FOREWORD

This paper is the first in a series of Working Papers on the "Multilevel Computer Model of World Development Systems." While the assumptions and the methodology of the various submodels pertaining to the above computer model are described in the IIASA Symposium Proceedings SP-74-1 to SP-74-6, this series aims at explaining the use of the models.

The series consists of seven papers, one for each submodel now available at IIASA. The descriptions relate to the state of the computer model in May, 1974. Since the research work under the leadership of M. Mesarovic and E. Pestel is still going on the model descriptions should not be looked upon as final. Further submodels will be documented as soon as they become available.

At present the various submodels are kept on a magnetic tape and partly on punched cards, and thus are easily accessible. I would like anybody who is interested in running a submodel from the M.P. Global Modelling Set to contact Günther Fischer (Ext. 411).
IMPLEMENTATION OF THE M.P. WORLD MODEL

In May 1974 a seminar was held by IIASA in Baden, at which the "Regionalized Multilevel World Modelling Project" headed by M. Mesarovic and E. Pestel was presented to scientists of various disciplines. In January 1975 the proceedings of this seminar were available at IIASA. In these reports (6 volumes; SP-74-1 to SP-74-6) the assumptions used within the models and in part the data are described.

We now have some of the submodels available on our inhouse computer which is a PDP 11/45. In order to facilitate the use of the models descriptions of the various submodels have been elaborated. These papers are not intended to provide a description of the submodels themselves, but merely of their use (requests from the model, input, output, data). The descriptions relate to the model versions implemented on the PDP 11 under the DOS-System, which is a single job operating system.

Due to the fact that a new multiprogramming operating system (UNIX) is used on the PDP 11/45 some of the models have been implemented under UNIX too, and some of the larger models may be run as batch jobs on the CYBER 74 at the Technical University in Vienna.

Models Available at IIASA

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THE POPULATION SUBMODEL

ABSTRACT

In the M.P. Regionalized World Model, one of the most important submodels is the population model. In its present state there are especially two purposes for which the model serves:

A. The model can be used to investigate different population policies. The model calculates an equilibrium fertility factor that would gradually lead to population equilibrium. The user of the model can specify the year when the equilibrium policy is to start, and the length of the transition interval after which the equilibrium fertility should be reached. Thus it is possible to investigate the effects of postponing the application of equilibrium policies;

B. A second feature of the model is that you may not only investigate a decreasing fertility, but also an increasing mortality due to lack of protein. This will be helpful for analysing the population growth of South East Asia.

For more details on the theoretical background see [1]

I. MATHEMATICS OF THE POPULATION MODEL

The computations of the model consist of two different periods. While the computations of the model for the years 1950-1970 are determined by the given data, various alternative strategies may be applied from 1970 on:
COMPUTER RUNS

A. Normal Runs
In the standard computer runs the fertility factor $c_f^t$ and the mortality factor $c_m^t$ are kept constant from 1970 on taking the values of 1970; i.e. $c_f^t = c_f^{1970}$; $c_m^t = c_m^{1970}$ for $t > 1970$.

B. Equilibrium Runs via Fertility Change
If you choose scenario 01-10 you will get special equilibrium runs according to the values of KONTR and INT. Mortality is kept constant, i.e. $c_m^t = c_m^{1970}$ for $t > 1970$; but fertility is changed (starting in year KONTR) until it reaches the value of the computed equilibrium fertility factor after a transition period of INT years.

C. Runs with Mortality Changes (Lack of Protein)
Scenario 11-33 provide runs with constant fertility but an increased mortality. The mortality multiplier $ZM(X,E,a)$ is computed according to the values of EO,EU,EA,XO,TL. These runs are to be produced only for region 09.

D. Change of Mortality Due to Lack of Protein and Change of Fertility Due to Equilibrium Policies
For region 09 you may also choose scenario 34-53 in order to get runs that take into consideration a combination of increased mortality and equilibrium policies.

E. Scenario 99
If you specify scenario 99 you will get a run with any parameters you specify. Again lack of protein is considered only for region 09.

NOTATION
In order to simplify the documentation of the mathematics of the model the following variables will be used (different from the notation of the FORTRAN-program).
\( p_a^t \) Number of people alive on \( 7/1/t \) who were born between \( 7/1/t - a \) and \( 7/1/t - a + 1 \), i.e. people that are \( a \) years of age

\( t_a^t \) Number of people who died between \( 7/1/t \) and \( 7/1/t + 1 \), as a subset contained in \( p_a^t \)

\( b_a^t \) Number of women who gave birth to children between \( 7/1/t \) and \( 7/1/t + 1 \), as a subset of \( p_a^t \)

\( r_a^t \) Difference between immigrants and emigrants in the time-interval between \( 7/1/t \) and \( 7/1/t + 1 \), as a subset contained in \( p_a^t \)

\( \text{Pop}^t \) Total number of people alive at \( 7/1/t \)

\( \text{Bab}^t \) Babies born between \( 7/1/t \) and \( 7/1/t + 1 \)

\( \text{Tot}^t \) People who died between \( 7/1/t \) and \( 7/1/t + 1 \)

\( \text{Imi}^t \) Difference between immigrants and emigrants between \( 7/1/t \) and \( 7/1/t + 1 \)

\( \text{cbr}^t \) Crude birth rate of year \( t \)

\( \text{cdr}^t \) Crude death rate of year \( t \)

\( f_a^t \) Age-specific fertility, i.e. the probability that a person will produce a child between \( 7/1/t \) and \( 7/1/t + 1 \) at an age between \( a - \frac{1}{2} \) and \( a + \frac{1}{2} \)

\( m_a^t \) Age-specific mortality, i.e. the probability that a person will die between \( 7/1/t \) and \( 7/1/t + 1 \) at an age between \( a - \frac{1}{2} \) and \( a + \frac{1}{2} \)

\( \text{cf}^t \) Time-dependent fertility factor

\( \text{af}_a \) Age-specific fertility factor (normalization 86 \( \sum_{a=1}^{86} \text{af}_a = 1 \))

\( \text{cm}^t \) Time-dependent mortality factor

\( \text{am}_a \) Age-specific mortality factor (normalization 86 \( \sum_{a=1}^{86} \text{am}_a = 1 \))
LE Life expectancy at birth

$\mathbf{PR}_t$ Protein (gramm) for people in region 9 in year $t$

$\mathbf{x}_t$ Gramm protein/capita for people in region 9

$\mathbf{ZM}_a$ Age-specific mortality multiplier

KONTR Start of equilibrium birth control

INT Transition period to reach equilibrium fertility factor

$\mathbf{SB}_t$ Accumulated number of babies from 1970 on

$\mathbf{ST}_t$ Accumulated number of deaths from 1970 on.

**POPULATION DEVELOPMENT BETWEEN 1950 AND 1970**

For each of the ten regions of the M.P. World Model the following data are used as initial values of the computations from 1950-1970:

$p_{1950}^{a} = 1, \ldots, 86$ (the age-groups were obtained by applying a spline interpolation subroutine to the available data)

$\mathbf{PopD}_t = 1950, \ldots, 1970$ Total number of population

$\mathbf{cbr}_t$ $t = 1950, \ldots, 1970$ Time series for the birth rates and death rates of the time-span 1950-1970

$\mathbf{cdr}_t$ $t = 1950, \ldots, 1970$

$\mathbf{af}_a$ $a = i, l, \ldots 86$ Age-specific fertility and mortality taken from the most recent available data and normalized such that

$86 \sum_{a=1}^{a=1} \mathbf{af}_a = 86 \sum_{a=1}^{86} \mathbf{am}_a = 1$
SET OF BASIC EQUATIONS

\[ \text{Pop}_t^a = \sum_{a=1}^{86} p_t^a \]

\[ \text{cf}_t = \frac{1}{2} \cdot (cbr_t \cdot \text{Pop}_t^a + cbr_t+1 \cdot \text{Pop}_t+1) / \left( \sum_{a=1}^{86} p_t^a \cdot af_a \right) \]

\[ \text{cm}_t = \frac{1}{2} \cdot (cdr_t \cdot \text{Pop}_t^a + cdr_t+1 \cdot \text{Pop}_t+1) / \left( \sum_{a=1}^{86} p_t^a \cdot am_a \right) \]

\[ \text{Im}_t = \text{Pop}_t^a - \text{Pop}_t \]

\[ I_a^t = \begin{cases} \text{Im}_t/50 & a = 2, \ldots, 51 \\ 0 & a = 1, 53, \ldots, 86 \end{cases} \]

\[ p_t^a = p_t^a + I_a^t \]

\[ \text{Pop}_t = \text{Pop}_t^a + \text{Im}_t \]

\[ \text{Bab}_t^a = \sum_{a=1}^{86} p_t^a \cdot af_a \cdot \text{cf}_t \]

\[ \text{Tot}_t = \sum_{a=1}^{86} p_t^a \cdot am_a \cdot \text{cm}_t + \frac{1}{2} \cdot \text{Bab}_t^a \cdot am_{\frac{1}{2}} \cdot \text{cm}_t \]

\[ p_{t+1}^{86} = p_{85}^t \cdot (1 - \text{cm}_t \cdot am_{85}) + p_{86}^t \cdot (1 - \text{cm}_t \cdot am_{86}) \]

\[ p_{t+1}^a = p_{a-1}^t \cdot (1 - \text{cm}_t \cdot am_{a-1}) \quad a = 2, \ldots, 85 \]

\[ p_{t+1}^1 = \text{Bab}_t^a \cdot (1 - \frac{1}{2} \cdot \text{cm}_t \cdot am_{\frac{1}{2}}) \]
The numerical output of year $t$ provides the computed values for $t$, $\text{Pop}^t$, $\text{cf}^t$, $\text{cbr}^{t+\frac{1}{2}}$, $\text{cm}^t$, $\text{cdr}^{t+\frac{1}{2}}$, $\text{SBab}^t$, $\text{STot}^t$. In case of normal runs also $\text{Pop}^t$ and $\text{Imit}$ are printed on a separate line.

**POPULATION DEVELOPMENT FROM 1970 ON**

From 1970 on various alternative strategies may be applied, such as equilibrium policies and the increase of mortality due to lack of protein.

**SET OF BASIC EQUATIONS**

\[
\text{Pop}^t = \sum_{a=1}^{86} p_a^t
\]

\[
\text{cf}^t = \begin{cases} 
\text{cf}^{1970} & \text{according to equilibrium policy} \\
\end{cases}
\]

\[
\text{cm}^t = \text{cm}^{1970}
\]

\[
\text{am}^t_a = \begin{cases} 
\text{am}_a & \text{according to lack of protein} \\
\end{cases}
\]

\[
\text{Bab}^t = \sum_{a=1}^{86} p_a^t \cdot \text{af}_a \cdot \text{cf}^t
\]
\[ \text{Tot}_t = \sum_{a=1}^{86} p_a^t \cdot a^t \cdot m^t + \frac{1}{2} \cdot \text{Bab}_t \cdot m^t \cdot c^t \]

\[ p_{86}^{t+1} = p_{85}^t \cdot (1 - c^t \cdot m_{85}^t) + p_{86}^t \cdot (1 - c^t \cdot m_{86}^t) \]

\[ p_{a}^{t+1} = p_{a-1}^t \cdot (1 - c^t \cdot m_{a-1}^t) \quad a = 2, \ldots, 85 \]

\[ p_1^{t+1} = \text{Bab}_t \cdot (1 - \frac{1}{2} \cdot c^t \cdot m_{1}^t) \]

\[ cbr_{t+\frac{1}{2}} = \frac{\text{Bab}_t^t}{(\text{Pop}_t^t + \frac{1}{2} \cdot (\text{Bab}_t^t - \text{Tot}_t^t))} \]

\[ cd_r_{t+\frac{1}{2}} = \frac{\text{Tot}_t^t}{(\text{Pop}_t^t + \frac{1}{2} \cdot (\text{Bab}_t^t - \text{Tot}_t^t))} \]

\[ SB_{\text{Bab}}^{t+1} = SB_{\text{Bab}}^t + \text{Bab}_t^t \]

\[ ST_{\text{Tot}}^{t+1} = ST_{\text{Tot}}^t + \text{Tot}_t^t \]

**EQUILIBRIUM POLICY**

In order to calculate the effects of various equilibrium policies the user of the population model may specify the values \text{KONTR} and \text{INT} as described before.

| \text{KONTR} | Start of equilibrium fertility control |
| \text{INT}    | Length of transition interval           |

In order to have stationary population the condition

\[ \text{Bab}_t^t = \text{Tot}_t^t \]

has to be satisfied. Furthermore, the model assumes that the age-specific fertility and mortality \( c_f^a \) and \( m_a^a \) remain constant for all times and \( c_m \) is chosen to be \( c_m = c_m^{1970} \).

From this follows the condition:

\[ p_{a}^{t} = p_{a}^t \quad (a = 1, 2, \ldots, 86) \]

Inserting these conditions in the demographic model one gets the following relationships:
\[ P_1 = \text{Bab} \cdot (1 - \frac{1}{2} \cdot \text{cm} \cdot \text{am}_2) \]

\[ P_{a+1} = P_a \cdot (1 - \text{cm} \cdot \text{am}_a) \quad a = 1, \ldots, 84 \]

\[ P_{86} = P_{85} \cdot (1 - \text{cm} \cdot \text{am}_{85}) + P_{86} \cdot (1 - \text{cm} \cdot \text{am}_{86}) \]

and therefore

\[ P_{86} = P_{85} \cdot (1 - \text{cm} \cdot \text{am}_{85})/(\text{cm} \cdot \text{am}_{86}) \]

Defining

\[ \text{Prod}(1) = 1 - \frac{1}{2} \cdot \text{cm} \cdot \text{am}_2 \]

\[ \text{Prod}(a) = \text{Prod}(a - 1) \cdot (1 - \text{cm} \cdot \text{am}_{a-1}) \quad a = 2, \ldots, 85 \]

\[ \text{Prod}(86) = \text{Prod}(85) \cdot (1 - \text{cm} \cdot \text{am}_{85})/(\text{cm} \cdot \text{am}_{86}) \]

One gets

\[ P_a = \text{Bab} \cdot \text{Prod}(a) \quad a = 1, \ldots, 86 \]

Using

\[ \text{Bab} = \sum_{a=1}^{86} \text{cf}_e \cdot \text{af}_a \cdot P_a \]

Leads to

\[ 1 = \text{cf}_e \cdot \sum_{a=1}^{86} \text{af}_a \cdot \text{Prod}(a) \]
The life expectancy at birth and the equilibrium birth rate and death rate are calculated using the relationships:

\[
LE = \frac{Pop}{Bab}
\]

\[
cbr^e = cdr^e = \frac{Bab}{Pop} = \frac{Tot}{Pop} = \frac{1}{LE}
\]

SET OF EQUILIBRIUM EQUATIONS

\[
P_{86} = (l/cm - am_{85})/ am_{86}
\]

\[
Prod(l) = (1 - \frac{1}{2} \cdot cm \cdot am_{\frac{1}{2}})
\]

\[
Prod(a) = Prod(a - 1) \cdot (1 - cm \cdot am_{a-1}) \quad a = 2, ..., 85
\]

\[
Prod(86) = Prod(85) \cdot (1 - cm \cdot am_{85})/ (am_{86} \cdot cm)
\]

\[
\text{cf}^e = \frac{1}{(\sum_{a=1}^{86} af_a \cdot Prod(a))}
\]

\[
LE = \sum_{a=1}^{86} Prod(a)
\]

\[
cbr^e = \frac{1}{LE}
\]

\[
FK^t = \begin{cases} 
0.1 \cdot 7/INT & \text{KONTR} \leq t \leq \text{KONTR} + 2 \cdot \text{INT/7} \\
0.2 \cdot 7/INT & \text{KONTR} + 2 \cdot \text{INT/7} < t \leq \text{KONTR} + 5 \cdot \text{INT/7} \\
0.1 \cdot 7/INT & \text{KONTR} + 5 \cdot \text{INT/7} < t \leq \text{KONTR} + \text{INT}
\end{cases}
\]

\[
\text{cf}^t = \begin{cases} 
\text{cf}^{1970} & 1970 < t < \text{KONTR} \\
\text{cf}^{t-1} - (\text{cf}^{1970} - \text{cf}^e) \cdot FK^t & \text{KONTR} \leq t \leq \text{KONTR} + \text{INT} \\
\text{cf}^e & \text{KONTR} + \text{INT} < t
\end{cases}
\]
LACK OF PROTEIN

In order to compute the increase of mortality due to lack of protein in region 9 of the M.P. World Model, the user may specify the values $E_0$, $E_A$, $E_U$, $X_0$ and $T_L$ as described before.

SET OF INCREASED MORTALITY EQUATIONS

\[ PR_{1970} = 44 \cdot Pop_{1970} \]

\[
PR_t = \begin{cases} 
   PR_{t-1} \cdot 1.005 & 1971 \leq t \leq 2000 \\
   PR_{t-1} & 2000 < t 
\end{cases}
\]

\[ X_t = \frac{PR_t}{Pop_t} \]

\[ am^t_a = ZM^t_a \cdot am_a \]

\[ ZM^t_a = \left[ \frac{(44 - X_0)/(X_t - T_L - X_0) - 1}{(E_0 - E_U) \cdot \exp (-a/E_A) + E_U} \right] + 1 \]
II. TERMINAL INPUT AND DATA BASE

A. Requests from the Model

Playing with the model requires the input of some specific parameters from the keyboard. For this purpose the model issues some appropriate statements on the terminal. Following each request there is an example of the expected input. These examples are primarily intended to show the user the format by which the data are to be entered rather than to give a meaningful set of data. During a session some or all of the following requests may be issued:

"SPECIFY ULTIMATE YEAR/INTERVAL"

The maximum value for the ultimate year is 2100. You may, for instance, specify 2100/05 (using format (I4, 1X, I2)) to run the model until 2100 getting an output with time-steps of 5 years. These values remain set until you finish your session.

"REGION, E.G. 08"

If you enter 01-10 (using format (I2)) you will get a "NORMAL RUN" for the specified region (see Table 1). If you enter 00 the model will ask

"GIVE POPUL. SCENARIO NUMBER, E.G. 22"

At this you must enter 01-53 or 99 (using format (I2)); if you enter anything else the model will write

"SCENARIO NUMBER NON EXISTENT"

The various scenarios are listed in Table 2. If you choose scenario number 99 the model will ask

"SPECIFY (N) EQUILIBRIUM CONTROL START/SPAN, E.G. 1975/14"

These equilibrium control parameters are used to specify a certain equilibrium policy.
"ENTER REGION"

After having specified scenario 99 you will be asked again for the region you want to run the model (since you have entered 00 at the first request); you may enter 01-10 (using format (I2)). In case you enter 09 the model will ask

"SPECIFY (N) EO,EU,EA,X0,TL
E.G. 1.0/.25/10./0.0/0.0"

These parameters influence the change of mortality due to lack of protein.

Now the model is run with the specified parameters for the region you are interested in. When the model has finished the run for your region it will ask again for a region, etc.

REMARK

You have to be careful because the parameters remain set from the last run until you reset them (i.e. by a scenario 01-53 or by means of scenario 99). Therefore, you have at first to produce the "NORMAL RUN" for the regions you are interested in, and then enter special scenarios.

The terms appearing in the above requests denote the following:

ULTIMATE YEAR : Last year to run the model ( ≤ 2100)

INTERVAL : Time steps for the line printer output

REGION : In the M.P. World Model, the world has been regionalized. There are ten regions:-
Table 1

<table>
<thead>
<tr>
<th>NR.</th>
<th>REGION</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>North America</td>
</tr>
<tr>
<td>02</td>
<td>Western Europe</td>
</tr>
<tr>
<td>03</td>
<td>Japan</td>
</tr>
</tbody>
</table>
| 04  | Rest of Developed (i.e. Israel
Australia, New Zealand) |
| 05  | East Europe and USSR                        |
| 06  | Latin America                               |
| 07  | Middle East                                 |
| 08  | Main Africa                                 |
| 09  | South East Asia                             |
| 10  | China                                       |

POPUL. SCENARIO NUMBER (= NSC)

There are 53 scenarios 01-53 with special sets of parameters available (Table 2). If you want to specify your own parameters you must enter 99. In any case lack of protein is only considered for region 09 (i.e. South East Asia). Therefore, scenario 11-53 ought to be run only for this region.

EQUILIBRIUM CONTROL START (= KONTR)

Start of the equilibrium policy; must be a multiple of 5, e.g. 1975, 1990, 2000, etc.

EQUILIBRIUM CONTROL SPAN (= INT)

Lenth of transition interval; number of years from the start of the equilibrium policy until the equilibrium fertility factor is reached; must be a multiple of 7, e.g. 0, 14, 35, etc.

EO : Sensitivity of babies to protein deficiency

EU : Sensitivity of older people to protein deficiency
EA: Time constant that indicates the number of years that pass until \( E(a) - EU \) drops to 37% of \( EO - EU \), where \( E(a) \) is defined as:

\[
E(a) = (EO - EU) \cdot \exp\left(-\frac{a}{EA}\right) + EU
\]

("age-specific sensitivity to protein deficiency")

XO: Minimal per capita protein consumption (in gramm) per day. If protein consumption/day \( \leq XO \) all people die due to lack of protein

TL: Time delay in the effect of protein deficiency (in years). Using these parameters an age-specific mortality multiplier is defined:

\[
ZM(X,E,a) = \left[\frac{44 - XO}{X(T - TL) - XO} - 1\right] \cdot E(a) + 1
\]

Where \( X(T) \) is the computed per capita protein consumption for year \( T \) and \( E \) the above defined sensitivity to protein deficiency

B. DATA BASE

To run the model two data files are needed. From unit number 4 the following time series and age distribution are read (Format (19X, 6 F10.5)).

**MIDYEAR POP**: Estimates for the aggregate midyear population of the respective region are given from 1950 to 1970. Data are given in millions of inhabitants.

**ANFANGSVERT**: Age distribution in 1950 or for the earliest available year, the age distribution is normalized to sum up to 1 and presented in the following way:

- Babies less than 1 year, 1 to 5 year olds, ... , 80 to 85 year olds, and people older than 85 years.
AF : Age-specific fertility calculated from the latest available historical data according to:

\[ AF_a = \frac{B_a}{B_{ab}} / \frac{P_a}{Pop} \quad a = 1, \ldots, 11 \]

In this context 'a' does not denote a single one-year age group, but five-year age groups. Furthermore, the first figure given is always 1.0, so age-specific fertility rates AF include: 1.0, 10-15 year-olds, ..., 45-50 year-olds, older than 50, unknown births.

AM : Age-specific mortality calculated from the latest available data according to:

\[ AM_a = \frac{T_a}{Tot} / \frac{P_a}{Pop} \quad a = 1, \ldots, 21 \]

As before the first figure given is 1.0. Thus AM include: 1.0, babies less than 1, 1-5 year-olds, 5-10 year olds, ..., 80-85 year-olds, people older than 85, and unknown deaths.

CDR : 21 values denoting the crude birth rates from 1951-1971 are given.

CBR : 17 figures are listed, the first of which is the average crude birth rate for the years 1950-1954. The remaining 16 values denote the birth rates from 1955-1969.

All the data dealt with above are listed for each of the ten regions. A listing of the data is given below. As for the UNIX-operating-system a file called PDAT.D, which has to contain all data is associated with unit number 4. Under DOS the respective file is called PDAT.DAT. A second file is needed to read the prepared scenario data using unit number 9. The corresponding FORMAT is (1X,2(F2.0,1X), F4.0,1X,F2.0,1X,6(F3.1,1X)). Each line contains the following values:
SCENARIO LABEL, SCENARIO NUMBER, KONTR, INT, EO, EU, EA, XO, and TL

The SCENARIO LABEL is used for classifying the various scenarios, i.e. all scenarios dealing with population policies only take a value 01, those investigating lack of protein take 02, etc.

The remaining 8 variables have been already described in section A. of this chapter. The actual file names are SCEDAT.D and SCEDAT.DAT for UNIX and DOS respectively.
<table>
<thead>
<tr>
<th>Date</th>
<th>Month</th>
<th>Year</th>
<th>Value</th>
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<td></td>
<td></td>
<td>10.  10.  15.</td>
</tr>
<tr>
<td>02 12</td>
<td></td>
<td></td>
<td>10.  15.</td>
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<td>20.  15.</td>
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<td>02 14</td>
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<td>02 15</td>
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**Notes:**
- Populations are given in thousands.
- R1, R2, R3, R4, R5 represent different categories or regions as indicated by the table headings.
- The table is organized by region, with columns for each category or population.
- The data is presented in a tabular format with numerical values for each category.
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<td>19.0</td>
<td>18.0</td>
</tr>
<tr>
<td>CBR</td>
<td>R10</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CBR</td>
<td>R10</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CBR</td>
<td>R10</td>
<td>37.12</td>
<td>38.0</td>
</tr>
<tr>
<td>CBR</td>
<td>R10</td>
<td>39.5</td>
<td></td>
</tr>
<tr>
<td>CBR</td>
<td>R10</td>
<td>39.4</td>
<td></td>
</tr>
</tbody>
</table>
III. OUTPUT

The head of the printout contains the name of the chosen region, the scenario number (or NORMAL RUN) and the values of the various parameters (i.e. KONTR, INT, EO, EU, EA, XO, TL). Then you get a table consisting of eight columns:

<table>
<thead>
<tr>
<th>YEAR</th>
<th>: Year t of consideration, 1950 ≤ t ≤ ULTIMATE YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL POP</td>
<td>: Total number of people living in year t as computed by the model for the specified region</td>
</tr>
<tr>
<td>FERTILITY</td>
<td>: Computed fertility factor ( cf^t ) for 1950 ≤ t ≤ 1970. For t &gt; 1970 the fertility factor is either constant (i.e. ( cf^t = cf^{1970} )) or determined by the chosen equilibrium policy</td>
</tr>
<tr>
<td>BAB/POP</td>
<td>: Ratio of babies born in year t to total end-year population in t, i.e. crude birth rate ( cbr^{t+\frac{1}{2}} )</td>
</tr>
<tr>
<td>MORTALITY</td>
<td>: Computed mortality factor ( cm^t ) for 1950 ≤ t ≤ 1970. For t &gt; 1970 the mortality factor is kept constant (i.e. ( cm^t = cm^{1970} ))</td>
</tr>
<tr>
<td>TOT(N)/POP</td>
<td>: Ratio of people that died in year t to total (end-year) population in year t, i.e. crude death rate ( cdrt^{t+\frac{1}{2}} )</td>
</tr>
</tbody>
</table>

SUMME BAB(N) 70: Accumulative sum of all babies from 1970 on

SUMME TOT(N) 70: Accumulative sum of all deaths from 1970 on.

Subsequent to the line printed for 1970 you find a few data concerning the equilibrium state:

| LE | : Life expectancy at birth |
| CFSTAT | : Fertility factor \( cf^e \) leading to equilibrium |
TOT/BAB : Ratio of babies to deaths for equilibrium
(= 1.0)

P86/P85 : Ratio of people that are older than 85 years
to number of people that are 85 years old.

If you have performed a NORMAL RUN you will also get
the actual population (from data), and the calculated
number of immigrants (both in millions); i.e. the calculated
difference between the computed population number and the
actual value.
DIMENSION PP1(1), GLH(1), OCH(1)
DIMENSION SCF(10,50)
DIMENSION FER(21,1), AMH(21,1)
DIMENSION FER(21,1), AMH(21,1), CF(21), GM(21), CM(21), U(21)
COMMON SCF, FER, AMH, FERT, AMHRT, CF, CH, G

66 CALL SFTFIL(4,"POAT.O")
       CALL SFTFIL(9,"SCEDAT.D")
IYT = 1950
ISTAT = 1970
ISS = 1950
WHITE(R,6)
READ(5,7) MAXYR, INTER
NCO = 0
WHITE(6,154)
READ(5,51)
CALL POPUL(-1, IYT, I, PP1(1), GLH(1), OCH(1), NCO, PROV, NALL)
REWIND 9
REWIND 4
2 DO 1 J = 1, 151
IYR = J + 1949
IF(IYR.GT. MAXYR) GOTO 66
CALL ALLPRT(IYR, IS, MAXYR, INTER, NALL)
CALL POPUL(ISTAT, IYR, I, PP1(1), GLH(1), OCH(1), NCO, PROV, NALL)
1 CONTINUE
GOTO 66
5 FORMAT(12)
6 FORMAT(///"SPECIFY ULTIMATE YEAR / INTERVAL ",/)
7 FORMAT(14,1X,12)
154 FORMAT(* REGION ,c,G ,G8",/)
99 STOP
END
SUBROUTINE POPUL(ISTAT, IYR, I, PP1(1), GLH(1), OCH(1), NCO, PROV, NALL)
DIMENSION AP2(R,1), AF2(R6,1), AM2(R6,1), SCE(10,50)
DIMENSION FER(21,1), AMH(21,1)
DIMENSION GSY(21), GP(21), GF(21), GM(21), POP(21), G(21)
DIMENSION FERT(21), AMHRT(21), CF(20,1), CM(20,1)
DIMENSION AP(R6,1), AM3(R6,1), AF(R6,1), AP1(R6), AF1(R6), AM1(R6)
DIMENSION NAME(12,1), XP(151), AM(R6,1), POP2(21,1)
DIMENSION S4E(1), SUT(1), TOT(1), BAB(1), GT(1), AMO(1)
DIMENSION AM(1), CH(1), CO(1)
DIMENSION S1(1), S2(1), FY(1), FX(1), FG(1), PG(1), F(1), FA(1), GRP4(1)
DIMENSION CH(1), CMH(1), TOT(1)
REAL*8 CH, CF, CO, AM, AMO, P, S1, S2, S3, S65, FY, FX, F, FA
REAL INT, INTV

C NDATA=0
   IF(ISTAT),2,3
   IF(NDATA.EQ.1)GOTO 2
   IF(I1 ,EQ. 0) GOTO 161
   NDATA=1
   KREG=1
   DO 202 IPT=1,11
   C C C READ PRIMARY DATA
   C
   READ(4,104)(NAME(L,KREG),L=1,12)
READ(4,109)POP
READ(4,109)GMP
DO 140, L = 1, 20
140 GF(L) = 0.
READ(4,109)P, (GF(I), I = 5, 13)
READ(4,109)GM
READ(4,109) (AMORT(I), I = P, 21), P
READ(4,109) (FERT(I), I = 4, 21)
200 CONTINUE
C
C ADJUST AMORT, FERT DATA
C
DO 141 L = 1, 3
141 FERT(L) = FERT(4)
AMORT(1) = AMORT(2)
DO 143 L = 2, 21
IF (AMORT(L)) 146, 146, 1477
146 AMORT(L) = AMORT(L - 1)
1477 CONTINUE
IF (FERT(L)) 143, 142, 143
142 FERT(L) = FERT(L - 1)
143 CONTINUE
DO 145 L = 1, 21
AMORT(L) = AMORT(L) * .P01
145 FERT(L) = FERT(L) * .P01
C
C CALCULATE SECONDARY DATA AP1, AF1, AM1
C
CALL SPLINE (GF, AP1, 1, 20)
GM(2) = GM(2) * 2
GM(5) = GM(5) * .8
GM(20) = GM(20) * 2
CALL SPLINE (GM, AM1, 2, 20)
N = 4
152 N = N + 1
IF (GF(N)) 152, 152, 153
153 N = N - 1
N = 14
154 N = N - 1
IF (GF(N)) 154, 154, 155
155 N2 = N
GF(1) = 0.1
CALL SPLINE (GF, AF1, N1, N2)
C
C SAVE DATA FOR ALL REGIONS
C
DO 160 L = 1, 86
AP2(L, KREG) = AP1(L) * POP(1) * 1.66
160 AMP(L, KREG) = AM1(L)
DO 190 L = 1, 85
190 AF2(L, KREG) = (AF1(L) + AF1(L+1)) * .5
DO 734 L = 1, 21
FERT(L, KREG) = FERT(L)
AMOR(L, KREG) = AMORT(L)
734 Popp(L, KREG) = POP(L)
IF (KONTR .EQ. 0) KONTR = 2200
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161  DO 201, I = 1, 153
201  CONTINUE
2
2 CONTINUE
IF (I1 .EQ. 0) GOTO 3
RETURN
3  IF (IYR .EQ. 1950) 167, 167, 168
C
C  INITIALISATION FOR 1950
C
167  IF (I1 .EQ. 0) GOTO 187
I = 1
N1 = 1
DO 54 N = N1, N2
C2R(N) = 0.0
C3R(N) = 0.0
C4R(N) = 0.0
AM(N) = AM2(1, N)
DO 166 L = 1, 86
AP(L, N) = AP2(L, N)
AF(L, N) = AF2(L, N)
AM(L, N) = (AM2(L, N) + AM2(L + 1, N)) * 5
AM(R6, N) = AM2(R6, N)
DO 704 L = 1, 86
AM3(L, N) = AM2(L, N)
SHAI(N) = 0.0
STOT(N) = 0.0
LAUS = 1
C
C  INTERACTIVE MODULE
C
187  IF (I1 .GE. 1 .AND. I1 .LE. 10) GOTO 1685
NP1 = 0
IF (I1 .GT. 10) NP1 = 1
WRITE (6, 169)
READ (5, 170) NSC
RSC = NSC
KONT = 2200
INT = 1400000
ED = 0.0
EU = 0.0
EA = 0.0
X = 0.0
TL = 0.0
IF (NSC = 99) 197, 176, 176
197  IF (NSC) 2, 131, 172
172  DO 173 IZ = 1, 60
173  CONTINUE
WRITE (6, 175)
GOTO 187
174  KONT = SCE (3, 12)
INT = SCE (4, 12)
EN=SCE(5,12)
EU=SCE(6,12)
EA=SCE(7,12)
K=SCE(8,12)
TL=SCE(9,12)
IF(SCE(1,12),EQ,2) KONTR = 2200
WRITE(6,913)
READ(5,914) I12
11 = I12
GOTO 181
176 WRITE(6,177)
READ(5,178) KONTR, INT11
WRITE(6,913)
913 FORMAT(1X,"ENTER REGION",/)  
READ(5,914) I12
11 = I12
914 FORMAT(12)
INT = INT11
1761 CONTINUE
IF(I11,NE,9) GOTO 1762
WRITE(6,179)
READ(5,184) ED, EU, EAX, TL
1762 CONTINUE
181 N6 = TL
LAUS = (KONTR-147.%) / 5
IF(LAUS=5)317,317,313
313 LAUS=10
317 IF(INT=108) 1681,1681,316
316 LAUS=1
1681 KAB=INT/7
GOTO 1
C
C WRITE HEADLINE
C
1685 INTV=INT
IF(INT=1MP) 718,719,719
719 INTV=0
718 IF(NALL)168,921,168
901 IF(NSC)961,962,961
961 WRITE(6,656)(NAME(L,1),L=1,12),NSC,KONTR,INTV,EO,EU,EAX,T
GOTO 963
962 WRITE(6,654)(NAME(L,1),L=1,12),KONTR,INTV
963 WRITE(6,108)
C
C MODEL
C
168 IF(I11,EQ,9)RETURN
KK=IYR-1949
K=IYR
DO 55 N=1, N2
GT(N) = 0.
TOT(N) = 0.
BAB(N) = 0.
DO 5 L=1, 86
TOT(N) = TOT(N) + AP(L,N)*AM(L,N)
5 BAB(N) = BAB(N)+AP(L,N)*AF(L,N)
DO 7 L=1,18
7  G(L) = 0,
DO 8 L=1,L6
8  G(L2) = G(L2)+AP(L,N)
DO 9 L=1,18
9  GT(N) = GT(N)+G(L)
55 CONTINUE

C MIGRATION

C IF (K=1970) 90,90,97
90  DO 56 N=N1,N2
91  AMIG(N) = POP2(KK,N)*108.*GT(N)*0.0001
92  IF(AMIG(N))91,92,92
93  AMIG(N) = AMIG(N)+1.0
94  MIG = AMIG(N)
DO 56 L=2,51
56  AP(L,N) = AP(L,N)*MIG*2.0.
57  IF (MIG)95,95,56
58  IF (K=1970) 10,10,50
59  GT(N) = GT(N) + MIG*1.04
60  XP(KK) = 44.
61  IF (NALL)1515,1515,1515
62  XTOT=STOT(I)/1.E6
63  XBAB=SHAB(I)/1.E6
64  XGT = GT(I)/1.E6
65  WRITE(K,1515)XGT,CB(I),CRR(I),CD(I),CDH(I),XBAB,XTOT
66  IF (K=1970) 10,10,50

C MORTALITY,FERTILITY. TILL 1969

C DO 57 N=N1,N2
57  BB = (FER(KK,N)*POP2(KK,N)+FER(KK+1,N)*POP2(KK+1,N))*.5E6
58  TT = (AMOR(KK,N)*POP2(KK,N)+AMOR(KK+1,N)*POP2(KK+1,N))*.5E6
59  IF (AMOR(KK+1,N)) 11,11,12
60  TT = (POP2(KK,N)+POP2(KK+1,N))*.1E6 + BB
61  TOT(N) = TOT(N)+BB*.5*AM0(N)
62  CB(N) = BB/ABH(N)
63  CD(N) = TT/TOT(N)
64  CM(KK,N) = CD(N)
65  IF (NALL+NSC)801,801,80
66  WRITE(K,801)801,80
81  GO TO 80

C CALCULATION OF EQUILIBRIUM STATE AND MORT. MULTIPL. (PROTEIN)

C DO 58 N=N1,N2
58  CB(N) = 0,
59  CD(N) = 0,
DO 35 L=1,LAUS
35  L1 = KK=L
36  CB(N) = CB(N)+CF(L1,N)
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35 CD(N) = CD(N) + CM(L1, N)
CD(N) = CD(N) + CM(L1, N)
CM(N) = CM(N) + CM(N)
P6(N) = (1 + CD(N) - AM(85, N)) / AM(86, N)
P = 1.5 * CD(N) * AM0(N)
S1(N) = P
S2(N) = AM(1, N) * CD(N) * P + 1.5 * P
S3 = 0.
DO 40 L=2, 85
P = P * (1 + AM(L-1, N) * CD(N))
S1(N) = S1(N) * P
S3 = S3 + AF(L, N) * P
40 S2(N) = S2(N) + AF(N) + CD(N) * P
AM = (1 - (1 - S2(N) / P) / CD(N)
P = P * (1 - AM(ES, N) + CD(N))
S1(N) = S1(N) + PF/AM(86, N) / CD(N)
S2(N) = S2(N) + P
FY(N) = 1.5 / S1(N)
FX(N) = 1.5 / S3
F(N) = CD(N)
58 FA(N) = FX(N) + FX(N)
IF(NALL) = 70, 701, 700
701 WHIP(R, 41) S1(1), F(1), S2(1), PG(1)
700 PR = 44 * GT(1)
PRO = PR * 2, 205
GO TO 80

C
C MORTALITY, FERTILITY LATER THAN 1970
C
50 IF (EO + FA + FU + XT + TL + EQ, N) GOTO 3065
50 IF (EO + FA + FU + XT + TL + EQ, N) GOTO 3065
50 IF (K<2, 12, 230, 230, 235)
230 IF (K<2, 12, 230, 230, 235)
1677 IF (K<2, 12, 230, 230, 235)
1677 IF (K<2, 12, 230, 230, 235)
235 XP(KK) = PR / GT(1)
235 XP(KK) = PR / GT(1)
DO 240 L=1, 85
DO 240 L=1, 85
E=EU
E=EU
IF (E0, E0, EU, OH, FA, EQ, EQ) GOTO 239
IF (E0, E0, EU, OH, FA, EQ, EQ) GOTO 239
239 ZM = ((44, N) / (XP(KK-KTOT) - X0) = 1) * E + 1.
240 IF (K<9, 1, AH(L, 1) = (AM3(L, 1) + AM3(L+1, 1)) * ZM * 5
240 IF (K<9, 1, AH(L, 1) = (AM3(L, 1) + AM3(L+1, 1)) * ZM * 5
240 IF (K<9, 1, AH(L, 1) = (AM3(L, 1) + AM3(L+1, 1)) * ZM * 5
240 IF (K<9, 1, AH(L, 1) = (AM3(L, 1) + AM3(L+1, 1)) * ZM * 5
3065 DO 52 N=1, N
3065 DO 52 N=1, N
307 IF (K<KONT) = 328, 3, 37, 307
307 IF (K<KONT) = 328, 3, 37, 307
308 IF (F(N) = FX(N)
308 IF (F(N) = FX(N)
GO TO 320
GO TO 320
309 FK = N/1 / KAB
309 FK = N/1 / KAB
310 IF (K<KONT = 7 * KAB) = 310, 320, 320
310 IF (K<KONT = 7 * KAB) = 310, 320, 320
311 IF (K<KONT = 2 * KAB) = 318, 315, 318
311 IF (K<KONT = 2 * KAB) = 318, 315, 318
315 FK = FK * 2.
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318 \( F(N) = F(N) = FA(N) * FK \)
321 \( CB(N) = F(N) \)
52 CONTINUE
81 IF \( 35 \leq 1 \leq 2 \)
85 IF \( (1 - CD(N) * AM(86, N)) \leq 355, 358, 355 \)
C
C CALCULATION OF POPULATION AT T=T+1
C
355 \( \text{BAB}(N) = \text{BAB}(N) * \text{CB}(N) \)
TOT (N) = \( \text{BAB}(N) * 1.5 * \text{AM}(N) * \text{CD}(N) \)
DO 75 L = 1, 86
75 TOT (N) = TOT (N) + AP \( L, N \) * AM \( L, N \) * CD \( N \)
AP (86, N) = AP (85, N) * \( 1 - \text{CD}(N) * \text{AM}(85, N) \)
+ AP (86, N) * \( 1 - \text{CD}(N) * \text{AM}(86, N) \)
DO 85 IL = 2, 85
L = 87 - IL
85 AP \( L, N = \text{AP}(L, N) * (1 - \text{CD}(N) * \text{AM}(L, N)) \)
AP \( L, N \) = \( \text{BAR}(N) * (1 - 0.5 * \text{CD}(N) * \text{AM}(N) \)
IF \( (N = 1970) 87, 85 \, 86 \)
86 SHA (N) = SM AN (N) + \text{VAR}(N) \)
STOT (N) = STOT (N) + TOT (N)
87 GT \( (N) = \text{GT}(N) * 0.5 + \text{GRAH}(N) * 0.5 + \text{TOT}(N) \)
CHR \( (N) = \text{BAB}(N) / \text{GT}(N) \)
CUNT \( (N) = \text{TOT}(N) / \text{GT}(N) \)
GRF \( P(4, N) \) = \( C(4, N) \)
DO 144 II = 15, 64
144 APSY \( (N) = \text{APSY}(N) \)
TSTK (N) = \( HAB(N) * 1.5 * \text{AP}(N) * \text{CD}(N) \)
1144 II = 1, 18
144 TOTK (N) = TOTK (N) + APSY \( II, N \) * AM \( II, N \) * CD \( N \)
59 CONTINUE
GOTO 2
350 CONTINUE
GOTO 2
41 FORMAT \( (* L5, CFSTAT, CHSTAT, TOT/BAB, P86/P85, *, 3x, F5, 2, 1) \)
& \( 3(2x, F6.4, 2x, F5.2) \)
104 FORMAT \( (* 12A2) \)
108 FORMAT \( (* \text{YEAR TOTAL POP, FERTIL, RAAB/POP MORTAL, TOT/POP} \) \)
& \( * \) \( \text{SHAB 70 STOT 70} \) \)
109 FORMAT \( (19x, 6F10.5) \)
112 FORMAT \( (1x, F11.2, *, 4, \text{ACTUAL POP}, F11.2, *, \text{CALCULATED IMMIGR} \) \)
149 FORMAT \( (1x, 2(F2.2, 1X), F4.0, 1X, F2.0, 1X, 5(F3.1, 1X)) \)
151 FORMAT \( (4(2X, F9.1, 4(3X, F7.4, 2(2X, F7.1))) \)
169 FORMAT \( (* \text{GIVE POPULATION SCENARIO NUMBER, E.G. 22}, /) \)
170 FORMAT \( (2) \)
175 FORMAT \( (* \text{SCENARIO NUMBER NOT EXISTENT} \) \)
177 FORMAT \( (* \text{SPECIFY(N) EQUILIBR. CONTROL START/SPAN, E.G. 1975/14}, /) \)
178 FORMAT \( (1x, 1X, 12) \)
179 FORMAT \( (* \text{SPECIFY(N) EO, EU, EA, TL, E.G. 0, 0/0.25/0.25/0.25/0.25}, /) \)
180 FORMAT \( (4(F3.1, 1X), F3.1) \)
654 FORMAT \( (12A2, 5X, F11.2, *, 15X, F11.2, *, \text{START OF CONTROL} = \) \)
& \( * \) \( I4, ^1, \text{TRANSITION PERIOD} = \) \( * \) \( F7.0, / \) \)
656 FORMAT \( (12A2, 5X, F11.2, *, 15X, F11.2, *, \text{START OF CONTROL} = \) \)
& \( * \) \( I4, ^1, \text{TRANSITION PERIOD} = \) \( * \) \( F7.0, /, 5X, \) \( * \) \( \text{EO} = \) \( * \) \( F9.1, 5X, \)
& \( * \) \( \text{EU = F9.1, 5X, EA = F9.1, 5X, X0 = F5.1, 5X, TL = F5.1, 5X}, / \) \)
END
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SUBROUTINE SPLINE (G,AG,N1,N2)
DIMENSION B(20),C(20),D(20),XX(20),YY(20),G(21),AG(86)

YY(1) = 0
Y1 = G(1)
YY(1) = Y1

20 YY(L) = G(L)+YY(L-1)
XX(L) = 5*L-10

21 YY(20) = YY(20) + 4*G(20)
GO TO 24

22 DO 23 L=N1,N2
EAG = YY(L)/Y2=1.

23 YY(L) = (EAG-1.) / (EAG-1.)
YY(L) = ALOG(YY(L))

24 CALL SPLXDO (L,L,L,X,X,YY,N1,N2)

25 L2 = 2
L3 = 86
IF (N1=2) 30,30,25

26 L2 = N1*5 = 9

29 IF (N2=20) 35,43,43
35 L3 = N2*5 = 9

40 DO 50 L=L3,86

50 AG(L) = G1+Y1-G(20)

DO 55 I=1,L2

55 AG(L) = YY(1)

DO 57 L=L2,L3L3

57 L1 = L+9
IF (L=5) 60,60,65

60 L1 = L1=1
65 I=I/5
D = L1-I=5
EAG = (D(I)*X+C(I))*/X+4*YY(I)

66 EAG = (EAG-1.) / (EAG+1.)
EAG = (EAG+1.)*Y2

70 AG(L) = EAG
DO 80 L=L1,85

71 AG(L) = (AG(L+1)-AG(L))/G1

80 CONTINUE
AG(86) = G(20)/G1
RETURN
END

SUBROUTINE SPLXDO (B,C,D,X,F,N1,N2)
DIMENSION B(20),C(20),D(20),X(20),F(20)
M1 = N1+1
M2 = N2+1
S=0
DO 10 I=M1,M2
D(I) = Y(I+1) - Y(I)
R = (F(I+1)-F(I)) / D(I)

10 S = R
S = 0
R = 0
C(N1) = 0
C(N2) = 0
DO 20 I=M1,M2
C(I) = C(I) + K*C(I-1)
B(I) = (Y(I-1)-Y(I+1)) / R = R*S
S = D(I)

20 P = S/B(I)
DO 30 I=M1,M2
I=M1+M2-1L

30 C(I) = (D(I)*C(I+1) - C(I)) / B(I)
DO 40 I=N1,M2
S = D(I)
P = C(I+1) - C(I)
D(I) = R/S
C(I) = C(I) + 3.
B(I) = (F(I+1)-F(I)) / S = (C(I)*R) * S

40 CONTINUE
RETURN
END
SUBROUTINE ALLPR(IYH,ISS,MAXI,INTER,NALL)
NALL=5
IF (IYH=MAX) 1,2,3
1 IF (ISS=IYH) 2,3
2 NALL=MNU(IYH,INTER)
3 RETURN
END
References


