

Working Paper 170

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

M. Plessis-Fraissard

and

P.H. Rees

School of Geography
University of Leeds
Leeds LS2 9JT.

November, 1976

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 section three of the longer paper and may be employed principally as a users' guide to the programme.

CONTENTS

Abstract

List of Figures

Acknowledgements

Sections

1. Introduction: the context of the programme
2. The theory of spatial demographic accounting: a brief review
 - 2.1 The accounts matrix
 - 2.2 The accounts based model
 - 2.3 The principal features of the programme
3. A description of the programme - see Working Paper 169
4. Users' notes on running the programme
 - 4.1 The type of computer on which the programme can be run
 - 4.2 The time, space and files needed to run the programme
 - 4.3 The output of the programme
 - 4.4 The output of the programme to a file
 - 4.5 The input
 - 4.5.1 The data required and the example of Middle Earth
 - 4.5.2 The switch for births data
 - 4.5.3 The switch for deaths data
 - 4.5.4 The switch for migrants
 - 4.5.5 The switches for infant migrants: the v and e coefficients
 - 4.5.6 Other coefficients needed: p_{rs}
 - 4.5.7 Other switches: IOUT
 - 4.5.8 The inputs summarized
 - 4.6 A summary list of the inputs and an example.

Appendices - See Working Paper 169

- A. Possible inputs to the programme: examples for Middle Earth.
- B. A full listing of the FORTRAN text of DAME.
- C. A listing of the full output of a run with Middle Earth data.
- D. A listing of the full output run with West Yorkshire data.

References.

List of Figures

1. The analysis framework in which DAME is embedded.
2. Age disaggregation of input data.
3. Typical elements of the demographic accounts matrix.
4. The correspondence between the algebraic variables and the FORTRAN variables.
5. The correspondence between the algebraic names for rates and populations at risk and the equivalent FORTRAN variables.
6. Coefficients used in the programme and their application.
7. Arrays used in the input and output processes.
8. FORTRAN names of the parameters giving the size of data arrays and the values of the switches.
9. Counters or indexes used in the programme.
10. The organization of the segments in the FORTRAN programme.
11. The general flow chart of the programme.
12. The general flow chart of the programme including the age iteration.
13. The complete flow chart of the programme including the age iteration.
14. The complete description of the direct access file.
15. The flow chart presenting the routine involved in reading large arrays from the file and their listing on a lineprinter via a subroutine.
16. The flow chart of the segment VECTOR.
17. The flow chart of the segment BALFAC.
18. The flow chart of the segment COEFF.
19. The flow chart of the segment PARDEATH.
20. The flow chart of the segment PARDEATHAG1.
21. The flow chart of the segment MINORFLOW.
22. The flow chart of the segment ARRAYKJ.
- 23a. Summary of the programme description.
- 23b. The output of the programme for the example of the Shire and the rest of Middle Earth.
24. The information output to a file.
25. The possible values of SWITCHBM, SWITCHHV, AND SWITCHE.
26. An example of the title cards.
27. The switch card.
28. An example of the switch card.
29. An example of the names of regions input.
30. An example of the names of age groups input.
31. An example of population stock data input.
32. An example of birth data input.
33. An example of f_{ru}^i and c_{rs}^{jx} coefficients input (disaggregated by region).

34. An example of C_{01} coefficients input
35. An example of infant death data input.
36. An example of infant migrant.
37. An example of V_{r1}^i coefficients input (not disaggregated by age at the end of the period).
38. A summary list of the inputs required.
39. An example of a data file.

Acknowledgments

The authors would like to acknowledge the support of the Social Science Research Council and the Centre for Computer Studies of the University of Leeds without which it would not have been possible to write the computer programme described in this paper. The Social Science Research, through their support of the project entitled "The spatial analysis of demographic growth in British regions" (Grant HR2914/2), enabled M. Plessis-Fraissard, research officer on the project, to work on the programme for about 18 months. The Centre for Computer Studies provided considerable resources on the 1906A Leeds computer for programme implementation, debugging and development and many hours of patient advice.

Our thanks are also due to Mrs. Shirley Dransfield for a splendid job of typing and to Mr. Gordon Bryant for much help with the figures.

1. Introduction: the context of the programme

The majority of computer programmes written in the course 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

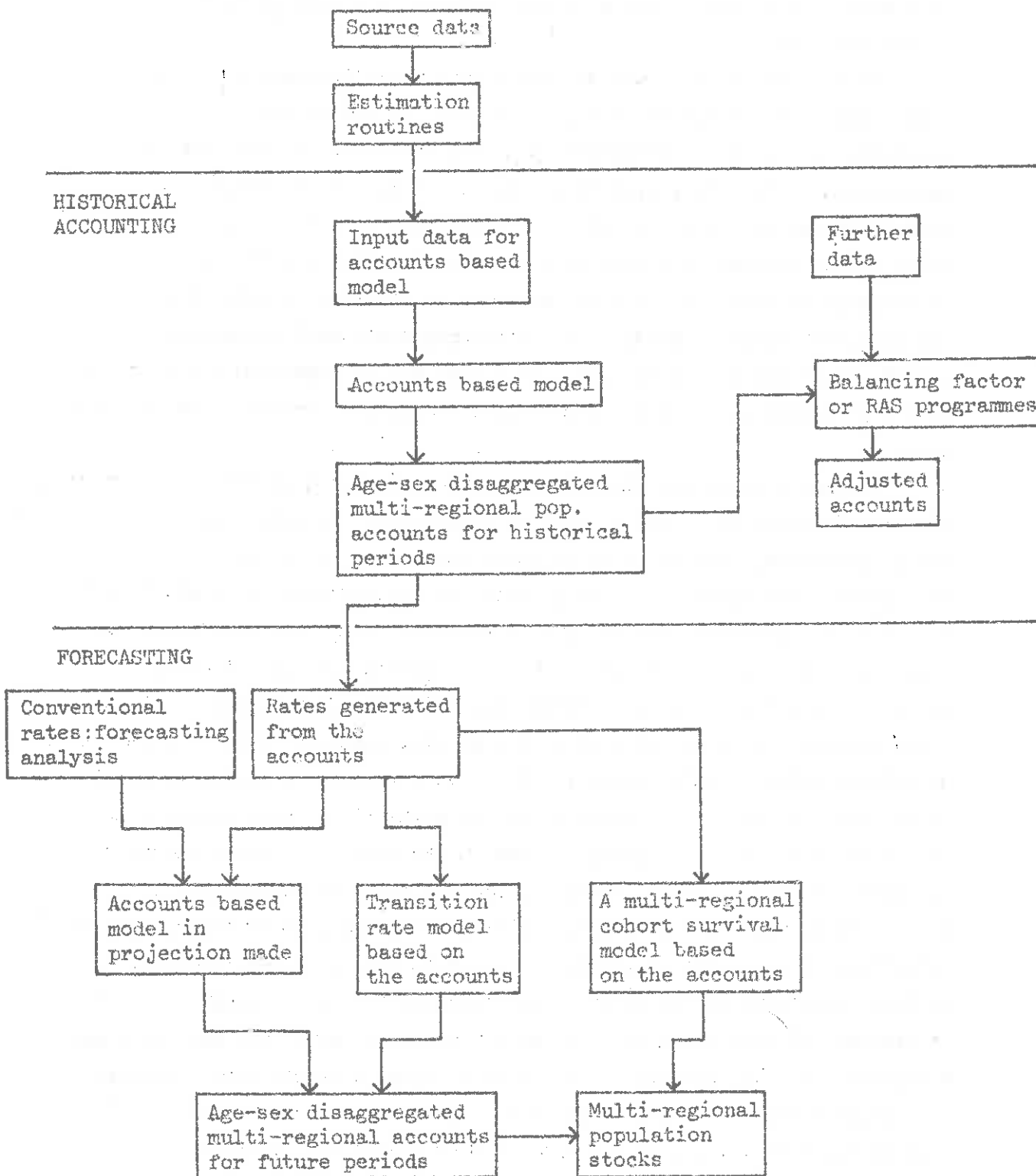
* In general, when we refer to "programme" in the text, we mean "computer programme"

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.

ESTIMATION

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:

$$\underline{K} = \begin{bmatrix} \underline{K}_{ES} & \underline{K}_{ED} \\ \underline{K}_{BS} & \underline{K}_{BD} \end{bmatrix} \quad (1)$$

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

* 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

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

and the other submatrices, \underline{K}_{ED} , \underline{K}_{ES} 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:

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

where $\underline{K}_{rr}^{\epsilon(i)\sigma(j)}$, an element of \underline{K}_{ES}^{ij} refers to the number of persons existing in region i , $\epsilon(i)$, 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 $K_{rr+1}^{\epsilon(i)\sigma(j)}$. 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 $K_{RR}^{\epsilon(i)\sigma(j)}$; 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 $K_{rr}^{\epsilon(i)\delta(j)}$ and $K_{rr+1}^{\epsilon(i)\delta(j)}$ 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

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

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 sex: \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, $i=1, \dots, N$, 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):

$$\underline{K} = \begin{array}{c|ccc|ccc} & \underline{K}^{11} & \underline{K}^{12} & \dots & \underline{K}^{1M} & \underline{K}^{1M+1} & \dots & \underline{K}^{1N} \\ & \underline{K}^{21} & \underline{K}^{22} & \dots & \underline{K}^{2M} & \underline{K}^{2M+1} & \dots & \underline{K}^{2N} \\ & \underline{K}^{M1} & \underline{K}^{M2} & \dots & \underline{K}^{MM} & \underline{K}^{MN+1} & \dots & \underline{K}^{MN} \\ \hline & \underline{K}^{M+11} & \underline{K}^{M+12} & \dots & \underline{K}^{MHN} & 0 & \dots & 0 \\ & \underline{K}^{N1} & \underline{K}^{N2} & \dots & \underline{K}^{NM} & 0 & \dots & 0 \end{array} \quad (5)$$

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:

$\frac{11}{K_{ES}} \dots \frac{1M}{K_{ES}}$	$\frac{1M+1}{K_{ES}} \dots \frac{1N}{K_{ES}}$	$\frac{11}{K_{ED}} \dots \frac{1M}{K_{ED}}$	$\frac{1M+1}{K_{ED}} \dots \frac{1N}{K_{ED}}$	$\times i =$	$\frac{1}{K_E}$	Initial Populations
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots	
$\frac{M1}{K_{ES}} \dots \frac{MM}{K_{ES}}$	$\frac{MM+1}{K_{ES}} \dots \frac{MN}{K_{ES}}$	$\frac{M1}{K_{ED}} \dots \frac{MM}{K_{ED}}$	$\frac{MM+1}{K_{ED}} \dots \frac{MN}{K_{ED}}$	\vdots	$\frac{M}{K_E}$	Immigrants
$\frac{M+11}{K_{ES}} \dots \frac{M+1M}{K_{ES}}$	0 ... 0	$\frac{M+11}{K_{ED}} \dots \frac{M+1M}{K_{ED}}$	0 ... 0	$\frac{M+1}{K_E}$	$\frac{M+1}{K_E}$	
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots	Births
$\frac{N}{K_{ES}} \dots \frac{NM}{K_{ES}}$	0 ... 0	$\frac{M1}{K_{ED}} \dots \frac{NM}{K_{ED}}$	0 ... 0	$\frac{N}{K_E}$	$\frac{N}{K_E}$	
$\frac{11}{K_{ES}} \dots \frac{1M}{K_{BS}}$	$\frac{1M+1}{K_{BS}} \dots \frac{1N}{K_{BS}}$	$\frac{11}{K_{BD}} \dots \frac{1M}{K_{BD}}$	$\frac{1M+1}{K_{BD}} \dots \frac{1N}{K_{BD}}$	$\frac{1}{K_B}$	$\frac{1}{K_B}$	Immigrants
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots	
$\frac{M1}{K_{BS}} \dots \frac{MM}{K_{BS}}$	$\frac{MM+1}{K_{BS}} \dots \frac{MN}{K_{BS}}$	$\frac{M1}{K_{BD}} \dots \frac{MM}{K_{BD}}$	$\frac{MM+1}{K_{BD}} \dots \frac{MN}{K_{BD}}$	$\frac{M}{K_B}$	$\frac{M}{K_B}$	Infant immigrants
$\frac{M+11}{K_{BS}} \dots \frac{M+1M}{K_{BS}}$	0 ... 0	$\frac{M+11}{K_{BD}} \dots \frac{M+1M}{K_{BD}}$	0 ... 0	$\frac{M+1}{K_B}$	$\frac{M+1}{K_B}$	
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots	
$\frac{N1}{K_{BS}} \dots \frac{NM}{K_{BS}}$	0 ... 0	$\frac{N1}{K_{BD}} \dots \frac{NM}{K_{BD}}$	0 ... 0	$\frac{N}{K_B}$	$\frac{N}{K_B}$	

and

$\frac{11}{K_{ES}} \dots \frac{1M}{K_{ES}}$	$\frac{1M+1}{K_{ES}} \dots \frac{1N}{K_{ES}}$	$\frac{11}{K_{ED}} \dots \frac{1M}{K_{ED}}$	$\frac{1M+1}{K_{ED}} \dots \frac{1N}{K_{ED}}$
\vdots	\vdots	\vdots	\vdots
$\frac{M1}{K_{ES}} \dots \frac{MM}{K_{ES}}$	$\frac{MM+1}{K_{ES}} \dots \frac{MN}{K_{ES}}$	$\frac{M1}{K_{ED}} \dots \frac{MM}{K_{ED}}$	$\frac{MM+1}{K_{ED}} \dots \frac{MN}{K_{ED}}$
$\frac{M+11}{K_{ES}} \dots \frac{M+1M}{K_{ES}}$	0 ... 0	$\frac{M+11}{K_{ED}} \dots \frac{M+1M}{K_{ED}}$	0 ... 0
\vdots	\vdots	\vdots	\vdots
$\frac{N1}{K_{ES}} \dots \frac{NM}{K_{ES}}$	0 ... 0	$\frac{N1}{K_{ED}} \dots \frac{NM}{K_{ED}}$	0 ... 0
$\frac{11}{K_{BS}} \dots \frac{1M}{K_{BS}}$	$\frac{1M+1}{K_{BS}} \dots \frac{1N}{K_{BS}}$	$\frac{11}{K_{BD}} \dots \frac{1M}{K_{BD}}$	$\frac{1M+1}{K_{BD}} \dots \frac{1N}{K_{BD}}$
\vdots	\vdots	\vdots	\vdots
$\frac{M1}{K_{BS}} \dots \frac{MM}{K_{BS}}$	$\frac{MM+1}{K_{BS}} \dots \frac{MN}{K_{BS}}$	$\frac{M1}{K_{BD}} \dots \frac{MM}{K_{BD}}$	$\frac{MM+1}{K_{BD}} \dots \frac{MN}{K_{BD}}$
$\frac{M+11}{K_{BS}} \dots \frac{M+1M}{K_{BS}}$	0 ... 0	$\frac{M+11}{K_{BD}} \dots \frac{M+1M}{K_{BD}}$	0 ... 0
\vdots	\vdots	\vdots	\vdots
$\frac{N1}{K_{BS}} \dots \frac{NM}{K_{BS}}$	0 ... 0	$\frac{N1}{K_{BD}} \dots \frac{NM}{K_{BD}}$	0 ... 0

 $\times i^1$

$$= \left[\begin{array}{cc} \frac{1}{K_S} \dots \frac{M}{K_S} & \frac{M+1}{K_S} \dots \frac{N}{K_S} \\ \text{Final} & \text{Surviving} \\ \text{Populations} & \text{Emigrants} \end{array} \right] \left[\begin{array}{cc} \frac{1}{K_D} \dots \frac{M}{K_D} & \frac{M+1}{K_D} \dots \frac{N}{K_D} \\ \text{Deaths} & \text{Non surviving} \\ & \text{Emigrants} \end{array} \right]$$

(6)

(7)

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,

$$K_{rr}^{\epsilon(i)\sigma(i)} = p_{rr} K_{r*}^{\epsilon(i)\sigma(i)} \quad (8)$$

$$K_{rr+1}^{\epsilon(i)\sigma(i)} = p_{rr+1} K_{r*}^{\epsilon(i)\sigma(i)} \quad (9)$$

(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	*	-	$K_{r*}^{\beta(i)*} (K_{r*}^{*(*)m(i)})$	$K_{r*}^{\epsilon(i)\sigma(j)}_{i \neq j}$	$K_{r*}^{\beta(i)\sigma(j)}_{i \neq j}$
r	s	$K_{rs}^{*(*)\delta(i)}$	$K_{r*}^{\beta(i)*} (K_{rs}^{*(*)m(i)})$	-	-
*	s	$K_{*s}^{*(*)\delta(i)}$	$K_{**}^{\beta(i)*} (K_{*s}^{*(*)m(i)})$	$K_{*s}^{\epsilon(i)\sigma(j)}_{i \neq j}$	-

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 bir
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, $K_{rs}^{\epsilon(i)\delta(i)X}$; and first
estimates of surviving migrants or stayers $K_{rs}^{\epsilon(i)\sigma(j)X}$

- 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.
- $K_{rs}^{\epsilon(i)\delta(j)X}$: 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.
- $K_{*s}^{\epsilon(i)\sigma(j)X}$: 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.
- $K_{r*}^{\epsilon(i)\delta(*)X}$: 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.
- $K_{r*}^{\epsilon(i)\delta(R)X}$: 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.
- $K_{*s}^{\epsilon(*)\delta(j)X}$: 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.
- $K_{*s}^{\epsilon(R)\delta(j)X}$: 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.
- $K_{rl}^{\beta(i)\sigma(j)X}$: 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.
- $K_{rl}^{\beta(i)\sigma(*)X}$: 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.
- $K_{rl}^{\beta(i)\sigma(R)X}$: 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.
- $K_{rl}^{\beta(*)\sigma(j)X}$: 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.

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

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 $K_{11}^{\epsilon(i)\delta(j)1}$ 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 $K_{r*}^{\epsilon(i)*(*)X}$ 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_{rl}^{*iX} . They are written one after another, as follows: `WRITE(1'IREC)(QWJ(I,LAG),I=1,IN),((QAIL(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 $d_{rl}^{\beta(*)jX}$ are written according to the rules presented for all other records.

4.5 The input.

4.5.1 The data required and the example of Middle Earth

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 disaggregate 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)
	$d_{rl}^{\beta(*)}jX$	QAIL(12,8,2)	QAIL(I,LAG,M)
6+((LAG-1)*10)	$d_{rs}^{\epsilon(*)}jX$	QAI(12,10,2,2)	QAI(I,LAG,K,M)
7+((LAG-1)*10)	$K_{rs}^{\epsilon(i)}\delta(j)_1$	K12(12,12,10,2,2)	K12(I,J,LAG,K,M)
8+((LAG-1)*10)	$K_{rs}^{\epsilon(i)}\delta(j)_2$	K12(12,12,10,2,2)	K12(I,J,LAG,K,M)
9+((LAG-1)*10)	$K_{rs}^{\epsilon(i)}\sigma(j)_1$	K12(12,12,10,2,2)	K11(I,J,LAG,K,M)
10+((LAG-1)*10)	$K_{rs}^{\epsilon(i)}\sigma(j)_2$	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	$K_{r*}^{\epsilon(i)}^{(*)}X$	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':~~I~~,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 The switch for birth data

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 and age of mother at time of birth. No birth coefficients are needed in this case.

4.5.3 The switch for death data

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

$K_{11}^{\epsilon(*)\delta(j)X} = (1 - C_{01}^{jX}) K_{*1}^{*(*)\delta(j)X}$. 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: $K_{rs}^{\epsilon(*)\delta(j)X}$

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 The switch for migrants

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 $K_{*s}^{\epsilon(i)\sigma(j)X}$

or the number of migrants by sex by age at the end of the period;

q_{rs}^{iX} coefficients which effect the deconsolidation

$K_{rs}^{\epsilon(i)\sigma(j)X} = q_{rs}^{iX} K_{*s}^{\epsilon(i)\sigma(j)X}$, where q is disaggregated by region of

origin (including the rest of the world) and sex.

If SWITCHMIG equals 2, the data required are:

$K_{r*}^{\epsilon(i)\sigma(j)X}$ or the number of migrants by sex by age at the beginning

of the period; x_{rs}^{iX} coefficients which carry out the deconsolidation

$K_{rs}^{\epsilon(i)\sigma(j)X} = x_{rs}^{iX} K_{r*}^{\epsilon(i)\sigma(j)X}$ where x is disaggregated by region of origin

(including the rest of the world) and sex.

4.5.5 The switches for infant migrants: the v and e coefficients

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 $K_{rl}^{\beta(i)\sigma(j)X}$. 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 $K_{*1}^{\beta(i)\sigma(j)X}$ 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:

$$K_{rl}^{\beta(i)\sigma(j)X} = v_{rl}^i \times K_{*1}^{\beta(i)\sigma(j)X}$$
 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 "inconsistencies 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 $K_{rs}^{\epsilon(i)\sigma(i)}X_{rs} = p_{rs} K_{r*}^{\epsilon(i)\sigma(i)}X$. 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.

FORTRAN STATEMENT

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		
				M	U	L	T	I	R	E	G	I	O	N	A	L	A	C	C	O	U	N	T																											
				R	E	G	I	O	N	S																																								
				2	0			Q	U	I	N	Q	U	E	N	N	I	A	L		A	G	E																											

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 $K_{r*}^{e(i)*(*)}X$ 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, age groups 1,2,3,4,5,6...,R.

The number of region in the rest of the world is $RW = 1$.

There are R age groups = 20

The first fertile age group is $\text{LBIRTH1} = 3$, the last fertile age group is $\text{LBIRTH2} = 10$.

The birth data are disaggregated by age of mother at birth (SWITCHBIRTH = 1).

The death data are given by age at death ($\text{SWITCHDEATH} = 1$).

The migration data are given by age at the end of the period (SWITCHIG = 1).

The migration data are given by age at the father (SWITCHM = 1). The birth and migration are disaggregated by age of mother (SWITCHM = 1).

No V_r coefficients are given (SWITCH = 2).

e Coefficients are provided (SWITCH = 1).

r. No intermediate results will be written (IOUT > 0)

Figure 28. An example of the Switchcard

STATEMENT		PORTMAN STATEMENT		IDENTIFICATION SEQUENCE	
1	2	3	4	5	6
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	69	70	71	72
73	74	75	76	77	78
79	80	81	82	83	84
85	86	87	88	89	90
91	92	93	94	95	96
97	98	99	100	101	102
103	104	105	106	107	108
109	110	111	112	113	114
115	116	117	118	119	120
121	122	123	124	125	126
127	128	129	130	131	132
133	134	135	136	137	138
139	140	141	142	143	144
145	146	147	148	149	150
151	152	153	154	155	156
157	158	159	160	161	162
163	164	165	166	167	168
169	170	171	172	173	174
175	176	177	178	179	180
181	182	183	184	185	186
187	188	189	190	191	192
193	194	195	196	197	198
199	200	201	202	203	204
205	206	207	208	209	210
211	212	213	214	215	216
217	218	219	220	221	222
223	224	225	226	227	228
229	230	231	232	233	234
235	236	237	238	239	240
241	242	243	244	245	246
247	248	249	250	251	252
253	254	255	256	257	258
259	260	261	262	263	264
265	266	267	268	269	270
271	272	273	274	275	276
277	278	279	280	281	282
283	284	285	286	287	288
289	290	291	292	293	294
295	296	297	298	299	300
301	302	303	304	305	306
307	308	309	310	311	312
313	314	315	316	317	318
319	320	321	322	323	324
325	326	327	328	329	330
331	332	333	334	335	336
337	338	339	340	341	342
343	344	345	346	347	348
349	350	351	352	353	354
355	356	357	358	359	360
361	362	363	364	365	366
367	368	369	370	371	372
373	374	375	376	377	378
379	380	381	382	383	384
385	386	387	388	389	390
391	392	393	394	395	396
397	398	399	400	401	402
403	404	405	406	407	408
409	410	411	412	413	414
415	416	417	418	419	420
421	422	423	424	425	426
427	428	429	430	431	432
433	434	435	436	437	438
439	440	441	442	443	444
445	446	447	448	449	450
451	452	453	454	455	456
457	458	459	460	461	462
463	464	465	466	467	468
469	470	471	472	473	474
475	476	477	478	479	480
481	482	483	484	485	486
487	488	489	490	491	492
493	494	495	496	497	498
499	500	501	502	503	504
505	506	507	508	509	510
511	512	513	514	515	516
517	518	519	520	521	522
523	524	525	526	527	528
529	530	531	532	533	534
535	536	537	538	539	540
541	542	543	544	545	546
547	548	549	550	551	552
553	554	555	556	557	558
559	560	561	562	563	564
565	566	567	568	569	570
571	572	573	574	575	576
577	578	579	580	581	582
583	584	585	586	587	588
589	590	591	592	593	594
595	596	597	598	599	600
601	602	603	604	605	606
607	608	609	610	611	612
613	614	615	616	617	618
619	620	621	622	623	624
625	626	627	628	629	630
631	632	633	634	635	636
637	638	639	640	641	642
643	644	645	646	647	648
649	650	651	652	653	654
655	656	657	658	659	660
661	662	663	664	665	666
667	668	669	670	671	672
673	674	675	676	677	678
679	680	681	682	683	684
685	686	687	688	689	690
691	692	693	694	695	696
697	698	699	700	701	702
703	704	705	706	707	708
709	710	711	712	713	714
715	716	717	718	719	720
721	722	723	724	725	726
727	728	729	730	731	732
733	734	735	736	737	738
739	740	741	742	743	744
745	746	747	748	749	750
751	752	753	754	755	756
757	758	759	760	761	762
763	764	765	766	767	768
769	770	771	772	773	774
775	776	777	778	779	780
781	782	783	784	785	786
787	788	789	790	791	792
793	794	795	796	797	798
799	800	801	802	803	804
805	806	807	808	809	810
811	812	813	814	815	816
817	818	819	820	821	822
823	824	825	826	827	828
829	830	831	832	833	834
835	836	837	838	839	840
841	842	843	844	845	846
847	848	849	850	851	852
853	854	855	856	857	858
859	860	861	862	863	864
865	866	867	868	869	870
871	872	873	874	875	876
877	878	879	880	881	882
883	884	885	886	887	888
889	890	891	892	893	894
895	896	897	898	899	900
901	902	903	904	905	906
907	908	909	910	911	912
913	914	915	916	917	918
919	920	921	922	923	924
925	926	927	928	929	930
931	932	933	934	935	936
937	938	939	940	941	942
943	944	945	946	947	948
949	950	951	952	953	954
955	956	957	958	959	960
961	962	963	964	965	966
967	968	969	970	971	972
973	974	975	976	977	978
979	980	981	982	983	984
985	986	987	988	989	990
991	992	993	994	995	996
997	998	999	1000	1001	1002
1003	1004	1005	1006	1007	1008
1009	1010	1011	1012	1013	1014
1015	1016	1017	1018	1019	1020
1021	1022	1023	1024	1025	1026
1027	1028	1029	1030	1031	1032
1033	1034	1035	1036	1037	1038
1039	1040	1041	1042	1043	1044
1045	1046	1047	1048	1049	1050
1051	1052	1053	1054	1055	1056
1057	1058	1059	1060	1061	1062
1063	1064	1065	1066	1067	1068
1069	1070	1071	1072	1073	1074
1075	1076	1077	1078	1079	1080
1081	1082	1083	1084	1085	1086
1087	1088	1089	1090	1091	1092
1093	1094	1095	1096	1097	1098
1099	1100	1101	1102	1103	1104
1105	1106	1107	1108	1109	1110
1111	1112	1113	1114	1115	1116
1117	1118	1119	1120	1121	1122
1123	1124	1125	1126	1127	1128
1129	1130	1131	1132	1133	1134
1135	1136	1137	1138	1139	1140
1141	1142	1143	1144	1145	1146
1147	1148	1149	1150	1151	1152
1153	1154	1155	1156	1157	1158
1159	1160	1161	1162	1163	1164
1165	1166	1167	1168	1169	1170
1171	1172	1173	1174	1175	1176
1177	1178	1179	1180	1181	1182
1183	1184	1185	1186	1187	1188
1189	1190	1191	1192	1193	1194
1195	1196	1197	1198	1199	1200
1201	1202	1203	1204	1205	1206
1207	1208	1209	1210	1211	1212
1213	1214	1215	1216	1217	1218
1219	1220	1221	1222	1223	1224
1225	1226	1227	1228	1229	1230
1231	1232	1233	1234	1235	1236
1237	1238	1239	1240	1241	1242
1243	1244	1245	1246	1247	1248
1249	1250	1251	1252	1253	1254
1255	1256	1257	1258	1259	1260
1261	1262	1263	1264	1265	1266
1267	1268	1269	1270	1271	1272
1273	1274	1275	1276	1277	1278
1279	1280	1281	1282	1283	1284
1285	1286	1287	1288	1289	1290
1291	1292	1293	1294	1295	1296
1297	1298	1299	1300	1301	1302
1303	1304	1305	1306	1307	1308
1309	1310	1311	1312	1313	1314
1315	1316	1317	1318	1319	1320
1321	1322	1323	1324	1325	1326
1327	1328	1329	1330	1331	1332
1333	1				

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 $C = 1, 2, \dots$), 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 of 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.

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) The birth coefficient card.

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) The format card for deaths (format card 3)

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

(11) Deaths data card

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 $c_{r-lr} + c_{rr} = 1.000$). 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.

STATEMENT N WHEN		INNO		FORTRAN STATEMENT		IDENTIFICATION SEQUENCE	
1	2	3	4	5	6	7	8
0.133	0.134	0.144	0.145	0.155	0.156	0.166	0.167
0.188	0.189	0.199	0.190	0.100			0.177
0.233	0.234	0.244	0.245	0.255	0.256	0.266	0.277
0.288	0.289	0.299	0.290	0.200			0.278

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 c_{ix}^{jx} and c_{is}^{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: $K_{11}^{\epsilon(*)\delta(j)X} = c_{01}^{jX} K_{11}^{*(*)\delta(j)X}$. 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 $K_{*s}^{\epsilon(i)\sigma(j)X}$.

If SWITCHMIG is set to 2, the migrants are disaggregated by age group at the beginning of the period; the variables have the form $K_{r*}^{\epsilon(i)\sigma(j)X}$; 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:

Figure 34. An example of c_j^X coefficients input

[illegible]

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) The Migrant coefficients

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

$$K_{rs}^{\epsilon(i)\sigma(j)X} = q_{rs}^{jX} K_{*s}^{\epsilon(i)\sigma(j)X}. \quad \text{If SWITCHMIG is set equal to 2,}$$

x_{rs}^{iX} coefficients are used to carry out the deconsolidation

$$K_{rs}^{\epsilon(i)\sigma(j)X} = x_{rs}^{iX} K_{r*}^{\epsilon(i)\sigma(j)X}.$$

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 and 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 in this case, and this case only, as dummies of zero.

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 $\sum_r v_{r1}^i = 1$.) 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:

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_{rl}^i 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 $K_{rs}^{\epsilon(i)\sigma(i)X} = p_{rs} K_{r*}^{\epsilon(i)\sigma(i)X}$. 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_{rl}^i coefficients

These are needed only if SWITCHE has been set to 1. They accomplish the disaggregation $K_{rl}^{\beta(i)\delta(j)X} = e_{rl}^i K_{*1}^{\beta(i)\delta(j)X}$.

The e_{rl}^i coefficients have the same characteristics and are input in the same way as the v_{rl}^i 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.

[illegible]

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 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 4 is 0.1400; the proportion born to mothers in age group 5 is 0.1500. We have: $0.1300 + 0.1400 + 0.1500 + \dots = 0.1000 = 1$.
The proportion of infant migrants moving from region 1 who have been born to mothers in age group 4 is 0.1400; the proportion born to mothers in age group 5 is 0.1500. We have: $0.1300 + 0.1400 + 0.1500 + \dots = 0.1000 = 1$.

mothers in age group 5 is 0.1500. We have: 0.1500 + 0.1300 = 0.2800. 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_{r1}^i coefficients input (not disaggregated by age at the end of the period).

Figure 38. A summary list of the input required

<u>Number</u>	<u>Item</u>	<u>General Format and comments</u>	<u>Figure to consult</u>	<u>Records/cards in the Figure 39 example</u>
(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	<p>If SWITCHBIRTH = 1 $K_{**}^{\beta(i)*(*)}X_{(u)}$ are expected;</p> <p>If SWITCHBIRTH = 2 $K_{r*}^{\beta(i)*(*)}X_{(*)}$ are expected;</p> <p>If SWITCHBIRTH = 3 $K_{r*}^{\beta(i)*(*)}X_{(u)}$ are expected</p>	32	10-11 (SWITCHBIRTH=1)
(9)	BIRTH COEFFICIENTS CARDS (f_{ru}^i)	<p>If SWITCHBIRTH = 1 f_{ru}^i coefficients are expected;</p> <p>If SWITCHBIRTH = 2 no coefficients are expected;</p> <p>If SWITCHBIRTH = 3, no coefficients are expected. The format is F8.6 for each coefficient</p>	33	12-13

Figure 38 (continued)

<u>Number</u>	<u>Item</u>	<u>General format and comments</u>	<u>Figure to consult</u>	<u>Records/cards in Figure 39 example</u>
(10)	FORMAT CARD FOR DEATHS	Real number format in parentheses.	See text of 4.6	14
(11)	DEATHS CARDS	<p>If SWITCHDEATH = 1, $K_{*s}^{*(*)\delta(j)X}$ are expected;</p> <p>If SWITCHDEATH = 2, $K_{rs}^{*(*) (j)X}$ are expected.</p>	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	<p>If SWITCHMIG = 1, $K_{*s}^{\epsilon(i)\sigma(j)X}$ are expected</p> <p>If SWITCHMIG = 2, $K_{r*}^{\epsilon(i)\sigma(j)X}$ are expected.</p>	31	21-22 (SWITCHMIG=1)
(17)	MIGRANT COEFFICIENT CARDS (q_{rs}^{jX}, x_{rs}^{iX})	<p>If SWITCHMIG = 1, q_{rs}^{jX} coefficients are expected</p> <p>If SWITCHMIG = 2, x_{rs}^{iX} coefficients are expected. In format 10F8.6</p>	33	23-24

Figure 38 (continued)

<u>Number</u>	<u>Item</u>	<u>General format and comments</u>	<u>Figure to consult</u>	<u>Records/cards in Figure 39 example</u>
(18)	FORMAT CARD FOR INFANT MIGRANTS	Real number format in parentheses	See text of 4.6	25
(19)	INFANT MIGRANT CARDS	If SWITCHBM = 1, $K_{rl}^{\beta(i)\sigma(j)X}$ 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_{rl}^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_{rl}^i)	Required only if SWITCHE = 1. In format 10F8.6	33	29-30

Figure 38. A summary list of the inputs required

DOCUMENT EARTHFIN

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 An example of a data file

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!

References

- Illingworth, D.R. (1976) Testing some new concepts in population accounting and related fields, Ph.D. dissertation, School of Geography, University of Leeds.
- Rees, P.H. and King, J.R. (1974) A simple model for population projections applied to ethnic group and small area populations, Working Paper 76, School of Geography, University of Leeds.
- Rees, P.H., Smith, A.P. and King, J.R. (1976) Population models, Chapter 3 in Wilson, A.G., Rees, P.H. and Leigh, C.M. (eds.) Models of cities and regions, John Wiley, London.
- Rees, P.H. and Wilson, A.G. (1973) Accounts and models for spatial demographic analysis 1: aggregate population, Environment and Planning, 5, pp 61-90.
- Rees, P.H. and Wilson, A.G. (1974) A computer programme for constructing spatial demographic accounts: user's manual, Working Paper 60, School of Geography, University of Leeds.
- Rees, P.H. and Wilson, A.G. (1977) Spatial population analysis, Edward Arnold, London.
- Smith, A.P. (1973) A computer version of a spatial demographic account building model: user's manual, Working Paper 51, School of Geography, University of Leeds.
- Smith, A.P. and Rees, P.H. (1974) Methods of constructing spatial demographic accounts for a British region, Working Paper 59, School of Geography, University of Leeds.
- Stone, R. (1966) Input-Output and demographic accounting: a tool for educational planning, Minerva, 4, pp 365-380.
- Stone, R. (1971) Demographical accounting and model building, O.E.C.D., Paris

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

LN_.jobname,:username
LF_:GEOLIB.DAMES,*LP,NU
LT

Offline

JOB_.jobname,:username
LF_:GEOLIB.DAMES,*LP,NU
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	SWITCHM	Birth	Death	Migrant	Infant migrant	Infant death	Exist-survive
I	DATADAME1	1	1	1	1	2	1	f_{ru}^i	c_{rs}^{jx}	q_{rs}^{jx}		e_{r1}^j	p_{rs}
II	ONEONE2	1	1	2	1	2	1	f_{ru}^i	c_{rs}^{jx}	x_{rs}^{ix}		e_{r1}^j	p_{rs}
III	ONETWO1	1	2	1	1	2	1	f_{ru}^i		q_{rs}^{jx}		e_{r1}^j	p_{rs}
IV	ONETWO2	1	2	2	1	2	1	f_{ru}^i		x_{rs}^i		e_{r1}^j	p_{rs}
V	TWOONE1	2	1	1	1	2	1		c_{rs}^{jx}	q_{rs}^{jx}		e_{r1}^j	p_{rs}
VI	TWOONE2	2	1	2	1	2	1		c_{rs}^{ix}	x_{rs}^{ix}		e_{r1}^j	p_{rs}
VII	TWOTWO1	2	2	1	1	2	1			q_{rs}^{jx}		e_{r1}^j	p_{rs}
VIII	TWOTWO2	2	2	2	1	2	1			x_{rs}^i		e_{r1}^j	p_{rs}
IX	THREEONE1	3	1	1	1	2	1		c_{rs}^{jx}	q_{rs}^{jx}		e_{r1}^j	p_{rs}
X	THREEONE2	3	1	2	1	2	1		c_{rs}^{jx}	x_{rs}^{ix}		e_{r1}^j	p_{rs}
XI	THREETWO1	3	2	1	1	2	1			q_{rs}^{jx}			p_{rs}
XII	THREETWO2	3	2	2	1	2	1			x_{rs}^{ix}		e_{r1}^j	p_{rs}
XIII	BM211	1	1	1	2	1	1	f_{ru}^i	c_{rs}^{jx}	q_{rs}^{jx}	v_{r1}^i		p_{rs}
XIV	BM212	1	1	1	2	1	2	f_{ru}^i	c_{rs}^{jx}	q_{rs}^{jx}	v_{r1}^o		p_{rs}
XV	BM221	1	1	1	2	2	1	f_{ru}^i	c_{rs}^{jx}	q_{rs}^{jx}		e_{r1}^j	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:

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)".

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.

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".