Working Paper 170

A COMPUTER PROGRAMME FOR CONSTRUCTING AGE-SEX DISAGGREGATED MULTI-REGIONAL POPULATION ACCOUNTS (DAME): USERS" NOTES

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ABSTRACT

The theory of spatial demographic accounting has recently been spelled out in Rees and Wilson (1976) and is briefly reviewed in the paper. The paper takes the accounts based model described in Chapter 11 of that work and converts it into a computer programme of fairly general application. The structure of the programme is described in some detail in section three of the paper in order that further development by interested users can be carried out. Detailed instructions on preparing data for running the programme are included in section four. Appendices A through D provide respectively : listings of the alternative inputs possible to the programme; a full listing of the FORTRAN text; the output of a run of the programme with "Middle Earth" data; and the output of a run of the programme with West Riding of Yorkshire data. The shorter version of the paper omits sec tion three of the longer paper and may be employed principally as a users' guide to the programme.

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Acknowledgments

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1. Introduction: the context of the programme

The majority of computer programmes written in thecourse of University research work in the Social Sciences are never documented. They die with the last use made of them by their creators who pass on to pastures new. For many programmes*this fate may be appropriate. However, in the case of the programme described in this paper, the intention was from the outset to develop a computer programme that would be of general use in the population field by researchers other than the original creators. To develop such a programme entails considerable effort over and above that devoted to a programme intended for use by the author alone. We hope that effort will have been justified when other researchers use the programme to create multi-regional age-sex disaggregated population accounts which we believe constitute an essential description of population change in a regional system and a foundation for forecasting analyses either through direct use of rates generated from the accounts or through forcing the forecaster to match his forecasting system with the framework of analysis revealed in the population accounts.

The programme described here implements the accounts based model developed by Rees and Wilson (1976, Chapter 11). It is essentially historical in nature. It can be used to construct a set of population accounts for some period in the recent past. Figure 1 shows the context in which the programme is embedded. The programme works with the input data required for the accounts based model and generates a set of population accounts from each period's input data. This input data is not normally available in raw form in the normal sources of population statistics but must be estimated from the source data. Descriptions of some of the estimation routines that need to be applied are contained in Smith (1974) Smith and Rees (1974), in Rees and Wilson (1976, Chapter 3 and Appendix 1), in Rees, Smith and King (1976) and in Illingworth (1976). We have left such estimation routines out of the present programme in order to make it of more general applicability. The user has the responsibility

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* In general, when we refer to "programme" in the text, we mean "computer programme"

of preparing the input data for the accounts based model (see Rees and Wilson, Chapter 11 and section 2.2) implemented in the programme.

Clearly, there is interest not only in past population change but also in future change. We hope to add to the accounting programme described here a set of connected forecasting programmes. The first will use a slight modification of the present programme as a generator of population accounts and embed it in a flexible forecasting routine in which schedules of forecast rates can be fed in and used to construct population accounts for future periods. A second programme will implement a particular version of the multi-regional cohort survival model in a way compatible with the population accounting framework used here.

The paper describes the computer programme developed for historical accounting called DAME or demographic accounts-based model estimator. In the next section the theory of spatial demographic accounting is briefly sketched out and the context in which the programme can be used is spelled out. Section three contains a detailed description of the programme that is intended to be a guide for other researchers who are implementing DAME. Section three has been omitted in the shorter version of the paper describing DAME (Working Paper 170) The flow chart description should enable them to trace any "bugs" that may develop in implementation and gives details of the linkage between programme variables and the algebraic variables in which the theory was initially specified. Most of this section may be skipped by readers interested only in the use of a fully implemented programme. However, all users are advised to look carefully at the step by step summary of the programme at the end of this section. A simple appreciation of how the programme works will help in its use. The next section, section four, contains the notes for users on preparing data and running the programme. A summary list of the inputs has been placed at the end of this section for quick reference purposes by users already familiar with the programme. Appendix A of the paper contains a set of accounts tables for the Middle Earth example which show the variety of ways in which data can be input to the programme.

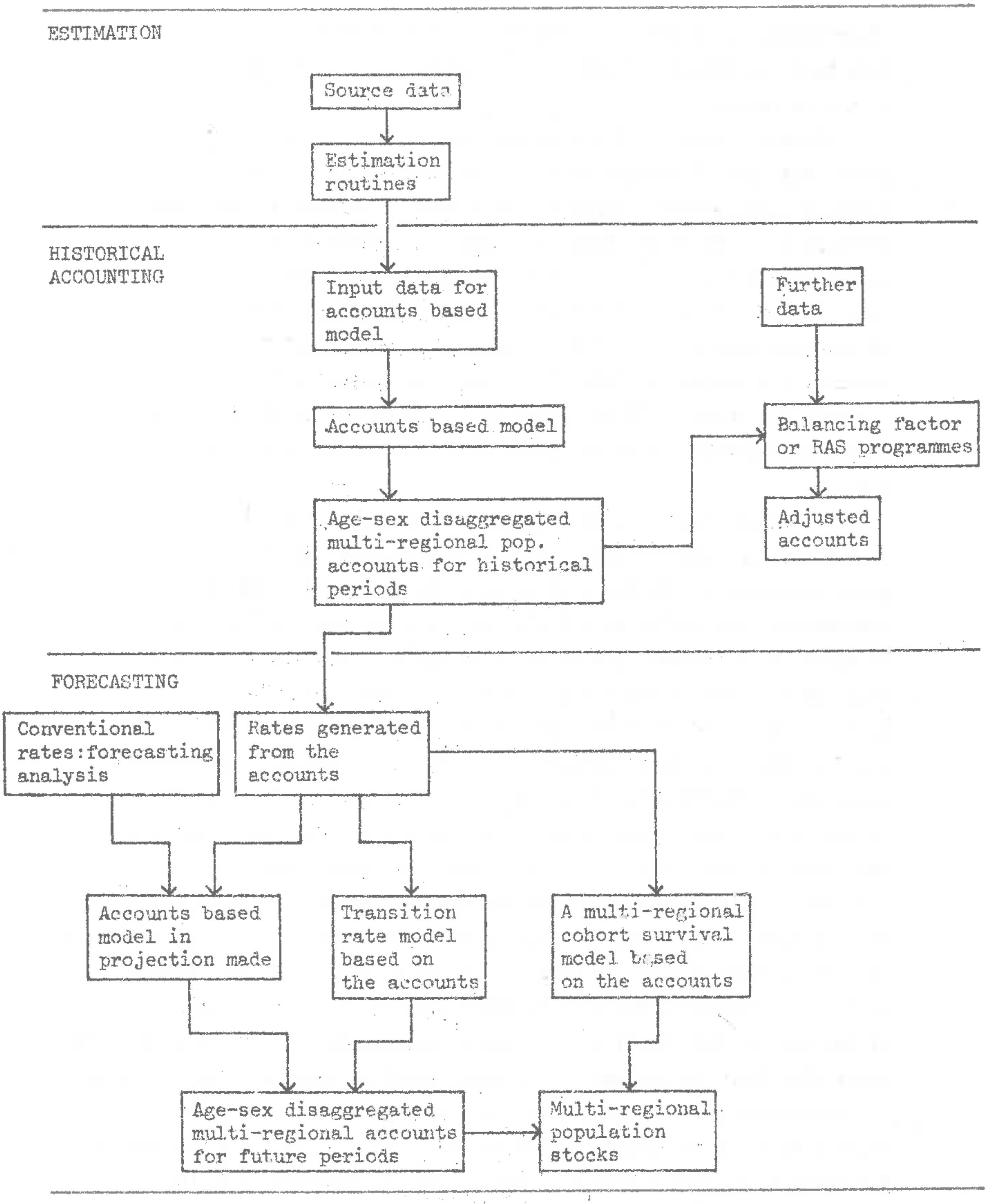

Figure 1. The analysis framework in which DAME is embedded

A full listing of the programme is included as Appendix B to the paper. This has not been reproduced in the Working Paper as such but will be supplied to interested users in the form of a listing printed out by line printer. Users interested in obtaining this and/or a machine readable copy of the programme (in the form of cards, paper tape, magnetic tape or via a link to another institution) should write to the authors at the School of Geography, University of Leeds. Appendix C contains a listing of the output of a test run of the programme with hypothetical data, and Appendix D contains a listing of the output of a similar run with data for West Yorkshire. These listings can be supplied on request*. The Appendices A to D have been omitted from the shorter version of the programme description (Working Paper 170).

2. The theory of spatial demographic accounting: a brief review

2.1 The accounts matrix

The theory, part of which is made operational in the programme described here, concerns the representation of change in the populations of regions through the processes of birth, death and migration. Demographic accounts, originally proposed in the work of Stone (1966, 1971) and made spatially explicit in the work of Rees and Wilson (1973,1976), are one such representation. Spatial demographic accounts consist of an accounts matrix of population flows between initial and final states represented by the rows and columns of the matrix, together with the row and column totals of the matrix. Thus, if we adopt $\underline{K}$ as the label for the accounts matrix, $\underline{K}$, can be partitioned into four submatrices thus:

$$\underline{K} = \left[\begin{array}{c|c} \underline{K}_{ES} & \underline{K}_{ED} \\ \hline \underline{K}_{BS} & \underline{K}_{BD} \end{array}\right] \qquad (1)$$

The labels of the submatrices are E referring to existence states at the start of the accounting period, D referring to death states attained during the period, B to birth states acquired during the period and S referring to survival states achieved at the end of the period. Each

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* Listings and machine readable copies will be provided at reproduction and mailing cost.

of the four quadrants of $\underline{K}$ can be further disaggregated into a set of submatrices each of which refers to a particular inter-regional transition. Thus, $\underline{K}_{ES}$ can be shown as follows

$$\underline{K}_{ES} = \begin{bmatrix} \underline{K}_{ES}^{11} & \underline{K}_{ES}^{12} & \cdots & \underline{K}_{ES}^{1j} & \cdots & \underline{K}_{ES}^{1N} \\ \underline{K}_{ES}^{21} & \underline{K}_{ES}^{22} & \cdots & \underline{K}_{ES}^{2j} & \cdots & \underline{K}_{ES}^{2N} \\ \vdots & \vdots & & \vdots & & \vdots \\ \underline{K}_{ES}^{i1} & \underline{K}_{ES}^{i2} & \cdots & \underline{K}_{ES}^{ij} & \cdots & \underline{K}_{ES}^{iN} \\ \vdots & \vdots & & \vdots & & \vdots \\ \underline{K}_{ES}^{N1} & \underline{K}_{ES}^{N2} & \cdots & \underline{K}_{ES}^{Nj} & \cdots & \underline{K}_{ES}^{NN} \end{bmatrix} \qquad (2)$$

and the other submatrices, $\underline{K}_{ED}$, $\underline{K}_{BS}$ and $\underline{K}_{BD}$ can be similarly partitioned.

Each submatrix shown on the right hand side of (2) can be disaggregated further by age group. The particular arrangement will depend on the number and type of age groups adopted. The DAME programme assumes that up to and including 20 age groups are used: for example we can consider that 20 periods including 5 years in length is adopted. The typical $\underline{K}_{ES}^{ij}$ submatrix is structured as follows:

$$\underline{K}_{ES}^{ij} = \begin{bmatrix} \underline{K}_{11}^{\varepsilon(i)\sigma(j)} & \underline{K}_{12}^{\varepsilon(i)\sigma(j)} & \cdots & 0 & 0 & \cdots & 0 & 0 \\ 0 & \underline{K}_{22}^{\varepsilon(i)\sigma(j)} & \cdots & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & \cdots & \underline{K}_{rr}^{\varepsilon(i)\sigma(j)} & \underline{K}_{rr+1}^{\varepsilon(i)\sigma(j)} & & 0 & 0 \\ \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & \cdots & \underline{K}_{R-1R-1}^{\varepsilon(i)\sigma(j)} & \underline{K}_{R-1R}^{\varepsilon(i)\sigma(j)} \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 & \underline{K}_{RR}^{\varepsilon(i)\sigma(j)} \end{bmatrix} \qquad (3)$$

where $\underline{K}_{rr}^{\varepsilon(i)\sigma(j)}$, an element of $\underline{K}_{ES}^{ij}$ refers to the number of persons existing in region i, $\varepsilon(i)$, at the start of the period who survive in region j, $\sigma(j)$, at the end of the period. At the start and at the end they are in age group r (though older, of course).

Those who move from one age group to the next are represented by variables of the form $K_{rr+1}^{\varepsilon(i)\sigma(j)}$. There are terms in the $\underline{K}_{ES}^{ij}$ submatrix in only the principal diagonal and the one above it. If the period length is exactly five years all the diagonal terms are zero but the last $\underline{K}_{RR}^{\varepsilon(i)\sigma(j)}$; if the period length is less than five years the terms in both diagonals will be non-zero. The $\underline{K}_{ED}^{ij}$ submatrix with elements $K_{rr}^{\varepsilon(i)\delta(j)}$ and $K_{rr+1}^{\varepsilon(i)\delta(j)}$ has exactly the same structure as that shown in equation (3) for $\underline{K}_{ES}^{ij}$ except that the elements will remain non-zero even in the five year period case since persons can always die in their initial age group.

The $\underline{K}_{BS}$ and $\underline{K}_{BD}$ submatrices have a simpler structure: entries occur only in the first column (referring to the first age group) and in those rows in which fertile mothers can occur since the row classification of the infants born in the period refers in part to the mother's characteristics. So, we breakdown $\underline{K}_{BS}^{ij}$ thus

$$\underline{K}_{BS}^{ij} = \begin{bmatrix} 0 & \cdots & 0 \\ 0 & \cdots & 0 \\ 0 & \cdots & 0 \\ K_{41}^{\beta(i)\sigma(j)} & \cdots & 0 \\ \vdots & & \vdots \\ K_{r1}^{\beta(i)\sigma(j)} & \cdots & 0 \\ \vdots & & \vdots \\ K_{101}^{\beta(i)\sigma(j)} & \cdots & 0 \\ 0 & \cdots & 0 \\ \vdots & & \vdots \\ 0 & \cdots & 0 \end{bmatrix} \qquad (4)$$

where $K_{r1}^{\beta(i)\sigma(j)}$ refers to persons born in region, (i) $\beta(i)$, to mothers in age group r either at time of maternity or at the start of the period. The babies survive in region j,$\sigma(j)$, in age group 1 (0-4), at the end of the period. The variable $K_{r1}^{\beta(i)\delta(j)}$ is the corresponding variable in the $\underline{K}_{BD}^{ij}$ submatrix where $\delta(j)$ refers to death in region j.

The final dimension of disaggregation is that of sex. The $\underline{K}$ matrix can be specified quite separately for each sez: $\underline{K}^M$ for males and $\underline{K}^F$ for females. The only point at which there is interaction between the sexes is in the classification of male births by female characteristics (age group of mother). Otherwise they can be analysed quite separately.

The $\underline{K}$ matrix of transitions of persons between states becomes an accounts matrix only when the regional system has been closed. This means that the list of regions, i=1,...,N, must exhaust the world: all possible population transitions with respect to the set of regions of interest must be included. This need not mean all population flows in the world need be included, fortunately. The accounts matrix will have the following structure (concentrating here on the regional disaggregation):

$$\underline{K} = \left[\begin{array}{cccc|ccc} \underline{K}^{11} & \underline{K}^{12} & \dots & \underline{K}^{1M} & \underline{K}^{1M+1} & \dots & \underline{K}^{1N} \\ \underline{K}^{21} & \underline{K}^{22} & \dots & \underline{K}^{2M} & \underline{K}^{2M+1} & \dots & \underline{K}^{2N} \\ \underline{K}^{M1} & \underline{K}^{M2} & \dots & \underline{K} & \underline{K}^{MN+1} & \dots & \underline{K}^{MN} \\ \hline \underline{K}^{M+11} & \underline{K}^{M+12} & \dots & \underline{K}^{MHN} & 0 & \dots & 0 \\ \underline{K}^{N1} & \underline{K}^{N2} & \dots & K^{NM} & 0 & \dots & 0 \end{array}\right] \tag{5}$$

Regions 1 to M are in the system of interest and all flows amongst them are included in $\underline{K}$; region M+1 to N are outside the system of interest and only flows between them and the regions in the system of interest are included.

If we compute from $\underline{K}$ the row and column totals in the following fashion we arrive at the full accounts table:

$$
\left[\begin{array}{ccc:ccc|ccc:ccc}
\underline{K}_{ES}^{11} & \cdots & \underline{K}_{ES}^{1M} & \underline{K}_{ES}^{1M+1} & \cdots & \underline{K}_{ES}^{1N} & \underline{K}_{ED}^{11} & \cdots & \underline{K}_{ED}^{1M} & \underline{K}_{ED}^{1M+1} & \cdots & \underline{K}_{ED}^{1N} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{ES}^{M1} & \cdots & \underline{K}_{ES}^{MM} & \underline{K}_{ES}^{MM+1} & \cdots & \underline{K}_{ES}^{MN} & \underline{K}_{ED}^{M1} & \cdots & \underline{K}_{ED}^{MM} & \underline{K}_{ED}^{MM+1} & \cdots & \underline{K}_{ED}^{MN} \\
\hdashline
\underline{K}_{ES}^{M+11} & \cdots & \underline{K}_{ES}^{M+1M} & 0 & \cdots & 0 & \underline{K}_{ED}^{M+11} & \cdots & \underline{K}_{ED}^{M+1M} & 0 & \cdots & 0 \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{ES}^{N} & \cdots & \underline{K}_{ES}^{NM} & 0 & \cdots & 0 & \underline{K}_{ED}^{M1} & \cdots & \underline{K}_{ED}^{NM} & 0 & \cdots & 0 \\
\hline
\underline{K}_{ES}^{11} & \cdots & \underline{K}_{BS}^{1M} & \underline{K}_{BS}^{1M+1} & \cdots & \underline{K}_{BS}^{1N} & \underline{K}_{BD}^{11} & \cdots & \underline{K}_{BD}^{1M} & \underline{K}_{BD}^{1M+1} & \cdots & \underline{K}_{BD}^{1N} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{BS}^{M1} & \cdots & \underline{K}_{BS}^{MM} & \underline{K}_{BS}^{MM+1} & \cdots & \underline{K}_{BS}^{MN} & \underline{K}_{BD}^{M1} & \cdots & \underline{K}_{BD}^{MM} & \underline{K}_{BD}^{MM+1} & \cdots & \underline{K}_{BD}^{MN} \\
\hdashline
\underline{K}_{BS}^{M+11} & \cdots & \underline{K}_{BS}^{M+1M} & 0 & \cdots & 0 & \underline{K}_{BD}^{M+11} & \cdots & \underline{K}_{BD}^{M+1M} & 0 & \cdots & 0 \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{BS}^{N1} & \cdots & \underline{K}_{BS}^{NM} & 0 & \cdots & 0 & \underline{K}_{BD}^{N1} & \cdots & \underline{K}_{BD}^{NM} & 0 & \cdots & 0
\end{array}\right]
\times \underline{i} =
\begin{array}{l}
\left[\begin{array}{c}
\underline{K}_{E}^{1} \\ \vdots \\ \underline{K}_{E}^{M} \\ \hdashline
\underline{K}_{E}^{M+1} \\ \vdots \\ \underline{K}_{E}^{N} \\ \hdashline
\underline{K}_{B}^{1} \\ \vdots \\ \underline{K}_{B}^{M} \\ \hdashline
\underline{K}_{B}^{M+1} \\ \vdots \\ \underline{K}_{N}^{B}
\end{array}\right]
\end{array}
\begin{array}{l}
\text{Initial Populations} \\ \\ \\ \text{Immigrants} \\ \\ \\ \text{Births} \\ \\ \\ \text{Infant immigrants}
\end{array}
$$

and

(6)

$$
\left[\begin{array}{ccc:ccc|ccc:ccc}
\underline{K}_{ES}^{11} & \cdots & \underline{K}_{ES}^{1M} & \underline{K}_{ES}^{1M+1} & \cdots & \underline{K}_{ES}^{1N} & \underline{K}_{ED}^{11} & \cdots & \underline{K}_{ED}^{1M} & \underline{K}_{ED}^{1M+1} & \cdots & \underline{K}_{ED}^{1N} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{ES}^{M1} & \cdots & \underline{K}_{ES}^{MM} & \underline{K}_{ES}^{MM+1} & \cdots & \underline{K}_{ES}^{MN} & \underline{K}_{ED}^{M1} & \cdots & \underline{K}_{ED}^{MM} & \underline{K}_{ED}^{MM+1} & \cdots & \underline{K}_{ED}^{MN} \\
\hdashline
\underline{K}_{ES}^{M+11} & \cdots & \underline{K}_{ES}^{M+1M} & 0 & \cdots & 0 & \underline{K}_{ED}^{M+11} & \cdots & \underline{K}_{ED}^{M+1M} & 0 & \cdots & 0 \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{ES}^{N1} & \cdots & \underline{K}_{ES}^{NM} & 0 & \cdots & 0 & \underline{K}_{ED}^{N1} & \cdots & \underline{K}_{ED}^{NM} & 0 & \cdots & 0 \\
\hline
\underline{K}_{BS}^{11} & \cdots & \underline{K}_{BS}^{1M} & \underline{K}_{BS}^{1M+1} & \cdots & \underline{K}_{BS}^{1N} & \underline{K}_{BD}^{11} & \cdots & \underline{K}_{BD}^{1M} & \underline{K}_{BD}^{1M+1} & \cdots & \underline{K}_{BD}^{1N} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{BS}^{M1} & \cdots & \underline{K}_{BS}^{MM} & \underline{K}_{BS}^{MM+1} & \cdots & \underline{K}_{BS}^{MN} & \underline{K}_{BD}^{M1} & \cdots & \underline{K}_{BD}^{MM} & \underline{K}_{BD}^{MM+1} & \cdots & \underline{K}_{BD}^{MN} \\
\hdashline
\underline{K}_{BS}^{M+11} & \cdots & \underline{K}_{BS}^{M+1M} & 0 & \cdots & 0 & \underline{K}_{BD}^{M+11} & \cdots & \underline{K}_{BD}^{M+1M} & 0 & \cdots & 0 \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots \\
\underline{K}_{BS}^{N1} & \cdots & \underline{K}_{BS}^{NM} & 0 & \cdots & 0 & \underline{K}_{BD}^{N1} & \cdots & \underline{K}_{BD}^{NM} & 0 & \cdots & 0
\end{array}\right]
\times \underline{i}^{1}
$$

$$
= \left[\begin{array}{ccc:ccc|ccc:ccc}
\underline{K}_{S}^{1} & \cdots & \underline{K}_{S}^{M} & \underline{K}_{S}^{M+1} & \cdots & \underline{K}_{S}^{N} & \underline{K}_{D}^{1} & \cdots & \underline{K}_{D}^{M} & \underline{K}_{D}^{M+1} & \cdots & \underline{K}_{D}^{N}
\end{array}\right] \qquad (7)
$$

Final Populations — Surviving Emigrants — Deaths — Non surviving Emigrants

where $\underline{i}$ = a column vector of ones.
The row and column totals consist of vectors of initial population, $\underline{K}_E^1$ to $\underline{K}_E^M$ of final population, $\underline{K}_S^1$ to $\underline{K}_S^M$, of births in the period, $\underline{K}_B^1$ to $\underline{K}_B^M$, of deaths in the period, $\underline{K}_D^1$ to $\underline{K}_D^M$, of immigrants to the system of interest, existing at start of the period, $\underline{K}_E^{M+1}$ to $\underline{K}_E^N$, of infant immigrants, born in the period, $\underline{K}_B^{M+1}$ to $\underline{K}_B^N$, of emigrants from the system of interest who survive, $\underline{K}_S^{M+1}$ to $\underline{K}_S^N$, and of emigrants who don't survive, $\underline{K}_D^{M+1}$ to $\underline{K}_D^N$.

2.2 The accounts based model

In principle, if we had good enough population records we could write down $\underline{K}$ using those records. In practice, we know only some of the elements of any $\underline{K}$ of interest and we need to estimate the rest of the matrix from the known elements. To do this we use a model which we will call the accounts based model since it relies in part on the accounting relationships embodied in equations (6) and (7) above. The accounts based model on which the DAME programme is based is described in full in Rees and Wilson (1976, Chapter 11) and the reader is advised to consult that reference for full details, particularly if section three of the paper is to be read with a view to implementation.

The model uses data on the initial populations births and deaths of the regions of interest and estimates of the numbers of migrants and infant migrants in the off-diagonal submatrices of the exist-survive (ES) and born-survive (BS) quadrants of the accounts matrix as set out in equations (6) and (7) and from them estimates the flows in the exist-die (ED) and born-die (BD) quadrants of the matrix, the flows of stayers in the submatrices in the principal diagonals of the ES and BS quadrants of the $\underline{K}$ matrix, the final population vectors for the regions of interest, and the immigrant and emigrant totals displayed in equations (6) and (7).

The steps in the accounts based model can be summarized as follows (Rees and Wilson, 1976, Chapter 11, Section 11.3)

Step 1: assemble known or estimated data and necessary coefficients.

Step 2: apply coefficients to flows which do not change during the iterative cycle.

Step 3: obtain initial values of unknown major flows (exist-die stayers, exist-survive stayers, born-die stayers, born-survive stayers) using the accounting equations.

Step 4: calculate at risk populations.

Step 5 calculate birth and death rates.

Step 6 calculate unknown minor flows (migrants in the ED and BD quadrants).

Step 7: calculate the major flows and new populations from the accounting equations.

Then steps 4 - 7 are repeated until convergence in the accounts is achieved. This is achieved when no element in the current iteration differs by more than a small proportion from its value in the previous iteration. A value of 0.01 is used in DAME but it can be adjusted to a finer tolerance by the user if this is required.

2.3 The principal features of the programme

The principal operational features of the programme is summarized here to enable the reader to assess how well adapted the programme is to his or her particular accounts building task.

(1) Regions

This version of the programme is designed to cater for up to and including 12 regions, one or several of which will normally but not necessarily be(a)rest of the world region(s).Should the reader wish to conduct an analysis for more than 12 regions he can alter the programme accordingly (although there will be difficulties associated with the structure of the file store occupied by such expanded versions) or he may wish to first construct aggregate population accounts using a programme that handles up to 60 regions (Rees and Wilson, 1974), and then select a smaller set of regions between which the more significant interactions of the larger system take place.

(2) Age groups

The programme assumes that up to and including 20 age groups are employed. The only restriction on their definition is that the age intervals involved are less than or equal to the length of the time period adopted. The age groups will normally be of equal age intervals though this is not a requirement. So, for example, we could use the 18 five year age groups 0-4 through 85 and over, or the 10 ten-year age groups 0-9 through 90 over or the 20 age groups 0 through 19 and over with period lengths less than or equal to five years, ten years or one year respectively. Or we could mix age groups using the single years 0,1,2,3 and 4 and then five year age groups thereafter. A one year period (or less) would be necessary in this case.

(3) Time period

The time period length is restricted only by the nature of the age groups adopted. In principle, one could use a fifty year period and two fifty year age groups. No explicit instructions on period lengths have to be supplied to the programme to determine the time period length: the length of period will be implicit in the age group definitions and in the values of the coefficients (p_{rs}, q_{rs}, c_{rs} and so on) input by the user to the programme. For example, if a one year period is used with five year age groups p_{rr} will be set to 0.8 and p_{rr+1} to 0.2; if a two year period is used with five year age groups p_{rr} will be set to 0.4 and p_{rr+1} to 0.6. The p_{rr} coefficients convert populations of surviving stayers computed by age group at the start of the period into fully disaggregated populations. For example,

$$K_{rr}^{\varepsilon(i)\sigma(i)} = p_{rr} \, K_{r*}^{\varepsilon(i)\sigma(i)} \tag{8}$$

$$K_{rr+1}^{\varepsilon(i)\sigma(i)} = p_{rr+1} \, K_{r*}^{\varepsilon(i)\sigma(i)} \tag{9}$$

(4) Age group disaggregation of the input data

Death, birth and migrant data can be disaggregated by age group in three ways: by initial age group (at time t, equivalent to cohort disaggregation), by final age group or by both. Figure 2 shows the possible input modes and those modes which are implemented in the programme.

Age disaggregation +		Data input to the programme			
Initial age groups	Final age grps ∅	Deaths %	Births %	Surviving Migrants	Surviving Infant Migrants
*	*	–	–	–	$K_{**}^{\beta(i)\sigma(j)}$ $i \neq j$
r	*	–	$K_{r*}^{\beta(i)*(*)}$ $(K_{r*}^{*(*)m(i)})$	$K_{r*}^{\varepsilon(i)\sigma(j)}$ $i \neq j$	$K_{r*}^{\beta(i)\sigma(j)}$ $i \neq j$
r	s	$K_{rs}^{*(*)\delta(i)}$	$K_{r*}^{\beta(i)*(*)}$ $(K_{rs}^{*(*)m(i)}$	–	–
*	s	$K_{*s}^{*(*)\delta(i)}$	$K_{**}^{\beta(i)*(*)}$ $(K_{*s}^{*(*)m(i)})$	$K_{*s}^{\varepsilon(i)\sigma(j)}$, $i \neq j$	–

Notes

+ * refers to summation over this index.

∅ Age groups refers respectively to age group at death for deaths age group of mother at time of maternity or at the start of the period for bi age group at the end of period for surviving migrants.

Figure 2. Age disaggregation of input data

Population event or transition data is most normally recorded by final age group (bottom row of Figure 2), and coefficients have to be included with this data to achieve the disaggregation by initial and final age group required in the accounts based model. However, the programme allows for the possibility that this data may be available directly (for deaths and births) or by initial age group (births and surviving migrants).

(5) Output

The output of the programme consists of a sequence of tables which contain the components of the full accounts matrix together with information on the population at risk and death rates employed in the accounts based model, the birth rates that can be generated from the accounts and various important totals and sub totals. These tables can then be assembled into an accounts matrix of appropriate form by the user (see Appendices, A, C and D for examples of different accounts tables).

We turn now to a detailed consideration of the programme: the FORTRAN variables employed, the structure of the programme and the flow of control involved finishing with a summary of the model steps as implemented in the programme.

4. Users notes on running the programme

4.1 The type of computer on which the programme can be run.

The programme contains arrays of more than three dimensions, and not all computers accept such arrays. So the user must make sure that the right type of machine is being used. For example, the CDC 7600 at the Manchester Regional Computing Centre does not accept such arrays.

4.2 The time, space and files needed to run the programme.

The maximum size needed to run the programme is: 200704 words or 196 K words. This amount of space needs to be specified on the job card when running the programme. The time needed to run this programme depends on the amount of data input and can not be forecast precisely. However, on an I.C.L. 1906A the compilation of the programme takes about 80 seconds. The running of an already compiled programme needs 30 seconds for a test example (4 age groups and 3 regions) and very little more with a more realistic system of 3 regions and 20 age groups. No more than 2 minutes should be necessary to run the programme with a 12 regions system and 20 age groups.

4.3 The output of the programme

The output of the programme is presented with the example for the Shire and the rest of Middle Earth taken from Chapter 13 of Rees and Wilson (1976) in Figure 23b. Only the main aggregations are represented in the Figure. The exact list of items written out consists of the following.

a) The main flows at the end of the first iteration are written out. These are first estimates of infants who die, $K_{*1}^{\beta(i)\delta(i)X}$; first estimates of persons who die, $K_{rs}^{\varepsilon(i)\delta(i)X}$; and first estimates of surviving migrants or stayers $K_{rs}^{\varepsilon(i)\sigma(j)X}$

b) The final results which are output are as follows.

d_{rs}^{*jX} : Death rates disaggregated by sex and age

d_{r1}^{*jX} : Death rates in the first age group, disaggregated by sex of child and by age of mother at the beginning of the period.

β_{r*}^{*j} : Birth rates disaggregated by age of mother at the beginning of the period.

$K_{r1}^{\beta(i)\delta(j)X}$ The population of infants of sex X born in region i who die in region j disaggregated by age of mother at the beginning of the period.

$K_{*1}^{\beta(*)\delta(j)X}$: The population of infants born anywhere who die in region j disaggregated by sex.

$K_{rs}^{\varepsilon(i)\delta(j)X}$: The population of sex X existing in region i at time t who die in region j disaggregated by age at the beginning of the period and age at time of death.

$K_{*s}^{\varepsilon(i)\sigma(j)X}$: The population of sex X existing in region i at time t who survive in region j at time t+T, disaggregated by age at the end of the period.

$K_{r*}^{\varepsilon(i)\delta(*)X}$: The people of sex X who exist in region i at the beginning of the period and die anywhere, disaggregated by age at the beginning of the period.

$K_{r*}^{\varepsilon(i)\delta(R)X}$: The people of sex X who exist in region i at the beginning of the period and die anywhere outside i, disaggregated by age at the beginning of the period.

$K_{*s}^{\varepsilon(*)\delta(j)X}$: The people who exist anywhere at the beginning of the period and die in region j, disaggregated by age at death and by sex.

$K_{rs}^{*(*)\delta(j)X}$: The people of sex X who die in region j, disaggregated by age at the beginning of the period and age at death.

$K_{*s}^{\varepsilon(R)\delta(j)X}$: The people of sex X who exist anywhere outside j at the beginning of the period and die in region j, disaggregated by age at death.

$K_{r1}^{\beta(i)\sigma(j)X}$: The population of infants of sex X migrating from region to region j who survive, disaggregated by age of mother at the beginning of the period.

$K_{r1}^{\beta(i)\sigma(*)X}$: The population of infants of sex X born in region i who survive anywhere, disaggregated by age of mother at the beginning of the period.

$K_{r1}^{\beta(i)\sigma(R)X}$: The population of infants of sex X born in region i who survive anywhere outside i, disaggregated by age of mother at the beginning of the period.

$K_{r1}^{\beta(*)\sigma(j)X}$: The population of infants of sex X born anywhere who survive in region j, disaggregated by age of mother at the beginning of the period

$K_{rs}^{\varepsilon(i)\sigma(j)X}$: The surviving population of sex X in existence in region i at time t and surviving in region j at time t+T disaggregated by age at the beginning of the period, age at the end of the period.

$K_{r*}^{\varepsilon(i)\sigma(*)X}$: The population of sex X of region i who survive anywhere disaggregated by age at the beginning of the period.

$K_{r*}^{\varepsilon(i)\sigma(R)X}$: The population of sex X of region i who survive anywhere outside region i, disaggregated by age at the beginning of the period.

$K_{*s}^{\varepsilon(*)\sigma(j)X}$: The population of sex X existing anywhere at the beginning of the period who survive in region j disaggregated by age at the end of the period.

$K_{*s}^{\varepsilon(R)\sigma(j)X}$: The population of sex X existing anywhere outside region j at the beginning of the period who survive in region j, disaggregated by age at the end of the period.

$K_{*1}^{\beta(i)\sigma(j)X}$: The population of sex X of infants born in region i who survive in region j, disaggregated by sex.

$K_{r1}^{\beta(R)\sigma(j)X}$: The population of infants of sex X born anywhere outside region j who survive in region j, disaggregated by age of mother at the beginning of the period.

$K_{*1}^{\beta(i)\delta(j)X}$: The population of infants of sex X born in region i who die in region j, disaggregated by sex.

$K_{r1}^{\beta(i)\delta(*)X}$: The population of infants of sex X born in region i who die anywhere, disaggregated by age of mother at the beginning of the period.

$K_{r1}^{\beta(i)\delta(R)X}$: The population of infants of sex X born in region i who die anywhere outside region i, disaggregated by age of mother at the start of the period.

$K_{r1}^{\beta(*)\delta(j)X}$: The population of infants of sex X born anywhere who die in region j, disaggregated by age of mother at the beginning of the period.

$K_{rl}^{\beta(R)\delta(j)X}$: The population of infants of sex X born anywhere outside region j who die in region j, disaggregated by age of mother at the beginning of the period.

$K_{rl}^{\beta(i)*(*)X}$: The total population of infants of sex X born in region i, disaggregated by age of mother at the beginning of the period.

$K_{r*}^{\varepsilon(i)*(*)X}$: The total population of sex X of region i at the beginning of the period disaggregated by age at the beginning of the period.

$K_{rl}^{\beta(*)\sigma(j)X}$: The total number of infants of sex X surviving in region j disaggregated by age of mother at the beginning of the period.

$K_{rs}^{*(*)\sigma(j)X}$: The population of sex X at the end of the period in region j disaggregated by age at the beginning of the period and age at the end of the period.

4.4 The output of the programme to a file

The programme does not only write the results presented previously on a listing, but it also preserves the rates and main population submatrices in a file that can be used as an input file for another programme. The file is a direct access file, with random access, with 202 records of 500 words each, unformatted. These characteristics are specified in the programme (just before step 1.1) as follows: DEFINEFILE1 (202, 500, U, IFI). The file must be created outside the programme before the programme can be run. This is done on a "create card" put before the "run card". It must specify the following characteristics:

(1) Bucket size to fit the 500 x 2 words. In units of 128 words the bucket size is 8. (8 x 128 = 1024).

(2) File length to fit the 202 x 1024 words. This is exactly 202 K words - so the create file instructions will be CE FiLE1(*DA, BUCK8,KWORDS202,RANDOM) for computers where the GEORGE operation system is available. The information written to the file consists of the following items (disaggregated by regions): The birth and death rates; The existence and survival submatrix fully disaggregated; the existence and death submatrix fully disaggregated; the birth and survival submatrix disaggregated by age of mother at the beginning of the period; the births and deaths submatrix disaggregated by age of mother at the

Figure 23b. <u>The output of the programme for the example of the Shire and the Rest of Middle Earth</u>

N.B. The programme lists the outputs in the form of 44 sub-tables. The relevant sub-tables have been put together and in some cases summed here to make up a full accounts table. Adjustments have been made to ensure consistency in rounding.

SURVIVAL — Location at time t+20

Initial states		Final states	Region 1 (Shire) 0-19	20-39	40-59	60+	•	Region 2 (RME) 0-19	20-39	40-59	60+	•	Sub total survival 0-19	20-39	40-59	60+	•
Existence: Location at time t	Region 1 (Shire)	1 0-19	0	810			310	0	100			100	0	910			910
		2 20-39		0	523		523		0	135		135		0	658		658
		3 40-59			0	58	58			0	25	25			0	83	83
		4 60+				21	21				3	3				24	24
		•	0	810	523	79	1412	0	100	135	28	263	0	910	658	107	1075
	Region 2 (RME)	1 0-19	0	200			200	0	3267			3267	0	3467			3467
		2 20-39		0	270		270		0	2113		2113		0	2383		2383
		3 40-59			0	50	50			0	252	252			0	302	302
		4 60+				5	5				174	174				179	179
		•	0	200	270	55	525	0	3267	2113	426	5806	0	3467	2383	481	6331
	Sub total existence	1 0-19	0	1010			1010	0	3367			3367	0	4377			4377
		2 20-39		0	793		793		0	2248		2248		0	3041		3041
		3 40-59			0	108	108			0	277	277			0	385	385
		4 60+				26	26				177	177				203	203
		•	0	1010	793	134	1937	0	3367	2248	454	6069	0	4377	3041	588	8006
Birth: Location of birth in period t to t+20	Region 1 (Shire)	1 0-19	1411				1411	67				67	1478				1478
		2 20-39	546				546	40				40	586				586
		3 40-59	18				18	1				1	19				19
		4 60+															
		•	1975				1975	108				108	2083				2083
	Region 2 (RME)	1 0-19	136				136	5832				5832	5968				5968
		2 20-39	77				77	2186				2186	2263				2263
		3 40-59	1				1	113				113	114				114
		4 60+															
		•	214				214	8131				8131	8345				8345
	Sub total birth	1 0-19	1547				1547	5899				5899	7446				7446
		2 20-39	623				623	2226				2226	2849				2849
		3 40-59	19				19	114				114	133				133
		4 60+															
		•	2189				2189	8239				8239	10428				10428
Totals final states		1 0-19	1547	1010			2557	5899	3367			9266	7446	4377			11823
		2 20-39	623	0	793		1416	2226	0	2248		4474	2849	0	3041		5890
		3 40-59	19		0	108	127	114		0	277	391	133		0	385	518
		4 60+				26	26				177	177				203	203
		•	2189	1010	793	134	4126	8239	3367	2248	454	14308	10428	4377	3041	588	18434

Location at death in period t to t+20; TOTALS initial states

Initial states		Final states	Region 1 (Shire) 0-19	20-39	40-59	60+	•	Region 2 (RME) 0-19	20-39	40-59	60+	•	Sub total death 0-19	20-39	40-59	60+	•	TOTALS initial states 0-19	20-39	40-59	60+	•
Existence: Location at time t	Region 1 (Shire)	1 0-19	13	69			82	2	6			8	15	75			90	15	985			1000
		2 20-39		96	115		211		16	15		31		112	130		242		112	788		[illegible]
		3 40-59			288	96	384			23	10	43			311	106	417			311	189	500
		4 60+				75	75				1	1				76	76				[illegible]	[illegible]
		•	13	165	403	171	752	2	22	38	11	73	15	187	441	182	825	15	1097	1099	289	[illegible]
	Region 2 (RME)	1 0-19	2	6			10	109	414			523	111	422			533	111	3889			4000
		2 20-39		19	24		43		613	560		1173		632	584		1216		632	2967		3599
		3 40-59			40	22	62			1319	317	1636			1359	339	1698			1359	641	2000
		4 60+				4	4				217	217				221	221				400	[illegible]
		•	2	27	64	26	119	109	1027	1879	534	3549	111	1054	1943	560	[illegible]	111	4521	4326	1041	[illegible]
	Sub total existence	1 0-19	15	77			92	111	420			531	126	497			623	126	4874			5000
		2 20-39		115	139		254		629	575		1204		744	714		1458		744	3755		4499
		3 40-59			328	118	446			1342	327	1669			1670	445	2115			1670	830	2500
		4 60+				79	79				218	218				297	297				500	[illegible]
		•	15	192	467	197	871	111	1049	1917	545	3622	126	1241	2384	742	4493	126	5618	5425	1331	[illegible]
Birth: Location of birth in period t to t+20	Region 1 (Shire)	1 0-19	86				86	4				4	90				90	1568				1568
		2 20-39	34				34	2				2	36				36	622				622
		3 40-59	1				1	0				0	1				1	20				20
		4 60+																				
		•	121				121	6				6	127				[illegible]					[illegible]
	Region 2 (RME)	1 0-19	4				4	710				710	714				714	6682				6682
		2 20-39	2				2	268				268	270				270	2533				2533
		3 40-59	0				0	14				14	14				14	128				128
		4 60+																				
		•	6				6	992				992	998				998	9343				9343
	Sub total birth	1 0-19	90				90	714				714	804				804	8250				8250
		2 20-39	36				36	270				270	306				306	3155				3155
		3 40-59	1				1	14				14	15				15	148				148
		4 60+																				
		•	127				127	998				998	1125				1125	11553				11553
Totals final states		1 0-19	105	77			182	825	420			1245	930	497			1427	8376	4874			13250
		2 20-39	36	115	139		290	270	629	575		1474	306	744	714		1764	3155	744	3755		7654
		3 40-59	1		328	118	447	14		1342	327	1683			1670	445	2130	148		1670	830	2648
		4 60+				79	79				218	218				297	297				500	[illegible]
		•	142	192	467	197	998	1109	1049	1917	545	4620	1251	1241	2384	742	5618	11679	5618	5425	1330	24052

beginning of the period; The population stock at the beginning of the period, disaggregated by age at the beginning of the period; the total birth disaggregated by age of mother at the beginning of the period; the final population, fully disaggregated; and the total number of death, fully disaggregated. These elements contain sufficient information to calculate all possible sub populations of the accounts matrix.

They are stored in the file in the order shown in Figure 24: When the age group loop, incremented with the index LAG is started, LAG is set to one. The record (1+((LAG-1)*10)) is the record one. The record (2+((LAG-1)*10)) is the record two. The record (10+((LAG-1) *10)) is the record ten.

In these ten first records, the ten first items of the column two of Figure 24 are written for the first age group. In record one are written the $K_{11}^{*(*)\sigma(j)X}$ and $K_{12}^{*(*)\sigma(j)X}$ figures for all regions j and all sexes X. In record two the $K_{11}^{*(*)\delta(j)X}$ and $K_{12}^{*(*)\delta(j)X}$ figures are written for all regions j and all sexes X. In record seven the $K_{11}^{\varepsilon(i)\delta(j)1}$ figures are written for all regions i and all regions j, and so on.

The index of the age group loop, is incremented to two; LAG equals two. The record (1+((LAG-1)*10)) is the record eleven. The record (2+((LAG-1)*10)) is the record twelve. The record (10+((LAG-1)*10)) is the record twenty. In these records 11 to 20 are stored the ten first items of the column two figure 24 for the second age group: in record eleven are stored the figures $K_{22}^{*(*)\sigma(j)X}$ and $K_{23}^{*(*)\sigma(j)X}$ for all regions j and all sexes X, in record twelve are stored the figures $K_{22}^{*(*)\delta(j)X}$ and $K_{23}^{*(*)\delta(j)X}$, and so on. In the record (1+((12-1)*10) are stored the figures of $K_{1212}^{*(*)\sigma(j)X}$ and $K_{1213}^{*(*)\sigma(j)X}$.

There are up to 20 age groups, so the total number of records used to store the ten first elements presented in column 2 of figure 24 use 200 records (20 times 10 records). For convenience the total births and the total existing population at the beginning of the period, which are the two last items to be stored on the file, are not stored in the same way as the previous ten ones. They are written completely, for all ages, in one record. In record 201 are written the figures of $K_{r*}^{\beta(i)*(*)X}$ for all sexes X, all regions i and all ages of mother r. In record 202 are written the figures of $K_{r*}^{\varepsilon(i)*(*)X}$ for all sexes X, all regions i and all ages r.

In all the 202 records, the information is written in a similar way. The write statements which transfer the figures to the file are of the form: WRITE(...)(((((ARRAY(I,J,L,K,M),K=1,2),M=1,NSEX), J=1,N),I=1,N), L=1,R) The implicit loops, incremented with the indexes. K,M,J,I,L always appear in the same order, although not all the indexes are used for all the arrays. For example the figures of $K_{rs}^{*(*)\sigma(j)X}$ will be written to the file, for all values of the age group r, in the following way: WRITE (1'IREC)(((KK9(J,LAG,K,M), K=1,2),M=1,NSEX),J=1,N). The figures of $K_{r*}^{\beta(i)\sigma(j)X}$ will be written to the file, for all values of the age group r in the following way; WRITE(1'IREC)(((K21R(I,J,LAG,M),M=1,NSEX),J=1,N)I=1,N). The figures of $K_{r*}^{\varepsilon(i)*(*)X}$ will be written on record 202 with the statement: WRITE(1'202)(((KK2(I,L,M),M=1,NSEX),J=1,N),L=1,R).

The order in which the information is written in each record corresponds to the order of the implicit loops. For example, in record one the following items are stored: $K_{11}^{*(*)\sigma(1)1}$, $K_{12}^{*(*)\sigma(1)1}$, $K_{11}^{*(*)\sigma(1)2}$, $K_{12}^{*(*)\sigma(1)2}$, $K_{11}^{*(*)\sigma(2)1}$, and so on. In record 24, which is record (4+((3-1)*10), are written the following elements: $K_{33}^{\beta(1)\delta(1)1}$, $K_{34}^{\beta(1)\delta(1)1}$, $K_{33}^{\beta(1)\delta(1)2}$, $K_{34}^{\beta(1)\delta(1)2}$, $K_{33}^{\beta(1)\delta(2)1}$, $K_{34}^{\beta(1)\delta(2)1}$, $K_{33}^{\beta(1)\delta(2)2}$ and so on.

We note, that in the records (5+((lag-1)*10)), two sets of figures are written: b_{r*}^{*i} and d_{r1}^{*iX}. They are written one after another, as follows: WRITE(1'IREC)(QWJ(I,LAG),I=1,IN),((QAI1(I,LAG,M), M=1,NSEX),I=1,N). The write statement means that all the birth rates b_{r*}^{*i} are written first according to the rules presented for all other records, then the infant death rates $d_{r1}^{\beta(*)jX}$ are written according to the rules presented for all other records.

4.5 <u>The input</u>.

4.5.1 <u>The data required and the example of Middle Earth</u>

The data required to run the programme can vary according to the size of the spatial system, the number of age groups and sex taken into account and the possibilities offered by the six switches. Basically the data needed are: population stocks at the beginning of the period; total number of births by regions during the period; total number of deaths by region during the period; migrants and infant migrants between regions during the period; and various coefficients used to disaggrate the population vectors in the required disaggregated forms.

Record	Item	Specification of the array from which the item is written to the file (all arrays are dimensioned in floating point)	Use of the dimensions of the array
1+((LAG-1)*10)	$K_{rs}^{*(*)\ (j)X}$	KK9(12,20,2,2)	KK9(I,LAG,K,M)
2+((LAG-1)*10)	$K_{rs}^{*(*)\delta(j)X}$	X(20,2,2,12)	X(LAG,K,M,I)
3+((LAG-1)*10)	$K_{r*}^{\beta(i)\delta(j)X}$	K22(12,12,8,2)	K22(I,J,LAG,M)
4+((LAG-1)*10)	$K_{r*}^{\beta(i)\sigma(j)X}$	K21R(12,12,8,2)	K21R(I,J, LAG,M)
5+((LAG-1)*10)	b_{r*}^{*i}	QWJ(12,8)	QWJ(I,LAG)
	$d_{r1}^{\beta(*)jX}$	QAI1(12,8,2)	QAI1(I,LAG,M)
6+((LAG-1)*10)	$d_{rs}^{\varepsilon(*)jX}$	QAI(12,10,2,2)	QAI(I,LAG,K,M)
7+((LAG-1)*10)	$K_{rs}^{\varepsilon(i)\delta(j)_1}$	K12(12,12,10,2,2)	K12(I,J,LAG,K,M)
8+((LAG-1)*10)	$K_{rs}^{\varepsilon(i)\delta(j)_2}$	K12(12,12,10,2,2)	K12(I,J,LAG,K,M)
9+((LAG-1)*10	$K_{rs}^{\varepsilon(i)\sigma(j)1}$	K12(12,12,10,2,2)	K11(I,J,LAG,K,M)
10+((LAG-1)*10)	$K_{rs}^{\varepsilon(i)\sigma(j)_2}$	K12(12,12,10,2,2)	K11(I,J,LAG,K,M)
201	$K_{r*}^{\beta(i)*(*)X}$	KK2(12,20,2)	KK2(I,LAG,M)
202	$K_{r*}^{\varepsilon(i)*(*)X}$	KK2(12,20,2)	KK2(I,LAG,M)

I is the label of the region at the beginning of the period.

J is the label of the region at the end of the period.

LAG is the label of the age at the beginning of the period.

K is one if the age at the end of the period is unchanged, K is two otherwise.

M is the label of the sex.

In all records, the implicit loops are run in the following order 1˙:K,2˙:M,3˙:J,4˙:L,5˙:LAG.

Figure 24 The information output to a file

In appendix A we present a set of 15 inputs out of the 36 possible ones for the example of the Shire and the rest of Middle Earth. Each input corresponds to a feasible combination of the values of the switches. Each input has been calculated from the known complete accounts of the Middle Earth example. All the programme results of these different input sets are identical. The switches can be divided into two independent groups. The fifteen examples of inputs exhaust all the combinations within these two independent groups.

4.5.2 <u>The switch for birth data</u>

The birth data can be input in three ways according to the value of the switch called SWITCHBIRTH. In all cases the data are given for all regions except the Rest of the World region(s) if any.

If SWITCHBIRTH equals one the data are $K_{**}^{\beta(i)*(*)X}(u)$ the number of births by sex by age of mother at time of birth, and f_{ru}^{i} coefficients, that effect the following disaggregation $K_{ru}^{\beta(i)*X} = f_{ru}^{i} \times K_{**}^{\beta(i)**X}(u)$. We note that f is disaggregated by region at time of birth but not by sex.

If SWITCHBIRTH equals 2, the data are: $K_{r*}^{\beta(i)*(*)X}(*)$ or births of sex X in region i classified by age group of mother at the beginning of the period. No birth coefficients are needed in this case.

If SWITCHBIRTH equals 3, the data are: $K_{r*}^{\beta(i)*(*)X}(u)$ or the number of births by sex by age of mother at the beginning of the period <u>and</u> age of mother at time of birth. No birth coefficients are needed in this case.

4.5.3 <u>The switch for death data</u>

The data can be input in two ways according to the value of SWITCHDEATH. The data are given for all regions except the rest of the world region(s), if any.

If SWITCHDEATH equals 1, the data are: $K_{*s}^{*(*)\delta(j)X}$. The number of deaths by sex by age at time of death; C_{rs}^{jX} coefficients that effect the disaggregation $K_{rs}^{*(*)\delta(j)X} = C_{rs}^{jX} K_{*s}^{*(*)\delta(j)X}$

The coefficients are disaggregated by region at time of death, and by sex. Also needed are C_{01}^{jX} coefficients which carry out the following disaggregations: $K_{*1}^{\beta(*)\delta(j)X} = C_{01}^{jX} \; K_{*1}^{*(*)\delta(j)X}$ and $K_{11}^{\varepsilon(*)\delta(j)X} = (1 - C_{01}^{jX}) \; K_{*1}^{*(*)\delta(j)X}$. The C_{01} coefficient is disaggregated like C_{rs} by sex and region at time of birth. It gives the proportions of deaths in the first age group to be allocated to infants born during the period and to persons already born at the beginning of the period.

If SWITCHDEATH equals 2, the data assumed are: $K_{rs}^{\varepsilon(*)\delta(j)X}$ or the number of deaths by sex, by age group at the beginning of the period and age group at time of death, and $K_{*1}^{\beta(*)\delta(j)X}$ The number of infants born during the period who die before the end of the period

4.5.4 <u>The switch for migrants</u>

The data can be input in two ways according to the value of SWITCHMIG. The data are given for all possible pairs of different regions of the system, including the rest of the world region(s), if any.

If SWITCHMIG equals 1, the data required are $K_{*s}^{\varepsilon(i)\sigma(j)X}$ or the number of migrants by sex by age at the end of the period; q_{rs}^{iX} coefficients which effect the deconsolidation $K_{rs}^{\varepsilon(i)\sigma(j)} = q_{rs}^{iX} \; K_{*s}^{\varepsilon(i)\sigma(j)X}$, where q is disaggregated by region of origin (including the rest of the world)and sex.

If SWITCHMIG equals 2, the data required are: $K_{r*}^{\varepsilon(i)\sigma(j)X}$ or the number of migrants by sex by age at the beginning of the period; x_{rs}^{iX} coefficients which carry out the deconsolidation $K_{rs}^{\varepsilon(i)\sigma(j)X} = x_{rs}^{iX} \; K_{r*}^{\varepsilon(i)\sigma(j)X}$ where x is disaggregated by region of origin (including the rest of the world) and sex.

4.5.5 <u>The switches for infant migrants: the v and e coefficients</u>

The switches for infant migrants referring to the e and v coefficients are not independent: they must be considered together.

The SWITCHBM switch describes the infant migrant input data $K^{\beta(i)\sigma(j)X}$. If SWITCHBM equals 1, the data assumed are $K_{rl}^{\beta(i)\sigma(j)X}$ or infant migrants disaggregated by age group of mother at the beginning of the period. If SWITCHBM equals 2, the data assumed are $K_{*l}^{\beta(i)\sigma(j)X}$ or infant migrants disaggregated by sex but not by age group of mother. In all cases the data is given for all possible pairs of different regions of the system, including the rest of the world region(s).

The switch SWITCHV is considered next. If SWITCHV equals 1, v_{rl} coefficients are input to disaggregate infant migrants by age group of mother. They accomplish disaggregations such as: $K_{rl}^{\beta(i)\sigma(j)X} = v_{rl}^{i} \times K_{*l}^{\beta(i)\sigma(j)X}$. The v_{rl} coefficients are not disaggregated by sex, they are disaggregated by region at birth. They are only assumed to be known for regions in the system of interest, but not for regions in the rest of the world.

We see that if SWITCHBM equals 1 and infant migrant data are disaggregated by age group of mother, there is no need for a v coefficient so it is inconsistent to set both SWITCHBM and SWITCHV to one.

If SWITCHBM equals 2 and SWITCH equals 2, the infant migrant data are not disaggregated by age group of mother and no v_{rs} coefficients are supplied to disaggregate them. In this case disaggregation is achieved through use of balancing factors.

The switch SWITCHE is considered next. If SWITCHE equals 1, e_{rl} coefficients must be supplied. The e_{rl} coefficients are used to disaggregate non surviving infant migrant data by age group of mother at the beginning of the period. They perform the following disaggregation: $K_{rs}^{\beta(i)\delta(i)X} = e_{rl}^{i} \; K_{*s}^{\beta(i)\delta(i)X}$

The e_{rl}^{i} coefficients are not disaggregated by sex. They must be supplied for all origin regions in the system of interest, but not for regions in the rest of the world. If SWITCHE is set to 2, then no e_{rl} coefficients are to be supplied and v_{rl} coefficients are used instead. So, it is not possible to have both SWITCHE and SWITCHV set to 2.

We summarize the process of setting the three switches SWITCHBM, SWITCHV, and SWITCHE to their values in Figure 25. If the switches are given an unacceptable combination of values, the programme stops after stating "inconsistensies in the switches input: program terminated".

4.5.6 Other coefficients required: p_{rs}

In all cases, whatever the value of the switches, p_{rs} coefficients are needed. They are used to disaggregate non-migrants disaggregated by age group at the beginning of the period into non migrants disaggregated by age group at the beginning of the period and at the end of the period.

They accomplish the following disaggregation $K_{rs}^{\varepsilon(i)\sigma(i)}X = p_{rs}\ K_{r*}^{\varepsilon(i)\sigma(i)}X$. They are not disaggregated by sex. They need to be supplied for all regions in the system excluding the rest of the world region(s).

4.5.7 Other switches: IOUT

If IOUT is set equal to 0, all the intermediate calculations are written out. All the results of the seven steps of the programme for all age groups and all iterations are written out before the final results are written out. This lengthens considerably the time needed by the programme to be run, and it is advisable to use this possibility only when required for methodological purposes. If IOUT has been set greater than 0, only the results at the end of the first iteration and the final results are written out.

We can now, item by item, make the list of data to input to the programme.

4.6 The inputs summarized

(1) The tital cards

Three cards, with 80 columns of text on each card in an A format, are needed. An example is given in Figure 26.

(2) The Switchcard

On this card the switches and sizes of the data are given in the following order with the format (13I4): SWITCHBIRTH, SWITCHDEATH, SWITCHMIG, SWITCHE, N, R, LBIRTH1, LBIRTH2, NSEX, SWITCHV, SWITCHBM, RW, and IOUT. The detailed description of this card is presented in Figure 27 and an example is given in Figure 28.

(3) The names of the regions

They are the names written out in the presentation of the results. They are read in format (10A8): the names must be no more than 8 characters long.

values of the switches

SWITCHBM	SWITCHV	SWITCHE	SWITCHBM	SWITCHV	SWITCHE	**comments**
=1 Infant migrants are input dis-aggregated by age of mother: $K^{\beta(i)\sigma(j)X}_{r1}$	=1 v_r coefficients are input to dis-aggregate infant migrants by age of mother	=1 e_r coefficients are given to disaggregate non surviving infant data by age of mother	1	1	1	existence of v_r redundant unacceptable
		=2 no e_r coefficients use v_r coefficients	1	1	2	v_r is in fact e_r coefficient unacceptable
	=2 no v_r coefficients balancing factors are used, if necessary, to disaggregate infant migrants by age of mother	=1 e_r	1	2	1	
		=2 no e_r use v_r	1	2	2	data missing unacceptable
=2 Infant migrants are input agg-regated over age of mother: $K^{\beta(i)\sigma(j)X}_{*1}$	=1 v_r coefficients	=1 e_r	2	1	1	
		=2 no e_r use v_r	2	1	2	
	=2 no v_r coefficient balancing factors are used.	=1 e_r	2	2	1	
		=2 no e_r use as r	2	2	2	data missing unacceptable

Figure 25. The possible values of SWITCHBM, SWITCHV, & SWITCHE

FORTRAN STATEMENT

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
          MULTIREGIONAL ACCOUNT
          REGIONS OF ENGLAND AND WALES 1966-1971.
          20 QUINQUENNIAL AGE GROUPS
```

Figure 26. An example of the title cards.

SWITCH	DESCRIPTION	FORMAT	COLUMN
SWITCHBIRTH (mother's age group).	= 1 age group at time of maternity = 2 age group at the beginning of the period	I4	1 - 4
SWITCHDEATH	= 1 age group at time of death = 2 age group at the beginning of the period and at death.	I4	5 - 8
SWITCHMIG (age group of migrants)	= 1 age group at the end of the period = 2 age group at the beginning of the period.	I4	9 - 12
SWITCHE	= 1 e_r coefficients are known = 2 e_r coefficients are unknown, V_r is used instead	I4	13 - 16
N	Total number of regions (minimum 1, maximum 12)	I4	17 - 20
R	Total number of age groups (minimum 1, maximum 20)	I4	21 - 24
LBIRTH1	First age group at which females are fertile	I4	25 - 28
LBIRTH2	Last age group at which females are fertile. (maximum is 10: LBIRTH2 - LBIRTH1 must not exceed 7; 8 fertile age groups are allowed).	I4	29 - 32
NSEX	Number of sexes must be set to 1 or 2. If NSEX=2; first sex is male, second sex is female.	I4	33 - 36
SWITCHV	= 1 V_r coefficients are known = 2 V_r coefficients are unknown and balancing factors are used instead	I4	37 - 40
SWITCHBM	= 1 Birth and migration are given disaggregated by age of mother at the beginning of the period = 2 Birth and migration aggregated over age of mother.	I4	41 - 44

RW	Number of regions in the Rest of the World of the system. (minimum 0, maximum 19: must be smaller than N).	I4	45 - 48
IOUT	=0 all intermediate calculation in the first iteration are written out. >0 only final results are written out.	I4	49 - 52

Figure 27. The Switchdata card.

They must be in the same order as the data. They must, as far as possible, be written in the center of the 8 characters left for them: for example "SUSSEX" should be written ‸SUSSEX and not ‸‸SUSSEX. An example is shown in Figure 29.

(4) The names of the age groups.

These are the names written out in the presentation of the results. They are read in format (10A8). The names must be no more than 8 characters long. Like the names of regions, they must, as far as possible, be written in the middle of the 8 spaces left for them and not off centred. There must be one age per age group. An example is presented in Figure 30.

(5) The format card for the population stock (format card 1)

A FORTRAN IV format expression enclosed in parenthesis must be supplied. No more than one card should be used. This format is the one used to read the following stock data. It must be a real number in F format, for example (10 F8.0).

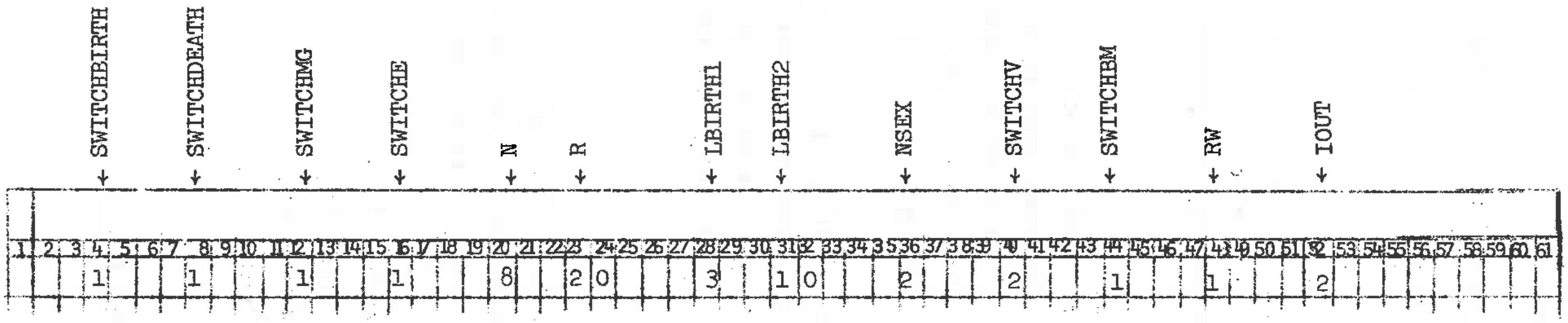
(6) Population stock cards.

They are $K_{r*}^{\varepsilon(i)*(*)X}$ the population stocks at the beginning of the period, for each sex, each region, excluding the rest of the world region(s) if any,and each age groups. The data will be ordered in the following way:

Sex 1 (male). Region 1, age groups 1,2,3,4,5,6...,R.
Region 2, age groups 1,2,3,4,5,6...,R.
Region IN, age groups 1,2,3,4,5,6...,R.
Sex 2 (female). Region 1, age groups 1,2,3,4,5,6...,R.

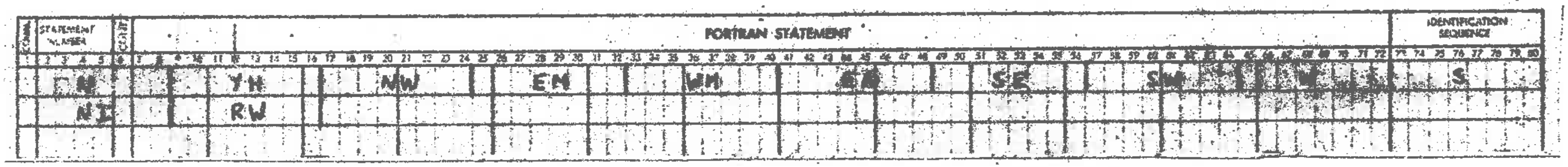
⋮

Region IN, ahe groups 1,2,3,4,5,6...,R.



The number of regions in the system is N=8 (including the rest of the world)
The number of region in the rest of the world is RW = 1.
There are NSEX sexes considered = 2.
There are R age groups = 20
The first fertile age group is LBIRTH1 = 3, the last fertile age group is LBIRTH2 = 10.
The birth data are disaggregated by age of mother at birth (SWITCHBIRTH = 1).
The death data are given by age at death (SWITCHDEATH = 1).
The migration data are given by age at the end of the period (SWITCHMIG = 1).
The birth and migration are disaggregated by age of mother (SWITCHBM = 1).
No V_{r*} coefficients are given (SWITCHV = 2).
e_r Coefficients are provided (SWITCHE = 1).
No intermediate results will be written (IOUT >0)

Figure 28. An example of the Switchcard



In this example there are 12 regions called: N (north), YH (Yorkshire and Humberside), NW (North West), EM (East Midlands), WM (West Midlands), EA (East Anglia), SE (South East), SW (South West), W(Wales), S(Scotland), NI (Northern Irelands), RW (Rest of the World).

Figure 29: An example of the names of regions input.

f 16

STATEMENT NUMBER								FORTRAN STATEMENT		IDENTIFICATION SEQUENCE
0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44		45-49
50-54	55-59	60-64	65-69	70-74	OVER 75					

In this example 16 quinquennial age groups are considered from the age 0 to 74 and from 75 onwards.

Figure 30 <u>An example of the names of age groups input.</u>

The number of regions for which population stock data is required is IN which equals N minus RW. If the format statement covers C cards (where C = 1,2...), there should be; NSEX*N*C population cards. An example is given in Figure 31.

(7) The format card for births inputs (format card 2).

This format describes the organization of birth data . It follows the same rules as format card 1.

(8) Births cards

If SWITCHBIRTH is 1, the inputs are births by age of mother at time of maternity; $K_{**}^{\beta(i)*X}(u)$ is SWITCHBIRTH is 2 , the inputs are Birth by age of mother at the beginning of the period $K_{r*}^{\beta(i)*X}$.

In both cases, the data are ordered by sex, by regions, for all regions excluding the rest of the World region(s) and by age of mother from the first fertile age(LBIRTH1) to the last fertile age (LBIRTH2), as follows:

Sex 1: Region 1: first fertile age, ..., last fertile age.
Region 2: first fertile age, ..., last fertile age.

⋮

Region IN: first fertile age, ..., last fertile age.

Sex 2: Region 1: first fertile age, ..., last fertile age.

⋮

Region IN: first fertile age, ..., last fertile age.

With proper definition og first and last fertile age groups, everything is input as for the stock data input. For the example see Figure 30.

If SWITCHBIRTH is equal to 3, the inputs are births by age group of mother at the beginning of the period and by age group at time of maternity: $K_{r*}^{\beta(i)*X}(u)$ The data are ordered by sex, regions excluding the rest of the World region(s), age of mother at the beginning of the period and age of mother at the time of birth, from the first fertile age group (=LBIRTHS1) to the last fertile age group (LBIRTH2)*, as follows:

Sex 1: Region 1: (LBIRTH1, LBIRTH1), (LBIRTH1, LBIRTH1+1), (LBIRTH1+1, LBIRTH1+1)....(LBIRTH2-1, LBIRTH2), (LBIRTH2, LBIRTH2).

Region 2: (LBIRTH1, LBIRTH1), (LBIRTH 1, LBIRTH1+1) ..... (LBIRTH2, LBIRTH2).

⋮

* The user should always supply explicit values of zero for the first age group transition and the last even if these are not recognized in the input data sources. This is for programming convenience.

100	200	300	400	500	600	700	800	900	1000
1100	1200								
1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
11000	12000								
102	202	302	402	502	602	702	802	902	1002
1102	1202								
1002	2002	3002	4002	5002	6002	7002	8002	9002	10002
11002	12002								

The system is composed of two regions (excluding the rest of the World). There are 12 age groups and two sexes. The reading format is (10 F8.0). In the first region and first sex there are 100 individuals in the first age group, 200 in the second age group and 1200 in the 12th age group. In the second sex there are 102 individuals in the first age group, 202 in the second age group and 1202 in the 12th age group. In the second region, first sex there are 1000 individuals in the first age group, 2000 in the second age group and 12000 in the 12th the group. In the second sex there are 1002 individuals, 2002, 3002 and 12002 individuals.

Figure 31 <u>An example of population stock data input</u>

Region IN: (LBIRTH1, LBIRTH1), (LBIRTH1, LBIRTH1+1)..... (LBIRTH2, LBIRTH2).

Sex 2: Region 1 : (LBIRTH1,LBIRTH1), (LBIRTH1,LBIRTH1+1) ..... (LBIRTH2, LBIRTH2).

⋮

Region IN (LBIRTH1, LBIRTH1), (LBIRTH1, LBIRTH1+1)..... (LBIRTH2, LBIRTH2)

(9) <u>The birth coefficient card.</u>

This is needed only when SWITCHBIRTH is set equal to 1. These coefficients accomplish the disaggregation $K_{r*}^{\beta(i)*(*)X}(u) = f_{ru}^{i} K_{**}^{\beta(i)*(*)X}(u)$.

We note that for all r; $f_{r-1} + f_{rr} = 1.000$. They must be read for all regions excluding the rest of the World region(s), for all age groups from the first fertile age group to the last fertile age group. They are not disaggregated by sex. They are read exactly in the same order as the birth data in the case when SWITCHBIRTH equals 3 (birth data disaggregated by age at the beginning of the period and at time of birth). They are read in the format (10F8.6). An example is given in figure 33.

(10) <u>The format card for deaths (format card 3)</u>

This format is used to read the deaths data. It follows the same rules as the format card for population stocks.

(11) <u>Deaths data card</u>

If SWITCHDEATH is set equal to 1, the deceased are assumed to be disaggregated by age group at time of death; $K_{*s}^{*(*)\delta(j)X}$.

The data is ordered by sex, by regions, for all regions excluding the rest of the World region(s), and by age from the first age group (age group 1) to the last age group (age group R) as follows:

Sex 1: Region 1: age 1, age 2,..., age R.
Region 2: age 1, age 2,..., age R.

⋮

Region IN: age 1, age 2,..., age R.

Sex 2: Region 1: age 1, age 2,..., age R.

⋮

Region IN: age 1, age 2,..., age R.

Everything is input as for the population stock. For an example of the layout required see Figure 31.

If SWITCHDEATH is set equal to 2, the deceased are assumed to be disaggregated by age group at the beginning of the period and age group at time of death $K_{rs}^{*(*)\delta(j)X}$. The data is ordered by sex, by regions, for all regions excluding the rest of the World region(s) and by age group at the beginning of the period and age group at time of death from the first age group (age 1) to the last age group (age R), as follows:

Sex 1: Region 1 (age group 1, age group 1), (age group 1, age group 2), ...(age group R, age group R).

Region 2 (age group 1, age group 1), (age group 1, age group 2), ...(age group R, age group R).

Region IN (age group 1, age group 1), (age group 1, age group 2), ...(age group R, age group R).

Sex 2: Region 1 (age group 1, age group 1), (age group 1, age group 2) ...(age group R, age group R).

⋮

Region IN (age group 1, age group 1), (age group 1, age group 2) ...(age group R, age group R).

With proper definition of the first and last age groups everything is input as for the births data disaggregated by age group of mother at the beginning of the period and at time of birth (the case when SWITCHBIRTH is set equal to 3). For an example of the layout required see Figure 32.

(12) The c_{rs}^{jx} coefficient cards

These coefficient cards are required if SWITCHDEATH has been set equal to 1. They accomplish the disaggregation $K_{rs}^{*(*)\delta(j)X} = c_{rs}^{jX} K_{*s}^{*(*)\delta(j)X}$ (Note that $c_{r-1r} + c_{rr} = 1.000$). C_{rs} coefficients are read for each sex for all regions excluding the rest of the World region(s), for all age groups from the first to the last (R). They are read exactly in the same order as the birth data in the case when SWITCHBIRTH is equal to 3 and the birth data are disaggregated by age group at the beginning of the period. They are read in the format (10F8.6). Figure 32 shows the layout required.

1133	1134	1144	1145	1155	1156	1166	1167	1177	1178
1188	1189	1199	1190	1100	1101				
1233	1234	1244	1245	1255	1256	1266	1267	1277	1278
1288	1289	1299	1290	1200	1201				
2133	2134	2144	2145	2155	2156	2166	2167	2177	2178
2188	2189	2199	2190	2100	2101				
2233	2234	2244	2245	2255	2256	2266	2267	2277	2278
2288	2289	2299	2290	2200	2201				

The system is composed of two regions (excluding the rest of the World). There are 8 fertile age groups (age group 3,4 ... 10). The reading format is (10 F8.0). In the sex 1, for the region 1: There are 1133 males born from mothers who are in age group 3 at the beginning of the period and in age group 3 at maternity; 1134 males born from mothers who are in age group 3 at the beginning of the period and age group 4 at maternity, 1144 born from mothers who are in age group 4 at the beginning of the period and in age group 4 at maternity and sc on. For the region 2 these males are 1233 born from mothers who are in age group 3 at the beginning of the period and in age group 3 at maternity. In the sex 2 for region 1 there are 2133 females born from mothers who are in age group 3 at the beginning of the period and in age group 3 at maternity. For region 2 there are 2233 such females and so on.

Figure 32 <u>An example of birth data input</u>

STATEMENT NUMBER	FORTRAN STATEMENT								IDENTIFICATION SEQUENCE
0.133	0.134	0.144	0.145	0.155	0.156	0.166	0.167	0.177	0.178
0.188	0.189	0.199	0.190	0.100					
0.233	0.234	0.244	0.245	0.255	0.256	0.266	0.267	0.277	0.278
0.288	0.289	0.299	0.290	0.200					

The system is composed of two regions (excluding the rest of the World). There are 8 fertile age groups (age group 3,4...10). The reading format is, as for all coefficients, F8.6. In region 1, the coefficients that disaggregate mothers by age group 3 at the beginning of the period and age group 3 at maternity is 0.133; the coefficient that disaggregate mothers by age group 3 at the beginning of the period and age group 4 at maternity is 0.134; the coefficient that disaggregate mothers by age group 5 at the beginning of the period and age group 6 at maternity is 0.156. In region 2, the corresponding coefficients are 0.233, 0.234 ... 0.256 ...

Figure 33 An example of f_{ru}^{iX} and c_{rs}^{jX} coefficients input (disaggregated by region)

(13) The c_{01}^{jX} coefficient cards

Following the c_{rs}^{jX} cards, the c_{01}^{jX} cards are read. They accomplish the disaggregation: $K_{11}^{\varepsilon(*)\delta(j)X} = c_{01}^{jX} K_{11}^{*(*)\delta(j)X}$. They contain coefficients disaggregated by sex and all regions of the system excluding the rest of the World, as follows:

Sex 1: c_{01} region 1, c_{01} region 2, ... c_{01} region IN.

sex 2: c_{01} region 1, c_{01} region 2, ... c_{01} region IN.

They are read in the same format as the c_{rs}^{jX} coefficients: (10F8.6). We note that the data is displayed on different cards for different sexes but not different regions. Figure 34 shows an example of c_{01}^{jX} coefficient cards.

(14) The infant death cards.

These are required only if SWITCHDEATH is set equal to 2. The variables have the form $K_{*1}^{\beta(*)\delta(j)X}$. The data is ordered by sex and all regions excluding the rest of the World region(s). They are not disaggregated by age group of mother:

sex 1: region 1, region 2 ..... region IN.

sex 2: region 1, region 2 ..... region IN.

They are read in the same format as the death data were read. We note that the data is displayed on different cards for different sexes but not for different regions. An example is given in Figure 35.

(15) The format card for migrants (format card 4)

This format is used to read the migrant data. It follows the same rules as format card 1.

(16) The migrant

If SWITCHMIG is set to 1, the migrants are disaggregated by age group at the end of the period. The variables have the form $K_{*s}^{\varepsilon(i)\sigma(j)X}$. If SWITCHMIG is set to 2, the migrants are disaggregated by age group at the beginning of the period; the variables have the form $K_{r*}^{\varepsilon(i)\sigma(j)X}$; in both cases, the data is ordered by sex, all regions of origins (including the rest of the World region(s)), all regions of arrival (including the rest of the World region(s)), and all age groups, from the first to the last.

The data for non-migrants or stayers, when the region of origin and the region of destination are identical, are omitted. The migrant data are input as follows:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
0	.	1	1	0	1			0	.	1	2	0	1			0	.	1	3	0	1			0	.	1	4	0	1			0	.	1	5	0	1																														
0	.	2	1	0	1			0	.	2	2	0	1			0	.	2	3	0	1			0	.	2	4	0	1			0	.	2	5	0	1																														

The system is composed of 5 regions. There are 2 sexes. The reading format is, as for all coefficients: 10F8.6. For the sex 1 the coefficient that gives the proportion of non-survivors in age group 1 who have been born since the beginning of the period is for region 1: 0.1101, for region 2: 0.1201, and so on. For sex 2: the coefficients are: for region 1, 0.2101, for region 2, 0.220 and so on.

Figure 34. An example of c_{01}^{jX} coefficients input

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
				1	1	0	0					1	2	0	0					1	3	0	0					1	4	0	0					1	5	0	0																						
				2	1	0	0					2	2	0	0					2	3	0	0					2	4	0	0					2	5	0	0																						

The system is composed of 5 regions. There are two sexes. The reading format is 10F8.0.
For the sex 1, the number of infants who die is: for region 1, 1100; for region 2, 1200 and so on.
For the sex 2, the number of infants who die is; for region 1, 2100; for region 2, 2200 and sc on.

Figure 35. An example of infant death data input.

Sex 1 region of origin 1, region of destination 2: age 1,2,3,...,R.
region of origin 1, region of destination 3: age 1,2,3,...,R.

⋮

region of origin 1, region of destination N: age 1,2,3,...,R.
region of origin 2, region of destination 1: age 1,2,3,...,R.
region of origin 2, region of destination 3: age 1,2,3,...,R.

⋮

region of origin 2, region of destination N: age 1,2,3,...,R.

⋮

region of origin N, region of destination N-1: age 1,2,3,...,R.

Sex 2 region of origin 1, region of destination 2: age 1,2,3,...,R.

⋮

region of origin 1, region of destination N: age 1,2,3,...,R.
region of origin 2, region of destination 1: age 1,2,3,...,R.
region of origin 2, region of destination 3: age 1,2,3,...,R.

⋮

region of origin N, region of destination N-1: age 1,2,3,...,R.

On each region of origin-region of destination card set of cards, . the data are ordered as shown in the example given in figure 31.

(17) <u>The Migrant coefficients</u>

The migrant coefficient is the coefficient needed to disaggregate migration data by age group at the beginning of the period and age group at the end of the period. If SWITCHMIG is set equal to 1, q_{rs}^{jX} coefficients are used to accomplish the disaggregation $K_{rs}^{\varepsilon(i)\sigma(j)X} = q_{rs}^{jX} \; K_{*s}^{\varepsilon(i)\sigma(j)X}$. If SWITCHMIG is set equal to 2, x_{rs}^{iX} coefficients are used to carry out the deconsolidation $K_{rs}^{\varepsilon(i)\sigma(j)X} = x_{rs}^{iX} \; K_{r*}^{\varepsilon(i)\sigma(j)X}$.

The coefficients are read in for each sex, for all regions of origin including the rest of the World region(s) and for all age groups from the first to the last (R.) They are not disaggregated by region of origin <u>and</u> region of destination. They are read in the format (10F8.6). The layout required is similar to the layout of c_{rs}^{jX} coefficients presented in Figure 33, except that q_{rs}^{jX} and x_{rs}^{iX} coefficients are needed for all regions and not only for the system of interest regions.

(18) The format card for infant migrants (format card 5)

This format is used to read the infant migrant data. It follows the same rules as the format card 1.

(19) The infant migrant cards.

If SWITCHBM is set equal to 1 the infant migrants are assumed to be disaggregated by age group of mother at the beginning of the period: $K_{rl}^{\beta(i)\sigma(j)X}$. The data is ordered by sex, all regions of origin (including the rest of the World region(s)) and all regions of destination (including the rest of the World region(s)), and all age groups of mother at the beginning of the period from the first fertile age group to the last fertile age group. The non-migrant data, when the region of origin and the region of destination are identical are not input.

The data are input as follows:

Sex 1, region of origin 1, region of destination 2: first fertile age group,..., last fertile age group.

region of origin 1, region of destination 3: first fertile age group,... ,last fertile age group.

⋮

region of origin 1, region of destination N: first fertile age group,..., last fertile age group.

region of origin 2, region of destination 1: first fertile age group,..., last fertile age group.

region of origin 2, region of destination 3: first fertile age group,..., last fertile age group.

⋮

region of origin 2, region of destination N: first fertile age group,..., last fertile age group.

region of origin N, region of destination N-1: first fertile age group,..., last fertile age group

Sex 2, region of origin 1, region of destination 2: first fertile age group,..., last fertile age group

⋮

region of origin 2, region of destination 1: first fertile age group,..., last fertile age group.

region of origin 2, region of destination 3: first fertile age group,..., last fertile age group.

⋮

region of origin N, region of destination N-1: first fertile age group,..., last fertile age group.

On each region of origin-region of destination card or set of cards, the data are ordered as in the example given in Figure 31.

If SWITCHBM is set equal to 2, the infant migrants are assumed to be aggregated over age group of mother: $K_{*1}^{\beta(i)\sigma(j)X}$. The data is ordered by sex by all the regions of origin (including the rest of the World region(s)) and by all the regions of destination (including the rest of the World region(s)). The non-migrant data, where the region of origin and the region of destination are identical, are input <u>in this case, and this case only, as dummies of zero</u>.

The data are input as follows:

Sex 1, region of origin 1: region of destination 1,2,3,4,...,N
region of origin 2: region of destination 1,2,3,4,...,N
region of origin 3: region of destination 1,2,3,4,...,N

⋮

region of origin N: region of destination 1,2,3,4,...,N
Sex 2, region of origin 1: region of destination 1,2,3,4,...,N

⋮

region of origin N: region of destination 1,2,3,4,...,N

An example of the required layout is given in Figure 36.

(20) The v_{r1}^{i} coefficients

Only if SWITCHV is set equal to 1 are these coefficients required. They accomplish the disaggregation: $K_{r1}^{\beta(i)\sigma(j)X} = v_{r1}^{i} K_{*1}^{\beta(i)\sigma(j)X}$. (Note that $\sum_r v_{r1} = 1$.) The v_{r1}^{i} coefficients are read in for all regions excluding the rest of the World region(s) and for all age groups from the first fertile age group to the last fertile age group as follows:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
							0			1	1	2	0	0	0			1	1	3	0	0	0																																
		1	2	1	0	0	0								0			1	2	3	0	0	0																																
		1	3	1	0	0	0			1	3	2	0	0	0								0																																
							0			2	1	2	0	0	0			2	1	3	0	0	0																																
		2	2	1	0	0	0								0			2	2	3	0	0	0																																
		2	3	1	0	0	0			2	3	2	0	0	0								0																																

The system is composed of 3 regions (including the rest of the World).
The reading format is 10F8.0
The number of male infants (which are in age group 1) who migrate from region 1 to region 2 is: 112000, from region 1 to region 3: 113000.
The number of male infants who migrate from region 2 to region 1 is: 121000, from region 2 to region 3: 123000.
The number of female infants who migrate from region 1 to region 2 is: 212000, from region 1 to region 3: 213000, from region 2 to region 3: 223000.......

Figure 36. An example of infant migrant data input.

Region 1: first fertile age group,..., last fertile age group.
Region 2: first fertile age group,..., last fertile age group.

⋮

Region IN: first fertile age group,..., last fertile age group.

The v^i_{r1} coefficients are not disaggregated by sex. They are used in the format (10F8.6). Figure 37 shows an example of the layout required.

(21) The p_{rs} coefficients

They are always inputs in order to carry out the disaggregation $K^{\varepsilon(i)\sigma(i)X}_{rs} = p_{rs}\ K^{\varepsilon(i)\sigma(i)X}_{r*}$. The p_{rs} coefficients are read in for all age groups at the beginning of the period and all age groups at the end of the period. They are not disaggregated by sex nor by regions. They are read in the format (10F8.6): as follows. (age group 1, age group 1), (age group 1, age group 2), (age group 2, age group 2),..., (age group R - 1 age group R), (age group R, age group R). The input data have the form of one region card or cards shown in Figure 33.

(22) The e^i_{r1} coefficients

These are needed only if SWITCHE has been set to 1. They accomplish the disaggregation $K^{\beta(i)\delta(j)X}_{r1} = e^i_{r1}\ K^{\beta(i)\delta(j)X}_{*1}$.

The e^i_{r1} coefficients have the same characteristics and are input in the same way as the v^i_{r1} coefficients.

4.6 A summary list of inputs and an example

We summarize the inputs required for the programme in Figure 38. This can serve as a check for those who have familiarized themselves with section 4 of the paper. In Figure 39 we show an example of a very simple data file that might be input to the programme, consisting of only 31 records or cards. This can serve as a guide to formats and layouts required.

0.1300	0.1400	0.1500	0.1600	0.1700	0.1800	0.1900	0.1000
0.2300	0.2400	0.2500	0.2600	0.2700	0.2800	0.2900	0.2000
0.3300	0.3400	0.3500	0.3600	0.3700	0.3800	0.3900	0.3000

The system contains 3 regions (excluding the rest of the World).

There are 8 fertile age groups. (age group 3,4,5,....10).

The reading format is, as for all coefficients; 10F8.6.

The proportion of infant migrants moving from region 1 who have been born to mothers in age group (at the beginning of the period) 3 is; 0.1300; the proportion born to mothers in age group 4 is 0.1400; the proportion born to mothers in age group 5 is 0.1500. We have: 0.1300 + 0.1400 + 0.1500 + ... 0.1000 = 1.

The proportion of infant migrants, moving from region 2, who are born to mothers in age group 3 is 0.2300, the proportion born to mothers in age group 4 is 0.2400, and so on. The proportions for all age groups of mother sum to 1.

Figure 37. An example of v^{i}_{r1} coefficients input (not disaggregated by age at the end of the period).

Figure 38. A summary list of the input required

Number	Item	General Format and comments	Figure to consult	Records/cards in the Figure 39 example
(1)	TITLE CARDS	3 cards, 80 columns A format	26	0- 2
(2)	SWITCH CARD	13I4. 13 switches or parameters must be set.	27,28	3
(3)	REGION NAME CARD(S)	One name per region, in format (10A8)	29	4
(4)	AGE GROUP NAME CARD(S)	One name per age group, in format (10A8)	30	5
(5)	FORMAT CARD FOR POPULATION STOCKS	Real number format in parentheses	See text of 4.6	6
(6)	POPULATION STOCKS CARD(S)	Population stocks at start of the period by sex, region, and age groups	31	7- 8
(7)	FORMAT CARD FOR BIRTHS	Real number format in parentheses	See text of 4.6	9
(8)	BIRTH CARDS	If SWITCHBIRTH = 1 $K_{**}^{\beta(i)*(*)}X_{(u)}$ are expected; If SWITCHBIRTH = 2 $K_{r*}^{\beta(i)*(*)}X_{(*)}$ are expected; If SWITCHBIRTH = 3 $K_{r*}^{\beta(i)*(*)}X_{(u)}$ are expected	32	10-11 (SWITCHBIRTH=1)
(9)	BIRTH COEFFICIENTS CARDS (f_{ru}^{i})	If SWITCHBIRTH = 1 f_{ru}^{i} coefficients are expected; If SWITCHBIRTH = 2 no coefficients are expected; If SWITCHBIRTH = 3, no coefficients are expected. The format is F8.6 for each coefficient	33	12-13

Figure 38 (continued)

Number	Item	General format and comments	Figure to consult	Records/cards in Figure 39 example
(10)	FORMAT CARD FOR DEATHS	Real number format in parentheses.	See text of 4.6	14
(11)	DEATHS CARDS	If SWITCHDEATH = 1, $K_{*s}^{*(*)\delta(j)X}$ are expected; If SWITCHDEATH = 2, $K_{rs}^{*(*)\ (j)X}$ are expected.	31,32	15-16 (SWITCHDEATH=1)
(12)	DEATHS COEFFICIENTS CARDS (c_{rs}^{jX})	These are required only if SWITCHDEATH = 1. In format 10F8.6	33	17-18
(13)	INFANT DEATHS COEFFICIENTS CARDS (c_{01}^{jX})	These are required only if SWITCHDEATH = 1. In format 10F8.6	34	19
(14)	INFANT DEATHS CARDS	These are required only if SWITCHDEATH = 2. In format 10F8.0	35	
(15)	FORMAT CARD FOR MIGRANTS	Real number format in parentheses.	See text of 4.6	20
(16)	MIGRANT CARDS	If SWITCHMIG = 1, $K_{*s}^{\varepsilon(i)\sigma(j)X}$ are expected If SWITCHMIG = 2, $K_{r*}^{\varepsilon(i)\sigma(j)X}$ are expected.	31	21-22 (SWITCHMIG=1)
(17)	MIGRANT COEFFICIENT CARDS $(q_{rs}^{jX},\ x_{rs}^{iX})$	If SWITCHMIG = 1, q_{rs}^{jX} coefficients are expected If SWITCHMIG = 2, x_{rs}^{iX} coefficients are expected. In format 10F8.6	33	23-24

Figure 38 (continued)

Number	Item	General format and comments	Figure to consult	Records/cards in Figure 39 example
(18)	FORMAT CARD FOR INFANT MIGRANTS	Real number format in parentheses	See text of 4.6	25
(19)	INFANT MIGRANT CARDS	If SWITCHBM = 1, $K_{r1}^{\beta(i)\sigma(j)X}$ are expected If SWITCHBM = 2, $K_{*1}^{\beta(i)\sigma(j)X}$ are expected.	31,36	26-27 (SWITCHBM=1)
(20)	INFANT MIGRANT COEFFICIENT (v_{r1}^{j})	Required only if SWITCHV = 1, in format 10F8.6.	37	
(21)	NON-MIGRANT OR SURVIVING STAYER COEFFICIENTS	Always required. In format 10F8.6.	33	28
(22)	INFANT DEATH COEFFICIENTS (e_{r1}^{i})	Required only if SWITCHE = 1. In format 10F8.6	33	29-30

Figure 38. A summary list of the inputs required

<u>DOCUMENT EARTHFIN</u>

Card
Number

```
 0   POPULATION OF MIDDLE EARTH
 1   EXAMPLE DATA
 2   JUNE 1975
 3     1   1   1   1   2   4   1   3   1   2   1   0   0
 4 MIDEARTH REST W
 5  0-25     25-50     50-75    75--100
 6 (4F4.0)
 7 1000 900 500 100
 8 400036002000 400
 9 (4F4.0)
10  7051439  67   0
11 33285590 426   0
12 1.0000000.5997000.4003000.7015000.2985000.0000000.000000
13 1.0000000.6000000.4000000.6995000.3005000.0000000.000000
14 (4F4.0)
15  142 192 468 197
16 110910491917 545
17 0.1056000.4010000.5990000.2991000.7009000.5990000.401000
18 0.1001000.4004000.5996000.2999000.7001000.6000000.400000
19 0.8944000.899900
20 (4F4.0)
21    0 100 135  28
22    0 200 270  55
23 0.0000001.0000000.0000001.0000000.0000000.8920000.1071000.000000
24 0.0000001.0000000.0000001.0000000.0000000.9091000.0909000.000000
25 (3F4.0)
26   67  40   1
27  136  77   1
28 0.0000001.0000000.0000001.0000000.0000001.0000001.0000000.000000
29 0.7087  0.2835  0.0079  0.000000
30 0.7155000.2705000.0140000.000000
31 ****
32
```

Figure 39 <u>An example of a data file</u>

5. Concluding remarks

In this paper we have presented the structure of and data inputs necessary for a programme to construct age-sex disaggregated multi-regional population accounts. The programme may be used to estimate such accounts for two sexes, for up to twenty age groups and for twelve regions. The user of the programme will find it useful to assemble the programme outputs into his own accounts charts. Only then will the full structure and potential for further use of multi-regional population accounts be apparent.

One final comment needs to be made. We have not in the accounts based model on which this programme is based made use of any information on the end of period population to constrain the accounts estimate. Users may wish to add this further constraint through use of a balancing factor or RAS routine. Alternatively, and this is a fairly frequent occurrence in the British situation, the user may wish to believe his externally derived final population vector and not to believe his initial population estimate. This might be the situation for the 1966-1971 intercensal period: the 1966 Sample Census suffers from severe underenumeration compared with the 1971 (full) Census . The results of DAME for surviving stayers and the initial population can be corrected by the difference between the programme's final population estimate and that of the external source. The user may wish to add this option to the existing programme. Be sure to let the authors have a copy of the routine!

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Appendix A. Possible inputs to the programme: examples for the Shire and rest of Middle Earth

A set of tables has been prepared for the Shire and rest of Middle Earth example to show some of the different combinations of data input that can be handled by the programme. Copies of these tables can be supplied by the authors to interested users.

Users of the University of Leeds 1906A computer or users with access to it may wish to produce their own listings of the input files for these examples. The files are stored under the : GEOLIB username and may be accessed by a list file command

LF‸:GEOLIB.filename,*LP,NU.

The accompanying table gives the filename and the characteristics of the input.

Appendix B. A full listing of the FORTRAN text of DAME

A full listing of the programme is available to interested readers. They should write to the authors at the School of Geography, University of Leeds.

University of Leeds users or users with access to the University of Leeds 1906A may wish to produce their own listing of the programme. The following instructions under the GEORGE operating system will produce a listing for the user.

Online	Offline
LN‸jobname,:username	JOB‸jobname,:username
LF‸GEOLIB.DAMES,*LP,NU	LF‸:GEOLIB.DAMES,*LP,NU
LT	EJ

A numbered listing of the FORTRAN text of the programme is produced.

Table A.1 Possible inputs to the programme

No.	Filename	Values of switches						Type of coefficient used					
		SWITCHBIRTH	SWITCHDEATH	SWITCHMIG	SWITCHE	SWITCHV	SWITCHRM	Birth	Death	Migrant	Infant migrant	Infant death	Exist-survive
I	DATADAME1	1	1	1	1	2	1	f^{i}_{ru}	c^{jx}_{rs}	q^{jx}_{rs}		e^{j}_{r1}	p_{rs}
II	ONEONE2	1	1	2	1	2	1	f^{i}_{ru}	c^{jx}_{rs}	x^{ix}_{rs}		e^{j}_{r1}	p_{rs}
III	ONETWO1	1	2	1	1	2	1	f^{i}_{ru}		q^{jx}_{rs}		e^{j}_{r1}	p_{rs}
IV	ONETWO2	1	2	2	1	2	1	f^{i}_{ru}		x^{i}_{rs}		e^{j}_{r1}	p_{rs}
V	TWOONE1	2	1	1	1	2	1		c^{jx}_{rs}	q^{jx}_{rs}		e^{j}_{r1}	p_{rs}
VI	TWOONE2	2	1	2	1	2	1		c^{ix}_{rs}	x^{ix}_{rs}		e^{j}_{r1}	p_{rs}
VII	TWOTWO1	2	2	1	1	2	1			q^{jx}_{rs}		e^{j}_{r1}	p_{rs}
VIII	TWOTWO2	2	2	2	1	2	1			x^{i}_{rs}		e^{j}_{r1}	p_{rs}
IX	THREEONE1	3	1	1	1	2	1		c^{jx}_{rs}	q^{jx}_{rs}		e^{j}_{r1}	p_{rs}
X	THREEONE2	3	1	2	1	2	1		c^{jx}_{rs}	x^{ix}_{rs}		e^{j}_{r1}	p_{rs}
XI	THREETWO1	3	2	1	1	2	1			q^{jx}_{rs}			p_{rs}
XII	THREETWO2	3	2	2	1	2	1			x^{ix}_{rs}		e^{j}_{r1}	p_{rs}
XIII	BM211	1	1	1	2	1	1	f^{i}_{ru}	c^{jx}_{rs}	q^{jx}_{rs}	v^{i}_{r1}		p_{rs}
XIV	BM212	1	1	1	2	1	2	f^{i}_{ru}	c^{jx}_{rs}	q^{jx}_{rs}	v^{o}_{r1}		p_{rs}
XV	BM221	1	1	1	2	2	1	f^{i}_{ru}	c^{jx}_{rs}	q^{jx}_{rs}		e^{j}_{r1}	p_{rs}

Appendix C. A listing of the full output of a run with Middle Earth data.

A listing of the full output from a run of the programme with Middle Earth data is available to interested readers. They should write to the authors at the School of Geography, University of Leeds.

University of Leeds users or users with access to the University of Leeds 1906A may wish to produce their own run and output. The following instructions under the GEORGE operating system will produce the necessary output:

Online

```
        LN‸jobname,:username
        CE‸FILE1(*DA,BUCK8,KWORDS32,RANDOM)
either  RJ‸jobname,PROG,JD(JT‸120,MZ‸200800), PARAM(FORTRAN-
        ‸:GEOLIB.DAMES,FILE*CRØ=:GEOLIB.DATADAME1,FILE*DA1=filename-
        (WRITE),TL‸120)
or      RJ‸jobname, PROG,JD(JT‸120,MZ‸200800),PARAM(BIN‸-
        ‸:GEOLIB.DAME,FILE*CRØ=:GEOLIB.DATADAME1,FILE*DAI= -
        filename (WRITE),TL‸120)
        LT
```

Note that the dash - within the PARAM list simply specifies end of a line.

Offline

```
        JOB‸jobname,:username
        CE‸FILE1(*DA,BUCK8,KWORDS32,RANDOM)
either  PROG‸FORTRAN‸:GEOLIB.DAMES,FILE*CRØ=:GEOLIB.DATADAME1,
        FILE*DA1=filename(WRITE),TL‸120,EXIT.
or      PROG‸BIN‸:GEOLIB.DAME,FILE*CRØ=:GEOLIB.DATADAME1,
        FILE*DA1=filename(WRITE),TL‸120,EXIT
        EJ
```

The first alternative given in either case (online or offline) refers to the FORTRAN version of DAME called DAMES (S for source); the second alternative refers to the BINARY version of DAME. Note that "filename" is the name of the file created in CE FILE1(*DA....) in which the full accounts matrix and the rates will be stored in the way specified in section 4.4.

Erratum

Appendix C

1. Replace "FILE1" in Online ... "CE‸FILE1(*DA,BUCK8,KWORDS32,RANDOM)" by "filename"

2. Replace "FILE1" in Offline... "CE‸FILE1(*DA,BUCK8,KWORDS32,RANDOM)" by "filename"

3. The filename thus specified should be the same as that designated in "FILE*DA1=filename (WRITE)".

Appendix D. A listing of the full output of a run with West Riding of Yorkshire data.

A listing of the full output of a run of the programme with West Riding of Yorkshire data is available to interested readers. They should write to the authors at the School of Geography, University of Leeds.

To produce his or her own run of the programme the University of Leeds or Leeds connected user should follow the instructions listed in Appendix C changing only ":GEOLIB.DATADAME1" to ":GEOLIB.DATADAME2".