kupiszewski 2002), for forecasting the regional population in Austria and the surrounding states, and for calculating replacement migration for Europe (Bijak et al 2005). Below, the results of one application - namely the forecast of the elderly population in Central and Eastern Europe - will be presented and their quality assessed by measuring the *ex-post* forecasting error and comparing it with those of selected Eurostat forecasts.

3.1. Geographical and temporal scope of the projection

Geographically, the forecast covered 14 countries and 154 regions in Central and Eastern Europe (see Table 4 for the list of countries). The countries were selected basing on two criteria: the geographic location and migration interaction. That was why Germany and Austria were included, despite an apparent difference in the level of economic and social development between these two countries and the former communist block countries. The forecast was based on data for 1994, which roughly speaking represented the situation in Central and East European countries in the transition period. The forecast horizon was 25 years (1994-2019) and included simple scenarios of changes of life expectancy at birth, total fertility rates, migration rates for internal and international intra-system migration, and net migration numbers for international migration with the Rest of the world.

The administrative division of the states had an impact on the way the data were collected and consequently on the way the projection was conducted. Whenever it was feasible, the first level of administrative division was used. The number of regions in the countries ranged from 1 to 49 (see Table 4). Some countries, namely all the Baltic States and Slovenia, have not been subdivided any further due to their small populations. For Belarus, Moldova and Ukraine, regional data were not available.

Table 4. List of the countries and the number of regions in each country modelled in the projection.

Country	Number of regions	Country	Number of regions
Austria	9	Lithuania	1
Belarus	1	Moldova	1
Czech Republic	8	Poland	49
Estonia	1	Romania	41
Federal Republic of Germany	16	Slovak Republic	4
Hungary	20	Slovenia	1
Latvia	1	Ukraine	1
		Total	154

Source: Own elaboration.

3.2. Data collection - problems and solutions

Population data concerning well-defined events such as births and deaths and somewhat less well-defined migration are routinely collected by national statistical offices. In practice, we have good quality data on births and deaths and much worse data on migration and on population stocks. Data on migration, both internal and international, are often underestimated (e.g. due to underreporting), the latter especially in politically turbulent times.

The MULTIPOLES model requires the following data: the data on population stocks and deaths by age (eighteen five-year age groups), sex and region; births by sex of the child born, and region and age of the mother (from 15-19 years to 45-49 years; births from mothers younger than 15 and older than 49 years were counted in the adjacent age groups); a full migration matrix (by region of origin, region of destination, age and sex) for internal migration; a matrix of international migration between the modelled countries (by country of origin and country of destination); and net migration for exchanges between each of the countries within the system and the Rest of the world.

3.2.1. Population stocks, births and deaths

Data on mortality and fertility are usually available and of good quality. The registration of such events is quite exact and carefully enforced by various administrative arrangements as well as social security regulations. We did not have problems obtaining these data and the amount of estimations needed was negligible. In most cases, there was a need to estimate the number of boys and girls born, the total number of births being known. This task was easy, as the ratio of girls to boys born in Europe is stable and well known. Sometime it was necessary to estimate mortality in the oldest age groups. In such cases standard age schedules were used.

The quality of data on stocks of population is usually directly affected by the poor quality of migration registration. This is clearly demonstrated by the magnitudes of post-census corrections, which in the 2000 Census round were for example -51 621 for the Czech Republic, -395 553 for Poland, -558 168 for Romania and -23 764 for the Slovak Republic (NIDI 2004). The availability of stock data is good, however in some cases it was necessary to estimate the regional age distribution for the oldest age groups, for which the national age distributions were used as benchmarks.

3.2.2. Migration

Data on both internal and international migration were more difficult to obtain. Ideally, origin-destination-age-sex data were sought after for interregional and international intra-system migration, and net international migration by age, sex and country for international migration to/from outside the system.

3.2.2.1. Internal migration

Full sets of data on internal migration were provided by only three countries: Poland, Romania and the Czech Republic. For the other countries it was necessary to reconstruct the full matrix of flows. The reconstruction was based on the concept of migration cube - a three dimensional array of migration flow data. The dimensions of the cube are origin, destination, and age. The array is estimated for each gender separately. In many cases only faces of this cube were available: the matrices representing migration by origin and destination, by origin and age, and by destination and age. Willekens, Por and Raquillet (1981) elaborated algorithms allowing for the estimation of the entire cube from the marginal values. Such algorithms were used for estimations when necessary. The process of the reconstruction of the data should not have introduced any significant errors. A more important problem was the comparability of data on internal migration (Poulain 1994; Rees and Kupiszewski 1999), which was far from good. In this study the data were used 'as is' and no attempt was made to bring them to a common denominator, which in itself is a major task.

3.2.2.2. International migration

Statistics of international migration are the main source of uncertainty. There is ample literature describing the problems with European data on international migration. They were first raised more than thirty years ago and the efforts to solve them were summarised by Kelly (1987) and Herm (2005). Much work on the comparability and usability of international migration data, mainly in the European Union, has been done by Poulain and his colleagues (Poulain, Debuisson Eggericks 1991, Poulain 1993, 1996) and recently within the THESIM project (Nowok and Kupiszewska 2005; Kupiszewska and Nowok 2005). Despite all these efforts, we do not seem to be much closer to the solution of the problem than we were 20 or 30 years ago.

Preparation of international migration data for the MULTIPOLES model may be split into two tasks: (i) estimation of migration between the countries covered in the study and (ii) estimation of net migration from the outside of the system to each of the countries inside the system.

Intra-system international flows

If we neglect the issue of quality and comparability of data, the most appropriate from the methodological point of view would be to use data on emigration by age and destination, that is data provided by the sending countries. Using sending countries' data allows for the consistent calculation of emigration rates. However, data on international migration collected by the sending and the receiving state differ enormously (Kupiszewski 1996; Kupiszewska and Nowok 2005). For illustration, we may inspect Table 5 containing a so-called double-entry matrix, that is a matrix presenting migration flows reported by sending and by receiving countries, for 14 modelled countries in 1994, the starting year of the projection. The numbers reported differ enormously, for example the number of migrants from Lithuania to Germany was 180 according to Lithuanian sources, but Germany reported the inflow of 2495 persons from Lithuania, a discrepancy by a factor of over 13! Large differences are also visible in the case of many other pairs of numbers. That means that we may have only a very vague idea of the magnitude of international migration. The reasons for such discrepancies have been discussed in a number of publications, see for example Okólski (1991), SOPEMI (1992), Kędelski (1990), Kupiszewski (1994), Kupiszewska and Nowok (2005), and Nowok and Kupiszewska (2005), and will not be reiterated here.

One option to solve the problems of the differences in the double-entry migration matrix is to try to estimate one matrix of flows using data from both sending and receiving countries. Poulain (1993) proposed an algorithm for the estimation of the interstate migration within the EU. However, Poulain's work was based on the assumption that all pairs of countries are subject to the same distortion which arises from differences in legal, economic, or social systems. This assumption is disputable in the case of migration between the Central and Eastern European states and evidently false in the case of migration from Central and Eastern Europe to Western Europe. Therefore, the use of Poulain's method was not a viable option. Another possibility, used frequently, is to use the data reported by receiving countries. The option to use the data from sending countries has not been considered as these data are almost always underestimated, mainly because emigrants have no or little incentive to report their departure, as they may receive social benefits of all sorts in the country of their departure and

Table 5. Matrix of international migration according to the sending and receiving countries, 1994.

	from \ to	Austria	Belarus	Czech Republic	Estonia	Germany	Hungary	Latvia	Lithuania	Moldova	Poland	Romania	Slovak Republic	Slovenia	Ukraine
according to the receiving country	**Austria**			314	1	15543		1	0	0	168	121	90	75	3
according to the sending country															
according to the receiving country	**Belarus**			14	36	2105		240	250	23	135				6448
according to the sending country					1296	464		6434	3364	900	101				9033
according to the receiving country	**Czech Republic**				0	11602		0	1	0	51	4	3144	4	110
according to the sending country		16			0	108	0	0	0	0	3	0	56	1	1
according to the receiving country	**Estonia**		88	2		1683		99	45	1	7		0		929
according to the sending country		0	281	0		311	0	62	56	39	5	0	0	0	585
according to the receiving country	**Germany**		0	1374	25			75	24	0	1843	228	128	146	3224
according to the sending country		15032	745	14375	665		25597	1118	1136	368	104789	102506	7165	2321	3562
according to the receiving country	**Hungary**			26	0	24853		2	0	0	17	60	37	3	250
according to the sending country															
according to the receiving country	**Latvia**		418	4	42	2800			179	5	21	0	2		1956
according to the sending country		5	1402	0	54	548	1		239	59	13	0	0	0	1254
according to the receiving country	**Lithuania**		634	2	15	2495		88		6	98	0	0		890
according to the sending country		1	548	0	6	180	0	56		32	75	0	0	0	265
according to the receiving country	**Moldova**		515	4	5	2131		11	8		13	66	4		8548
according to the sending country		1		0	0	1729	7	2	0		17	16	1	2	0
according to the receiving country	**Poland**			223	3	81740		7	10	3		1	41		354
according to the sending country		441	10	53	0	18876	9	0	7	0		0	6	0	13
according to the receiving country	**Romania**			48	0	86559		0	0	34	17		86		16
according to the sending country		1255		98	1	6867	1773	0	0	4	13		11	0	2
according to the receiving country	**Slovak Republic**			4076	1	6953		1	0	0	17	0			22
according to the sending country		5		95	0	15	10	0	0		0	0		0	2
according to the receiving country	**Slovenia**			9	0	2960		0	0	0	5	0	3		4
according to the sending country		161		2		252									
according to the receiving country	**Ukraine**		11772	456	102	15112		208	161	382	434	1	388		
according to the sending country		52	9030	176	161	9335	845	385	401	8370	530	21	356	6	

Source: ECE UN, Council of Europe 1995, 1996 they often wish to maintain as close links with the homeland as possible.

Another option is to take the maximum of the values reported by sending and receiving countries. In this study we chose this option, mainly due to our belief that international migration is underestimated in any official statistics, therefore the larger of the two numbers is likely to estimate the migration size more accurately[1]. Table 5 shows that in the system of the modelled countries this option differs only insignificantly from the option to use the data reported by receiving countries, with the exception of outflows from Belarus and Germany. Small flows (less than 100) have been omitted, mainly because disaggregation of these flows by age, sex and region resulted in insignificant changes of each subpopulation. The sex structures of migrants have been reconstructed using the Rogers-Castro model (Rogers and Castro 1981a, 1981b,1981c) and partial information (six broad age groups) concerning the age structure of migrants to and from Germany (this was the only country for which the disaggregation of international migration by origin, destination and age group was available to us). Migration flows that did not originate from or aim for Germany have been assumed to have an identical age and sex structure as those involving Germany. Therefore, all emigration from a specific country to all other countries was attributed the age and sex structure of the flows from this country to Germany. Immigration was treated in a similar manner. The final stage - the spatial distribution of migrants - was based on the population weight of the destination regions in relation to the total population of each country. This method of distributing international migrants was confirmed as correct by van der Gaag and van Wissen (2002).

Net international migration from the Rest of the world

The estimation of net migration between each of the modelled countries and the Rest of the world involved a very substantial uncertainty. For each country an overall net migration was calculated and then the net migration from the countries within the modelled system was subtracted. The difference between the total net migration and the net intrasystem migration was assumed to be the net migration from the Rest of the world. The geographical allocation of “net migrants” to regions was performed as in the case of international migration between the analysed states.

[1] At the time of preparing the data for the forecast we did not have enough information about international migration statistics in individual countries to devise a more country-specific approach.

3.3. The population scenario – theoretical background, methods and results

In the projection, a population scenario based on the Authors' educated guess of the changes of key fertility, mortality and migration indicators was used. The assumptions adopted are discussed below.

3.3.1. Assumptions on mortality

The mortality scenario has been defined via changes in life expectancy at birth for males and females. All countries have been divided into four categories based mostly on two variables: economic performance and recent trends in life expectancy. The following categories have been selected: post-Soviet (Belarus, Moldova and Ukraine), the Baltic States (Estonia, Latvia and Lithuania), post-socialist (the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia) and mature capitalist economies (Austria, Germany).

In the mid 1990s, the post-Soviet class was characterised by a deteriorating economy, a lack of economic reforms and a life expectancy declining over the previous decade. In the Baltic States the economic performance was improving, economic reforms were in progress and life expectancy had been declining over the previous decade. The post-socialist countries were characterised by a quite diversified pattern – from the fairly successful and advanced in transition towards market economy countries, as Slovenia, Hungary, Poland or the Czech Republic, to the relatively stagnant ones, as Romania. Changes in life expectancy varied, but in most cases showed a moderate increase in the 1990s. The mature capitalist economies were growing steadily as was the life expectancy in these countries.

It was assumed that there is a link between the economic well-being and the changes of age-specific mortality patterns. The high income countries with growing economies would have higher life expectancies than the low income countries with shrinking economies.

There is plenty of evidence that the changes in life expectancy in Central and Eastern Europe occurred due to shifts in the intensity of mortality in some rather than in all the age groups. The decrease in life expectancy, in particular of male populations, was due to the overmortality in the older working age groups (Okólski 1987,1993, Meslé 1991, Guo 1993, Hertrich and Meslé 1999). The increase in life expectancy occurred mainly due to the falling infant mortality (Hertrich and Meslé 1999). In some cases – as in Poland – an increase in the life expectancy of males occurred because a rapid reduction in infant mortality influenced the life expectancy more than the overmortality in the older working age groups.

In order to better model the changes in mortality, five types of changes in mortality patterns, specified below, have been defined. The first two types, labelled 0 and 1, denote respectively a stagnation of life expectancy and an increase in life expectancy due to the decrease of mortality in all age groups. Type 2 represented a very likely development for those countries that at the time had a high infant mortality which could be reduced faster than the mortality in working ages. Type 3 has been defined in order to express the authors' belief that in future the reduction of adult overmortality through the reduction of deaths due to circulatory diseases and violent causes would be widespread. The decrease in life expectancy in Type 4 was assumed to be due to the worsening of mortality in the 20+ age groups. An alternative scenario of the life expectancy decrease due to an increase in mortality in all age groups has not been taken into account in this forecast as being too pessimistic. A concise summary of the typology of the mortality change patterns is shown in Table 6.

Table 6. Types of the mortality change patterns in Central and Eastern Europe, in the MULTIPOLES model.

Type	Change of e(0)	Age-specific mortality changes
0	no change	no change
1	rising	mortality reduction in all the age groups
2	rising	mortality reduction in the 0-19 age groups
3	rising	mortality reduction in the 20+ age groups
4	falling	mortality increase in the 20+ age groups

Source: Own elaboration.

Mortality scenarios consisted of two parameters: the target life expectancy in each five-year projection step and the type of mortality change. The target life expectancies for post-socialist countries and mature capitalist economies were estimated based on the assumption of either a continuation of the reduction of mortality observed in the last decade or an onset of such a reduction. Two different strategies have been adopted in the modelling of the speed of the changes. For the low mortality countries it was assumed that the decrease would slow down over time, as practiced by most national statistical offices (Cruijsen and Edind 1999), in order to express the belief of experts that the higher the life expectancy, the more difficult a further reduction of mortality. The countries with a high mortality would increase their gains in life expectancy as their economic situation improved.

In the post-Soviet class and the Baltic States, a rapid decrease in life expectancy was observed in the previous decade. It was assumed that this trend would be reverted in the post-Soviet group of countries and that a slow improvement would occur. For the Baltic States the trend had already changed at the time of setting the scenarios. The timing and the strength of the reversal is a factor differentiating both classes. The results of the scenario setting are presented in Table 7.

Table 7. Life expectancy target values and types of mortality changes assumed in the projection.

Males

	Life expectancy target values					Type of mortality changes (see Table 6)				
	1999	2004	2009	2014	2019	1999	2004	2009	2014	2019
Austria	74.3	75.2	76	76.7	77.1	1	1	1	1	1
Belarus	62.3	60.3	58.6	58.6	59.4	4	4	4	0	3
Czech Republic	70.8	72.3	73.7	74.8	75.6	1	1	1	1	1
Estonia	62	62.5	63.5	64.5	65.8	2	2	3	3	3
Germany	73.8	74.8	75.7	76.4	76.9	1	1	1	1	1
Hungary	65.7	66	66.8	67.7	68.7	2	2	3	3	3
Latvia	60	60.6	61.2	62	62.8	2	2	3	3	3
Lithuania	63	63.2	63.4	63.6	63.8	2	2	2	3	3
Moldova	59.6	57.7	56	56	56.8	4	4	4	0	3
Poland	68.6	70	71.3	72.2	72.9	1	1	1	1	1
Romania	66.7	67	67.6	68.2	69.2	2	2	2	3	3
Slovenia	71.5	73.4	75	76.4	76.8	1	1	1	1	1
Slovakia	70.4	70.8	72	73	73.6	2	2	3	3	3
Ukraine	60.1	57.7	55.5	55.5	56.4	4	4	4	0	3

Females

	Life expectancy target values					Type of mortality changes (see Table 6)				
	1999	2004	2009	2014	2019	1999	2994	2009	2014	2019
Austria	80.9	81.9	82.8	83.5	84	1	1	1	1	1
Belarus	74.4	74.1	73.8	73.8	73.9	4	4	4	0	3
Czech Republic	77.9	79.1	80.2	81.1	81.7	1	1	1	1	1
Estonia	74.2	75.4	76.1	77	78.1	2	1	1	1	1
Germany	80.5	81.4	82.2	82.8	83.3	1	1	1	1	1
Hungary	75.1	76.6	77.8	79	79.9	2	3	3	3	1
Latvia	73	73.7	74.4	75.2	75.7	2	2	3	3	3
Lithuania	75.1	75.3	75.7	76	76.3	2	2	2	3	3
Moldova	68.8	68.4	67.7	67.7	68	4	4	4	0	3
Poland	77.4	78.8	80.1	81	81.7	1	1	1	1	1
Romania	74.8	75.2	76	77	78.1	2	2	3	3	3
Slovenia	79.4	81	82	82.6	83.2	1	1	1	1	1
Slovakia	78	78.3	78.6	79.1	79.5	1	1	1	1	1
Ukraine	71.8	71.1	70.5	70.5	70.8	4	4	4	0	3

Source: Own elaboration.

Our scenarios were less optimistic than those assumed by the US Census Bureau's International Data Base (IDB) and in general ignored the warning that in the past, forecasters were overpessimistic in their mortality decrease predictions (Cruijsen and Edind 1999, Rees et al. 1999). For Belarus, Moldova and Ukraine, the values assumed were slightly lower than those assumed by Andreev (1995) in his main scenario, but higher than those in his pessimistic one. This relative pessimism was motivated by the belief that economic recovery, the European integration processes and the transformation of life styles in Central and Eastern Europe would be slow and painful processes with an uncertain success.

3.3.2. Fertility changes

Lutz (1996) reviewed the arguments in favour of and against assuming higher fertility scenarios in population forecasts. The homeostasis of the population system, the assumption of fertility cycles, the effects of pronatalistic policies, and national and ethnic rivalry counted among the former. Individualistic values, the economic emancipation of females, the instability of partnership, consumerism and improved contraception belonged to the latter. Rees (1996b) considered the arguments in favour of fertility recovery as unconvincing and arguments in favour of low fertility as persuasive. In particular, the argument that populations will eventually return to some form of equilibrium, because such is the nature of highly organised systems, Rees (1996b:8.) described as "philosophical wishful thinking". He also did not support Easterlin's cyclic hypothesis, arguing that a high degree of unemployment will counter the cyclic changes. The arguments in favour of low fertility seemed to be much closer to reality.

Basing on the arguments provided by Lutz(1996) and Rees (1996b), a fertility scenario based on two qualitative assumptions was adopted. The first one, also supported by a large number of other researchers, represented for example by Palomba (1999), is that the changes in life styles, values and preferences observed in Europe are a permanent phenomena leading to a long-term reduction of fertility. There was and still is controversy whether the increase in fertility rates similar to that observed recently in Sweden will be a widespread feature. This was thought to be unlikely to happen in Central and Eastern Europe, as such an increase was attributed to the highly developed social security and maternal benefits system, which would not be affordable to any of the post-socialist countries. Instead, the competition on the labour market and the modernisation of rural areas might have caused a further reduction in fertility.

The second assumption was that there would be a limited convergence in the values of total fertility rates observed in various countries, reducing the gap between the highest and the lowest values from 0.8 observed in 1994 to 0.4 in 2019. The values adopted by us (Table 8) are lower than those in de Beer and van Wissen's (1999) uniformity scenario and similar but not identical to those in the IDB (US Census Bureau 1999).

Table 8. Total fertility target values assumed in the projection.

	1999	2004	2009	2014	2019
Austria	1.4	1.4	1.3	1.3	1.3
Belarus	1.3	1.2	1.2	1.3	1.4
Czech Republic	1.3	1.3	1.3	1.4	1.4
Estonia	1.3	1.4	1.4	1.4	1.5
Germany	1.3	1.3	1.3	1.3	1.3
Hungary	1.3	1.3	1.3	1.4	1.4
Latvia	1.2	1.2	1.4	1.4	1.5
Lithuania	1.4	1.4	1.6	1.6	1.6
Moldova	1.9	1.8	1.8	1.7	1.7
Poland	1.5	1.4	1.4	1.5	1.5
Romania	1.3	1.2	1.2	1.3	1.4
Slovenia	1.2	1.3	1.3	1.3	1.3
Slovakia	1.2	1.2	1.3	1.3	1.4
Ukraine	1.3	1.2	1.3	1.3	1.5

Source: Own elaboration.

3.3.3. Internal migration changes

It was assumed that there would be no changes in the intensity of internal migration and that the substantial part of migration-induced population shifts would occur between urban centres and their suburban hinterlands. At the geographical scale in which the projection was conducted the substantial share of these shifts remained intraregional (Kupiszewski and Rees 1999).

3.3.4. International migration changes

It was assumed that in the 1994-2019 period there would be a moderate economic growth in all the countries except Romania, Moldova, Belarus and Ukraine. Simultaneously, migration policies would be tightened by all countries experiencing economic growth. The migration of Aussiedler would be slowly reduced to nil due to the exhaustion of potential candidates who could prove German roots. Poland, the Czech Republic, Slovenia, Estonia and Hungary - the countries which at the time of the preparation of the projection were expected to join the European Union in 2004, would, as a result, experience a limited increase in migration to/from Austria and Germany and between themselves. It should be noted that Slovakia, Latvia and Lithuania were not seen as serious candidates to the EU at the time. Restrictive migration policies of the European Union would limit immigration. Korcelli (1998) suggested that there would be no rapid changes.

These qualitative assumptions were quantified in a very simplistic way, assuming a reduction of outflows from all countries except post-Soviet and Romania by 1/3 in the first projection period (1994-1999) and an increase of migration between the EU countries (including new members) by 50% after 2004. No changes in the intrasystem international migration were expected after 2009, but a 5% reduction in inflows from the Rest of the world was assumed. After 2014, international migration numbers were set to be constant, which reflected our inability to propose a reasonable long-term scenario rather than a belief that migration would really stabilise.

The scenario presented above was rather static, assuming that the temporary reduction in international migration between the modelled states would be partially offset by the admission of the applicant countries to the European Union. Migration from the outside of the modelled system would be slowly reduced. It was assumed that no rapid changes would take place.

3.4. The results: the future of the elderly population in Central and Eastern Europe as seen in 1995

Under the assumptions described above, we investigated the regional change in elderly populations. Here the focus will be not on the changes in population numbers but mainly on the changes in the structures. There is a number of measures of the advancement of the ageing of population, such as mean age, percentage of population over a certain age or dependency ratios designed to express how many people in a certain age bracket there are per person in another age bracket. In particular, the old age dependency ratio (ODR), which is defined here as the number of persons aged 60 years and over per 100 population in the working age (20-59 years).

In 1994, the ODR pattern for males showed, in general, a gradual increase from the North-East (below 15 per 100 in the Baltic Republics, Belarus, northern and western Poland and the north-eastern part of the former GDR) to the South (above 24 in Southern Romania). For females, the pattern was slightly different: Central and Eastern Europe could be divided with two lines going from the North-West to the South-East into three areas: high ODRs in the south-western belt of Germany and Austria, medium-level ODRs in the North-East (the former Soviet Union countries) and low ODRs in the centre, going from Poland to Romania. So defined areas were by no means homogeneous. For the male population, Romania experienced the largest interregional differences with two regions having an ODR in the range 33-36 and two regions having an ODR in the range 15-18. A similar heterogeneity could be seen in Hungary, Poland and Austria. Germany and the Czech Republic demonstrated a slightly smaller diversity. As expected, there were striking differences in the ODR values between the sexes. Not only were the values of the ODR considerably higher for females than for males, but their regional spread was also much larger.

After 25 years from the beginning of the projection, the dividing line between the high and the low ODR values basically cuts Belarus, Moldova and Ukraine off from the rest of Central Europe. West of the dividing line, the increase of the ODR for both sexes was predicted to be very considerable. For males, 55 regions would note ODR values of over 24 (two regions in 1994). For females, an ODR of under 25 would be observed in only one region, in comparison to 152 regions in 1994. The unweighted mean value of the ODR would increase by 44% for males and 37% for females. The regional spread of the values for males increased, becoming comparable to that for females.

To assess the impact of ageing on regional populations, the differences in the ODRs at the starting and final points of the projection were compared. This was done by subtracting the latter from the former and mapping the results. For males, four units: Belarus, Ukraine, Moldova and Arad in Romania would decrease their ODRs. In the three former countries, the very high observed and predicted overmortality in the working age apparently contributed to the phenomenon. The highest increases in the ODR - over 15 per 100 - would be observed in north-eastern Germany. The rest of Germany, the Czech Republic, Slovenia, Austria excluding Steiermark, Slovakia excluding Zapadoslovensky Kraj, Estonia and several voivodships in south-western and western Poland would all have an increase of the ODR in the range of 10 to 15. Hungary, Romania, the rest of Poland, Latvia and Lithuania would experience a considerably smaller degree of population ageing.

The distribution of the increase in the ODR for the female population would have a different pattern. Four out of five regions in which the ODR would increase by more than 15 were located in Poland: Warsaw, Łódź, Szczecin and Legnica. The three former are large cities, the fourth is a highly industrialised region. Bratislava was the fifth region with an extreme increase in population ageing. This was a direct consequence of past internal migration patterns with a high number of females in their twenties migrating from rural areas to urban centres (Kupiszewski, Durham, Rees 1996) in the 1970s and 1980s. This group would be in their sixties and seventies in 2019. All the Baltic States, most of Poland, the Czech Republic, Slovakia, Slovenia, central Hungary, western Austria and most of Romania would witness a substantial advancement in female population ageing. The rest of Central and Eastern Europe would experience a moderate increase in the ODR. As in the case of the male population, there would be a decrease in the ODR for females in the three former Soviet republics (Moldova, Ukraine and Belarus).

Over the period 1994 – 2019, a substantial change in the numbers of the oldest old (85+) would occur. In all German, Austrian, Czech and Slovak regions, in Slovenia and western Hungary, as well as in highly urbanised and industrialised regions in other countries, there would be a very substantial – often more than twofold – increase in the very old population, in relative terms higher for males than females, in absolute terms higher for females. In most of Romania, eastern Hungary and in parts of rural Poland, the very old male population would remain stagnant or would increase very moderately. In the former Soviet Union the increase in the number of the oldest old would either stagnate (the Baltic States and Belarus) or would decrease (Moldova), sometimes dramatically (Ukraine).

These changes would have a very significant impact on the demand for health and care services. The decline in the numbers of the oldest old in some regions, against pan-European trends, should be treated with the utmost attention as a sign of a very poor epidemiological and sanitary situation.

Summarising, the forecast showed clearly that there would be two parallel patterns of the dynamics of the elderly population in Central and Eastern Europe. The Central European pattern encompassing all countries except Moldova, Ukraine and Belarus would be characterised by a high level of advancement of the process of population ageing, measured both by the change of the old age dependency ratio and the number of the oldest old. The degree of ageing in Central Europe would have a regional dimension and would be different for male and female populations. The very significant increase in the old age dependency ratio and in the 85+ populations analysed above should make social security planners think of the allocation of resources early enough to absorb the ageing population shock. The East European pattern (Belarus, Ukraine, Moldova) would be characterised by high mortality which would effectively prevent the ageing process.

3.5. Assessment of the forecast: The *ex-post* error of the forecast of the population of Central and Eastern Europe

In order to assess the quality of the forecast we have calculated ex-post errors for a 10-year time span (1994-2004). The magnitude of the errors of this forecast has been compared with the magnitude of the errors of the 1985 Eurostat projection for the period 1985-1995 taken from Rees et al. (1999).

The figures on the population stocks in some countries were corrected by national statistical offices after the recent round of censuses, by introducing post-census population corrections. To get rid of the effect of post census adjustments on the magnitude of the forecast errors we have deducted the corrections from the 2004 population stocks for five countries: the Czech Republic, Moldova, Poland, Romania and the Slovak Republic. For Moldova, which as from 2000 does not include population on the East bank of the Dniestr River in its statistics, the adjustment was calculated based on Council of Europe (2004), while for the other countries - based on NIDI (2004).

The errors (Table 9) of the forecast in comparison to the observed populations, if the post-census corrections were not removed, varied from 19.6% for Moldova, to 0,2% for Austria and Hungary. The average unweighted error calculated for the absolute values of the country

Table 9. Percentage errors of the population forecast for the period 1994-2004.

	Forecasted total population	Observed total population including post-census corrections	Error of the forecast	Post-Census correction	Total population excluding post-census corrections	Error of the forecast when corrections were removed
			%			%
Austria	8154229	8140122	0.17		8 140 122	0.17
Belarus	9765761	9849062	-0.85		9 849 062	-0.85
Czech Republic	10304212	10211455	0.91	-51621	10 263 076	0.40
Estonia	1365174	1350792	1.06		1 350 792	1.06
Germany	83950316	82531671	1.72		82 531 671	1.72
Hungary	10140106	10116742	0.23		10 116 742	0.23
Latvia	2264463	2319203	-2.36		2 319 203	-2.36
Lithuania	3618679	3445857	5.02		3 445 857	5.02
Moldova	4314175	3607435	19.59	-643750	4 251 185	1.48
Poland	39120887	38190608	2.43	-395553	38 586 161	1.39
Romania	22061348	21226120	3.93	-558168	21 784 288	1.27
Slovak Republic	5396621	5380053	0.31	-23764	5 403 817	-0.13
Slovenia	1961138	1996433	-1.77		1 996 433	-1.77
Ukraine	45921027	47442079	-3.21		47 442 079	-3.21
Average unweighted error			3.07			1.50

Source: Own calculations, Eurostat, Council of Europe, NIDI 2004.

errors was 3.1%. However, the average error, as well as the error for Moldova, reduced to 1.5%, when calculated in relation to the population without the post-census adjustments. The largest error concerned Lithuania (5,0%), Ukraine (-3.2%) and Latvia (-2,4%). However, one should note that both Lithuania and Latvia introduced post-census corrections but the authors were unable to obtain any documentation of these changes. Removing these two countries from the calculations (in relation to the population without the post-census adjustments) reduces the average error to 1,2%. This magnitude of error compares favourably with the average unweighted error for the 1985 Eurostat projection for the period 1985-1995 calculated based on data in Rees et al. (1999), which equalled 3.8%, and with the average unweighted error for the 1990 Eurostat projection for the period 1990-2000, which was 1.9%.

4. Conclusions

The paper presents a modification of well established concepts in the field of multiregional population projections. The MULTIPOLES model we have created allows for a systemic treatment of the population of a large multi-country territory, parting with the traditional approach of country-by-country population projections. In particular, it permits a more elegant inclusion of international migration into the process of modelling population change. In the analysis of the results of the scenario based projection, we concentrated on just a fraction of the information available, namely on the size and ageing of the population.

The MULTIPOLES model proved to be an effective tool, tested in a number of research projects. The ex-post errors generated in the forecasts using the model are low. Obviously, forecast errors depend not only on the quality of the model but also on the correctness of the input data and the assumptions. Therefore, reliable statistics are crucial for producing meaningful short-term and long-term forecasts.

In 1989, Philip Rees noted that “The multistate model has proved to be an adaptable beast and is likely to live on into the 1990s” (Rees 1989). Today, we can add that it is likely to thrive in the twenty first century, in parallel to the new modelling approaches.

Bibliography

Andreev E. (1995) *The last mortality trend in Belarus, Moldova, Russia and Ukraine.* Paper for the Task Force Meeting on alternative population projections in European countries in economic transition. Groningen.

de Beer J. and L. van Wissen (eds.) (1999) *Europe: one continent, different worlds. Population scenarios for the 21st century.* European Studies of Population, 7. Kluwer Academic Publishers, Dordrecht.

Bijak J., D. Kupiszewska, M. Kupiszewski and K. Saczuk (2005) *Impact of international migration on population dynamics and labour force resources in Europe*, CEFMR Working Paper 1/2005.

Council of Europe (1995) *Recent demographic developments in Europe*. Strasbourg.

Council of Europe (1996) *Recent demographic developments in Europe*. Strasbourg.

Council of Europe (2004) *Recent demographic developments in Europe*. Strasbourg.

Cruijsen H. and H Eding (1999) *Latest national mortality forecasts in the ECE area*. Joint ECE-Eurostat Work Session on Demographic Projections. Perugia 3-7 May.

van der Gaag N., E. van Imhoff and L. van Wissen (1997) Long-term internal migration scenarios for the European Economic Area. *Eurostat Working Papers*, E4 1997-5, Eurostat

van der Gaag N. and L. van Wissen (2002) Modelling regional immigration: Using stocks to predict flows. *European Journal of Population*,18, 387 – 409.

Guo G. (1993) Mortality trends and causes of death - a comparison between Eastern and Western Europe, 1960s-1980s. *European Journal of Population* 9, 3, 287-312.

Herm A. (2005) Recommendations on international migration statistics and development of the data collection on international level, [in:] *Towards harmonised statistics on international migration.* Report from the THESIM project.

Hertrich V. and F. Meslé (1999) *The health crisis in the Baltic countries: a common and varied experience*. Paper presented to the European Population Conference, the Hague.

de Jong A. and H. Visser (1997) *Long-term international migration scenarios for the European Economic Area.* Eurostat Working Paper E4 1997-6, Eurostat

de Jong A. (1997) *Analysing and forecasting of fertility by generation and birth order*. Paper presented to the Working Party on Demographic Projections, Eurostat.

Johnson P. (1999) *U.S. Census Bureau international population projections: focus on the ECE area.* Joint ECE-Eurostat Work Session on Demographic Projections. Perugia 3-7 May.

Keilman N. (2001) Data quality and accuracy of United Nations population projections, 1950-95, *Population Studies* 55, 2, 149 – 164.

Kelly J. (1987) Improving the comparability of international migration Statistics. Contributions by the Conference of European Statisticians from 1971 to date. *International Migration Review*, 21, Winter 1987, 1017 – 1037.

Kędelski M. (1990) Fikcja demograficzna w Polsce i RFN (Ze studiów nad migracjami zagranicznymi), *Studia Demograficzne* 1/99, s. 21–55.

Korcelli P. (ed.) (1998) *Przemiany w zakresie migracji ludności jako konsekwencja przystąpienia Polski do Unii Europejskiej*. Biuletyn KPZK 184.

Kupiszewska D. and B. Nowok (2005) *Comparability of statistics on international migration flows in the European Union.* CEFMR Working Paper 7/2005, Warsaw.

Kupiszewski M. (1994) Polen als Migrationsquelle. [In:] Jordan P. (ed.*) Atlas Ost- und Südosteuropa*. Österreichishes Ost- und Südosteuropa Institut, Vienna.

Kupiszewski M. (1996) Extra-union migration: the east-west perspective. [in:] P. Rees, J. S. C. Stillwell, A. Convey and M. Kupiszewski (eds). *Population migration in the European Union*. John Wiley and Sons, London, 11-35.

Kupiszewski M. (2001) *Prognoza dynamiki przemian siły roboczej w Europie Środkowo-wschodniej i jej konsekwencje dla procesów integracji europejskiej – podejście regionalne.* Raport z grantu Komitetu Badań Naukowych nr. 6P04E05217.

Kupiszewski M. (2002) *Modelowanie dynamiki przemian ludności w warunkach wzrostu znaczenia migracji międzynarodowych*. Prace Geograficzne 181. IGiPZ PAN, Warszawa.

Kupiszewski M., H. Durham and P. Rees (1996) *Internal Migration and Regional Population Dynamics in Europe: Polish Case Study,* Report prepared for the Council of Europe and for the European Commission.

Kupiszewski M. and D. Kupiszewska (1997) *Projection of Central and East European populations- the model, the data and preliminary results*. Working Paper 97/11. School of Geography. The University of Leeds

Kupiszewski M. and D. Kupiszewska (1999) *Forecasts of regional structures of the elderly populations in Central and Eastern Europe.* Paper presented to the ECE UN conference Status of the older population: Prelude to the 21st Century, Sion, 13-15.12.

Kupiszewski M. and P. Rees (1999) *Lessons for the projection of internal migration from studies in ten European countries.* Joint ECE-Eurostat Work Session on Demographic Projections. Perugia 3-7 May.

Lutz W. (1996) Future reproductive behaviour in industrialised countries. [in:] W. Lutz (ed.) *The future population of the World. What can we assume today? Revised edition*. IIASA, Laxenburg, 253-277.

Lutz W., W. Sanderson and S. Scherbov (1996) Probabilistic population projections based on expert opinion. [in:] W. Lutz (ed.) *The future population of the World. What can we assume today? Revised edition*. IIASA, Laxenburg, 397-428.

Lutz W., W. C. Sanderson and S. Scherbov (eds.) (2004) *The End of World Population Growth in the 21st Century: New Challenges for Human Capital Formation and Sustainable Development*, Earthscan, London.

Meslé F. (1991) Mortality in East European countries. *Population* 46, 3, 599-649.

NEI (1986) *Long-term regional demographic developments up to the beginning of the next century and regional policy*, Commission of the European Communities and NEI, Rotterdam.

NEI (1990) *Demographic evolution through time in European regions.* Netherlands Economic Institute, Rotterdam.

NEI (1994) *Regional population and migration scenarios for the European Union. Part I: two long term population scenarios*. Netherlands Economic Institute, Department of Regional and Urban Development, Department of Public Health, Erasmus University; Netherlands Interdisciplinary Demographic Institute (NIDI); Rotterdam, June 1994.

NIDI (2004) *Final report on data availability and quality of national demographic data series. Compilation of Long-term National and Regional Population Scenarios for the 10 New EU Member States and 2 EU Accession Countries*. Project report, the Hague.

Nowok B. and D. Kupiszewska (2005) *Official European statistics on international migration flows: availability, sources and coverage*. CEFMR Working Paper 5/2005, Warsaw.

Okólski M. (1987) Male mortality trends in Eastern and Western Europe. [Umieralność mężczyzn w Europie Wschodniej i w Europie Zachodniej.] *Studia Demograficzne*, 3/89, 3-28.

Okólski M. (1991) *Migratory movements from countries of Central and Eastern Europe*. Paper prepared for the 4th Conference of European Ministers responsible for migration affairs, Council of Europe, Strasbourg.

Okólski M. (1993) East-West mortality differentials. [in:] A. Blum and J-L. Rallu (eds.), *European population. 2: Demographic dynamics*, 165-89. John Libbey Eurotext: Montrouge.

Palomba R. (1999) *Values in life and reproductive intentions.* Joint ECE-Eurostat Work Session on Demographic Projections. Perugia 3-7 May.

Poulain M. (1993) Confrontation des statistiques de migration intra-Europeenes: vers plus d'harmonisation. *European Journal of Population*, 9, 4, 353-181.

Poulain M. (1994) La mobilite interné en Europe. Quelles données statistiques? *Espace, Populations, Societes*, 1:13-30.

Poulain M. (1996) Migration between the countries of the European Union: Current trends.. Chapter 4 [in:] P. Rees, J. S. C. Stillwell, A. Convey and M. Kupiszewski (eds.) *Population migration in the European Union*. John Wiley and Sons, London, 51 - 66.

Poulain M., M. Debuisson and T. Eggerickx (1991) *Proposals for the harmonization of European Community Statistics on International Migration*. Institute of Demography, Catholic University of Louvain, Louvain-la-Neuve.

Rees P. (1973) A revised notation for spatial demographic accounts and models, *Environment and Planning A* 5, s. 147-155.

Rees P. (1989) *Old model faces new challenges: A review of the state of the art in multistate population modelling*, Working Paper 531, School of Geography, University of Leeds, Leeds.

Rees P. (1996a) Projecting the national and regional populations of the European Union using migration information. Chapter 18 [in:] P. Rees, J. S. C. Stillwell, A. Convey and M. Kupiszewski (eds.) *Population migration in the European Union*. John Wiley and Sons, London, 331 - 364.

Rees P. (1996b) *The second demographic transition: What does it mean for the future of Europe's Population?* Working Paper 96/19, School of Geography, University of Leeds, Leeds.

Rees P. and M. Kupiszewski (1999) Internal migration: What data are available in Europe? *Journal of Official Statistics* 15(4), 551-586.

Rees P., M. Kupiszewski, H. Eyre, T. Wilson, and H. Durham (1999) *The evaluation of regional population projections for the European Union.* ERDF Study 97/00/74/018.

Rees P., J. Stillwell and A. Convey (1992) *Intra-Community migration and its impact on the demographic structure at the regional level.* Working Paper 92/1, School of Geography, University of Leeds, Leeds.

Rogers A. and Castro L. J. (1981a) *Model migration schedules,* RR-81-30, IIASA, Laxenburg.

Rogers A. and Castro L. J. (1981b) Age patterns of migration: Cause-specific profiles, [in:] A. Rogers (red.), *Advances in multiregional demography*, RR-81-6, IIASA, Laxenburg.

Rogers A. and Castro L. J. (1981c) *Model schedules in multistate demographic analysis: The case of migration,* WP-81-22, IIASA, Laxenburg.

SOPEMI (1992) *Trends in international migration*. OECD, Paris.

Tabeau E., P. Ekamper, C. Huisman and A. Bosh (1997) *Forecasting of mortality by gender, age/generation and main cause of death*. Paper presented to the Working Party on Demographic Projections, Eurostat.

UN (2005) *World Population Prospects: 2004 Revision*, New York.

US Census Bureau (1999) *International Data Base*.

Vu M. T. and E. Bos (1992) *Latin America and the Caribbean region (and North America) population projections. 1992-93 Edition*. Working Paper WPS 1033. Population and Human Resources Department, World Bank.

World Bank (2005) *World Development Indicators 2005*, http://www.worldbank.org/data/wdi2005/wditext/Section2.htm

Willekens F. and P. Drewe (1984) *A multiregional model for regional demographic projection,* [in:] H. ter Heide and F. Willekens (red.), *Demographic research and spatial policy. The Dutch experience*, Academic Press, London, s. 309-334.

Willekens F., A. Por and R. Raquillet (1981) Entropy, multiproportional and quadratic techniques for inferring patterns of migration from aggregate data. [in:] A. Rogers (ed.) *Advances in multiregional demography*, Research Report RR-81-06, International Institute for Applied Systems Analysis, Laxenburg, Austria.

■

ISSN 1732-0631
ISBN 83-921915-9-5

Printed in Poland