SOFTWARE PACKAGE FOR THE LOGISTIC SUBSTITUTION MODEL

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SUMMARY

This report describes the computer program designed to generate the dynamics of market substitution of products and technologies. The report includes a simplified description of the substitution model but does not go into detail about the model, the results achieved by using it, or the methodology of the analysis; this manual should be used in conjunction with the report on energy substitution (Marchetti and Nakicenovic, RR-79-13).

The computer program is interactive: it prompts the user, and the user responds with parameters affecting the course of program execution. Input data (usually historical) are organized as time series. Model coefficients can be directly estimated by the program, or they can be assumed beforehand. Model results can be projected for any specified time interval. An output file can be generated containing all information pertinent to the results obtained. These results can be plotted on a linear or semilog scale.

PREFACE

One of the objectives of the Energy Systems Program of the International Institute for Applied Systems Analysis (IIASA) is to improve the methodology of medium- and long-range forecasting of the energy market and energy use.

This is commonly accomplished by using models that try to capture and put into equations the numerous relationships and feedbacks characterizing the operation of an economic system or parts of it. Such an approach encounters many difficulties, which are linked to the extreme complexity of the system and the fairly short-term variation of the parameters and even of the equations used. Consequently, these models lend themselves to short- and perhaps medium-range predictions, but usually fail to be useful for predictions over a period of about 50 years, the time horizon the Energy Systems Program has chosen for study.

Following the current scheme of attacking similar problems in the physical sciences, we have left aside all details and interactions and have attempted a macroscopic description of the system via the discovery of long-term invariants. Heuristically, this approach is certainly not new. In a broad sense, all science can in fact be seen as a systematic search for invariants.

This work is dedicated to the empirical testing and theoretical formulation of a certain invariant, namely, the logistic learning curve, as it applies to the structural evolution of energy systems and systems related to energy, such as coal mining, for example.

The great success of the model in organizing data of the past, and the insensitivity of the structures obtained to major political and economic perturbations seem to suggest that this invariant has great predictive power.

This Research Report represents only part of the work done in this area at the International Institute for Applied Systems Analysis, under a grant from the Volkswagenwerk Foundation, of the Federal Republic of Germany, for exploring the potential of logistic analysis in describing energy systems. The work is completely documented in an Administrative Report to the Foundation, *The Dynamics of Energy Systems and the Logistic Substitution Model*, by C. Marchetti, N. Nakicenovic, V. Peterka, and F. Fleck (AR-78-1A,B,C; July 1978).

The present paper describes the computer program designed to generate the dynamics of market substitution; it is a manual that includes a complete FORTRAN source code as an Appendix. Although a simplified description of the logistic substitution model is also given, the paper discusses in detail neither the model nor the results or the methodology of the analysis. It should be used in conjunction with the descriptive part of the analysis (AR-78-1B) reproduced in *The Dynamics of Energy Systems and the Logistic Substitution Model*, by C. Marchetti and N. Nakicenovic (RR-79-13).

As for the theoretical treatment in AR-78-1C, by V. Peterka, a new issue of *Macrodynamics of Technological Change: Market Penetration by New Technologies* (RR-77-22) is available. F. Fleck's contributions on the regularity of market penetration are part of his forthcoming doctoral dissertation at the University of Karlsruhe.

1 INTRODUCTION

This report describes the computer program Pene.r that was designed to generate the dynamics of market substitution. After formulating the phenomenological model of market substitution, our primary goal was to analyze as many substitution examples as possible, in order to gain a better understanding of the substitution rule and also in the hope of learning something about the exceptions to this rule. Each of these examples involves considerable data handling and considerable calculation effort, especially if the model is projected over long time intervals. Thus, it was obvious that the model in its initial form had to be implemented on a computer.

The program itself is designed in modules, each having a distinct function, so that it was possible to add new subroutines and modify or delete existing ones as the model evolved, or if necessary for some special applications. Thus the structure of the program is quite flexible, allowing the application of the program to any substitution process, even though it was designed primarily to handle energy substitution behavior.

The computer program was designed for interactive use; however, it can be also used in batch mode. It gives prompts to the user, and the user responds to them with parameters affecting the course of program execution. In batch mode, an input file called "Cards" controls the program execution.

Input (historical) data are organized as time series, one series per record, with a logical record number and name. They can then be used selectively in the program by identifying the desired record number and the program responds with the appropriate record name; this avoids possible confusion if an incorrect record number should accidentally be chosen.

Model coefficients can be estimated directly by the program, read from the coefficients input file, or explicitly specified during the program execution. Finally, the market substitution simulation (projection) by the model can be conducted for any desired time interval whether it overlaps with the historical one (i.e., time period for which data are available) or not. At the end, an output file that contains the results and the input data can be generated, and all of this can be plotted on a linear or semilog scale.

A simplified description of the model is given in the next section. This report does not go into the details of the model; these may be found in *The Dynamics of Energy Systems and the Logistic Substitution Model* (Marchetti and Nakicenovic, 1979). Next we will describe the Input and Output file structure, shown in Figure 3, and then we will deal directly with the computer program itself and its nine subroutines. Section 6 gives a complete description of all input information (see Figure 4) necessary for program execution, and, finally, Section 7 offers a simple tutorial example.

2 THE LOGISTIC SUBSTITUTION MODEL

Substitution of a new way of satisfying a given need for the old way has been the subject of a large number of studies. One general finding is that almost all binary substitution processes, expressed in fractional terms, follow characteristic S-shaped curves, which have been used for forecasting further competition between the two alternative technologies or products, and also for forecasting the final takeover by the new competitor.

One of the most notable models of binary technological substitution was formulated by Fisher and Pry (1970). This model uses the two-parameter logistic function to describe the substitution process. The basic assumption postulated by Fisher and Pry is that once substitution of the new for the old has progressed as far as a few percent, it will proceed to completion along a logistic substitution curve

$$f/(1 - f) = \exp(\alpha t + \beta)$$

where t is the independent variable usually representing some unit of time, α and β are constants, f is the fractional market share of the new competitor, and $1 - f$ that of the old one.

In dealing with more than two competing technologies, we have had to generalize the Fisher–Pry model since logistic substitution cannot be preserved in all phases of the substitution process. Every given technology undergoes three distinct substitution phases: growth, saturation, and decline. The growth phase is similar to the Fisher–Pry binary logistic substitution, but it usually ends before full substitution is reached. It is followed by the saturation phase, which is not logistic but which encompasses the slowing of growth and the beginning of decline. After the saturation phase of a technology, its market share declines logistically.

We assume that only one technology saturates the market at any given time, that declining technologies fade away steadily at logistic rates uninfluenced by competition from new technologies, and that new technologies enter the market and grow at logistic rates. The current saturating technology is then left with the residual market share and is forced to follow a nonlogistic path that connects its period of growth to its subsequent period of decline. After the current saturating technology has reached a logistic rate of decline, the next oldest technology enters its saturation phase, and the process is repeated until all but the most recent technology are in decline.

In effect, our model assumes that technologies that have already entered their period of market phaseout are not influenced by the introduction of new ones. The deadly competition exists between the saturating technology and all other technologies.

Let us assume that there are n competing technologies ordered chronologically in the sequence of their appearance in the market, technology 1 being the oldest and technology n the youngest. Over a certain historical interval we estimate the coefficients of the logistic functions for the technologies in the logistic substitution phases. Historical periods we have investigated range from 130 to 20 years; the substitution process can be simulated, however, over any desired time interval, which need not overlap with the historical period. Let us call the beginning of this interval t_B and the end t_E.

After the coefficients have been estimated by the ordinary least squares (OLS) method in the subroutine Fitlin.f (see section 5 and Figure 5), we have n equations:

$$f_i(t) = 1/[1 + \exp(-\alpha_i t - \beta_i)]$$

where $i = 1, \ldots, n$ and where α_i and β_i are the estimated coefficients. Now we identify the saturating technology, j, as the oldest technology still increasing its market share. The market shares are then defined by

$$f_i(t) = 1/[1 + \exp(-\alpha_i t - \beta_i)] \qquad \text{for } i \neq j$$

and

$$f_j(t) = 1 - \sum_{i \neq j} f_i(t)$$

At this time technology j is in its saturation phase, and all other technologies are either growing or declining logistically.

Now we need a criterion for the end of the saturation phase and the beginning of decline for technology j, at which point the function $f_j(t)$ will once again become logistic on its way down and the burdens of saturation will fall on technology $j + 1$. To establish this criterion we use the properties of the function

$$y_j(t) = \log \frac{f_j(t)}{1 - f_j(t)}$$

If $f_j(t)$ were logistic, $y_j(t)$ would be linear in t. However, for $f_j(t)$ in its saturation stage, the function $y_i(t)$ has negative curvature, passes through a maximum where technology j has its greatest market penetration, and then starts down. The curvature diminishes for a time, indicating that $f_j(t)$ is approaching the logistic form, but then, unless technology j is shifted into its period of decline, the curvature can begin to increase as newer technologies enter the marketplace. Phenomenological evidence from a number of substitutions suggests that the end of the saturation phase should be identified with the time at which the curvature of $y_j(t)$, relative to its slope, reaches its minimum value. We take this criterion as the final constraint in our generalization of the substitution model, and from it we determine the parameters for the jth technology in its logistic decline.

In mathematical form, the criterion for termination of the saturation phase for technology j is

$$y_j''(t)/y_j'(t) = \text{minimum}$$

(note that y'' and y' are both negative in the region of the minimum). When the minimum condition is satisfied, we call this time point t_{j+1}, the time of the beginning of the saturation for technology $j + 1$, and we determine coefficients α and β for the declining phase of technology j from the relationships

$$\alpha_j = y_j'(t_{j+1})$$

$$\beta_j = y_j(t_{j+1}) - \alpha_j t_{j+1}$$

Then the next oldest technology $j + 1$ enters its saturation phase, and the process is repeated until the last technology n enters its saturation phase, or the end of the time period t_E is encountered.

These expressions determine the temporal relationships between the competing technologies. They have been formulated in algorithmic form, so that the interpretation of the subroutine Penetr.f (see section 5) that estimates the fractional market shares is straightforward. We call this algorithm Penetration; it is illustrated in Figure 6. Only time t and the estimated coefficients α_i and β_i extracted from historical data in subroutine Fitlin.f have been treated as independent variables.

3 INPUT FILES

Punch

The Punch file contains the time series, their names and logical numbers. The Punch file is compatible with the Norman's Bank program (Norman 1977). The Bank program can create and maintain the time series on a random file. Thus it can be used in conjunction with the Pene program to generate, modify, and store the Punch file. Table 1 reproduces the primary energy inputs for the world from different *primary energy* sources from 1860 to 1974 in the Punch file format with documentation. The original data are from Schilling and Hildebrandt (1977) and Putnam (1953).

The Punch file can be also generated directly by a simple FORTRAN program. An example of such a program is given in Table 2, and input and output files in the Punch file format are shown in Table 3.

Coef

The coefficients file can be generated by the program Pene if the parameters are estimated or read directly by the program from the Coef file. This file is compatible with Norman's Auto program (Norman 1977), which offers wider options than the OLS estimates of the Pene program. Thus the coefficients can also be read by program Pene if they were generated either by Auto or by Pene in some previous run. An Incards file is generated by the program Pene when the option for the estimation of the coefficients is used. This file can be renamed and used as Cards file. Table 4 gives an example of a Coef file generated from the data given in Table 1.

Cards

Storing the program execution instructions on this file permits the omission of the interactive mode of program execution. An Incards file is generated during each program execution, which can then be renamed and used as Cards input file if a repetition or batchlike execution of a given program run should be desired. An example of a Cards file is given in Table 5.

4 OUTPUT FILES

Output

The Output file is generated with the original data, the estimated coefficients and their *t*-statistics, the correlation coefficients, the variance of the estimates, and the estimated values. An example of the Output file is given in Table 6.

Incoef

When the coefficients are estimated in the program, the Incoef file is generated; it can be renamed Coef and used later as an input file (see Table 4).

Incards

Each time the program is executed, an Incards file is generated; it can be renamed Cards and used later to control the program execution (see Table 5).

Plotter

The Plotter output can be sent either to the Plotter or to a file name (chosen by the user); the file can be displayed or plotted later. Figures 1 and 2 give an example of Plotter output using the Punch file in Table 1 and the Cards file in Table 5.

5 PROGRAM PENE.R

This program was designed to be executed on the PDP 11/70 with the Unix operating system. The source code is written in FORTRAN.IV, so that the program could be modified for implementation in another system. With the exception of the plot subroutines, most modifications could easily be made. Figure 3 shows the file structure of the program Pene.r, and the complete FORTRAN source code is given in the Appendix. The program Pene.r consists of a main program and nine subroutines:

Main.f

The Main program reads the input files, generates the output files, and controls the course of execution in accordance with the execution parameters provided by the user. This is illustrated by the flowchart in Figure 4.

Tdatfrc.f

This subroutine converts the absolute values of the time series competing for a market into fractional shares and puts them into a work matrix.

Fitlin.f

This subroutine generates OLS estimates of the coefficients for each fractional time series and the time series of the sum of all absolute values. The flow chart of this subroutine is given in Figure 5.

Penetr.f

This subroutine uses the estimated coefficients and the algorithm Penetration to estimate the fractional market shares for the period specified by the user. The flowchart of algorithm Penetration is illustrated in Figure 6.

Testtot.f

This subroutine uses the estimated fractional market shares and the estimated coefficients of the sum of all absolute values to estimate the absolute market shares and puts them into the work matrix.

Tdattot.f

This subroutine transfers the time series of the absolute market shares (original data) to the work matrix.

Func.f

This subroutine calculates the coefficients from two given values of fractional market shares.

Plotf.f

This subroutine plots the content of the work matrix – either the original absolute and/or original fractional market shares or the estimated absolute and/or estimated fractional shares are plotted.

Plotlin.f

This subroutine establishes scale, axes, and labels for all linear plots.

Plotlog.f

This subroutine establishes scale, axes, and labels for all semilog plots.

6 INPUT LINES

In the interactive mode the program supplies as prompts mnemonic names for program execution parameters. The user then assigns parameter values under the mnemonic names right-adjusted (only names and titles are left-adjusted) and enters CR (carriage return) when he is finished. If he wishes to use default values for parameters, only CR is necessary (for names, default values do not exist; however, if an input line starting with a name should be omitted, $$$, left-adjusted, must be given). This section explains the parameter values and their meanings. Error messages are supplied before the prompts of the next input line. If it is possible to correct an error, the program will correct it or repeat the input line in question. Figure 4 gives the flowchart of the program execution in response to the parameter lines (see above under Main.f).

A. Title

```
        Market Penetration by N. Nakicenovic
               IIASA Version 20.03.78

*       give one-line title within this field          *absolute units*
```

Under this prompt a title (up to 50 characters long) characterizing the particular application of the model should be given within the specified field: To the right, under *absolute units*, the units of the data under analysis should be given (centered). Appropriate conversion of the units should be given if the scaling option for the data is used (see parameter exp in the next section).

B. Parameter Line

```
        plt frc tot  iy  no dat est prt par sca exp
```

Mnemonic	Default	Value	Explanation
plt	0	0	To plot
		−1	Plot but do not draw or label the axis
		1	No plot
frc	0	0	Semilog plot for fractional market shares
		1	Linear plot for fractional market shares
		2	Linear plot for summed fractional shares
tot	0	0	Semilog plot for absolute market shares
		1	Linear plot for absolute market shares
		2	Linear plot for summed absolute shares
		4	Semilog plot for summed absolute shares
iy	0	Integer	Initial year expressed as positive or negative difference from 1900
no	100	Integer	Number of points (cannot be greater than 300)
dat	0	0	Original time series as fractions and absolute values
		1	Only fractions
		2	Only absolute values
		3	No original data
est	0	0	Estimated market shares as fractions and absolute values
		1	Only fractions
		2	Only absolute values
		3	No estimated market shares
prt	0	0	No output file
		1	Output file is generated; zeros are suppressed
		2	Output file is generated; zeros are not suppressed
par	0	0	Do not sum absolute values
		1	Sum only the absolute values
sca	0	0	Time-scale of standard length (4 cm/50 years)
		n	Where n is an integer, time-scale will be $1 + n/2$ times standard length
exp	0	0	Data will be unchanged
		n	Where n is an integer, data will be multiplied by 10**(n)

The parameters iy and no should be used with care: iy specifies the beginning of the time period to be investigated as the difference between this point and the year 1900 – e.g., 1860 would be specified as iy = –40, and 1940 as iy = 40. no determines the end of the time period under investigation. The parameter value is specified as the difference in years from the initial time point iy, excluding the year 1900 – e.g., investigation of the period 1860 to 2000 is specified by iy = –40 and no = 140. Furthermore, no is rounded by the program by default to the nearest half century. For example, iy = –40 and no = 111 would imply the initial year 1860 and the final year 1971; however, the program will by default change no to 140 making 2000 the final year. If this option is not desired 9000, should be added to the desired value of no; thus iy = –40 and no = 9111 determine the interval of 1860 to 1971.

C. Parameter Line

```
write numbers of desired series from punch file:
nu1 nu2 nu3 nu4 nu5 nu6 nu7
```

Logical numbers of time series to be used in the model are to be given under nu1 to nu7 (a maximum of seven separate time series can be entered). The program will respond by giving the number and the names of the time series extracted from the Punch file.

D. Parameter Line

```
enter $$$ for default, values otherwise:
default  iyd nod
```

iyd stands for the initial year of the time series to be used, expressed as positive or negative difference from 1900. If the default option is used, the initial year will be the first year occurring in the time series.

The value entered for nod determines the number of observations of the time series to be used. If the default option is used, all of the observations in the time series will be used.

E. Parameter Line

```
enter: 0 to read       coef
       1 to estimate
       2 to add/change
```

To read the model coefficients from the Coef file (see Coef and Incoef files above), zero should be entered; this leads directly to G. Parameter Line. To estimate coefficients (provided option dat = 3 in B. Parameter Line is not used), 1 should be entered. The third option, entering 2, also leads directly to G. Parameter Line, but in this case *all* coefficients are set to zero.

F. Parameter Line

```
year year na nu
```

If option 1 is used in E. Parameter Line, the user must give the time interval for which the coefficients are to be estimated by typing in the first and the last years of this interval. nu and na stand for the logical number and the name of the time series in question and are provided by the program. The time intervals for different series need not be the same.

G. Parameter Line

```
if you do not change/add coef give $$$ under name
name     eqn year fraction year fraction
```

This option offers the possibility of adding scenarios about the behavior of new competitions that may not be available in the historical data base. It can also be used to change the estimated coefficients. The name of the competitor and its logical equation number (eqn) must be given, together with the two desired fractional market shares (fraction) and the corresponding year. $$$ is typed left-adjusted under name in order to go to the next parameter line.

The exponential growth rate of the sum of all absolute values can be changed four times throughout the estimation period by entering total under name and 8 under eqn. year in this case denotes the beginning year for the new growth rate, and the growth rates should be entered under fraction (in fractional terms). The values entered will be displayed.

H. Parameter Line

```
write sequence numbers for n equations:
  1      2      3      4      5      6      7
 na1    na2    na3    na4    na5    na6    na7
```

Because of the possible changes of the coefficients in G. Parameter Line, the user must establish a chronological order of competitors. n stands for the number of competitors defined by the user in the previous steps, and na1 to na7 stand for the names of these competitors. Directly under these names and the numbers displayed above, which denote the current chronological order, the new sequence numbers must be given by the user.

7 TUTORIAL EXAMPLE

The use of the program Pene.r is illustrated below by the example of primary energy consumption of the world given in the Punch file (Table 1). The Punch file, containing the time series with consumption levels of different primary energy sources in million tons of coal equivalent between the years 1860 and 1974, is read by the program. The model coefficients are estimated over the whole historical period, and the file Incoef will be generated automatically (Table 4). An alternative nuclear energy penetration scenario is included specifying a 1 percent nuclear share in 1970 and a 6 percent share in 2000. In addition, total primary energy growth is changed twice from the long-term historical growth rate estimated over the period 1890 to 1950. The annual growth rate is changed to 6 percent in 1955 and to 3 percent in 1970. The model estimates are generated only for the historical period of 1860 to 1978. Two plots are generated in the plotter file (Figures 1 and 2). The first shows fractional market substitution on a linear axis plotted in the summed form, and the second shows the absolute consumption levels plotted on the logarithmic axis. Incards and Output files are also generated (Tables 5 and 6).

In the example below, the lines marked "u" in the left column show user input lines; other lines are program prompts.

```
              Market Penetration by N. Nakicenovic
                   IIASA Version 20.03.78

  *           give one-line title within this field      *absolute units*
u             world - primary energy substitution           bill. tce

   plt frc tot  iy  no dat est prt par sca exp
u        2      -509118         1       1  -3
    0   2   0 -50 118   0   0   1   0   1  -3
   write series numbers on punch file:
   nu1 nu2 nu3 nu4 nu5 nu6 nu7
u    1   4   5   7   8
     1   4   5   7   8   0   0
    5 series are read from punch file to locations:
     1       2       3       4       5       6       7
  wood pt oil      nat-gas coal-totnuclear
  enter $$$ for default, values otherwise:
  default  iyd nod
u $$$
             -40  115
```

```
  enter: 0 to read      coef
         1 to estimate
         2 to add/change
u 1
  year year 1 wood pt
u 1860 1974
  1860 1974
  year year 2 oil
u 1860 1974
  1860 1974
  year year 3 nat-gas
u 1860 1974
  1860 1974
  year year 4 coal-tot
u 1860 1974
  1860 1974
  year year 5 nuclear
u 1860 1974
  1860 1974
       ERROR *** 2 observations for this eqn
       therefore no statistics, both observations explained
  year year 8 total
u 1860 1950
  1860 1950
  if you do not change/add coef give $$$ under name
  name     eqn year fraction year fraction
u nuclear    5 1970 0.01     2000 0.06
  nuclear    5 1970 0.010000 2000 0.060000
  name     eqn year fraction year fraction
u total      8 1955 0.06     1970 0.03
  total      8 year  growth  year  growth
  total      8 1955 0.060000 1970 0.030000
  name     eqn year fraction year fraction
u $$$
   write sequence numbers for 5 equations:
    1      2      3      4      5      6      7
  wood pt oil     nat-gas coal-totnuclear
u   1      3      4      2      5
    1      3      4      2      5      0      0
   new sequence of equations is:
    1      2      3      4      5      6      7
  wood pt coal-totoil     nat-gas nuclear
```

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TABLES AND FIGURES

TABLE 1 Punch file. World primary energy inputs, by source, 1860–1974.

1 wood pt	91 -40	1 1					
317.000	317.000	317.000	317.000	318.000	318.000	318.000	318.000
318.000	318.000	318.000	318.000	319.000	319.000	320.000	320.000
324.000	323.000	322.000	321.000	320.000	319.000	319.000	318.000
317.000	317.000	316.000	314.000	313.000	311.000	310.000	308.000
308.000	307.000	304.000	302.000	301.000	299.000	297.000	296.000
296.000	293.000	292.000	288.000	288.000	287.000	284.000	282.000
281.000	276.000	275.000	274.000	273.000	270.000	266.000	263.000
261.000	259.000	257.000	252.000	249.000	247.000	242.000	231.000
230.000	227.000	226.000	224.000	220.000	216.000	212.000	209.000
203.000	202.000	198.000	194.000	191.000	191.000	184.000	181.000
176.000	173.000	169.000	166.000	162.000	159.000	157.000	152.000
149.000	147.000	144.000					
2 coal	115 -40	1 1					
132.000	140.000	139.000	149.000	162.000	172.000	181.000	194.000
192.000	199.000	204.000	227.000	247.000	263.000	256.000	264.000
267.000	273.000	273.000	287.000	314.000	338.000	363.000	388.000
390.000	381.000	382.000	408.000	441.000	448.000	475.000	494.000
499.000	487.000	509.000	536.000	552.000	577.000	608.000	667.000
701.000	718.000	734.000	807.000	812.000	858.000	926.000	1023.000
906.000	1010.000	1057.000	1077.000	1134.000	1216.000	1086.000	1070.000
1152.000	1215.000	1195.000	1040.000	1192.000	993.000	1056.000	1208.000
1188.000	1185.000	1177.000	1245.000	1357.000	1325.000	1217.000	1072.000
952.000	997.000	1092.000	1125.000	1233.000	1291.000	1204.000	1297.000
1417.000	1463.000	1508.000	1534.000	1496.000	1167.000	1215.000	1369.000
1405.000	1319.000	1431.000	1504.000	1490.000	1489.000	1469.000	1590.000
1680.000	1733.000	1815.000	1891.000	1975.000	1938.000	2051.000	2187.000
2266.000	2128.000	2308.000	2334.000	2035.000	2110.000	2166.000	2127.000
2200.500	2226.600	2276.100					
3 lig-coal	115 -40	1 1					
2.000	2.000	2.000	3.000	3.000	3.000	3.000	3.000
4.000	4.000	4.000	5.000	5.000	6.000	6.000	6.000
7.000	7.000	7.000	7.000	8.000	8.000	9.000	9.000
9.000	10.000	10.000	10.000	11.000	12.000	13.000	14.000
14.000	15.000	15.000	16.000	17.000	19.000	20.000	21.000
24.000	25.000	25.000	26.000	27.000	29.000	31.000	34.000
35.000	36.000	36.000	37.000	41.000	43.000	40.000	41.000
44.000	45.000	47.000	44.000	52.000	56.000	60.000	54.000
57.000	62.000	62.000	67.000	72.000	77.000	65.000	60.000
56.000	58.000	63.000	68.000	74.000	84.000	87.000	95.000
102.000	104.000	103.000	106.000	93.000	58.000	80.000	88.000
96.000	107.000	127.000	131.000	145.000	148.000	164.000	178.000
186.000	198.000	204.000	206.000	212.000	219.000	228.000	238.000
248.000	246.000	244.000	240.000	246.000	252.000	261.000	260.000
266.400	272.200	278.800					
4 oil	113 -38	1 1					
1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	2.000	2.000	2.000	2.000	3.000
3.000	4.000	5.000	6.000	6.000	5.000	6.000	6.000
8.000	8.000	9.000	11.000	13.000	14.000	16.000	16.000
16.000	16.000	20.000	21.000	22.000	23.000	26.000	29.000
32.000	34.000	38.000	38.000	37.000	46.000	50.000	52.000
57.000	60.000	62.000	68.000	71.000	75.000	80.000	88.000
88.000	97.000	121.000	134.000	151.000	173.000	178.000	187.000
192.000	221.000	232.000	260.000	247.000	241.000	230.000	253.000
267.000	290.000	314.000	357.000	248.000	366.000	377.000	339.000
367.000	396.000	454.000	455.000	481.000	530.000	602.000	597.000
636.000	705.000	749.000	797.000	843.000	946.000	1026.000	1069.000
1137.000	1222.000	1321.000	1402.000	1517.000	1652.000	1784.000	1921.000
2075.000	2218.000	2414.000	2611.000	2854.000	3029.000	3179.700	3426.600
3396.900							

TABLE 1 *Continued.*

```
  5 nat-gas    90 -15    1   1
     3.000      4.000      6.000      7.000      8.000      9.000      8.000      8.000
     7.000      6.000      5.000      6.000      7.000      8.000      9.000      9.000
    12.000     11.000     11.000     12.000     13.000     15.000     16.000     15.000
    18.000     19.000     20.000     21.000     22.000     23.000     24.000     29.000
    31.000     29.000     30.000     33.000     27.000     31.000     41.000     46.000
    46.000     53.000     58.000     63.000     78.000     79.000     69.000     64.000
    65.000     74.000     79.000     97.000    108.000    104.000    112.000    116.000
   124.000    130.000    145.000    157.000    169.000    176.000    196.000    220.000
   234.000    273.000    318.000    340.000    361.000    382.000    397.000    428.000
   464.000    505.000    566.000    618.000    665.000    729.000    793.000    864.000
   925.000   1010.000   1064.000   1182.000   1295.000   1417.000   1513.000   1583.700
  1619.900   1646.100
  6 hydronuc  75    0    1   1
     6.000     10.000     11.000     13.000     15.000     18.000     21.000     25.000
    25.000     26.000     31.000     34.000     38.000     42.000     40.000     41.000
    47.000     52.000     53.000     49.000     58.000     52.000     58.000     68.000
    69.000     65.000     74.000     66.000     64.000     88.000     85.000     80.000
    81.000     84.000     87.000     96.000    105.000    119.000    120.000    127.000
   128.000    137.000    140.000    156.000    140.000    136.000    145.000    153.000
   161.000    156.000    180.000    199.000    204.000    204.000    207.000    222.000
   236.000    246.000    263.000    272.000    290.000    299.000    310.000    318.000
   333.000    358.000    389.000    390.000    410.000    440.000    452.000    481.000
   517.400    543.700    583.600
  7 coal-tot 115 -40     1   1
   134.000    142.000    141.000    152.000    165.000    175.000    184.000    197.000
   196.000    203.000    208.000    232.000    252.000    269.000    262.000    270.000
   274.000    280.000    280.000    294.000    322.000    346.000    372.000    397.000
   399.000    391.000    392.000    418.000    452.000    460.000    488.000    508.000
   513.000    502.000    524.000    552.000    569.000    596.000    628.000    688.000
   725.000    743.000    759.000    833.000    839.000    887.000    957.000   1057.000
  1003.000   1046.000   1093.000   1114.000   1175.000   1259.000   1126.000   1111.000
  1196.000   1260.000   1242.000   1084.000   1244.000   1049.000   1116.000   1262.000
  1245.000   1247.000   1239.000   1312.000   1429.000   1402.000   1282.000   1132.000
  1008.000   1055.000   1155.000   1193.000   1307.000   1375.000   1291.000   1392.000
  1519.000   1587.000   1611.000   1640.000   1591.000   1225.000   1295.000   1457.000
  1501.000   1426.000   1558.000   1635.000   1635.000   1637.000   1633.000   1768.000
  1868.000   1931.000   2019.000   2097.000   2187.000   2157.000   2279.000   2425.000
  2514.000   2374.000   2552.000   2574.000   2281.000   2362.000   2427.000   2387.000
  2466.900   2498.300   2554.900
  8 nuclear    14   61    1   1
     1.760      2.600      4.240      6.000      9.680     13.840     16.760     20.880
    24.640     30.920     42.800     57.280     76.240     93.440
    $$$

  1 wood pt    8                                                   $
world fuel wood consumption in 10**6 tce extrapolated by Putnam
  2 coal       9                                                   $
world coal consumption in 10**6 tce from Hildebrandt, Schilling, Peters
  3 lig-coal   9                                                   $
world lig-coal consumption in 10**6 tce from Hildebrandt, Schi., Pet.
  4 oil        9                                                   $
world oil consumption in 10**6 tce from Hildebrandt, Schilling, Peters
  5 nat-gas    9                                                   $
world natural gas consumption in 10**6 tce from Hildebrandt, Schi., Pet.
  6 hydronuc   9                                                   $
world hydro & nuclear consumption in 10**6 tce from Hildebrandt, S., P.
  7 coal-tot   9                                                   $
world total coal consumption in 10**6 tce from Hildebrandt, Schi., Pet.
  8 nuclear    9                                                   $
world nuclear consumption in 10**6 tce from Hild., Schi., (1TWh=0.4tce)
    $$$
```

TABLE 2 Simple FORTRAN program.

```
        real*8 t,for
        dimension f(300,7),t(7),for(9)
105     format(i2)
106     format(9a8)
107     format(i4,x,a8,4i4/(8f10.3))
108     format(5x,3h$$$//5x,3h$$$/)

        read (5,105) n
        read (5,106) (for(j),j=1,9)
        do 3 j=1,n
3       read (5,106) t(j)
        do 1 i=1,300
        read (5,for,end=2) iyi,(f(i,j),j=1,n)
        no=i-1
        if (i.gt.1) go to 1
        iy=iyi
1       continue
2       ni=iy-1900
        ip1=1
        ib1=1
        do 9 j=1,n
        write (8,107) j,t(j),no,ni,ip1,ib1,(f(i,j),i=1,no)
9       continue
        write (8,108)
        stop
        end
```

TABLE 3 Input and Output files for the simple FORTRAN program.

INPUT

```
 5
(i4,5(f10.2))
total
oil
nat-gas
coal
nuclear
1960    4126.00    1321.00    618.00    2187.00      0.00
1961    4225.76    1402.00    665.00    2157.00      1.76
1962    4527.60    1517.00    729.00    2279.00      2.60
1963    4874.24    1652.00    793.00    2425.00      4.24
1964    5168.00    1784.00    864.00    2514.00      6.00
1965    5229.68    1921.00    925.00    2374.00      9.68
1966    5650.84    2075.00   1010.00    2552.00     13.34
1967    5892.76    2218.00   1084.00    2574.00     16.76
1968    5897.88    2414.00   1182.00    2281.00     20.88
1969    6292.64    2611.00   1295.00    2362.00     24.64
1970    6728.92    2854.00   1417.00    2427.00     30.92
1971    6971.80    3029.00   1513.00    2387.00     42.80
1972    7287.58    3179.70   1583.70    2466.90     57.28
1973    7621.54    3426.60   1619.90    2498.80     76.24
1974    7691.34    3396.90   1646.10    2554.90     93.44
```

OUTPUT

```
 1 total      15  60   1   1
4126.000  4225.760  4527.600  4874.240  5168.000  5229.680  5650.840  5892.760
5897.880  6292.640  6728.920  6971.800  7287.580  7621.540  7691.340
 2 oil        15  60   1   1
1321.000  1402.000  1517.000  1652.000  1784.000  1921.000  2075.000  2218.000
2414.000  2611.000  2854.000  3029.000  3179.700  3426.600  3396.900
 3 nat-gas    15  60   1   1
 618.000   665.000   729.000   793.000   864.000   925.000  1010.000  1084.000
1182.000  1295.000  1417.000  1513.000  1583.700  1619.900  1646.100
 4 coal       15  60   1   1
2167.000  2157.000  2279.000  2425.000  2514.000  2374.000  2552.000  2574.000
2281.000  2362.000  2427.000  2387.000  2466.900  2498.800  2554.900
 5 nuclear    15  60   1   1
   0.000     1.760     2.600     4.240     6.000     9.680    13.340    16.760
  20.880    24.640    30.920    42.800    57.280    76.240    93.440
                                                                          $$$
                                                                          $$$
```

TABLE 4 Incoef and Coef files.

```
wood pt     1   2   -0.03968587    74.54809570
oil         2   2    0.04901962   -96.73044586
nat-gas     3   2    0.04833411   -96.53026581
coal-tot    4   2    0.00273743    -4.88342714
nuclear     5   2    0.19531250 -389.94577026
total       8   2    0.01958038   -37.19755936
$$$

$$$
```

TABLE 5 Incards and Cards files.

```
           world - primary energy substitution                bill. tce
   0    2    0 -509118    0    0    1    0    1  -3
   1    4    5    7    8    0    0
$$$          0    0
1
1860  1974
1860  1974
1860  1974
1860  1974
1860  1974
1860  1950
nuclear     5  1970  0.010000  2000  0.060000
total       8  1955  0.060000  1970  0.030000
$$$         0     0  0.000000     0  0.000000
   1         3         4         2         5         0         0
```

TABLE 6 Output file.

MARKET PENETRATION BY N. NAKICENOVIC
IIASA VERSION 20.03.78

WORLD - PRIMARY ENERGY SUBSTITUTION BILL. TCE

OBSERVED VALUES

YEAR	TOTAL	WOOD ET	F	OIL	F	NAT-GAS	F	COAL-TOT	F	NUCLEAR	F
1860	0.45	0.32	0.703					0.13	0.297		
1861	0.46	0.32	0.691					0.14	0.309		
1862	0.46	0.32	0.691	0.00	0.002			0.14	0.307		
1863	0.47	0.32	0.674	0.00	0.002			0.15	0.323		
1864	0.45	0.32	0.658					0.17	0.342		
1865	0.49	0.32	0.644	0.00	0.002			0.18	0.354		
1866	0.52	0.32	0.632	0.00	0.002			0.18	0.366		
1867	0.52	0.32	0.616	0.00	0.002			0.20	0.382		
1868	0.52	0.32	0.617	0.00	0.002			0.20	0.381		
1869	0.52	0.32	0.609	0.00	0.002			0.20	0.389		
1870	0.53	0.32	0.603	0.00	0.002			0.21	0.395		
1871	0.55	0.32	0.577	0.00	0.002			0.23	0.421		
1872	0.57	0.32	0.556	0.00	0.002			0.25	0.441		
1873	0.59	0.32	0.541	0.00	0.003			0.27	0.456		
1874	0.58	0.32	0.548	0.00	0.003			0.26	0.449		
1875	0.59	0.32	0.541	0.00	0.003			0.27	0.456		
1876	0.60	0.32	0.540	0.00	0.003			0.27	0.457		
1877	0.61	0.32	0.533	0.00	0.005			0.28	0.462		
1878	0.61	0.32	0.532	0.00	0.005			0.28	0.463		
1879	0.62	0.32	0.519	0.00	0.006			0.29	0.475		
1880	0.65	0.32	0.495	0.01	0.008			0.32	0.498		
1881	0.67	0.32	0.475	0.01	0.009			0.35	0.516		
1882	0.70	0.32	0.458	0.01	0.009			0.37	0.534		
1883	0.72	0.32	0.442	0.01	0.007			0.40	0.551		
1884	0.72	0.32	0.439	0.01	0.008			0.40	0.553		
1885	0.72	0.32	0.442	0.01	0.008	0.00	0.004	0.39	0.545		
1886	0.72	0.32	0.439	0.01	0.011	0.00	0.006	0.39	0.544		
1887	0.75	0.31	0.421	0.01	0.011	0.01	0.008	0.42	0.560		
1888	0.78	0.31	0.401	0.01	0.012	0.01	0.009	0.45	0.579		
1889	0.79	0.31	0.394	0.01	0.014	0.01	0.010	0.46	0.582		
1890	0.82	0.31	0.378	0.01	0.016	0.01	0.011	0.49	0.595		
1891	0.84	0.31	0.368	0.01	0.017	0.01	0.010	0.51	0.606		
1892	0.85	0.31	0.364	0.02	0.019	0.01	0.009	0.51	0.607		
1893	0.83	0.31	0.369	0.02	0.019	0.01	0.008	0.50	0.603		
1894	0.85	0.30	0.358	0.02	0.019	0.01	0.007	0.52	0.616		
1895	0.88	0.30	0.344	0.02	0.021	0.01	0.006	0.55	0.629		
1896	0.90	0.30	0.336	0.02	0.022	0.01	0.007	0.57	0.635		
1897	0.92	0.30	0.324	0.02	0.023	0.01	0.008	0.60	0.646		
1898	0.96	0.30	0.311	0.02	0.023	0.01	0.008	0.63	0.658		
1899	1.02	0.30	0.291	0.02	0.023	0.01	0.009	0.69	0.677		
1900	1.06	0.30	0.283	0.03	0.025	0.01	0.009	0.73	0.687		
1901	1.08	0.29	0.272	0.03	0.027	0.01	0.011	0.74	0.690		
1902	1.09	0.29	0.267	0.03	0.029	0.01	0.010	0.76	0.694		
1903	1.17	0.29	0.247	0.03	0.029	0.01	0.009	0.83	0.714		
1904	1.18	0.29	0.245	0.04	0.032	0.01	0.010	0.84	0.713		
1905	1.23	0.29	0.234	0.04	0.031	0.01	0.011	0.89	0.724		
1906	1.29	0.28	0.220	0.04	0.029	0.02	0.012	0.96	0.740		
1907	1.40	0.28	0.201	0.05	0.033	0.02	0.011	1.06	0.754		
1908	1.35	0.28	0.208	0.05	0.037	0.02	0.011	1.00	0.744		
1909	1.39	0.28	0.198	0.05	0.037	0.02	0.013	1.05	0.751		
1910	1.44	0.27	0.190	0.06	0.039	0.02	0.013	1.09	0.757		
1911	1.47	0.27	0.187	0.06	0.041	0.02	0.014	1.11	0.759		

TABLE 6 *Continued.*

YEAR	TOTAL	WOOD PT	F	OIL	F	NAT-GAS	F	COAL-TOT	F	NUCLEAR	F
1912	1.53	0.27	0.178	0.06	0.040	0.02	0.014	1.18	0.767		
1913	1.62	0.27	0.167	0.07	0.042	0.02	0.014	1.26	0.776		
1914	1.49	0.27	0.179	0.07	0.048	0.02	0.015	1.13	0.758		
1915	1.47	0.26	0.178	0.08	0.052	0.02	0.016	1.11	0.754		
1916	1.57	0.26	0.167	0.08	0.051	0.03	0.019	1.20	0.764		
1917	1.64	0.26	0.155	0.09	0.054	0.03	0.019	1.26	0.769		
1918	1.62	0.26	0.159	0.09	0.054	0.03	0.018	1.24	0.769		
1919	1.46	0.25	0.172	0.10	0.066	0.03	0.021	1.08	0.741		
1920	1.65	0.25	0.151	0.12	0.073	0.03	0.020	1.24	0.755		
1921	1.46	0.25	0.170	0.13	0.092	0.03	0.019	1.05	0.720		
1922	1.54	0.24	0.157	0.15	0.098	0.03	0.020	1.12	0.725		
1923	1.71	0.23	0.135	0.18	0.104	0.04	0.024	1.26	0.737		
1924	1.70	0.23	0.135	0.18	0.105	0.05	0.027	1.25	0.733		
1925	1.71	0.23	0.133	0.19	0.109	0.05	0.028	1.25	0.730		
1926	1.71	0.23	0.132	0.19	0.112	0.05	0.031	1.24	0.725		
1927	1.82	0.22	0.123	0.22	0.122	0.06	0.032	1.31	0.723		
1928	1.94	0.22	0.113	0.23	0.119	0.06	0.032	1.43	0.735		
1929	1.96	0.22	0.110	0.26	0.133	0.08	0.040	1.40	0.717		
1930	1.82	0.21	0.116	0.25	0.136	0.08	0.043	1.29	0.704		
1931	1.65	0.21	0.127	0.24	0.146	0.07	0.042	1.13	0.686		
1932	1.51	0.20	0.135	0.23	0.153	0.06	0.043	1.01	0.670		
1933	1.58	0.20	0.128	0.25	0.161	0.07	0.041	1.06	0.670		
1934	1.69	0.20	0.117	0.27	0.158	0.07	0.044	1.16	0.682		
1935	1.76	0.19	0.110	0.29	0.165	0.08	0.045	1.19	0.679		
1936	1.91	0.19	0.100	0.31	0.164	0.10	0.051	1.31	0.685		
1937	2.03	0.19	0.094	0.36	0.176	0.11	0.053	1.38	0.677		
1938	1.83	0.18	0.101	0.25	0.136	0.10	0.057	1.29	0.707		
1939	2.05	0.18	0.088	0.37	0.178	0.11	0.055	1.39	0.679		
1940	2.19	0.18	0.080	0.38	0.172	0.12	0.053	1.52	0.694		
1941	2.27	0.17	0.076	0.39	0.171	0.12	0.055	1.59	0.698		
1942	2.28	0.17	0.074	0.37	0.161	0.13	0.057	1.61	0.708		
1943	2.35	0.17	0.071	0.40	0.169	0.15	0.062	1.64	0.699		
1944	2.36	0.16	0.069	0.45	0.192	0.16	0.066	1.59	0.673		
1945	2.01	0.16	0.079	0.46	0.227	0.17	0.084	1.23	0.610		
1946	2.11	0.16	0.074	0.48	0.228	0.18	0.083	1.30	0.614		
1947	2.34	0.15	0.065	0.53	0.227	0.20	0.084	1.46	0.624		
1948	2.47	0.15	0.060	0.60	0.244	0.22	0.089	1.50	0.607		
1949	2.40	0.15	0.061	1.60	0.246	0.23	0.097	1.43	0.593		
1950	2.51	0.14	0.055	0.64	0.244	0.27	0.105	1.56	0.597		
1951	2.66			0.71	0.265	0.32	0.120	1.64	0.615		
1952	2.72			0.75	0.275	0.34	0.125	1.64	0.600		
1953	2.81			0.80	0.285	0.36	0.129	1.64	0.586		
1954	2.86			0.84	0.295	0.38	0.134	1.63	0.571		
1955	3.11			0.95	0.305	0.40	0.128	1.77	0.568		
1956	3.32			1.03	0.309	0.43	0.129	1.87	0.562		
1957	3.46			1.07	0.309	0.46	0.134	1.93	0.557		
1958	3.66			1.14	0.311	0.50	0.138	2.02	0.551		
1959	3.89			1.22	0.315	0.57	0.146	2.10	0.540		
1960	4.13			1.32	0.320	0.62	0.150	2.19	0.530		
1961	4.23			1.40	0.332	0.67	0.157	2.16	0.510	0.00	0.000
1962	4.53			1.52	0.335	0.73	0.161	2.28	0.503	0.00	0.001
1963	4.87			1.65	0.339	0.79	0.163	2.43	0.498	0.00	0.001
1964	5.17			1.78	0.345	0.86	0.167	2.51	0.486	0.01	0.001
1965	5.23			1.92	0.367	0.93	0.177	2.37	0.454	0.01	0.002
1966	5.65			2.08	0.367	1.01	0.179	2.55	0.452	0.01	0.002
1967	5.89			2.22	0.376	1.08	0.184	2.57	0.437	0.02	0.003
1968	5.90			2.41	0.409	1.18	0.200	2.28	0.387	0.02	0.004
1969	6.29			2.61	0.415	1.30	0.206	2.36	0.375	0.02	0.004
1970	6.73			2.85	0.424	1.42	0.211	2.43	0.361	0.03	0.005
1971	6.97			3.03	0.434	1.51	0.217	2.39	0.342	0.04	0.006

TABLE 6 *Continued.*

YEAR	TOTAL	WOOD PT	F	OIL	F	NAT-GAS	F	COAL-TOT	F	NUCLEAR	F
1972	7.29			3.18	0.436	1.58	0.217	2.47	0.339	0.06	0.008
1973	7.62			3.43	0.450	1.62	0.213	2.50	0.328	0.08	0.010
1974	7.69			3.40	0.442	1.65	0.214	2.55	0.332	0.09	0.012

INTEGRALS FROM 1860 TO 1974 ARE:

	TOTAL	WOOD PT	F	OIL	F	NAT-GAS	F	COAL-TOT	F	NUCLEAR	F
	228.	24.	0.106	53.	0.233	24.	0.104	126.	0.556	0.	0.002

COEFFICIENTS ESTIMATED IN FITLIN,F

```
EQN 1  WOOD PT   IS: Y = -0.040*T+  76.548      R**2 = 0.990  VAR = 0.011
                        (-94.885) ( 93.514)

EQN 2  OIL       IS: Y =  0.049*T+ -96.730      R**2 = 0.984  VAR = 0.027
                        ( 72.373) (-73.976)

EQN 3  NAT-GAS   IS: Y =  0.049*T+ -96.530      R**2 = 0.979  VAR = 0.025
                        ( 58.058) (-60.698)

EQN 4  COAL-TOT  IS: Y =  0.003*T+  -4.883      R**2 = 0.224  VAR = 0.344
                        (  1.662) ( -1.547)

EQN 6  TOTAL     IS: Y =  0.020*T+ -37.198      R**2 = 0.972  VAR = 0.308
                        ( 55.570) (-55.412)

EQN 5  NUCLEAR   IS: Y =  0.061*T+-125.657     STARTING 1960

EQN 7  TOTAL     IS: Y =  0.060*T+-116.219     STARTING 1955

EQN 8  TOTAL     IS: Y =  0.030*T+ -57.118     STARTING 1970
```

ESTIMATED VALUES

YEAR	TOTAL	WOOD PT	F	COAL-TOT	F	OIL	F	NAT-GAS	F	NUCLEAR	F
1860	0.46	0.31	0.675	0.15	0.319						
1861	0.47	0.31	0.667	0.15	0.328						
1862	0.48	0.31	0.658	0.16	0.337						
1863	0.49	0.32	0.649	0.17	0.345						
1864	0.50	0.32	0.640	0.18	0.354						
1865	0.51	0.32	0.630	0.18	0.363						
1866	0.52	0.32	0.621	0.19	0.372						
1867	0.53	0.32	0.612	0.20	0.381						
1868	0.54	0.32	0.602	0.21	0.390						
1869	0.55	0.32	0.593	0.22	0.399						
1870	0.56	0.33	0.583	0.23	0.408						
1871	0.57	0.33	0.573	0.24	0.418						
1872	0.58	0.33	0.564	0.25	0.427						
1873	0.59	0.33	0.554	0.26	0.436						
1874	0.60	0.33	0.544	0.27	0.446						
1875	0.62	0.33	0.534	0.28	0.455						
1876	0.63	0.33	0.524	0.29	0.464						
1877	0.64	0.33	0.514	0.30	0.474						
1878	0.65	0.33	0.505	0.32	0.483						
1879	0.67	0.33	0.495	0.33	0.492						
1880	0.68	0.33	0.485	0.34	0.502	0.01	0.010				

TABLE 6 *Continued.*

YEAR	TOTAL	WOOD PT	F	OIL	F	NAT-GAS	F	COAL-TOT	F	NUCLEAR	F
1881	0.69	0.33	0.475	0.35	0.511	0.01	0.011				
1882	0.71	0.33	0.465	0.37	0.520	0.01	0.011				
1883	0.72	0.33	0.455	0.38	0.529	0.01	0.012				
1884	0.73	0.33	0.445	0.40	0.538	0.01	0.012				
1885	0.75	0.33	0.435	0.41	0.547	0.01	0.013				
1886	0.76	0.33	0.426	0.42	0.556	0.01	0.014				
1887	0.78	0.32	0.416	0.44	0.565	0.01	0.014				
1888	0.79	0.32	0.406	0.46	0.573	0.01	0.015				
1889	0.81	0.32	0.397	0.47	0.582	0.01	0.016				
1890	0.83	0.32	0.387	0.49	0.590	0.01	0.017				
1891	0.84	0.32	0.378	0.50	0.599	0.01	0.017				
1892	0.86	0.32	0.369	0.52	0.607	0.02	0.018				
1893	0.88	0.32	0.360	0.54	0.615	0.02	0.019				
1894	0.89	0.31	0.350	0.56	0.623	0.02	0.020				
1895	0.91	0.31	0.341	0.57	0.630	0.02	0.021				
1896	0.93	0.31	0.333	0.59	0.638	0.02	0.022				
1897	0.95	0.31	0.324	0.61	0.645	0.02	0.023				
1898	0.97	0.30	0.315	0.63	0.652	0.02	0.024				
1899	0.99	0.30	0.307	0.65	0.659	0.03	0.026				
1900	1.01	0.30	0.298	0.67	0.666	0.03	0.027				
1901	1.03	0.30	0.290	0.69	0.672	0.03	0.028				
1902	1.05	0.29	0.282	0.71	0.679	0.03	0.029				
1903	1.07	0.29	0.274	0.73	0.685	0.03	0.031	0.01	0.010		
1904	1.09	0.29	0.266	0.75	0.690	0.04	0.032	0.01	0.011		
1905	1.11	0.29	0.259	0.77	0.696	0.04	0.034	0.01	0.012		
1906	1.13	0.28	0.251	0.79	0.701	0.04	0.036	0.01	0.012		
1907	1.15	0.28	0.244	0.81	0.706	0.04	0.037	0.01	0.013		
1908	1.18	0.28	0.236	0.84	0.711	0.05	0.039	0.02	0.013		
1909	1.20	0.27	0.229	0.86	0.716	0.05	0.041	0.02	0.014		
1910	1.22	0.27	0.222	0.88	0.720	0.05	0.043	0.02	0.015		
1911	1.25	0.27	0.216	0.90	0.724	0.06	0.045	0.02	0.015		
1912	1.27	0.27	0.209	0.93	0.728	0.06	0.047	0.02	0.016		
1913	1.30	0.26	0.202	0.95	0.731	0.06	0.049	0.02	0.017		
1914	1.32	0.26	0.196	0.97	0.734	0.07	0.052	0.02	0.018		
1915	1.35	0.26	0.190	0.99	0.737	0.07	0.054	0.02	0.019		
1916	1.37	0.25	0.184	1.02	0.740	0.08	0.057	0.03	0.019		
1917	1.40	0.25	0.178	1.04	0.742	0.08	0.060	0.03	0.020		
1918	1.43	0.25	0.172	1.06	0.744	0.09	0.062	0.03	0.021		
1919	1.46	0.24	0.167	1.09	0.746	0.10	0.065	0.03	0.022		
1920	1.49	0.24	0.161	1.11	0.747	0.10	0.068	0.03	0.023		
1921	1.52	0.24	0.156	1.13	0.748	0.11	0.072	0.04	0.025		
1922	1.55	0.23	0.151	1.16	0.749	0.12	0.075	0.04	0.026		
1923	1.58	0.23	0.146	1.18	0.749	0.12	0.078	0.04	0.027		
1924	1.61	0.23	0.141	1.20	0.749	0.13	0.082	0.05	0.028		
1925	1.64	0.22	0.136	1.23	0.748	0.14	0.086	0.05	0.030		
1926	1.67	0.22	0.132	1.25	0.748	0.15	0.090	0.05	0.031		
1927	1.71	0.22	0.127	1.27	0.747	0.16	0.094	0.06	0.033		
1928	1.74	0.21	0.123	1.30	0.745	0.17	0.098	0.06	0.034		
1929	1.77	0.21	0.119	1.32	0.743	0.18	0.102	0.06	0.036		
1930	1.81	0.21	0.114	1.34	0.741	0.19	0.107	0.07	0.037		
1931	1.84	0.20	0.111	1.36	0.739	0.21	0.112	0.07	0.039		
1932	1.88	0.20	0.107	1.38	0.736	0.22	0.117	0.08	0.041		
1933	1.92	0.20	0.103	1.40	0.731	0.23	0.122	0.08	0.043		
1934	1.96	0.19	0.099	1.42	0.727	0.25	0.127	0.09	0.045		
1935	1.99	0.19	0.096	1.44	0.723	0.26	0.133	0.09	0.047		
1936	2.03	0.19	0.092	1.46	0.718	0.28	0.138	0.10	0.049		
1937	2.07	0.19	0.089	1.48	0.713	0.30	0.144	0.11	0.052		
1938	2.12	0.18	0.086	1.50	0.708	0.32	0.151	0.11	0.054		
1939	2.16	0.18	0.083	1.51	0.702	0.34	0.157	0.12	0.057		
1940	2.22	0.18	0.080	1.53	0.696	0.36	0.164	0.13	0.059		

TABLE 6 *Continued.*

YEAR	TOTAL	WOOD PT	F	OIL	F	NAT-GAS	F	COAL-TOT	F	NUCLEAR	F
1941	2.24	0.17	0.077	1.54	0.689	0.38	0.179	0.14	0.062		
1942	2.29	0.17	0.074	1.56	0.681	0.41	0.177	0.15	0.065		
1943	2.33	0.17	0.072	1.57	0.674	0.43	0.185	0.16	0.068		
1944	2.38	0.16	0.069	1.58	0.666	0.46	0.192	0.17	0.071		
1945	2.43	0.16	0.067	1.59	0.657	0.48	0.200	0.18	0.074		
1946	2.47	0.16	0.064	1.60	0.648	0.51	0.208	0.19	0.078		
1947	2.52	0.16	0.062	1.61	0.638	0.54	0.216	0.21	0.081		
1948	2.57	0.15	0.060	1.62	0.628	0.58	0.224	0.22	0.085		
1949	2.62	0.15	0.057	1.62	0.618	0.61	0.233	0.23	0.089		
1950	2.68	0.15	0.055	1.62	0.607	0.65	0.242	0.25	0.093		
1951	2.73	0.15	0.053	1.63	0.596	0.68	0.251	0.26	0.097		
1952	2.78	0.14	0.051	1.62	0.584	0.72	0.260	0.28	0.101		
1953	2.84	0.14	0.049	1.62	0.571	0.77	0.270	0.30	0.106		
1954	2.89	0.14	0.048	1.62	0.559	0.81	0.280	0.32	0.111		
1955	2.95	0.13	0.046	1.61	0.545	0.85	0.290	0.34	0.115		
1956	3.13	0.14	0.044	1.67	0.532	0.94	0.299	0.38	0.120		
1957	3.33	0.14	0.042	1.72	0.518	1.03	0.309	0.42	0.126		
1958	3.53	0.14	0.041	1.78	0.505	1.12	0.318	0.46	0.131		
1959	3.75	0.15	0.039	1.84	0.492	1.23	0.327	0.51	0.137		
1960	3.99	0.15	0.038	1.90	0.478	1.34	0.336	0.57	0.142		
1961	4.23	0.15	0.036	1.97	0.465	1.46	0.345	0.63	0.148		
1962	4.49	0.16	0.035	2.03	0.451	1.58	0.353	0.69	0.155		
1963	4.77	0.16	0.034	2.09	0.438	1.72	0.361	0.77	0.161		
1964	5.06	0.16	0.032	2.15	0.425	1.86	0.368	0.85	0.168		
1965	5.38	0.17	0.031	2.21	0.412	2.02	0.375	0.94	0.175		
1966	5.71	0.17	0.030	2.28	0.399	2.18	0.382	1.04	0.182		
1967	6.06	0.18	0.029	2.34	0.386	2.35	0.388	1.15	0.189		
1968	6.44	0.18	0.028	2.40	0.373	2.53	0.393	1.26	0.196		
1969	6.84	0.18	0.027	2.47	0.361	2.73	0.399	1.40	0.204		
1970	7.26	0.19	0.026	2.53	0.349	2.93	0.403	1.54	0.212		
1971	7.48	0.19	0.025	2.52	0.337	3.05	0.408	1.65	0.220	0.08	0.011
1972	7.71	0.18	0.024	2.50	0.325	3.17	0.412	1.76	0.229	0.09	0.011
1973	7.94	0.18	0.023	2.49	0.313	3.29	0.415	1.89	0.237	0.10	0.012
1974	8.18	0.18	0.022	2.47	0.302	3.42	0.417	2.02	0.246	0.10	0.013
1975	8.43	0.18	0.021	2.45	0.290	3.54	0.420	2.15	0.255	0.11	0.014
1976	8.69	0.18	0.020	2.43	0.279	3.66	0.421	2.30	0.265	0.13	0.014
1977	8.95	0.18	0.020	2.41	0.269	3.78	0.422	2.45	0.274	0.14	0.015
1978	9.23	0.17	0.019	2.38	0.258	3.90	0.423	2.62	0.284	0.15	0.016
INTEGRALS FROM 1860 TO 1975 ARE:											
	229.	28.	0.122	124.	0.540	53.	0.231	24.	0.105	0.	0.001
INTEGRALS FROM 1975 TO 1978 ARE:											
	35.	1.	0.020	10.	0.279	15.	0.421	9.	0.265	1.	0.014

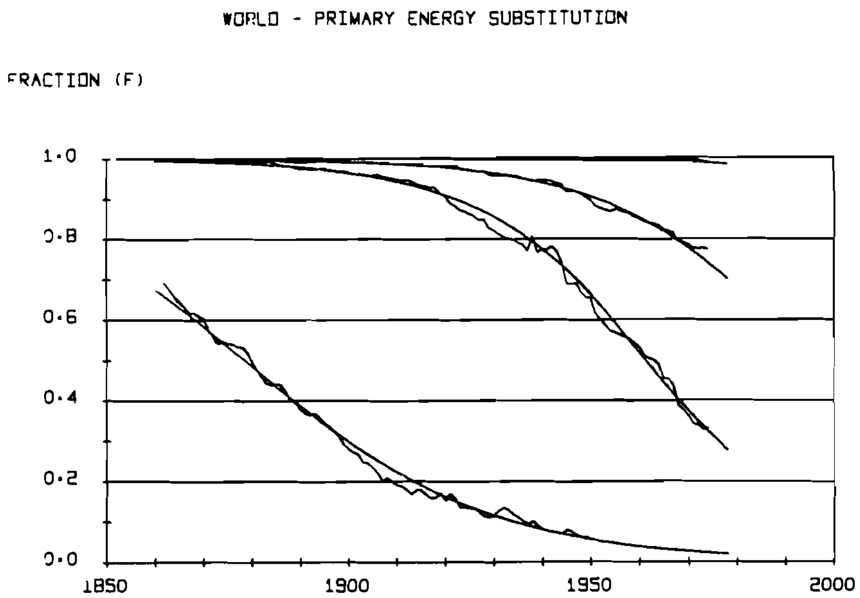

FIGURE 1 Example of Plotter output using Punch and Cards files.

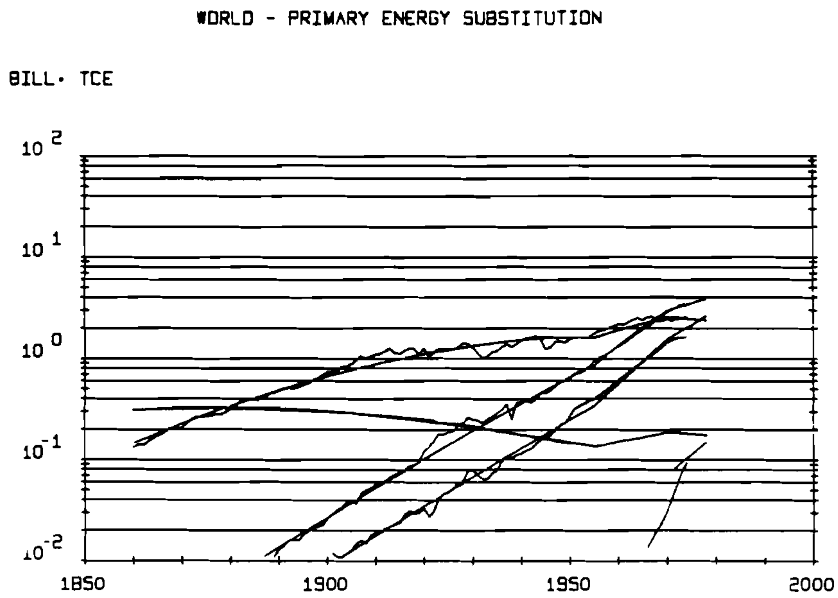

FIGURE 2 Example of Plotter output using Punch and Cards files.

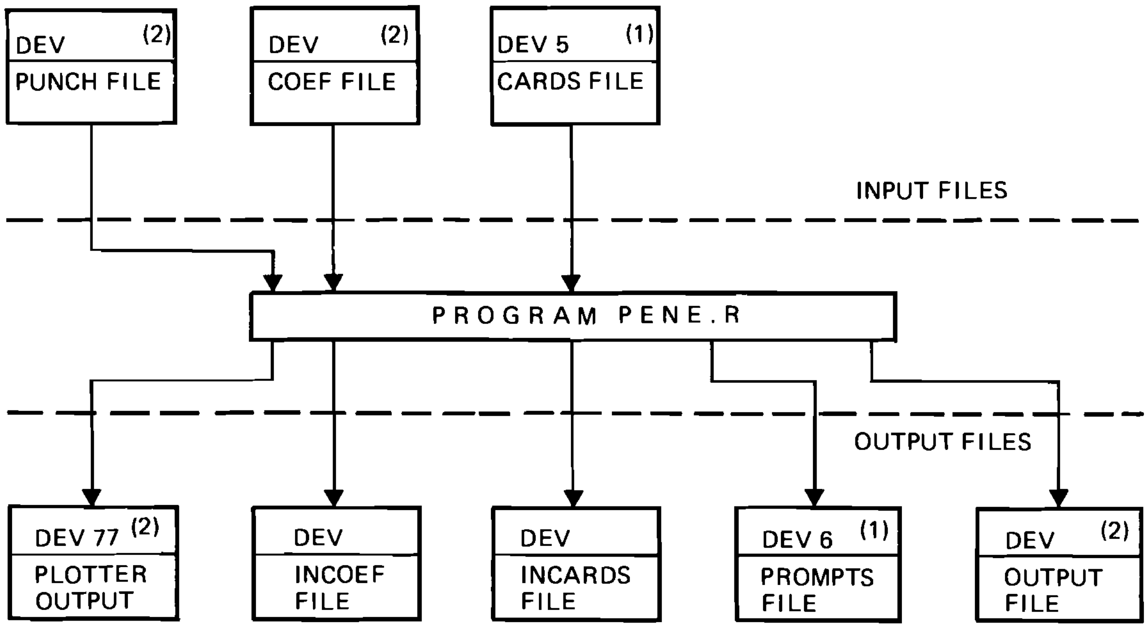

FIGURE 3 File structure of the program Pene.r. *1*. Cards file contains control parameters. In interactive use, DEV 5 (device 5) should be the terminal input, and prompts file should also be sent there; DEV 6 (device 6) should be the output to the terminal. Incards file has the same information and structure as Cards file.

2. These files are optional and will be read or generated in accordance with the control parameters. Incoef file has the same structure as Coef file.

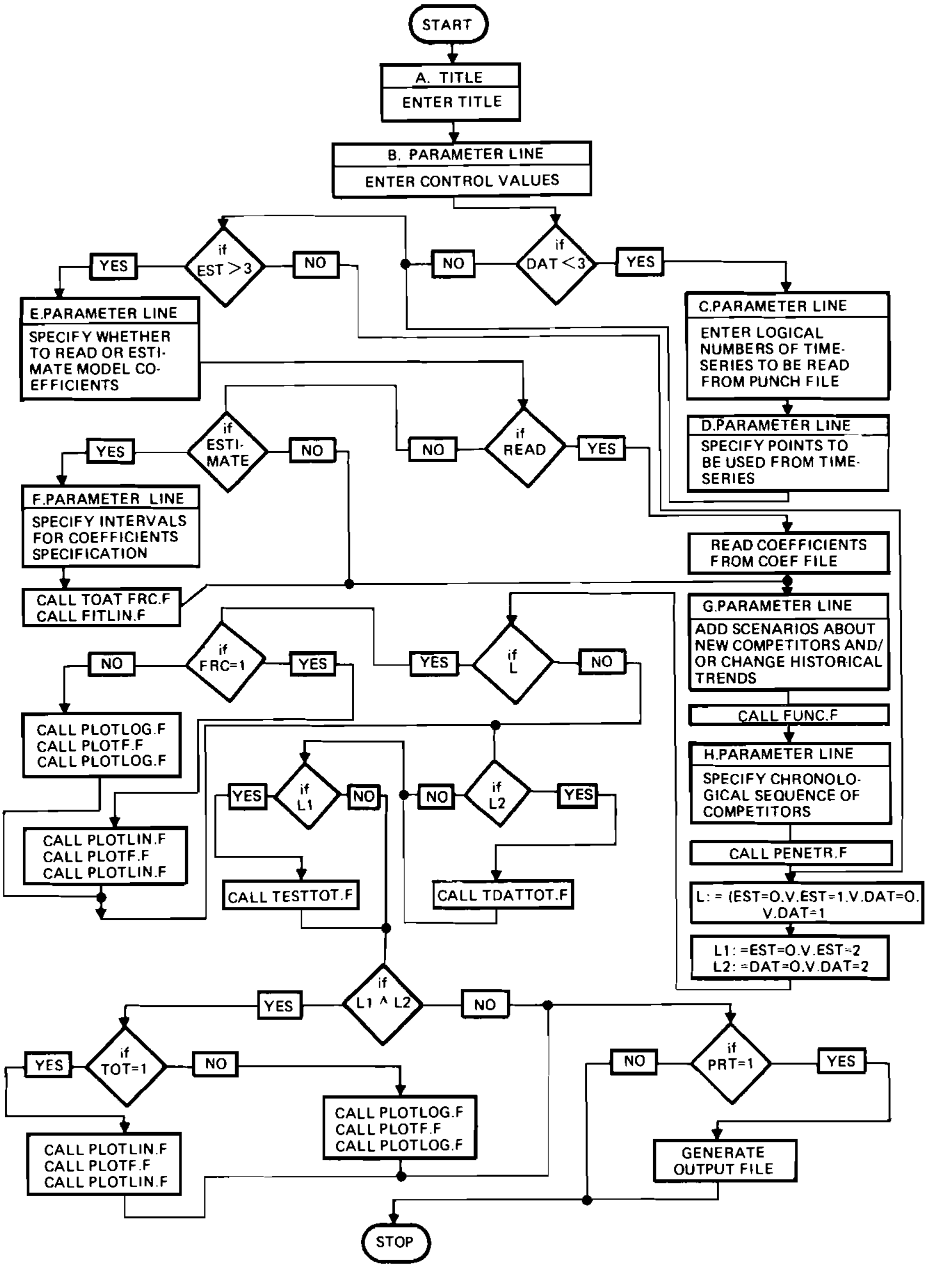

FIGURE 4 Flowchart of the main program: Pene.r.

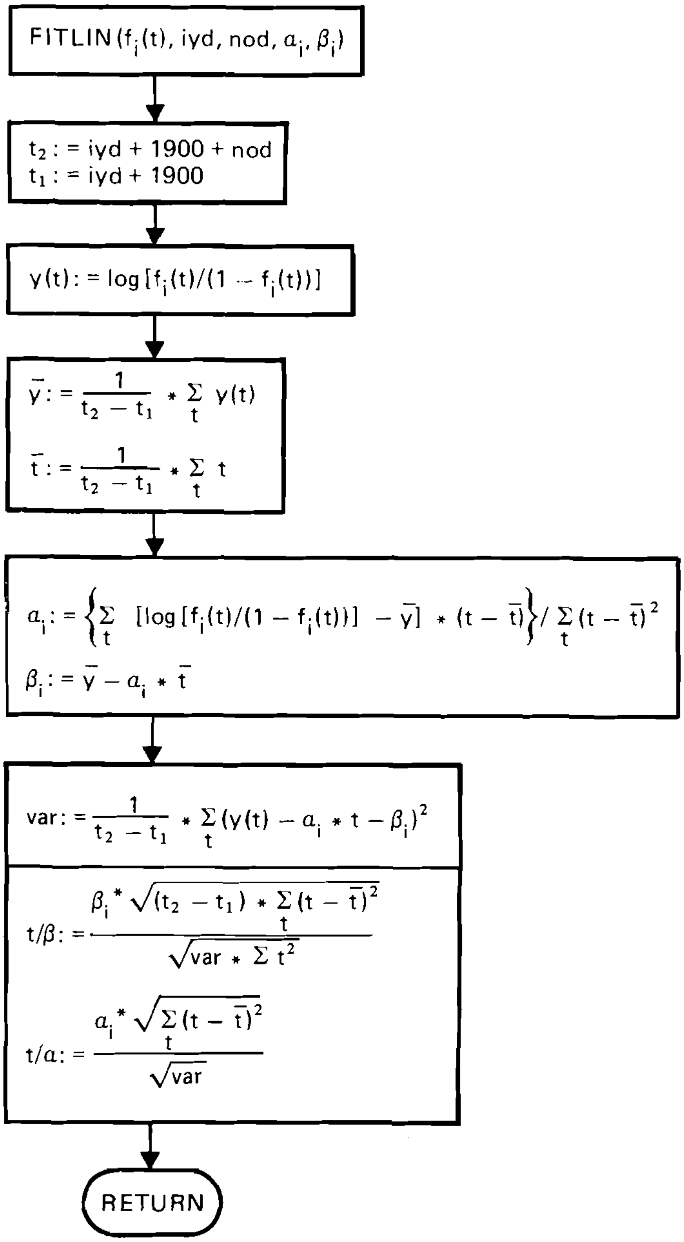

FIGURE 5 Flowchart of the estimation subroutine fitlin.f. *var* is the variance of $y(t)$; t/α and t/β are t-statistics with $t_2 - t_1 - 2$ degrees of freedom under the hypotheses $\alpha = 0$ and $\beta = 0$.

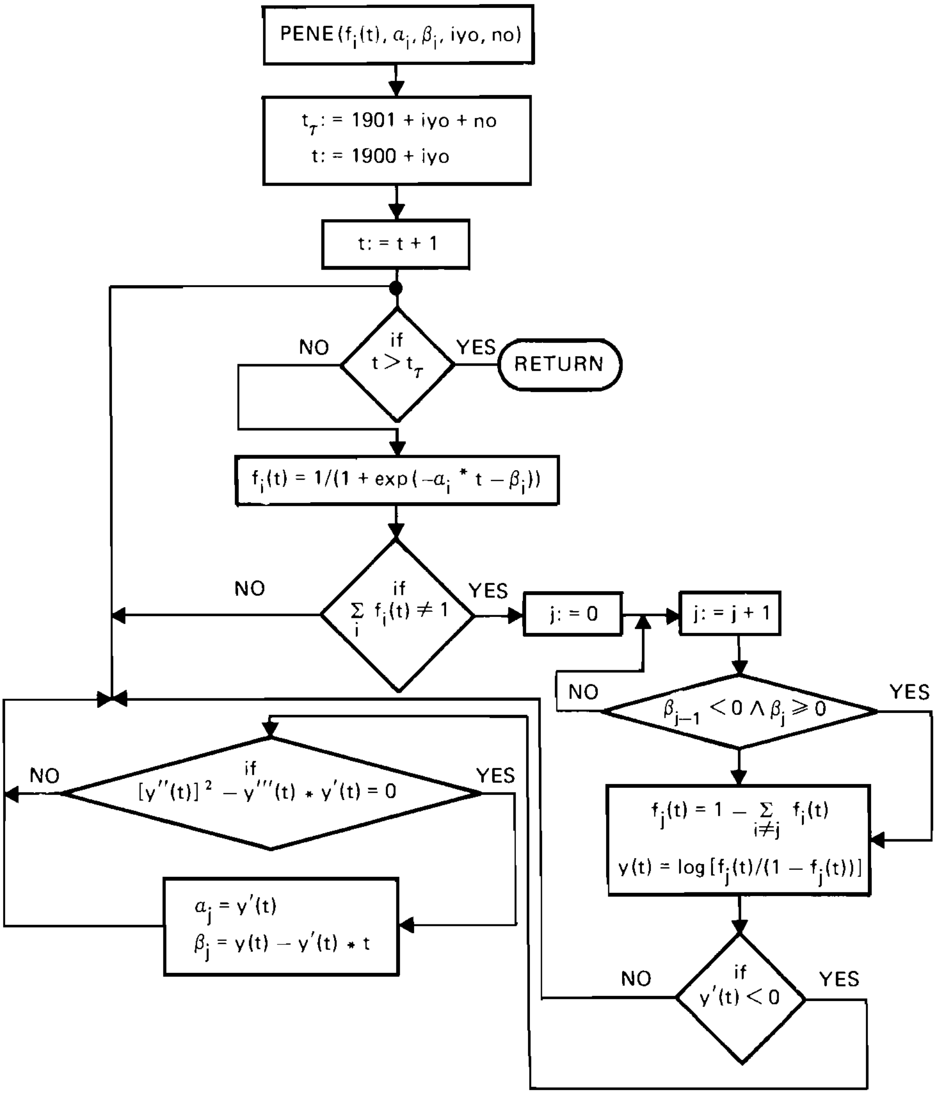

FIGURE 6 Flowchart of the market substitution subprogram: Penetr.f (algorithm Penetration).

Appendix

FORTRAN Source Code

Main.f

```
      COMMON /DATA/W(7,152),DLAB(7,10),ND,IYD,NOD,
     &             NUD(7),NAD(7),NU(7),IY(7)
     &        /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &             NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &        /COMM/NUO(7),IYO,IPO,IBO,PRT,PAR,FOR(8),
     &             PLT,FRC,IFRC,TOT,DAT,EST,YMAX,YMIN

      REAL*8 DLAB,FLAB,NAD,NAF,NA1,TS,ISS,BL,NATOT,NAT,TITLE,BB,FOR
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,FIT,PAR,SCA,EXP
      LOGICAL LOGIC
      DIMENSION W(7),IW(7),TITLE(2,7),TYPE(2,10)
      DATA TS,ISS,BL,IPO,IBO,SCALEX/1H$,3H$$$,4H    ,1,1,2./
      DATA NATOT,YMIN,YMAX/8HTOTAL    ,0.,0./
      DATA TYPE(2,2),TYPE(2,3),TYPE(2,4)/4HFRAC,4HTION,4H (F)/
      DATA ABSOL,UTE,UNI,TS/4HABSO,4HLUTE,4H UNI,4HTS  /
      DATA FOVE,ONEF,BL4/4HF/(1,4H-F) ,4H    /
      DATA BB,YEAR(1)/8HSTARTING,1.E30/
      DATA FOR(1),FOR(2),FOR(3),FOR(4),FOR(5),FOR(6),FOR(7),FOR(8)
     & /',G12.3',',F12.1',',F10.2',',F7.3',',3X,A4',',6X,A4','(I4',')'/


      CALL SETFIL(8,'OUTPUT')
      CALL SETFIL(4,'PUNCH')
      CALL SETFIL(3,'COEF')
      CALL SETFIL(2,'INCARDS')
      CALL SETFIL(1,'INCOEF')

100   FORMAT(I4,1X,A8,4I4/(8F12.3))
101   FORMAT(10X,'ERROR *** SERIES',I2,': IB.GT.IP')
102   FORMAT(A8,I3,' YEAR  GROWTH  YEAR  GROWTH')
103   FORMAT(1X,I2,' SERIES ARE READ FROM PUNCH FILE
     & TO LOCATIONS:'/7(I4,4X)/7A8)
104   FORMAT(' WRITE NUMBERS OF DESIRED SERIES FROM PUNCH FILE:'
     & /' NU1 NU2 NU3 NU4 NU5 NU6 NU7')
105   FORMAT(/8X,' MARKET PENETRATION BY N. NAKICENOVIC'/
     & 16X,'IIASA VERSION 28.03.78'/)
106   FORMAT(I4,1X,A8,I3/(9A8))
107   FORMAT(/' PLT FRC TOT  IY  NU DAT EST PRT PAR SCA EXP')
108   FORMAT(11I4)
109   FORMAT(1X,I2,' EQATIONS ARE READ FROM COEF FILE
     & TO LOCATIONS:'/7(I4,4X)/8A8)
110   FORMAT(' WRITE SEQUENCE NUMBERS FOR '
     &,I1,' EQUATIONS:'/7(I4,4X)/7A8)
111   FORMAT(7(I4,4X))
112   FORMAT(' NEW SEQUENCE OF EQUATIONS IS:
     &'/7(I4,4X)/7A8)
113   FORMAT('IF YOU DO NOT CHANGE/ADD COEF GIVE $$$ UNDER NAME')
114   FORMAT('NAME',4X,'EQN YEAR FRACTION YEAR FRACTION')
115   FORMAT(A8,I3,2(I5,F9.6))
116   FORMAT(5X,'ERROR *** EQN',I2,' SAME TITLE AS EQN',I2,' : ',A8)
117   FORMAT(5X,'ERROR *** EQN',I2,'.GT.7')
118   FORMAT('ENTER: 0 TO READ      COEF'/
     & 7X,'1 TO ESTIMATE'/
     & 7X,'2 TO ADD/CHANGE')
119   FORMAT(I1)
120   FORMAT(A8,2I4,4F14.8,/(16X,4F14.8))
121   FORMAT('YEAR YEAR ',I1,1X,A8)
122   FORMAT(I4,I5)
123   FORMAT('ENTER $$$ FOR DEFAULT, VALUES OTHERWISE:'/
     &'DEFAULT  IYO NOD')
```

Main.f continued

```
124     FORMAT(A8,2I4)
125     FORMAT('$$$'//'$$$'/)
126     FORMAT('*           GIVE ONE-LINE TITLE WITHIN THIS FIELD'
     &,'             *ABSOLUTE UNITS*')
127     FORMAT(7A8,4A4)
128     FORMAT(//10X,'COEFFICIENTS FROM FILE COEF'/)
129     FORMAT(/5X,'EQN',I2,'  ',A6,' IS: Y =',F7.3,'*T+' -
     &,4X,A6,I5/)
130     FORMAT(//10X,'COEFFICIENTS ESTIMATED IN FITLIN.F'/
131     FORMAT(/5X,'ERROR *** NO.GT.300 *TRY AGAIN*'//)
132     FORMAT(/5X,'ERROR *** WRONG PARAMETER SPECIFICATIONS '
     &,'*TRY AGAIN*'//)
133     FORMAT(/5X,'ERROR *** ',I4,'.GT.',I4,' *TRY AGAIN*'//)
134     FORMAT(/5X,'ERROR *** NOD.EQ.0 NO OBSERVATIONS READ')
135     FORMAT(/'ENTER DATA SCALING; MULTIPLICATION FACTOR,',
     &' EXPONENT AND UNITS IF CHANGED:'/
     &'FACTOR EXP *ABSOLUTE UNITS*')
136     FORMAT(F6.4,I4,1X,4A4)
137     FORMAT(/5X,'ERROR *** SERIES',I2,': NOD.GT.150 *TRY AGAIN*'//)
138     FORMAT(' NUMBERS AND TITLES OF SERIES ON PUNCH FILE:')
139     FORMAT(10(I4,4X))
140     FORMAT(10A8)


        NAT=BL
        NO=0
        YEAR(2)=YEAR(1)
        YEAR(3)=YEAR(1)
        YEAR(4)=YEAR(1)
        DO 21 I=1,7
        NUF(I)=I
        NAD(I)=BL
21      NAF(I)=BL
        WRITE (6,105)
        WRITE (6,126)
        READ  (5,127) (TITLE(1,I),I=1,7),(W(J),J=1,4)
        WRITE (2,127) (TITLE(1,J),J=1,7),(W(J),J=1,4)
        WRITE (6,127) (TITLE(1,J),J=1,7),(W(J),J=1,4)
58      WRITE (6,107)
        READ (5,108)  PLT,IFRC,TOT,IYO,NOD,IDAT,EST,PRT,PAR,SCA,EXP
        NO2=NOD
        IF (NOD.GE.9000) NOD=NOD-9000
        FRC=IFRC
        IF (FRC.EQ.-1) FRC=0
        DAT=IDAT
        IF (DAT.GE.9000) DAT=DAT-9000
        IF (NOD.GT.300) WRITE (6,131)
        IF (NOD.GT.300) GO TO 58
        IF (NOD.EQ.0) NOD=100
        WRITE (6,108) PLT,FRC,TOT,IYO,NOD,DAT,EST,PRT,PAR,SCA,EXP
        WRITE (2,108) PLT,IFRC,TOT,IYO,NOD,DAT,EST,PRT,PAR,SCA,EXP
        LOGIC=.FALSE.
        LOGIC=PLT.LT.-1.OR.PLT.GT.1.OR.
     &        FRC.LT. 0.OR.FRC.GT.2.OR.
     &        TOT.LT. 0.OR.TOT.GT.4.OR.
     &        NOD.LT. 0.OR.NOD.EQ.0.OR.
     &        DAT.LT. 0.OR.DAT.GT.3.OR.
     &        EST.LT. 0.OR.EST.GT.3.OR.
     &        PRT.LT. 0.OR.PRT.GT.2.OR.
     &        PAR.LT. 0.OR.PAR.GT.1.OR.
```

Main.f continued

```
     &        TOT.EQ.3
      IF (LOGIC) WRITE (6,132)
      IF (LOGIC) GO TO 58
      SCALEX=SCALEX+FLOAT(SCA)
      IPAR=PAR
      PAR=0
      XMUL=1.
      IF (EXP.LT.999) GO TO 66
      WRITE (6,135)
      READ (5,136) XMUL,EXP,(TYPE(1,J),J=1,4)
      I=0
68    IF (XMUL.LE.1.) GO TO 67
      XMUL=XMUL/10.
      I=I+1
      IF (XMUL.GT.1.) GO TO 68
67    EXP=EXP+I
      WRITE (2,136) XMUL,EXP,(TYPE(1,J),J=1,4)
      DO 70 J=1,4
70    IF (TYPE(1,J).NE.BL4) LOGIC=.TRUE.
      DO 69 J=1,4
      IF (LOGIC) W(J)=TYPE(1,J)
69    TYPE(1,J)=BL4
      WRITE (6,135) XMUL,EXP,(W(J),J=1,4)
66    IF (PRT.EQ.0) GO TO 57
      WRITE (8,125)
      WRITE (8,127) (TITLE(1,J),J=1,7),(W(I),I=1,4)
57    LOGIC=.TRUE.
      DO 56 I=1,4
56    LOGIC=LOGIC.AND.BL4.EQ.W(I)
      IF (LOGIC) GO TO 45
      ABSOL=W(1)
      UTE=W(2)
      UNI=W(3)
      TS=W(4)
45    IF (PLT.LE.0) CALL P1130
      IF (DAT.LT.3) GO TO 46
      IYF=IYO
      IYD=IYO
      I1=1
46    IF (DAT.EQ.3) GO TO 18

C        READ ORIGINAL DATA FROM PUNCH FILE

      IF (IDAT.LT.9000) GO TO 75
      M=1
      K=1
      WRITE (6,138)
      DO 73 I=1,70
      READ (4,100) NU1,DLAB(M,K),NO1,IY1,IP1,IB1,(Q,J=1,NO1)
      N=K
      IF (DLAB(M,K).EQ.ISS) N=K-1
      LOGIC=K.EQ.10.OR.DLAB(M,K).EQ.ISS
      IF (LOGIC)  WRITE (6,139) (J,J=1,N)
      IF (LOGIC)  WRITE (6,140) (DLAB(M,J),J=1,N)
      IF (DLAB(M,K).EQ.ISS) GO TO 74
      K=K+1
      IF (K.GT.10) M=M+1
73    IF (K.GT.10) K=1
74    REWIND 4
```

Main.f continued

```
        CALL SETFIL(4  PUNCH')
75      WRITE (6,134)
        READ (5,12     NUD(L),L=1,7)
        WRITE (6,1   (NUD(I1),I1=1,7)
        WRITE (2      (NUD(I2),I2=1,7)
        DO 1 I=1,
        IF (NUD(I).GT.0) ND=ND+1
        DO 1 J=1,150
1       D(I,J)=0.
        J=0
3       J=J+1
        READ (4,130) NL1,NA1,NO1,IY1,IP1,IB1,(D(1,I),I=1,NO1)
        IF (IB1.GT.IP1) WRITE (6,121) NO1
        IF (NO1.GT.150) WRITE(6,137) NO1
        IF (NO1.GT.150) GO TO 58
        IF (NA1.EQ.ISS) GO TO 2
        K=0
        DO 4 I=1,ND
4       IF (NUD(I).EQ.NO1) K=1
        IF (K.EQ.0) GO TO 5
        DO 65 J1=1,150
        F(J,J1)=D(1,J1)
        IF (J1.GT.NO1) GO TO 65
        D(1,J1)=0.
65      CONTINUE
        NUD(J)=NO1
        NAD(J)=NA1
        NO(J)=NO1
        IY(J)=IY1
        GO TO 3
5       DO 71 J1=1,150
71      D(1,J1)=0.
        J=J-1
        GO TO 3
2       WRITE (6,133) ND,(L,L=1,7),(NAD(I),I=1,ND)
        IYD=3000
        NOD=0
        DO 6 I=1,ND
        IX=1900+IY(I)+(NO(I)+IBO-2)/IPO
        IYD=MIN0(IYD,IY(I))
6       NOD=MAX0(NOD,IX)
        NOD=(NOD-1900-IYD)*IPO-IBO+2
        WRITE (6,123)
        READ (5,124) NA1,IY1,NO1
        WRITE(2,124) NA1,IY1,NO1
        IF (NA1.EQ.ISS) IY1=IYD
        IF (IY1.LT.IYD) IY1=IYD
        IF (NA1.EQ.ISS) NO1=NOD
        IF (IY1.GT.IYD+NOD) IY1=IYD+NOD
        IF (IY1+NO1.GT.IYD+NOD) NO1=NOD+IYD-IY1
        WRITE (6,124) BL,IY1,NO1
        IYD=IY1
        IYF=IYD
        IF (IYO.LT.IYD) IYO=IYD
        IF (IYO-IYD.LT.0) NOO=NOO+IYD-IYO
        IF (IYO-IYD.LT.0) IYO=IYD
        I1=1-IYD+IYO
        NOD=NO1
        IF (NOD.EQ.0) WRITE (6,134)
        IF (NOD.EQ.0) GO TO 63
```

Main.f continued

```
      DO 7 J=1,ND
      I2=IY(J)-IY1
      L=-I2
      NU1=1
      IF (I2.GT.0) NU1=I2+1
      DO 7 I=NU1,ND1
7     Q(J,I)=F(J,I+L)*XMULT*10.**EXP

C        READ DOCUMENTATION FROM PUNCH FILE

63    I=0
20    I=I+1
      READ (4,106) NU1,NA1,I2,(FLAB(I,J),J=1,I2)
      IF (NU1.EQ.0) GO TO 12
      IF (NA1.EQ.ISS) GO TO 12
      K=0
      DO 10 J=1,ND
10    IF (NAD(J).EQ.NA1) K=J
      IF (K.EQ.0) GO TO 8
      DO 11 J=1,10
11    DLAB(K,J)=FLAB(I,J)
      GO TO 20
8     I=I-1
      GO TO 20
12    CONTINUE
18    INDEX=0
      IF (PLT.LT.2) INDEX=PLT
      LOGIC=DAT.LT.2
      IF (DAT.LT.3.AND.NOD.GT.0) CALL TDATFRC
      YMAX=1.
      YMIN=0.
      IF (FRC.EQ.0) YMAX=ALOG(100.)
      IF (FRC.EQ.0) YMIN=ALOG(0.01)
      LOGIC=LOGIC.OR.EST.LT.2
      XMIN=IYD+1900+(IBD+I1-2)/IPO
      XMAX=IYD+1900+(IBD+NOD-2)/IPO
      YI1=IFIX(XMAX/100.)*100
      YI2=XMAX-YI1
      IF (YI2.GT.0.) YI1=YI1+50.
      IF (YI2.GT.50.)YI1=YI1+50.
      NOF=(IFIX(YI1)-IYF-1900)*IPO+2-IBO
      IF (NOD.GT.9000) NOF=NOD+1
      LOGIC=LOGIC.AND.PLT.LE.2
      TYPE(1,2)=FOVE
      TYPE(1,3)=ONEF
      IF (LOGIC.AND.FRC.EQ.0)
     & CALL PLOTLOG(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
      TYPE(1,2)=TYPE(2,2)
      TYPE(1,3)=TYPE(2,3)
      TYPE(1,4)=TYPE(2,4)
      IF (LOGIC.AND.(FRC.EQ.1.OR.FRC.EQ.2))
     & CALL PLOTLIN(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
      IF (EST.EQ.3) GO TO 19

C        READ COEFFICIENTS FROM COEF FILE

64    WRITE (6,118)
      READ (5,119) FIT
      WRITE (2,119) FIT
      IF (DAT.LT.3.AND.NOD.EQ.0) WRITE (6,134)
```

Main.f continued

```
        IF (NAT.LT.3.AND.NOD.EQ.0) GO TO 42
        IF (FIT.EQ.1) GO TO 41
        IF (FIT.EQ.2) GO TO 42
        IF (FIT.GT.2.OR.FIT.LT.0) WRITE (6,132)
        IF (FIT.GT.2.OR.FIT.LT.0) GO TO 64
        IF (PRT.EQ.1.OR.PRT.EQ.2) WRITE (8,128)
        I1=0
        I2=0
        J=0
13      J=J+1
        READ (3,120) NA1,NUMC,MC,(W(L),L=1,MC)
        IF (NA1.EQ.ISS) GO TO 14
        IF (PRT.EQ.1.OR.PRT.EQ.2) WRITE (8,129) NUMC,NA1,(W(L),L=1,MC)
        WRITE (6,129) NUMC,NA1,(W(L),L=1,MC)
        K=0
        DO 15 I=1,ND
15      IF (NA1.EQ.NAD(I)) K=I
        IF (K.NE.0) I2=I2+1
        IF (K.NE.0) GO TO 16
        I1=I1+1
        K=ND+I1
        M=K
        IF (NA1.EQ.NATOT) K=8
        IF (K.LT.8) GO TO 16
        I1=I1-1
        NAT=NA1
16      NAF(K)=NA1
        DO 17 L=1,MC
17      COEF(K,L)=W(L)
        IF (K.EQ.8) K=M
        GO TO 13
14      LF=ND+I1
        NF=I1+I2
        WRITE (6,139) NF,(I1,I1=1,7),(NAF(I2),I2=1,7),NAT

C         ETIMATES COEFFICIENTS IN FITLIN.F

        GO TO 42
41      IF (PRT.EQ.1.OR.PRT.EQ.2) WRITE (8,130)
        DO 43 I=1,ND
62      WRITE (6,121) I,NAD(I)
        READ (5,122) IY1,IY2
        I1=1900+IYD+(IBD-1)/IBD
        IF (IY1.LT.I1) IY1=I1
        IF (IY2.LT.I1) IY2=I1
        I2=1900+IYD+(NOD+IBD-2)/IBD
        IF (IY1.GT.I2) IY1=I2
        IF (IY2.GT.I2) IY2=I2
        IF (IY2.LT.IY1) WRITE (6,133) IY1,IY2
        IF (IY2.LT.IY1) GO TO 62
        WRITE(6,122) IY1,IY2
        WRITE(2,122) IY1,IY2
        NAF(I)=NAD(I)
        CALL FITLIN(I,IY1,IY2)
43      WRITE (1,120) NAF(I),I,2,(COEF(I,J),J=1,2)
72      WRITE (6,121) 8,NATOT
        READ  (5,122) IY1,IY2
        I1=1900+IYD+(IBD-1)/IBD
        IF (IY1.LT.I1) IY1=I1
        IF (IY2.LT.I1) IY2=I1
```

Main.f continued

```
      I2=1900+IY0+(MOD+IBO-2)/IBO
      IF (IY1.GT.I2) IY1=I2
      IF (IY2.GT.I2) IY2=I2
      IF (IY2.LT.IY1) WRITE (6,133) IY1,IY2
      IF (IY2.LT.IY1) GO TO 72
      WRITE (6,122) IY1,IY2
      WRITE (2,122) IY1,IY2
      NAF(8)=NATOT
      CALL FITLIN(8,IY1,IY2)
      WRITE (1,128) NAF(8),8,2,(COEF(8,I),I=1,2)
      WRITE (1,125)
      NF=N0
      LF=N0

C        CHANGE/ADD COEFFICENTS

42    WRITE (6,113)
30    WRITE (6,114)
      READ (5,115) NA1,NUMC,IY1,P1,IY2,P2
      WRITE (2,115)NA1,NUMC,IY1,P1,IY2,P2
      IF (NA1.EQ.ISS) GO TO 25
      J1=7
      IF (NUMC.EQ.999) J1=999
      IF (NUMC.EQ.999) NUMC=8
      IF (NUMC.EQ.6.AND.NA1.EQ.NATOT) GO TO 54
      IF (NUMC.GT.7) GO TO 31
      DO 26 I=1,7
      K=I
26    IF (NA1.EQ.NAF(I)) GO TO 27
      LF=LF+1
      NF=NF+1
      K=LF
      GO TO 28
27    IF (K.NE.NUMC) GO TO 29
28    WRITE (6,115) NA1,NUMC,IY1,P1,IY2,P2
      P1=ALOG(P1/(1.-P1))
      P2=ALOG(P2/(1.-P2))
      YI1=IY1
      YI2=IY2
      CALL FUNC(P1,P2,YI1,YI2,COEF(K,1),COEF(K,2))
      NAF(K)=NA1
      IY2=1900+IY0
      GO TO 55
54    WRITE (6,102) NA1,NUMC
      WRITE (6,115) NA1,NUMC,IY1,P1,IY2,P2
      YI1=IY1
      YI2=IY2
      COEF(9,2)=COEF(8,1)*YI1+COEF(8,2)
      COEF(9,1)=P1
      COEF(9,2)=COEF(9,2)-COEF(9,1)*YI1
      COEF(10,2)=COEF(9,1)*YI2+COEF(9,2)
      COEF(10,1)=P2
      COEF(10,2)=COEF(10,2)-COEF(10,1)*YI2
      IF (YI1.EQ.0.) YI1=YEAR(1)
      IF (YI2.EQ.0.) YI2=YEAR(2)
      YEAR(1)=YI1
      YEAR(2)=YI2
      IF (PRT.EQ.1.OR.PRT.EQ.2)
     & WRITE (8,129) NUMC,NA1,COEF(9,1),COEF(9,2),BB,IY1
      K=10
```

Main.f continued

```
          IF (J1.EQ.0) GO TO 55
          IF (PRT.EQ.1.OR.PRT.EQ.2)
        & WRITE (8,129) NUMC,NA1,COEF(K,1),COEF(K,2),BB,IY2
          WRITE (6,102) NA1,NUMC
          READ  (5,115) NA1,NUMC,IY1,P1,IY2,P2
          WRITE (6,115) NA1,NUMC,IY1,P1,IY2,P2
          WRITE (2,115) NA1,NUMC,IY1,P1,IY2,P2
          IF (NUMC.NE.6.OR.NA1.NE.NATOT) GO TO 30
          YI1=IY1
          YI2=IY2
          COEF(11,2)=COEF(10,1)*YI1+COEF(10,2)
          COEF(11,1)=P1
          COEF(11,2)=COEF(11,2)-COEF(11,1)*YI1
          COEF(12,2)=COEF(11,1)*YI2+COEF(11,2)
          COEF(12,1)=P2
          COEF(12,2)=COEF(12,2)-COEF(12,1)*YI2
          IF (YI1.EQ.0.) YI1=YEAR(3)
          IF (YI2.EQ.0.) YI2=YEAR(4)
          YEAR(3)=YI1
          YEAR(4)=YI2
          IF (PRT.EQ.1.OR.PRT.EQ.2)
        & WRITE (8,129) NUMC,NA1,COEF(11,1),COEF(11,2),BB,IY1
          K=12
55        IF (PRT.EQ.1.OR.PRT.EQ.2)
        & WRITE (8,129) NUMC,NA1,COEF(K,1),COEF(K,2),BB,IY2
          GO TO 30
29        WRITE (6,116) NUMC,K,NA1
          GO TO 30
31        WRITE (6,117) NUMC
          GO TO 30

C           SPECIFY SEQUENCE

25        WRITE (6,110) NF,(L,L=1,7),(NAF(I2),I2=1,7)
          READ  (5,111) (IW(L),L=1,7)
          WRITE (6,111) (IW(L),L=1,7)
          WRITE (2,111) (IW(L),L=1,7)
          DO 22 I=1,7
          DO 22 J=1,7
22        IF (IW(I).EQ.J) NUF(J)=I
          WRITE (6,112) (L,L=1,7),(NAF(NUF(J)),J=1,NF)
19        IF (FRC.NE.2.OR.DAT.EQ.3) GO TO 60
          DO 61 I=1,NOD
          YI1=0.
          DO 61 J=1,ND
          F(NUF(J),I)=F(NUF(J),I)+YI1
61        YI1=F(NUF(J),I)
60        IF (LOGIC.AND.DAT.LT.2.AND.NOD.GT.0) CALL PLOTF
          IF (EST.EQ.3) GO TO 59
          IF (EST.LT.3) CALL PENETR
          IF (LOGIC.AND.EST.LT.2) CALL PLOTF
59        INDEX=2
          DO 44 I=1,7
          TITLE(2,I)=NAF(NUF(I))
44        IF (EST.EQ.3) TITLE(2,I)=NAD(I)
          IF (LOGIC.AND.FRC.EQ.0)
        & CALL PLOTLOG(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
          IF (LOGIC.AND.(FRC.EQ.1.OR.FRC.EQ.2))
        & CALL PLOTLIN(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
          INDEX=0
```

Main.f continued

```
      PAR=IPAR
      IF (PLT.LT.0) INDEX=PLT
      LOGIC=EST.EQ.0.OR.EST.EQ.2
      IF (LOGIC) CALL TESTTOT
      IF (YMIN.EQ.YMAX) GO TO 24
      LOGIC=EST.EQ.2.OR.EST.EQ.0
      LOGIC=LOGIC.AND.PLT.LE.0
      TYPE(1,1)=ABSOL
      TYPE(1,2)=UTE
      TYPE(1,3)=INT
      TYPE(1,4)=TS
      IF (LOGIC.AND.(TOT.EQ.0.OR.TOT.EQ.4))
     & CALL PLOTLOG(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
      IF (LOGIC.AND.(TOT.EQ.1.OR.TOT.EQ.2))
     & CALL PLOTLIN(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
      NU1=100
      IF (LOGIC) CALL PLOTF
      IF (LOGIC) GO TO 23
24    YMIN=+1.E+30
      YMAX=-1.E-30
      NU1=0
      LOGIC=DAT.EQ.2.OR.DAT.EQ.0
23    LOGIC=LOGIC.AND.PLT.LE.0
      IF ((DAT.EQ.0.OR.DAT.EQ.2).AND.NOD.GT.0) CALL TDATTOT
      IF (LOGIC.AND.NU1.EQ.0.AND.(TOT.EQ.0.OR.TOT.EQ.4))
     & CALL PLOTLOG(INDEX,XMAX,XMIN,YMAX,YMIN,SCALFX,TITLE,TYPE)
      IF (LOGIC.AND.NU1.EQ.0.AND.(TOT.EQ.1.OR.TOT.EQ.2))
     & CALL PLOTLIN(INDEX,XMAX,XMIN,YMAX,YMIN,SCALFX,TITLE,TYPE)
      IF (LOGIC.AND.NOD.GT.0) CALL PLOTF
      INDEX=1
      LOGIC=LOGIC.OR.EST.EQ.0.OR.EST.EQ.2
      LOGIC=LOGIC.AND.PLT.LE.0
      IF (LOGIC.AND.(TOT.EQ.0.OR.TOT.EQ.4))
     & CALL PLOTLOG(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
      IF (LOGIC.AND.(TOT.EQ.1.OR.TOT.EQ.2))
     & CALL PLOTLIN(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)
      STOP
      END
```

Tdatfrc.f

```
      SUBROUTINE TDATFRC
      COMMON /DATA/D(7,150),DLAB(7,10),ND,IYD,NOD,
     &              NUD(7),NAD(7),NO(7),IY(7)
     &        /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &              NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &        /COMM/NUD(7),IYO,IPD,IBO,PRT,PAR,FOR(8),
     &              PLT,FRC,IFRC,TOT,DAT,EST,YMAX,YMIN

      REAL*8 DLAB,FLAB,NAD,NAF,FOR,FORMAT
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,PAR
      DIMENSION SUM(8),FF(7),FORMAT(17)
      DATA BL/4H    /
100   FORMAT(/23X,'OBSERVED VALUES',//
     & 'YEAR   ','  TOTAL',3X,7(A8,4X,'F',4X)//)
101   FORMAT(/2X,'INTEGRALS FROM ',I4,' TO',I5,' ARE:'//
     & F14.0,7(F10.0,F7.3))
      IBEG=1900+IYD
      I75=IBEG+(NOD+IBO-2)/IPD
      DO 3 J=1,7
      SUM(J)=D(J,1)/2.
      J1=2*J+1
      J2=2*J+2
      FORMAT(J2)=FOR(4)
      FORMAT(J1)=FOR(3)
      DO 3 I=1,300
3     F(J,I)=0.
      IF (PRT.EQ.1.OR.PRT.EQ.2) WRITE(6,100) (NAD(J),J=1,ND)
      DO 1 I=1,NOD
      SS=0.
      DO 2 M=1,ND
      IF (I.EQ.1) GO TO 2
      SUM(M)=SUM(M)+(D(M,I)+D(M,I-1))/2.
2     SS=SS+D(M,I)
      IF (SS.EQ.0.) GO TO 1
      DO 5 J=1,ND
5     F(J,I)=D(J,I)/SS
      IIY=IYD+1900+(IBO+I-2)/IPD
      IF (PRT.EQ.0) GO TO 8
      FORMAT(1)=FOR(7)
      FORMAT(2)=FOR(3)
      IF (SS.GT.999999.99) FORMAT(2)=FOR(2)
      IF (SS.GT.9999999.9) FORMAT(2)=FOR(1)
      IF (SS.EQ.0..AND.PRT.EQ.1) FORMAT(2)=FOR(6)
      IF (SS.EQ.0..AND.PRT.EQ.1) SS=BL
      FORMAT(17)=FOR(8)
      DO 9 J=1,ND
      J1=2*J+1
      J2=2*J+2
      FORMAT(J1)=FOR(3)
      FORMAT(J2)=FOR(4)
      XX=99999.999
      DO 10 JJ=1,2
      XX=XX*10.
10    IF (D(J,I).GT.XX) FORMAT(J1)=FOR(3-JJ)
      IF (PRT.EQ.2) GO TO 9
      IF (D(J,I).EQ.0.) FORMAT(J1)=FOR(6)
      IF (F(J,I).EQ.0.) FORMAT(J2)=FOR(5)
      IF (F(J,I).EQ.0.) F(J,I)=BL
      IF (D(J,I).EQ.0.) D(J,I)=BL
9     CONTINUE
```

Tdatfrc.f continued

```
      WRITE(8,FORMAT) IIY,SS,(D(J,I),F(J,I),J=1,ND)
8     DO 4 J=1,ND
      IF (D(J,I).EQ.BL) D(J,I)=0.
      IF (F(J,I).EQ.BL) F(J,I)=0.
      IF (F(J,I).GT..9999) F(J,I)=.9999
      IF (FRC.EQ.1.OR.FRC.EQ.2) GO TO 4
      F(J,I)=F(J,I)/(1.-F(J,I))
      IF (F(J,I).LT.0.001) F(J,I)=0.
      IF (F(J,I).LT.0.01.AND.IFRC.NE.-1) F(J,I)=0.
      IF (F(J,I).EQ.0.) GO TO 4
      F(J,I)=ALOG(F(J,I))
4     CONTINUE
1     CONTINUE
      SUM(8)=0.
      DO 6 J=1,ND
6     SUM(8)=SUM(8)+SUM(J)
      DO 7 J=1,ND
7     FF(J)=SUM(J)/SUM(8)
      IF (PRT.EQ.1.OR.PRT.EQ.2)
     6 WRITE (8,101) IBEG,I75,SUM(8),(SUM(J),FF(J),J=1,ND)
      RETURN
      END
```

Fitlin.f

```
      SUBROUTINE FITLIN(J,IY1,IY2)
      COMMON /DATA/D(7,150),DLAB(7,10),ND,IYO,NOD,
     &              NUD(7),NAD(7),NU(7),IY(7)
     &        /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &              NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &        /COMM/NUO(7),IYO,IPO,IBO,PRT,PAR,FOR(8),
     &              PLT,FRC,IFRC,TOT,DAT,EST,YMAX,YMIN

      REAL*8 DLAB,FLAB,NAD,NAF,FOR
     &,NAT
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,PAR


102    FORMAT(5X,'ERROR *** LESS THAN 2 OBSERVATIONS FOR THIS EQN'/
     & 5X,'COEFFICIENTS ARE SET TO ZERO, CHANGE OR TRY AGAIN !')
103    FORMAT(5X,'ERROR *** 2 OBSERVATIONS FOR THIS EQN'/
     & 5X,'THEREFORE NO STATISTICS, BOTH OBSERVATIONS EXPLAINED')
104    FORMAT(/5X,'EQN',I2,'  ',A8,' IS: Y =',F7.3,'*T+',F8.3,
     & '     R**2 =',F6.3,'  VAR =',F6.3)
105    FORMAT(28X,'(',F7.3,') (',F7.3,')')

       IL=(IY1-1900-IYO)*IPO-IBO+2
       IU=(IY2-1900-IYO)*IPO-IBO+2
       IF (IY1.EQ.IY2) GO TO 5
       YU=ALOG(99.)
       YL=ALOG(.0101010101)
       XN=0.
       SYX=0.
       SX2=0.
       SX=0.
       SY=0.
       SY2=0.
       DO 2 I=IL,IU
       IF (J.LT.8) GO TO 7
       Y=0.
       DO 8 K=1,ND
8      Y=Y+D(K,I)
       IF (Y.GT.0.) Y=ALOG(Y)
       IF (Y.EQ.0.) GO TO 2
       GO TO 6
7      IF (F(J,I).EQ.0.) GO TO 2
       Y=F(J,I)
       IF (FRC.EQ.0.) GO TO 1
       Y=ALOG(Y/(1.-Y))
1      IF (Y.GT.YU.OR.Y.LT.YL) GO TO 2
6      X=IYO+1900+(IBO+I-2)/IPO
       SYX=X*Y+SYX
       SX2=X*X+SX2
       SX=X+SX
       SY=Y+SY
       SY2=Y*Y+SY2
       XN=XN+1.
2      CONTINUE
       IF (XN.LT.2.) GO TO 5
       COEF(J,1)=(XN*SYX-SX*SY)/(XN*SX2-SX*SX)
       COEF(J,2)=SY/XN-COEF(J,1)*SX/XN
       IF (XN.EQ.2.) GO TO 12
       SIG2=(SY2-SY*SY/XN)/(XN-2.)
       SE=0.
       SE2=0.
```

Fitlin.f continued

```
         DO 3 I=IL,IU
         IF (J.LT.8) GO TO 9
         Y=0.
         DO 10 K=1,N
10       Y=Y+F(K,I)
         IF (Y.GT.0.) Y=ALOG(Y)
         GO TO 11
9        IF (F(J,I).EQ.0.) GO TO 3
         Y=F(J,I)
         IF (FAC.EQ.0) GO TO 4
         Y=ALOG(Y/(1.-Y))
4        IF (Y.GT.YU.OR.Y.LT.YL) GO TO 3
11       X=IYR+1900+(IBO+I-2)/IPO
         YH=COEF(J,1)*X+COEF(J,2)
         E=Y-YH
         SE=SE+E
         SE2=SE2+E*E
3        CONTINUE
         VAR=SE2/(XN-2.)
         R2=1.-VAR/SIG2
         T2=COEF(J,2)*SQRT(XN*SX2-SX*SX)/SQRT(VAR*SX2)
         T1=COEF(J,1)*SQRT(SX2-SX*SX/XN)/SQRT(VAR)
         IF (PRT.EQ.1) GO TO 13
         WRITE (6,104) J,NAF(J),COEF(J,1),COEF(J,2),R2,VAR
         WRITE (6,105) T1,T2
13       RETURN
5        WRITE (6,102)
         COEF(J,1)=0.
         COEF(J,2)=0.
         RETURN
12       WRITE (6,103)
         RETURN
         END
```

Penetr.f

```
      SUBROUTINE PENETR
      COMMON /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &             NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &       /COMM/NUD(7),IYC,IPD,IBO,PRT,PAR,FOR(8),
     &             PLT,FRC,IFRC,TOT,DAT,EST,YMAX,YMIN

      LOGICAL LOGIC
      REAL*8 FLAB,NAF,BL,FOR
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,PAR
      DIMENSION Z(7),Y(7)
      DATA BL/4H /

       DO 1 J=1,7
       DO 1 I=1,300
1      F(J,I)=0.
       DO 53 J1=1,NF
       J=NUF(J1)
       IF (NAF(J).EQ.BL) GO TO 53
       DO 52 I=1,NOF
       X=1900+IYF+(I+IBO-2)/IPD
52     F(J,I)=COEF(J,2)+X*COEF(J,1)
53     CONTINUE
       DO 51 J1=1,NF
       J=NUF(J1)
       IF (NAF(J).EQ.BL) GO TO 51
       FP=0.
       YI=0.
       YII=0.
       FINDEX=0.
       RATIOI=100.
       DO 2 I=1,NOF
       SUM=0.
       X=1900+IYF+(I+IBO-2)/IPD
       DER1=0.
       DER2=0.
       DO 3 M1=1,NF
       M=NUF(M1)
       Y(M)=F(M,I)
       Y(J)=COEF(J,2)+X*COEF(J,1)
       IF (Y(M).GT.60.) Y(M)=60.
       IF (Y(M).LT.-60.) Y(M)=-60.
       Z(M)=1.-(1./(1.+EXP(Y(M))))
       IF (Z(M).GT.1.) Z(M)=1.
       IF (Z(M).LT..001) Z(M)=0.
       SUM=SUM+Z(M)

C        DETERMINE SLOPE OF Z(J)

       IF (M.EQ.J) GO TO 3
       DER1=DER1-COEF(M,1)*Z(M)*(1.-Z(M))
       DER2=DER2-COEF(M,1)*COEF(M,1)*(1.-Z(M))*Z(M)*(1.-2.*Z(M))
3      CONTINUE
       IF (COEF(J,1).LT.0.) GO TO 6
       IF (SUM.NE.1.) Z(J)=1.-SUM+Z(J)
       IF (FINDEX.GT.0.) GO TO 9
       IF (SUM.GT.1.) FINDEX=Z(J)
9      CONTINUE
       IF (Z(J).LE.0.) Z(J)=.001
       IF (Z(J).EQ.1.) Z(J)=.999
       Y(J)=ALOG(Z(J)/(1.-Z(J)))
```

Penetr.f continued

```
      IF (FINDEX.EQ.0.) GO TO 6
      DEN=(1.-Z(J))*Z(J)
      YDER1=DER1/DEN
      YDER2=DER2/DEN-DER1*DER1*(1.-2.*Z(J))/(DEN*DEN)
      RATIO=0.
      IF (ABS(YDER2).GT.1.E-15) RATIO=YDER2/YDER1
      LOGIC=RATIO.GT.RATIOI.AND.RATIOI.GT.0.
      IF (YDER1.LT.0..AND.LOGIC) GO TO 5
      GO TO 6
5     CONTINUE
      CALL FUNC(YI,YII,X-1.,X-2.,COEF(J,1),COEF(J,2))
      Y(J)=COEF(J,2)+X*COEF(J,1)
6     CONTINUE
      F(J,I)=Y(J)
      YII=YI
      YI=Y(J)
2     RATIOI=RATIO
51    CONTINUE
      YMAX=ALOG(100.)
      YMIN=ALOG(.01)
      IF (FRC.EQ.0) GO TO 4
      YMAX=1.
      YMIN=0.
4     DO 7 I=1,NOF
      YI=0.
      DO 7 M=1,NF
      J=NUF(M)
      IF (FRC.EQ.1.OR.FRC.EQ.2) GO TO 8
      IF (F(J,I).LT.YMIN) F(J,I)=0.
      IF (FRC.EQ.0) GO TO 7
8     IF (F(J,I).EQ.0.) GO TO 7
      F(J,I)=1.-(1./(1.+EXP(F(J,I))))
      IF (FRC.EQ.2) F(J,I)=F(J,I)+YI
      YI=F(J,I)
      IF (F(J,I).LE.0.001) F(J,I)=0.
7     CONTINUE
      RETURN
      END
```

Testtot.f

```
      SUBROUTINE TESTTOT
      COMMON /DATA/D(7,150),DLAB(7,10),ND,IYD,NOD,
     &                NUD(7),NAD(7),NO(7),IY(7)
     &          /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &                NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &          /COMM/NUO(7),IYO,IPU,IBO,PRT,PAR,FOR(8),
     &                PLT,FRC,IFRC,TOT,DAT,EST,YMAX,YMIN

      REAL*8 DLAB,FLAB,NAD,NAF,FOR,FORMAT
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,PAR
      DIMENSION FF(7),SUM(8,2),FORMAT(17)
      DATA BL/4H    /
100   FORMAT(/20X,'ESTIMATED VALUES'//
     & 'YEAR  ','  TOTAL',3X,7(A8,4X,'F',4X)//)
101   FORMAT(/2X,'INTEGRALS FROM ',I4,' TO',I5,' ARE:'//
     & F14.0,7(F13.0,F7.3))
      IF (PRT.EQ.1.OR.PRT.EQ.2) WRITE(8,100) (NAF(NUF(J)),J=1,NF)
      DO 10 I=1,2
      DO 10 I=1,8
10    SUM(J,I)=0.
      IDATEND=IYD+(NOD+IBO-2)/IPU
      IFND=1900+IYF+(NOF+IBO-2)/IPU
      IF (IYF.GT.IDATEND) IDATEND=IYF
      YMIN=+1.E+37
      YMAX=-1.E-37
      DO 1 I=1,NOF
      X=1900+IYF+(I+IBO-2)/IPO
      IX=X
      K=8
      IF (X.GE.YEAR(1)) K=9
      IF (X.GE.YEAR(2)) K=10
      IF (X.GE.YEAR(3)) K=11
      IF (X.GE.YEAR(4)) K=12
      X=COEF(K,1)*X+COEF(K,2)
      IF (X.GT.60.) X=60.
      IF (X.LT.-60.) X=-60.
      X=EXP(X)
      DO 4 J2=1,NF
      J=NUF(NF-J2+1)
      IF (F(J,I).EQ.0..OR.FRC.NE.0) GO TO 8
      F(J,I)=1.-(1./(1.+EXP(F(J,I))))
8     IF (F(J,I).LT.0.01) F(J,I)=0.
      IF (FRC.NE.2) GO TO 15
      XX=0.
      IF (NF-J2.GT.0) XX=F(NUF(NF-J2),I)
      F(J,I)=F(J,I)-XX
      IF (F(J,I).LT.0.01) F(J,I)=0.
15    J1=1
      IF (I.GE.IDATEND-IYF+1) J1=2
      SS=(FF(J)+F(J,I)*X)/2.
      SUM(J,J1)=SUM(J,J1)+SS
      SUM(8,J1)=SUM(8,J1)+SS
4     FF(J)=F(J,I)*X
      IF (PRT.EQ.0) GO TO 5
      FORMAT(1)=FOR(7)
      FORMAT(2)=FOR(3)
      IF (X.GT.999999.99) FORMAT(2)=FOR(2)
      IF (X.GT.9999999.9) FORMAT(2)=FOR(1)
      IF (X.EQ.0..AND.PRT.EQ.1) FORMAT(2)=FOR(6)
      IF (X.EQ.0..AND.PRT.EQ.1) X=BL
```

Testtot.f continued

```
      FORMAT(17)=FOR(8)
      DO 14 J=1,7
      J1=2*J+1
      J2=2*J+2
      FORMAT(J1)=FOR(3)
14    FORMAT(J2)=FOR(4)
      DO 12 J=1,NF
      J1=2*J+1
      J2=2*J+2
      XX=99999.999
      DO 13 JJ=1,2
      XX=XX*10.
13    IF (FF(NUF(J)).GT.XX) FORMAT(J1)=FOR(3-JJ)
      IF (PRT.EQ.2) GO TO 12
      IF (FF(NUF(J)).EQ.0.) FORMAT(J1)=FOR(6)
      IF (F(NUF(J),I).EQ.0.) FORMAT(J2)=FOR(5)
      IF (F(NUF(J),I).EQ.0.) F(NUF(J),I)=BL
      IF (FF(NUF(J)).EQ.0.) FF(NUF(J))=BL
12    CONTINUE
      WRITE(8,FORMAT) IX,X,(FF(NUF(J)),F(NUF(J),I),J=1,NF)
      IF (X.EQ.BL) X=0.
5     IF (PAR.EQ.1) GO TO 9
      XX=0.
      DO 1 J1=1,NF
      J=NUF(J1)
      IF (F(J,I).EQ.BL) F(J,I)=0.
      IF (TOT.EQ.4.OR.TOT.EQ.2) F(J,I)=F(J,I)+XX
      XX=F(J,I)
9     IF (PAR.EQ.1) J=1
      IF (PAR.EQ.1) F(1,I)=X
      IF (F(J,I).EQ.0.) GO TO 1
      IF (PAR.EQ.2) F(J,I)=F(J,I)*X
      YMAX=AMAX1(YMAX,F(J,I))
      IF ((TOT.EQ.0.OR.TOT.EQ.4).AND.F(J,I).LT..01) GO TO 3
      YMIN=AMIN1(YMIN,F(J,I))
3     IF (TOT.EQ.1.OR.TOT.EQ.2) GO TO 1
      IF (F(J,I).GT.0.) F(J,I)=ALOG(F(J,I))
1     CONTINUE
      IF (PRT.EQ.0) GO TO 6
      DO 7 J=1,NF
      IF (SUM(8,1).EQ.0.) GO TO 16
7     FF(J)=SUM(J,1)/SUM(8,1)
      J1=1900+IYF
      IDATEND=1900+IDATEND
      IF (IEND.LT.IDATEND) IDATEND=IEND
      WRITE(8,101) J1,IDATEND,SUM(8,1),
     & (SUM(NUF(J),1),FF(NUF(J)),J=1,NF)
16    DO 11 J=1,NF
      IF (SUM(8,2).EQ.0.) GO TO 6
11    FF(J)=SUM(J,2)/SUM(8,2)
      WRITE(8,101) IDATEND,IEND,SUM(8,2),
     & (SUM(NUF(J),2),FF(NUF(J)),J=1,NF)
6     IF (TOT.EQ.1.OR.TOT.EQ.2) GO TO 2
      IF (YMAX.LE.0.) YMAX=100.
      IF (YMIN.LE.0.) YMIN=0.01
      YMAX=ALOG(YMAX)
      YMIN=ALOG(YMIN)
2     RETURN
      END
```

Tdattot.f

```
      SUBROUTINE TDATTOT
      COMMON /DATA/D(7,150),DLAB(7,10),ND,IYD,NOD,
     &               NUD(7),NAD(7),ND(7),IY(7)
     &        /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &               NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &        /COM /NUD(7),IYO,IPO,IRO,PRT,PAR,FOR(8),
     &               PLT,FRC,IFRC,TOT,DAT,EST,YMAX,YMIN

      REAL*8 DLAB,FLAB,NAD,NAF,NA1,IS,ISS,BL,FOR
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,PAR
      DO 3 J=1,7
      DO 3 I=1,300
3     F(J,I)=0.
      YMAX1=-1.E-30
      YMIN1=+1.E+30
      DO 1 I=1,NOD
      S=0.
      X=0.
      DO 1 J1=1,NF
      J=NUF(J1)
      F(J,I)=D(J,I)
      X=X+D(J,I)
      IF (TOT.EQ.2.OR.TOT.EQ.4) F(J,I)=F(J,I)+S
      S=F(J,I)
      IF (PAR.EQ.1) F(1,I)=X
      IF (PAR.EQ.1) J=1
      YMAX1=AMAX1(YMAX1,F(J,I))
      IF ((TOT.EQ.3.OR.TOT.EQ.4).AND.F(J,I).LT..01) GO TO 5
      YMIN1=AMIN1(YMIN1,F(J,I))
5     IF (TOT.EQ.1.OR.TOT.EQ.2) GO TO 1
      IF (F(J,I).LT..01) F(J,I)=0.
      IF (F(J,I).GT.0.) F(J,I)=ALOG(F(J,I))
1     CONTINUE
      IF (YMAX.LT.YMAX1.AND.YMAX.NE.-1.E-30) YMAX=YMAX1
      IF (YMIN.NE.1.E30.AND.YMAX.NE.-1.E-30) GO TO 2
      YMAX=YMAX1
      YMIN=YMIN1
      IF (TOT.EQ.1.OR.TOT.EQ.2) GO TO 2
      YMAX=ALOG(YMAX)
      YMIN=ALOG(YMIN)
2     RETURN
      END
```

Func.t

```
SUBROUTINE FUNC(Y1,Y2,X1,X2,A,B)
A=(Y1-Y2)/(X1-X2)
B=Y2-A*X2
RETURN
END
```

Plotf.f

```
      SUBROUTINE PLOTF
      COMMON /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     &              NUF(7),NAF(8),COEF(12,2),YEAR(4)
     &        /COMM/NUO(7),IYO,IPO,IBO,PRT,PAR,FOR(8),
     &              PLT,FLC,IFRC,TOT,DAT,EST,YMAX,YMIN

      REAL*8 FLAB,NAF,FOR
      INTEGER PLT,PRT,FRC,TOT,DAT,EST,PAR
      YMIN1=YMIN
      IF (IFRC.EQ.-1) YMIN1=ALOG(0.001)
      IF (YMIN.LT.YMIN1) YMIN1=YMIN
      I1=1-IYF+IYO
      DO 1 J=1,7
      IF (PAR.EQ.1.AND.J.GT.1) GO TO 1
      K=0
      DO 2 I=I1,NOF
      IF (F(J,I).EQ.0..OR.F(J,I).GT.YMAX
     & .OR.F(J,I).LE.YMIN1) GO TO 2
      X=IYF+1900+(IBO+I-2)/IPO
      K=K+1
      IF (K.EQ.1) CALL FPLOT(-2,X,F(J,I))
      CALL FPLOT(0,X,F(J,I))
2     CONTINUE
      CALL PENUP
1     CONTINUE
      RETURN
      END
```

Plotlin.f

```
      SUBROUTINE PLOTLIN(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)

C       SUBROUTINE ESTABLISHES SCALE, AXIS AND LABELS FOR LINEAR PLOTTING
C       THE PEN IS ASSUMED  TO BE =1 PLOTTER UNITS IN X DIRECTION AND
C       =3 PLOTTER UNITS IN Y DIRECTION AWAY FORM THE PLOTTING ORIGIN
C       (XMIN,YMIN) => "BOTTOM OF THE PAPER"
C       WHEN CALLED WITH:
C       INDEX=0 SCALE WILL BE SET AND AXES WILL BE DRAWN AND LABELED
C       INDEX<0 SCALE AND AXES GRID WILL BE SET
C       INDEX>0 PEN WILL BE RETURNED TO THE "BOTTOM OF THE PAPER" FOR
C               THE NEXT PLOT
C       XMAX = MAXIMUM VALUE ON X-AXIS
C       XMIN = MINIMUM VALUE ON X-AXIS AND Y-AXIS INTERCEPT
C       YMAX = MAXIMUM VALUE ON Y-AXIS
C       YMIN = MINIMUM VALUE ON Y-AXIS BUT INTERCEPT OF X-AXIS WILL
C             ALWAYS BE AT Y=0.
C       SCALEX = THE MULTIPLICATION FACTOR FOR THE LENGTH OF THE
C                X-AXIS, LENGTH IS 5.*SCALEX PLOTTER UNITS PER USER UNITS
C                Y-AXIS IS ALWAYS 5 PLOTTER UNITS HIGH
C       TITLE(1,7) = LITERAL TITLE OF THE PLOT
C       TITLE(2,7) = LITERAL TITLE WHEN INDEX>0
C       TYPE(1,10) = LITERAL TYPE OF UNITS ON THE Y-AXIS
C       TYPE(2,10) = LITERAL, BUT HAS NO FUNCTION

      REAL*8 TITLE
      DIMENSION TITLE(2,7),TYPE(2,10),IDATE(6)
   10 FORMAT(F10.1)
   11 FORMAT(I4)
   12 FORMAT(' ','IIASA VERSION ',2(A2,'.'),A2,
     &' BY N. NAKICENOVIC')
   13 FORMAT(10A4)
   14 FORMAT(' ',7A8)
   15 FORMAT(' ',7(A8,' '))

      IF (INDEX.GT.0) GO TO 1

C        SET INITIAL DATA FOR PLOTTING

      XMIN1=IFIX(XMIN/100.)*100
      CHK=XMIN-XMIN1
      IF (CHK.GE.50.) XMIN1=XMIN1+50.
      XMAX1=IFIX(XMAX/100.)*100
      CHK=XMAX-XMAX1
      IF (CHK.GT.0.) XMAX1=XMAX1+50.
      IF (CHK.GT.50.) XMAX1=XMAX1+50.
      IF (YMIN.EQ.YMAX) YMAX=YMIN+10.
      IF (ABS(YMIN).LE.1.E-5) YMIN=0
      YMIN1=YMIN
      YMAX1=YMAX
      IF (YMAX.EQ.0.) GO TO 46
      YMM=YMAX
      IF (YMM.LT.0.) YMM=-YMM
      GO TO 45
44    CHK=YMAX/10.**II
      IF (CHK.GT.0.) CHK=CHK+0.999999
      YMAX1=IFIX(CHK)*10.**II
46    IF (YMIN.EQ.0.) GO TO 43
      YMM=YMIN
      IF (YMM.LT.0.) YMM=-YMM
45    DO 41 I=1,5
```

Plotlin.f continued

```
      II=I
      IF (YMM.LE.1.) II=-I
      CHK=YMM/10.**II
      IF (CHK.LE.10..AND.CHK.GE.1.) GO TO 42
41    CONTINUE
      IF (YMM.GE.1..AND.YMM.LT.10.) II=0
42    IF (YMM.EQ.ABS(YMAX)) GO TO 44
      CHK=YMIN/10.**II
      IF (CHK.LT.0.) CHK=CHK-0.999999
      YMIN1=FLOAT(IFIX(CHK))*10.**II
      CHK=YMAX1/YMIN1
      IF (CHK.GE.10..AND.CHK.GE.YMIN1) YMIN1=0.
43    CONTINUE
      YL=5.
      TY=(YMAX1-YMIN1)/(10.)
      TX=10.
      YS=YL/(YMAX1-YMIN1)
      XS=0.32*SCALEX
      MAX=IFIX(XMAX1)
      MIN=IFIX(XMIN1)
      M1=(MAX-MIN)/10
      STEPY=-2.*TY+YMIN1
      YSTA=YMIN1-TY*0.75
      X3MIN=XMIN1-90./SCALEX

C        SET SCALF, AXIS AND LABEL THEM

      CALL SCALF(1.,1.,0.,0.)
      CALL FPLOT(1,0.,-14.)
      CALL SCALF(1.,1.,0.,0.)
      CALL FPLOT(1,4.,2.)

C        IF INDEX<0 ONLY GRID THE AXES

      CALL SCALF(XS,YS,XMIN1,YMIN1)
      CALL FGRID(0,XMIN1,YMIN1,TX,M1)

      IF (INDEX.LT.0) GO TO 6

      DO 3 I=MIN,MAX,50
      XI=FLOAT(I)-15./SCALEX
      CALL FCHAR(XI,YSTA,.12,.15,0.)
      WRITE (7,11) I
    3 CALL PFLAG(1)
    6 CALL FGRID(1,XMIN1,YMIN1,TY,10)

      IF (INDEX.LT.0) GO TO 2

      DO 4 I=1,6
      STEPY=STEPY+2.*TY
      IF (I.EQ.1.OR.I.EQ.6) GO TO 5
      CALL FPLOT(-2,XMIN1,STEPY)
      CALL FPLOT(-1,XMAX1,STEPY)
    5 STEPYV=STEPY-0.075*TY
      CALL FCHAR(X3MIN,STEPYV,.12,.15,0.)
      WRITE(7,10) STEPY
    4 CALL PFLAG(1)
      TIT1=1.18*YMAX1
      CALL FCHAR(X3MIN,TIT1,.12,.15,0.)
      WRITE (7,13) (TYPE(1,I),I=1,10)
```

Plotlin.f continued

```
      CALL PFLAG(1)
      TIT1=1.33*YMAX1
      CALL FCHAR(XMIN1,TIT1,.12,.15,0.)
      WRITE (7,14) (TITLE(1,I),I=1,7)
      CALL PFLAG(1)
      CALL FPLOT(-2,XMIN1,YMAX1)
      CALL FPLOT(0,XMAX1,YMAX1)
      CALL FPLOT(-1,XMAX1,YMIN1)
      CALL DATIME(IDATE)
      TIT1=YMIN1-0.35*YMAX1
      CALL FCHAR(XMIN1,TIT1,.12,.15,0.)
      WRITE (7,12) (IDATE(II),II=1,3)
      CALL PFLAG(1)
    2 RETURN

C         IF INDEX=2
C         MOVE THE PEN FOR THE NEXT PLOT

    1 TIT1=YMIN1-0.27*YMAX1
      CALL FCHAR(XMIN1,TIT1,.12,.15,0.)
      WRITE (7,15) (TITLE(2,I),I=1,7)
      CALL PFLAG(1)
      CALL FPLOT (0,XMAX1,YMIN1)
      CALL SCALE(1.,1.,0.,0.)
      CALL FPLOT (0,6.,-4.)
      RETURN
      END
```

Plotlog.f

```
      SUBROUTINE PLOTLOG(INDEX,XMAX,XMIN,YMAX,YMIN,SCALEX,TITLE,TYPE)

C        SUBROUTINE ESTABLISHES SCALE, AXIS AND LABELS FOR LOG E (ALOG)
C        Y-AXIS AND LINEAR X-AXIS
C        FOR GRID AND LABELS OF Y-AXIS SUBROUTINE YLOGA.F IS CALLED
C        THE PEN IS ASSUMED  TO BE -1 PLOTTER UNITS IN X DIRECTION AND
C        -3 PLOTTER UNITS IN Y DIRECTION AWAY FROM THE PLOTTING ORIGIN
C        (XMIN,YMIN) => "BOTTOM OF THE PAPER"
C        WHEN CALLED WITH:
C        INDEX=0 SCALE WILL BE SET AND AXES WILL BE DRAWN AND LABELED
C        INDEX<0 SCALE AND AXES GRID WILL BE SET
C        INDEX>0 PEN WILL BE RETURNED TO THE "BOTTOM OF THE PAPER" FOR
C                THE NEXT PLOT WITH "RIGHT" Y-AXIS LABELED AND TITLED
C        INDEX=1 THE SAME AS WHEN INDEX>0 BUT NO LABELS OR TITLE
C        XMAX = MAXIMUM VALUE ON X-AXIS
C        XMIN = MINIMUM VALUE ON X-AXIS AND Y-AXIS INTERCEPT
C        YMAX = MAXIMUM VALUE ON Y-AXIS (FOR PLOTTING % 100.)
C        YMIN = MINIMUM VALUE ON Y-AXIS (FOR PLOTTING % 0.01)
C        SCALEX = THE MULTIPLICATION FACTOR FOR THE LENGTH OF THE
C                X-AXIS, LENGTH IS 5.*SCALEX PLOTTER UNITS PER USER UNITS
C                Y-AXIS IS ALWAYS 5 PLOTTER UNITS HIGH
C        TYPE(1,10) = LITERAL TYPE OF UNITS ON THE "LEFT" Y-AXIS
C        TYPE(2,10) = LITERAL TYPE OF UNITS ON THE "RIGHT" CLOSING
C                     Y-AXIS
C        TITLE(1,7) = LITERAL TITLE OF THE PLOT
C        TITLE(2,7) = LITERAL TITLE WHEN INDEX>0

      REAL*8 TITLE
      DIMENSION TITLE(2,7),TYPE(2,10),IDATE(6)
40    FORMAT (1H )
50    FORMAT (F4.2)
60    FORMAT (I4)
70    FORMAT (7X,'10')
80    FORMAT (9X,I2)
90    FORMAT (' ','IIASA VERSION ',2(A2,'.'),A2,
     &' BY N. NAKICENOVIC')
140   FORMAT (1H ,3(10X,E14.7))
100   FORMAT ('  ',10(A4))
110   FORMAT (' ',7(A8,' '))
120   FORMAT (' ',7A8)

C          SET INITIAL DATA FOR PLOTTING

      XMIN1=IFIX(XMIN/100.)*100
      CHK=XMIN-XMIN1
      IF (CHK.GE.50.) XMIN1=XMIN1+50.
      XMAX1=IFIX(XMAX/100.)*100
      CHK=XMAX-XMAX1
      IF (CHK.GT.0.) XMAX1=XMAX1+50.
      IF (CHK.GT.50.) XMAX1=XMAX1+50.
      YMM=EXP(YMIN)
      II=0
      IF (YMM.GE.1..AND.YMM.LT.10.) GO TO 41
      DO 46 I=1,5
      CHK=YMM*10.**I
      IF (YMM.GT.1.) CHK=YMM/10.**I
      IF (CHK.LE.10..AND.CHK.GE.1.) II=I
46    CONTINUE
41    YMIN1=1./10.**II
      IF (YMM.GT.1.) YMIN1=10.**II
```

Plotlog.f continued

```
      IF (YMN.LT.1.) II=-II
      II=I1-1
      YMAX1=YMIN1*10000.
      X2MIN=XMIN1-3./SCALEX
      X3MIN=XMIN1-90./SCALEX
      X4MIN=X3MIN-3./SCALEX
      XMIN11=XMIN1+10./SCALEX
      SCX=3.02*SCALEX
      M1=(XMAX1-XMIN1)/10.
      YMAX1L=ALOG(YMAX1)
      YMIN1L=ALOG(YMIN1)
      YL=ALOG(.5*YMIN1)
      YL1=ALOG(0.04*YMIN1)
      MAX=IFIX(XMAX1)
      MIN=IFIX(XMIN1)
      IF (INDEX.GT.0) GO TO 30
C       SET SCALE, AXIS AND LABEL THEM
      CALL SCALE(1.,1.,2.,0.)
      CALL FPLOT(1,0.,-10.)
      CALL SCALE(1.,1.,0.,0.)
      CALL FPLOT(1,4.,2.)
      CALL YLOGA(YMIN1,YMAX1,YMIN1,4,5.,0.,XMIN1,SCX,SCY)
      CALL FGRID(0,XMIN1,YMIN1L,10.,M1)
C       IF INDEX<0 ONLY GRID THE AXES
      IF (INDEX.LT.0) GO TO 9
      DO 6 I=MIN,MAX,50
      XI=FLOAT(I)-16./SCALEX
      CALL FCHAR(XI,YL,.12,.15,0.)
      WRITE (7,60) I
6     CALL PFLAG(1)
      DO 7 I=1,5
      II=II+1
      BE=YMIN1*10.**(I-1)
      BEL=ALOG(BE)
      CALL FCHAR(X3MIN,BEL,.12,.15,0.)
      WRITE (7,70)
      CALL PFLAG(1)
      BE=BE*1.3
      BEL=ALOG(BE)
      CALL FCHAR(X4MIN,BEL,.12,.15,0.)
      WRITE (7,80) II
7     CALL PFLAG(1)
      TIT1=ALOG(YMAX1*5.)
      CALL FCHAR(X3MIN,TIT1,.12,.15,0.)
      WRITE (7,100) (TYPE(1,I),I=1,10)
       CALL PFLAG(1)
C       PLOT EVERY SECOND DECADE
      YHIG=YMIN1
      DO 25 I6=1,4
      YHIG1=YHIG+YHIG
      YHIGL=ALOG(YHIG1)
      CALL FPLOT(1,XMIN1,YHIGL)
      CALL FPLOT(2,XMAX1,YHIGL)
```

Plotlog.f continued

```
      DO 26 I7=1,3
      YHIG1=YHIG1+2.*YHIG
      YHIGL=ALOG(YHIG1)
      CALL FPLOT(1,XMIN1,YHIGL)
      CALL FPLOT(2,XMAX1,YHIGL)
26    CONTINUE
      YHIG=YHIG*10.
      YHIGL=ALOG(YHIG)
      CALL FPLOT(1,XMIN1,YHIGL)
      CALL FPLOT(2,XMAX1,YHIGL)
25    CONTINUE
      CALL FPLOT(1,XMAX1,YHIGL)
      TITH=ALOG(YMAX1*20.)
      CALL FCHAR(X2MIN,TITH,.12,.15,0.)
      WRITE (7,120) (TITLE(1,K1),K1=1,7)
      CALL PFLAG(1)
      CALL DATIME(IDATE)
      CALL FCHAR(XMIN1,YL1,.12,.15,0.)
      WRITE (7,90) (IDATE(K2),K2=1,3)
      CALL PFLAG(1)
9     CONTINUE
      RETURN

C       IF INDEX>0
C       GRID, LABLE AND TITLE THE "RIGHT" Y-AXIS AND
C       MOVE THE PEN FOR THE NEXT PLOT

30    TITH=ALOG(YMIN1*0.08)
      CALL FCHAR(XMIN1,TITH,.12,.15,0.)
      WRITE (7,110) (TITLE(2,K1),K1=1,7)
      CALL PFLAG(1)
      CALL FPLOT(1,XMAX1,YMIN1L)
      CALL YLOGA(YMIN1,YMAX1,YMIN1,4,5.,0.,XMIN1,SCX,SCY)

C       IF INDEX=1 DO NOT LABEL OR TITLE

      IF (INDEX.EQ.1) GO TO 6

      CALL FCHAR(XMIN11,YMIN1L,.12,.15,0.)
      FMIN=YMIN1/(1.+YMIN1)
      WRITE (7,50) FMIN
      CALL PFLAG(1)
      DO 17 I=1,9,2
      YVA=FLOAT(I)/10.
      YLA=ALOG(YVA/(1.-YVA))
      CALL FCHAR(XMIN11,YLA,.12,.15,0.)
      WRITE (7,50) YVA
      CALL PFLAG(1)
17    CONTINUE
      CALL FCHAR(XMIN11,YMAX1L,.12,.15,0.)
      FMAX=YMAX1/(1.+YMAX1)
      WRITE (7,50) FMAX
      CALL PFLAG(1)
      XMO=XMIN1+150.
      TIT1=ALOG(YMAX1*5.)
      CALL FCHAR(X3MIN,TIT1,.12,.15,0.)
      WRITE (7,100) (TYPE(2,I),I=1,10)
      CALL PFLAG(1)
6     CONTINUE
      CALL FPLOT(1,XMIN1,YMIN1L)
```

Plotlog.f continued

```
CALL SCALE(1.,1.,0.,0.)
CALL FPLOT(1,6.,-4.)
RETURN
END
```

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