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# Software Package for the Logistic Substitution Model

Nakicenovic, N.

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# SOFTWARE PACKAGE FOR THE LOGISTIC SUBSTITUTION MODEL

N. Nakicenovic

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
Laxenburg, Austria

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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, $\alpha$ and $\beta$ 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 $\alpha_i$ and $\beta_i$ 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 $j$th 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 $\alpha$ and $\beta$ 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 $\alpha_i$ and $\beta_i$ 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 |
| 966.000 | 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 | 37.000 | 95.000 |
| 102.000 | 104.000 | 103.000 | 106.000 | 93.000 | 58.000 | 30.000 | 38.000 |
| 96.000 | 107.000 | 127.000 | 131.000 | 145.000 | 148.000 | 164.000 | 178.000 |
| 188.000 | 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 | 273.800 | | | | | |
| 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 |
| 38.000 | 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 | 1734.000 | 1921.000 |
| 2075.000 | 2216.000 | 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  1084.000  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    28.000    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  2574.000  2552.000  2574.000  2281.000  2362.000  2427.000  2387.000
 2466.900  2498.500  2554.900
  8 nuclear    14  61    1   1
    1.760     2.000     4.240     6.000     9.680    13.340    16.760    20.380
   24.040    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 PT | 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 | 0.48 | 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 | 0.558 | 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 | 0.398 | 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 | 0.017 | 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 | 1.72 | 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 | 1.29 | 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 | 1.47 | 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 | 1.59 | 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 | 2.21 | 0.16 | 0.079 | 0.46 | 0.227 | 0.17 | 0.084 | 1.23 | 0.610 | | |
| 1946 | 2.11 | 0.16 | 0.070 | 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 | 1.45 | 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 | 0.60 | 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 | 2.87 | | | 0.80 | 0.285 | 0.36 | 0.129 | 1.64 | 0.586 | | |
| 1954 | 2.96 | | | 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 | 3.39 | | | 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 | 5.92 | | | 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 | | | 2.35 | 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+  74.548     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 0  TOTAL    IS: Y =  0.020*T+ -37.198     R**2 = 0.972  VAR = 0.008
                        ( 55.570) (-55.412)

EQN 5  NUCLEAR  IS: Y =  0.001*T+-125.657     STARTING 1960

EQN 6  TOTAL    IS: Y =  0.060*T+-116.218     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 | 0.558 | 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 | 0.19 | 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 | 2.20 | 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 | 0.629 | 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 | 3.25 | 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 |

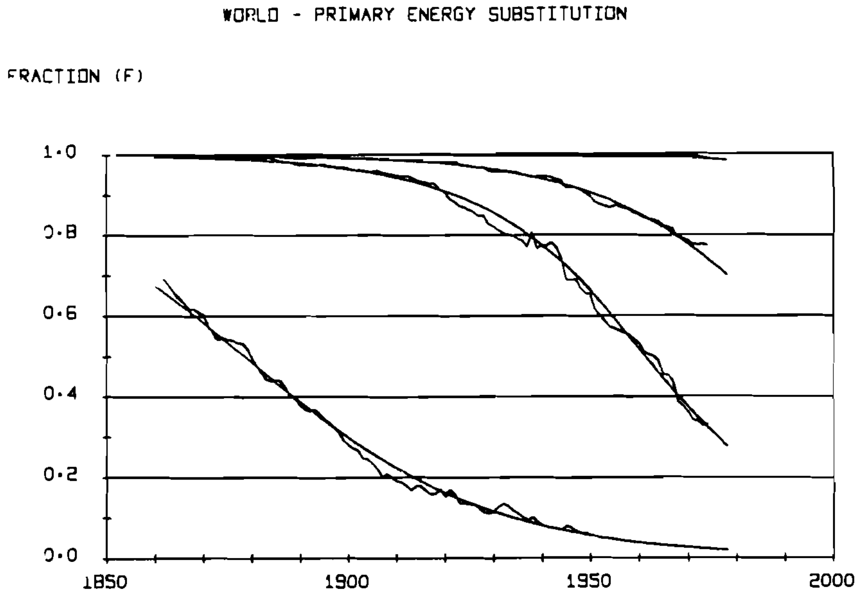


FIGURE 1 Example of Plotter output using Punch and Cards files.

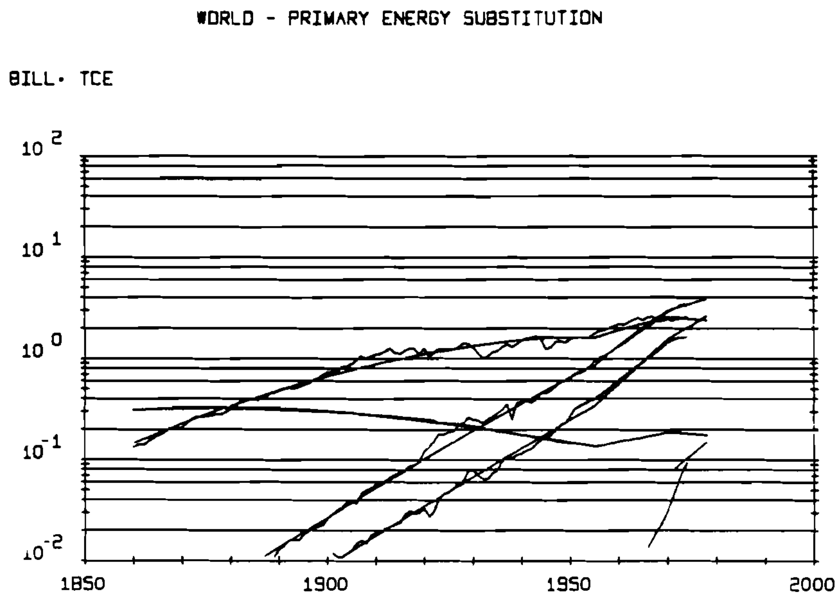


FIGURE 2 Example of Plotter output using Punch and Cards files.

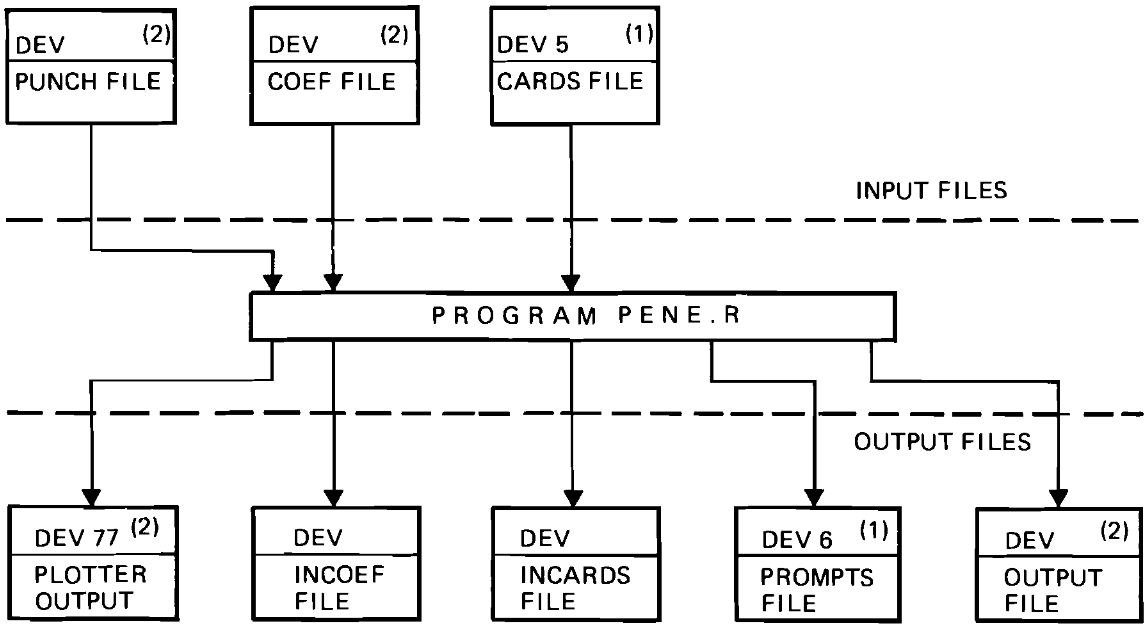


FIGURE 3 File structure of the program Pene.r. *1*. Cards file contains control parameters. In interactive use, DEV 5 (device 5) should be the terminal input, and prompts file should also be sent there; DEV 6 (device 6) should be the output to the terminal. Incards file has the same information and structure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

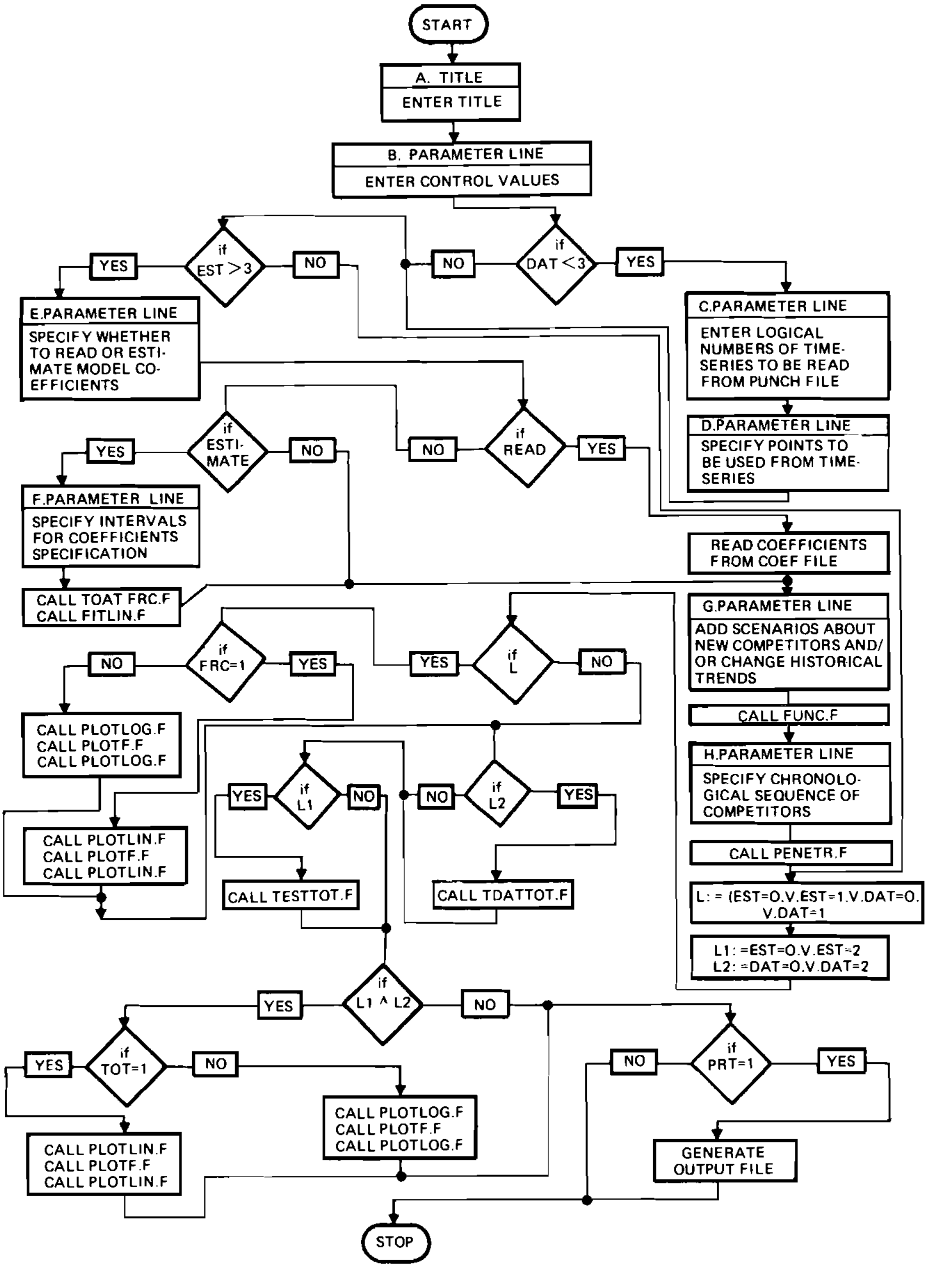


FIGURE 4 Flowchart of the main program: Pene.r.

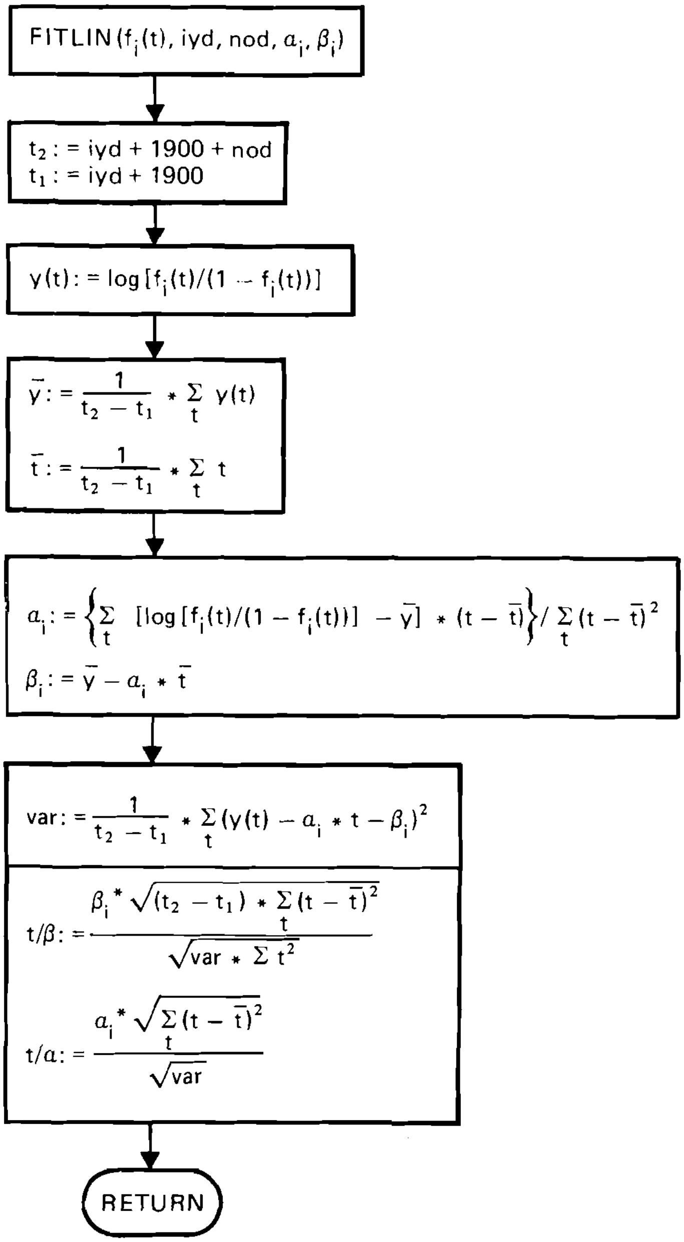


FIGURE 5 Flowchart of the estimation subroutine fitlin.f. *var* is the variance of $y(t)$; $t/\alpha$ and $t/\beta$ are $t$-statistics with $t_2 - t_1 - 2$ degrees of freedom under the hypotheses $\alpha = 0$ and $\beta = 0$.

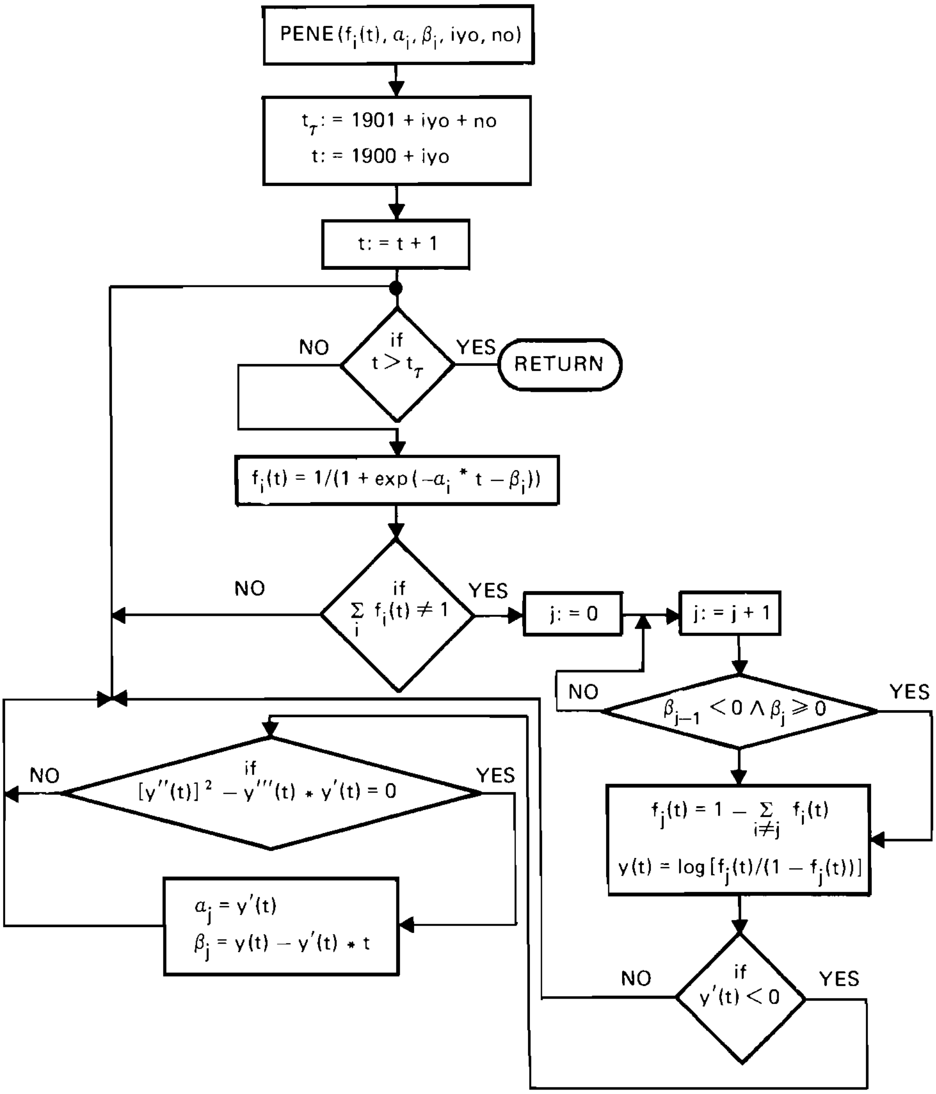


FIGURE 6 Flowchart of the market substitution subprogram: Penetr.f (algorithm Penetration).

*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/NUD(7),IYC,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)
     & /',G10.3',',F10.1',',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/(8F10.3))
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 20.03.78'/)
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  IYC 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 SPECIFICAT  NS '
      &,'*TRY AGAIN*'//)
133     FORMAT(/5X,'ERROR *** ',I4,'.GT.',I4,' *TRY AGA  *'//)
134     FORMAT(/5X,'ERROR *** NOD.EQ.0 NO OBSERVATIONS  EAD')
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,NOO,IDAT,EST,PRT,PAR,SCA,EXP
        NO2=NOO
        IF (NOO.GE.9000) NOO=NOO-9000
        FRC=IFRC
        IF (FRC.EQ.-1) FRC=0
        DAT=IDAT
        IF (DAT.GE.9000) DAT=DAT-9000
        IF (NOO.GT.300) WRITE (6,131)
        IF (NOO.GT.300) GO TO 58
        IF (NOO.EQ.0) NOO=100
        WRITE (6,108) PLT,FRC,TOT,IYO,NOO,DAT,EST,PRT,PAR,SCA,EXP
        WRITE (2,108) PLT,IFRC,TOT,IYO,NOO,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.
      &        NOO.LT. 0.OR.NOO.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 (8,105)
      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=IY0
      IYD=IY0
      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=1,72
      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     NOD(L),L=1,7)
        WRITE (6,1   ( (NOD(I1),I1=1,7)
        WRITE (2      (NOD(I2),I2=1,7)
        DO 1 I=1,
        IF (NOD(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) NU1,NA1,NO1,IY1,IP1,IB1,(D(1,I),I=1,NO1)
        IF (IB1.GT.IP1) WRITE (6,121) NU1
        IF (NO1.GT.150) WRITE(6,137) NU1
        IF (NO1.GT.150) GO TO 58
        IF (NA1.EQ.ISS) GO TO 2
        K=0
        DO 4 I=1,ND
4       IF (NOD(I).EQ.NU1) 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)=NU1
        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)+IBD-2)/IPD
        IYD=MIN0(IYD,IY(I))
6       NOD=MAX0(NOD,IX)
        NOD=(NOD-1900-IYD)*IPD-IBD+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) NOD=NOD+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,NO1
7       D(J,I)=F(J,I+L)*XMUL*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+(IBO+I1-2)/IPO
        XMAX=IYD+1900+(IBO+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)=CUEF
        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.3) 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+(IBO-1)/IBO
      IF (IY1.LT.I1) IY1=I1
      IF (IY2.LT.I1) IY2=I1
      I2=1900+IYD+(NOD+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 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+(IBO-1)/IBO
      IF (IY1.LT.I1) IY1=I1
      IF (IY2.LT.I1) IY2=I1
```

Main.f continued

```
      I2=1900+IY0+(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 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
C        CHANGE/ADD COEFFICENTS
C
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=0
      IF (NUMC.EQ.999) J1=999
      IF (NUMC.EQ.999) NUMC=8
      IF (NUMC.EQ.8.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 (6,132) 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=13
```

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.2.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=122
      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/NUO(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)
     & 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(26X,'(',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(.01010101)
       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,[illegible]
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 (FWC.EQ.0) GO TO 4
      Y=ALOG(Y/(1.-Y))
4     IF (Y.GT.YU.OR.Y.LT.YL) GO TO 3
11    X=IYO+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/NUO(7),IYC,IPO,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)/IPO
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)/IPO
       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,IPO,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 J=1,8
10    SUM(J,I)=0.
      IDATEND=IYD+(NOD+IBO-2)/IPO
      IFND=1900+IYF+(NOF+IBO-2)/IPO
      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,
     6            NUD(7),NAD(7),NU(7),IY(7)
     6       /FRAC/F(7,300),FLAB(7,10),NF,IYF,NOF,
     6            NUF(7),NAF(8),COEF(12,2),YEAR(4)
     6       /COM /NUD(7),IYO,IPO,IRO,PRT,PAR,FOR(8),
     6            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,
     &              NOF(7),NAF(8),COEF(12,2),YEAR(4)
     &        /COMM/NOD(7),IY0,IPO,IBO,PRT,PAR,FOR(8),
     &              PLT,FRC,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+IY0
      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+(IPO+I-2)/IPD
      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(I0)
   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=1
      IF (YMM.LE.1.) II=-1
      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=0.02*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 SCALE, AXIS AND LABEL THEM

      CALL SCALF(1.,1.,0.,0.)
      CALL FPLOT(1,0.,-10.)
      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 (2,XMAX1,YMIN1)
      CALL SCALE(1.,1.,0.,0.)
      CALL FPLOT (2,6.,-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=II-1
      YMAX1=YMIN1*10000.
      X2MIN=XMIN1-3./SCALEX
      X3MIN=XMIN1-90./SCALEX
      X4MIN=X3MIN-3./SCALEX
      XMIN11=XMIN1+10./SCALEX
      SCX=0.02*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 SCALF(1.,1.,0.,0.)
      CALL FPLOT(1,0.,-10.)
      CALL SCALF(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>3
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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