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GENVAR: A GENERAL LINEAR COMPUTER PROGRAM FOR MODEL FORECASTING
AND VARIANCE ANALYSIS

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CONTENTS

Abstract	1
Description of the Program	1
Model	1
Input and Output	3
Comments	3
Summary	8
Appendix A: GENVAR Graphics	A1
Appendix B: Source Code Listing (GLMVAR)	B1

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GENVAR: A GENERAL LINEAR COMPUTER PROGRAM
FOR MODEL FORECASTING AND VARIANCE ANALYSIS

ABSTRACT

This report describes GENVAR, an interactive computer program which can perform a least-squares fit to the matrix equation $\beta X=Y$, where X is a matrix of observable inputs and Y is a vector of observable outcomes for the input values. The program is controlled by teletypewriter and is written in LRLTRAN for compilation by CHAT and execution on a CDC 7600.

The report describes the way the program operates as well as ways GENVAR can be used to make statistically considered forecasts. Samples of graphic output and the source code listing (GLMVAR) are provided.

DESCRIPTION OF THE PROGRAM

GENVAR is written in LRLTRAN as source code GLMVAR. GLMVAR can be compiled under CHAT for the Lawrence Livermore Laboratory's CDC 7600 computer. It is a small code, requiring only 102172 octal words for its file size. Both GLMVAR and GENVAR can be read from photostore by typing ELF RSL .865750:FORECAST GLMVAR GENVAR

Model

The general linear model (GLM) can be written in matrix form as

$\beta X = Y$, where

- X = input values (independent),
- β = model parameters, and
- Y = output values (dependent).

By setting the partial derivatives of Eq. (1) to equal zero, we can derive

$$(X'X) \hat{\beta} - X'Y = 0 \quad (2)$$

and

$$\hat{\beta} = (X'X)^{-1} X'Y, \text{ where} \quad (3)$$

- $\hat{\beta}$ = the parametric estimators, and
- X' = the transpose of the X matrix.

If β_0 carries with it the dummy variable $X_0 = 1$, then the β_0 value calculated will be equal to a quantity around which the values of the remaining terms in the GLM will vary.

From Ch. 7 of Ref. 1, we can see that the variances and covariances of $\hat{\beta}$ are

$$V(\hat{\beta}_i) = C_{ij}\sigma^2 \text{ and} \quad (4)$$

$$\text{COV}(\hat{\beta}_i, \hat{\beta}_j) = C_{ij}\sigma^2, \text{ respectively.}$$

The C's are the elements of $(X'X)^{-1}$, and the σ^2 's are the global variances of the Y values around a mean. Since σ^2 's are generally unknown, we can use the estimator

$$S^2 = \frac{\text{SSE}}{n-(k+1)} \text{ where} \quad (5)$$

S = the unbiased variance estimator,

n = the number of experimental points (equations),

$k + 1$ = the number of variables (independent inputs plus the X_0 dummy), and

$n - (k + 1)$ = the degrees of freedom.

SSE is the sum of the square of errors

$$\text{SSE} = Y'Y - \hat{\beta}'X'Y \text{ or, by definition} \quad (6)$$

$$\text{SSE} = \sum_i (Y_i - \bar{Y})^2, \text{ where} \quad (7)$$

$\bar{Y}$ = mean average of the Y values, and

Y_i = the Y value of the i^{th} experiment, $i = 1, 2, \dots, n$.

In GENVAR, the forecasting function of the code is the last set of information provided. When the $\hat{\beta}$'s are determined with Eq. (3), and their variances are established with Eqs. (4) and (5), these parameters can be used to predict a likely Y value if we have expected X values (for example, $X = a$). We can show that

$$V(\hat{Y}) = [a'(X'X)^{-1}a]S^2 \quad (8)$$

1. Wm. Mendenhall, *Introduction to Linear Models and the Design and Analysis of Experiments* (Wadsworth Publishing Company, Inc., Belmont, California, 1968).

is the variance of the forecasted Y value (Ref. 1). If the predicted $\hat{Y} = E(\hat{Y})$, that is, if we predict that the Y value will be the expected value of Y as determined from

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 a_1 + \hat{\beta}_2 a_2 + \dots + \hat{\beta}_k a_k,$$

then we can show that if error = $Y - \hat{Y}$, then

$$E(\text{error}) = E(Y) - E(\hat{Y}). \quad (9)$$

Since the predicted value of Y is independent of its true value (that is, $\text{COV}(Y, \hat{Y}) = 0$),

$$\begin{aligned} V(\text{error}) &= V(Y) + V(\hat{Y}) \\ &= \sigma^2 + \sigma^2 [a'(X'X)^{-1}a], \end{aligned} \quad (10)$$

or, for example,

$$V(\text{error}) = S^2 [1 + a'(X'X)^{-1}a]. \quad (11)$$

Thus, from Eq. (11), we see that for a $(1-\alpha)$ interval of confidence, a Y-forecasted value will have an error bar around it of value

$$E(\hat{Y}) \pm t_{\alpha/2} S [1 + a'(X'X)^{-1}a]^{1/2}.$$

Input and Output

GENVAR is controlled only by teletypewriter (TTY). Table 1 (printed on the foldout pages beginning on p. 9) is a TTY interaction sample of GENVAR execution beginning with no previously created data files. The following explanation is keyed to the numbered sections of Table 1.

1. This calls up the routine once the user has it on his working disk files. (The previous section explains how the user can get GENVAR off photo-store with ELF.)

2. This can provide the user with a help package. Note that the FR80 files mentioned in the help package are not created if the GLM used contains terms in addition to the user-chosen polynomial terms. This is because additional X inputs require graphics in 3-D or above, and GENVAR is limited to a 2-D plot.

3. Because no data file (EQNSDATA) was to be used, NEW was chosen. This signifies that the user intends to input his own new set of X and Y values to TTY,

4. This allows the user to choose the highest-order term of his GLM. Thus, by choosing 1, the GLM contains strictly first-order terms. If, for example, 3 were picked, the GLM would be

$$Y = \beta_0 X_0 + \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_1^3 + \text{ASVT}$$

where

β_1 = the model's parameters to be determined by GENVAR,

$X_0 = 1$ = the dummy X used,

X_1 = the X value to be used for subsequent polynomial values (up to X_1^3), and

ASVT = Additional Single-Valued Terms (if any).

5. This begins the input phase of GENVAR's execution. The prompt, "TYPE EQUATION, n," will appear. The user then responds by typing the nth equation's Y value followed by up through nine X values. The formats for both X and Y are F7.2. When the user has no more equations to input, he simply punches the "RETURN" key of the TTY to indicate that no more equations will be inputted. As an example, the first equation inputted in Table 1 is

$$0. = \beta_0 + \beta_1(-2.)$$

Note that the X_0 value was not inputted; it is assigned by the code automatically. Note, also, that commas can be used as delimiters to each F7.2 field so that the user need not count out blank spaces to complete each value inputted.

6. Self-explanatory, but note that because LRLTRAN cannot handle 0 subscripts, BETA (1) $\equiv \beta_0$, etc, in the computer program.

7. In this example, Equation 3 was incorrectly inputted in part 6. By typing "3," the user was able to rewrite Equation 3 to correct it.

8. Equation 3 is re-entered in the same format as part 6.

9. Self-explanatory.

10. Same as part 7.

11. NVAR indicates the maximum number of different independent variables in the user's GLM. COEF points to the values of the calculated β 's in the estimator equation. In this example, that equation is

$$\hat{Y} = 1.00 + .70X$$

where

$$\hat{\beta}_0 = 1.00 \text{ and}$$

$$\hat{\beta}_1 = .70,$$

12. SIGMA $\equiv$ S in the previous mathematical modeling. Thus, in this example there is slightly over a 2/3 probability that the true outcome value (Y) will fall within the expected value of $\hat{Y}$, ± 0.61 units. The assumption in this modeling is that the β estimators ($\hat{\beta}_1$) are true representations of the real-world model, but that all errors in the model are lumped together into one Gaussian-distributed error term. Thus,

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X = \beta_0 + \beta_1 X + \epsilon$$

where

$$\epsilon = \text{the Gaussian distributed error term} = f(\epsilon_0, \epsilon_1),$$

$$\hat{\beta}_0 = \beta_0 + \epsilon_0, \text{ and}$$

$$\hat{\beta}_1 = \beta_1 + \epsilon_1.$$

The BETA variances and/or covariances are listed in proper matrix array.

So

$$V(\beta_{00}) = V(\beta_0) = 7.32E-02,$$

$$\text{COV}(\beta_0, \beta_1) = 0. = \text{COV}(\beta_1, \beta_0), \text{ and}$$

$$V(\beta_{11}) = V(\beta_1) = 3.67E-02$$

in this example.

13. If the user's GLM contains only a polynomial (no additional single-valued terms), then GENVAR will ask for the TV option. If "YES" is typed, the user will be able to put onto any TMDS monitor a graphic of inputted data points, an estimator line with its one-sigma spread, and forecast points with their one-sigma error bars. The pictures displayed on the screen are exactly those obtainable from the FR80 files which are being concurrently created by GENVAR.

14. This test can be used to determine the adequacy of the user's GLM. The null hypothesis (H_0) is

$$H_0 : \hat{\beta}_i = 0.$$

where

$\hat{\beta}_i$ = the parametric terms of the GLM, $i = 0 \dots$ number of terms.

Thus, if a t-value for a given $\hat{\beta}_i$ fails the test, the user must reject the null hypothesis. That is, the $\hat{\beta}_i$ corresponding to that particular t-value tested against a table for the indicated degrees of freedom must (statistically speaking) have a non-zero value. Accepting that, the user can conclude that the corresponding term does affect the Y outcome of his GLM. That is, the treatment or characteristic represented by that term can be considered germane to the model and should not be discarded.

On the other hand, should the t-test indicate that a $\hat{\beta}$ for a term is essentially zero, then the user might consider eliminating that particular treatment or characteristic from his GLM.

15. This brings us to the forecast part of GENVAR's execution. If the TV option was selected, the forecasted points selected will appear on the monitor screen after each point is entered. The user need not make a forecast at this time. He can close out the GENVAR execution and recall it later using the created files FOREDATA and EQNSDATA to do his forecasting.

16. The equation with $Y(1) =$ is just a check to assure the user that he properly inputted his forecast equation. The input format for the forecast equation must be the same as that for the original input data equation, but, of course, there is no Y outcome term.

STNDEV is the standard deviation around YFORE. Note that, as one would expect, STNDEV becomes larger the farther the X estimates are from the X data points. That is, the farther one moves from known data, the more uncertain the forecast becomes.

17. This is a repeat of part 17 with a different input.

18. By entering "NO," the program comes to a normal end. WARNING: GENVAR will repeat a prompt should a user accidentally enter something other than a Hollorith character when required. But if a numeric is required and something else is inputted, GENVAR will yield an error statement and dump out abnormally.

Table 2 (printed on the foldout on p. 12) is an example of GENVAR teletypewriter execution when the user has an old set of data points (equations) which he wishes to remodel by changing the order of the polynomial portion of the GLM. This mode of execution is especially useful when one is trying to do a best fit of the data by adjusting the highest order of the model. In this table, as well as in Table 3, only those points of the execution which have not yet been addressed will be discussed.

1. The user here chose to change the value of the highest order in the polynomial of his GLM. However, old data points from file EQNSDATA were used to formulate the new input equations.

2. The integer 2 entry has converted the formerly single-order-only equations into second-order equations. This section confirms that the user's GLM consists of at least a second-order polynomial. It also points out that if more than one X value were entered in any one of the input equations, those corresponding terms would be single-valued terms starting with the $N_{th} + 2$ term.

3. The recapitulation of the equations to be solved reflects that term 3 for each is a square of term 2. The value of term 2 in the input equations alone determines the values of the remaining terms in the polynomial function of the GLM. Thus, GENVAR's model is positioned as

$$GLM(1, X_2, NTH, X_3 \dots X_N) = P(1, X_2, NTH) + S(X_3 \dots X_N)$$

where

$P(1, X_2, NTH)$ = the polynomial as a function of $X_1 = 1$, X_2 and the order (NTH), and

$S(X_3 \dots X_N)$ = the additional, single-valued terms.

4. This is a blank section. However, had the elements of the A matrix not been symmetric, where $A = XX'$, then the A matrix would have been printed. In addition, if, after conducting parallel operations on an A matrix and its associated identity matrix, I, the A matrix was not transformed into a symmetric matrix while inverting A, then the A^{-1} matrix would have been listed also.

Both the A and the A^{-1} matrices should be symmetric when calculations by GENVAR are complete. If they are not, then the printout of A and/or A^{-1} should call the user's attention to this fact. A common cause of this asymmetry is

an A matrix which is singular or nearly singular (usually brought about by a column or row which is a multiple or nearly a multiple of another column or row, respectively).

Table 3 (on foldout p. 14) contains only one unique quality: both mode options, for input equations and Nth-order polynomials, are using "OLD" data.

1. Note that when the "XXXXDATA" files are used, a recapitulation of the old input equations is not printed. However, should the user want them printed on the TTY paper, he can proceed as in Table 2 for a new Nth-order polynomial using old equations. Instead of entering a new Nth value when prompted by the code, the user simply re-enters the old value, and the equations previously inputted will be listed.

Note also that the values for NVAR, COEF, SIGMA, etc., generally confirm that the user is operating from the data equations and estimator equations previously generated by the Table 2 execution.

Comments

Any units can be analyzed using the GLM and variance analysis of GENVAR. X is simply an observable input, and Y is an observable output. The $\hat{\beta}$'s are Y/X slope estimates which describe how Y varies around $\hat{\beta}_0$ as X values are changed. Thus, as long as the user keeps the units straight, he can forecast and analyze the variance (ANOVA) for any quantitative characteristics.

A sample of GENVAR's graphics appears in Appendix A; its source code listing (GLMVAR) is presented in Appendix B.

SUMMARY

GENVAR is a teletypewriter interactive computer program which can fit data points in multiple variables to a general linear model (GLM). By linear regression, the tested model is assigned $\hat{\beta}$'s which are coefficient estimators to the GLM. Standard deviations for the $\hat{\beta}$'s, the observed output versus the modeled, and the predicted output versus the modeled are calculated and listed on the TTY by GENVAR. Therefore, given any quantitative, experimental inputs and observable outcomes, GENVAR can derive a GLM with proper, fixed coefficients. The GLM, in turn, can be tested by ANOVA to determine its validity. If the GLM is valid, then, given a set of experimental or predicted inputs, it can (through GENVAR) be used and analyzed as a forecaster of outcomes.

Table 1. A teletypewriter (TTY) interaction sample of GENVAR execution starting with no previously created data files.

1. GENVAR

PROGRAM ...GENVAR... HAS BEGUN.

2. FOR INSTRUCTIONS: TYPE 'HELP'; OTHERWISE, ...RETURN...KEY.

HELP

IN THE LINEAR, MATRIX EQUATION, $BETA \times Y$ (Y=DEPENDENT, X=INDEPENDENT); GENVAR SOLVES FOR ESTIMATOR COEFFICIENTS, BETA. IT THEN USES THE BETA VALUES TO FORECAST Y ESTIMATES, GIVEN NEW X VALUES. STANDARD DEVIATIONS, FOR ERROR BAR CALCULATIONS, ARE GENERATED FOR EACH Y-FORECAST.

WHEN ASKED TO TYPE YOUR OUTPUTS AND INPUTS, USE FORMAT, (10F7.2). AFTER THE PROMPT 'TYPE EQUATION' AND THERE ARE NO MORE Y/X VALUES TO BE ENTERED, TYPE ...RETURN... KEY TO SHOW THAT CALCULATIONS CAN BEGIN. THE FIRST F7.2 FIELD TAKES THE Y VALUE OF EACH LINE; THE REMAINING 9 F7.2 FIELDS TAKE THE X VALUES.

CAUTION...THE NUMBER OF X VARIABLES, NVAR, PLUS 1, MUST BE LESS THAN THE NUMBER OF INPUT LINES, LINE (NVAR+1.LT.LINE). NOTE...XEQN(1), ASSOCIATED WITH BETA(1), ALWAYS = 1.00 AND SHOULD NOT...NOT...BE ENTERED AS AN X-VALUE AT ANYTIME. THUS, EACH EQUATION IS AS: $Y(1) = BETA(1) + BETA(2) \times X(2) + BETA(3) \times X(3) + \dots$ NOTE...THE NUMBER OF INPUT LINES MUST NOT EXCEED TWENTY (20).

GENVAR CREATES 3 DATA FILES FOR LATER USE IF DESIRED. 'FOREDATA' CONTAINS DATA BY WHICH FORECASTING CAN BE DONE USING PREVIOUSLY GENERATED BETAS, ETC. 'EQNSDATA' IS USED TO CHANGE THE ORDER OF A POLYNOMIAL WHILE USING THE Y/X INPUT DATA FROM A PREVIOUS RUN (GOOD FOR BEST FITTING GIVEN DATA POINTS). AN FR80 FILE IS ALSO CREATED IF THE GLM HAS ONLY A POLYNOMIAL.

3. IF NEW TTY Y/X VALUES (INPUT EQUATIONS) ARE NEEDED;
TYPE 'NEW'; TYPE 'OLD' OTHERWISE -- THEN...RETURN...KEY.

NEW

4. TYPE INTEGER (NTH=1...9) TO SET HIGHEST ORDER TERM
IN YOUR GENERAL LINEAR MODEL -- THEN...RETURN...KEY.

1

FOR EACH EQUATION, THE FIRST X-INPUT SETS THE X-VALUES FOR THE 2-TERMS OF A 1 ORDER POLYNOMIAL. ADDITIONAL X-INPUTS ADD SINGLE-VALUED TERMS TO THE GENERAL LINEAR MODEL, STARTING WITH TERM 3.

Table 1. (Continued)

5. TYPE EQUATION: 1
 0.,-2.
 TYPE EQUATION: 2
 0.,-1.
 TYPE EQUATION: 3
 1.,1.
 TYPE EQUATION: 4
 1.,1.
 TYPE EQUATION: 5
 3.,2.
 TYPE EQUATION: 6

6. YOUR INPUT EQUATIONS WERE:

Y(1)=BETA(1)*1.00 +BETA(2) * -2.00
 Y(2)=BETA(1)*1.00 +BETA(2) * -1.00
 Y(3)=BETA(1)*1.00 +BETA(2) * 1.00
 Y(4)=BETA(1)*1.00 +BETA(2) * 1.00
 Y(5)=BETA(1)*1.00 +BETA(2) * 2.00

7. EQUATIONS OK? IF OK, TYPE ...RETURN...; IF NOT, TYPE
 NUMBER OF THE EQUATION (LINE NO.) IN ERROR.

3

8. RE-TYPE EQUATION: 3
 1.

9. YOUR CORRECTED EQUATION IS:

Y(3)=BETA(1)*1.00 +BETA(2) * 0.00

10. EQUATIONS OK? IF OK, TYPE ...RETURN...; IF NOT, TYPE
 NUMBER OF THE EQUATION (LINE NO.) IN ERROR.

11. YOUR OUTPUT ESTIMATOR COEFFICIENTS (IN ORDER) ARE:

NVAR= 2; COEFF= 1.00 0.70

12. FOR SIGMA= 0.61,

THE BETA VARIANCES/COVARIANCES ARE:

7.33E-02 0.
 0. 3.67E-02

Table 1. (Continued)

13. TV PICTURE? TYPE YES OR NO; THEN...RETURN...KEY.

YES
MONITOR NO.7524

14. IF YOU WISH A BETA T-STUDENTS STATISTICAL TEST; TYPE
YES; IF NOT; TYPE NO. THEN PUSH THE ..RETURN.. KEY.
NOTE...THE NULL HYPOTHESIS IS THAT THE BETA VALUE IS ZERO.

YES
FOR 3-DEGREES OF FREEDOM;
THE STUDENTS T-TEST FOR THE DIAGONAL BETAS ARE:

3.693 3.656

15. IF YOU WISH TO MAKE AN OUTPUT FORECAST; TYPE
YES; NO OTHERWISE -- THEN ...RETURN...KEY.

YES

16. TYPE X-VALUES; FORMAT 9F7.2.

3.
 $Y(1) = \text{BETA}(1) * 1.00 + \text{BETA}(2) * 3.00$

YOUR Y FORECAST IS; YFORE= 3.100
THE STANDARD DEVIATION OF YFORE IS; STNDEV= 0.88

17. TYPE YES FOR ANOTHER FORECAST - NO OTHERWISE.

YES
TYPE X-VALUES; FORMAT 9F7.2.

-1.5
 $Y(1) = \text{BETA}(1) * 1.00 + \text{BETA}(2) * -0.50$

YOUR Y FORECAST IS; YFORE= 0.650
THE STANDARD DEVIATION OF YFORE IS; STNDEV= 0.67

18. TYPE YES FOR ANOTHER FORECAST - NO OTHERWISE.

NO

ALL DONE

Table 2. A TTY example of GENVAR's execution using an old equations file (EQNSDATA) and a new-order polynomial.

```

GENVAR

      PROGRAM ...GENVAR... HAS BEGUN.

FOR INSTRUCTIONS, TYPE 'HELP'; OTHERWISE,...RETURN...KEY.

IF NEW TTY Y/X VALUES (INPUT EQUATIONS) ARE NEEDED,
TYPE 'NEW'; TYPE 'OLD' OTHERWISE -- THEN...RETURN...KEY.

OLD
1. FOR A NEW NTH-ORDER POLYNOMIAL FROM OLD Y/X VALUES IN
'EQNSDATA' FILE, TYPE 'NEW'; TYPE 'OLD' TO COMMENCE FORECASTING
USING OLD DATA FROM FILE 'FOREDATA' -- THEN ...RETURN...KEY.

NEW
TYPE INTEGER (NTH=1...9) TO SET HIGHEST ORDER TERM
IN YOUR GENERAL LINEAR MODEL -- THEN...RETURN...KEY.

2
2. FOR EACH EQUATION, THE FIRST X-INPUT SETS THE X-VALUES
FOR THE 3-TERMS OF A 2 ORDER POLYNOMIAL.
ADDITIONAL X-INPUTS ADD SINGLE-VALUED TERMS TO THE GENERAL
LINEAR MODEL, STARTING WITH TERM 4.

YOUR INPUT EQUATIONS WERE:

3. Y( 1)=BETA( 1)+1.00 +BETA( 2) *    -2.00 +BETA( 3) *    4.00
   Y( 2)=BETA( 1)+1.00 +BETA( 2) *    -1.00 +BETA( 3) *    1.00
   Y( 3)=BETA( 1)+1.00 +BETA( 2) *     0.00 +BETA( 3) *    0.00
   Y( 4)=BETA( 1)+1.00 +BETA( 2) *     1.00 +BETA( 3) *    1.00
   Y( 5)=BETA( 1)+1.00 +BETA( 2) *     2.00 +BETA( 3) *    4.00

EQUATIONS OK? IF OK, TYPE ...RETURN...; IF NOT, TYPE
NUMBER OF THE EQUATION (LINE NO.) IN ERROR.

YOUR OUTPUT ESTIMATOR COEFFICIENTS (IN ORDER) ARE:

NVAR= 3; CDEF=    0.57    0.70    0.21

4.
FOR SIGMA= 0.49,
THE BETA VARIANCES/COVARIANCES ARE:

    1.11E-01    0.    -3.27E-02
    0.    2.29E-02    0.
   -3.27E-02    0.    1.63E-02

```

Table 2. (Continued)

TV PICTURE? TYPE YES OR NO; THEN...RETURN...KEY.

NO

IF YOU WISH A BETA T-STUDENTS STATISTICAL TEST; TYPE
YES; IF NOT; TYPE NO. THEN PUSH THE ..RETURN.. KEY.
NOTE...THE NULL HYPOTHESIS IS THAT THE BETA VALUE IS ZERO.

YES

FOR 2-DEGREES OF FREEDOM;

THE STUDENTS T-TEST FOR THE DIAGONAL BETAS ARE:

1.715 4.630 1.677

IF YOU WISH TO MAKE AN OUTPUT FORECAST; TYPE
YES; NO OTHERWISE -- THEN ...RETURN...KEY.

NO

ALL DONE

Table 3. A TTY example of GENVAR execution using old equations data (EQNSDATA) and estimator equations, expected BETA values, etc. (FOREDATA) to forecast outcomes.

```

GENVAR
      PROGRAM ...GENVAR... HAS BEGUN.

FOR INSTRUCTIONS, TYPE 'HELP'; OTHERWISE, ...RETURN...KEY.

IF NEW TTY Y/X VALUES (INPUT EQUATIONS) ARE NEEDED,
TYPE 'NEW'; TYPE 'OLD' OTHERWISE, -- THEN ...RETURN...KEY.

OLD
FOR A NEW NTH-ORDER POLYNOMIAL FROM OLD Y/X VALUES IN
'EQNSDATA' FILE, TYPE 'NEW'; TYPE 'OLD' TO COMMENCE FORECASTING
USING OLD DATA FROM FILE 'FOREDATA' -- THEN ...RETURN...KEY.

1. OLD
FOR A LINEAR MODEL WITH A 2-DEGREE POLYNOMIAL,
YOUR OUTPUT ESTIMATOR COEFFICIENTS (IN ORDER) ARE:

NVAR= 3; COEFF=    0.57    0.70    0.21

FOR SIGMA= 0.48,
THE BETA VARIANCES/COVARIANCES ARE:

    1.11E-01    0.    -3.27E-02
    0.    2.29E-02    0.
   -3.27E-02    0.    1.63E-02

TV PICTURE? TYPE YES OR NO; THEN ...RETURN...KEY.

YES
MONITOR NO. 7524

IF YOU WISH A BETA T-STUDENTS STATISTICAL TEST, TYPE
YES; IF NOT, TYPE NO. THEN PUSH THE ..RETURN.. KEY.
NOTE...THE NULL HYPOTHESIS IS THAT THE BETA VALUE IS ZERO.

NO

IF YOU WISH TO MAKE AN OUTPUT FORECAST, TYPE
YES; NO OTHERWISE -- THEN ...RETURN...KEY.

///

IF YOU WISH TO MAKE AN OUTPUT FORECAST, TYPE
YES; NO OTHERWISE -- THEN ...RETURN...KEY.

```

Table 3. (Continued)

YES

TYPE X-VALUES; FORMAT 9F7.2.

2.5

$Y(1) = \text{BETA}(1) \diamond 1.00 + \text{BETA}(2) \diamond 2.50 + \text{BETA}(3) \diamond 6.25$

YOUR Y FORECAST IS; YFORE= 3.661

THE STANDARD DEVIATION OF YFORE IS; STNDEV= 0.84

TYPE YES FOR ANOTHER FORECAST - NO OTHERWISE.

YES

TYPE X-VALUES; FORMAT 9F7.2.

-.5

$Y(1) = \text{BETA}(1) \diamond 1.00 + \text{BETA}(2) \diamond -0.50 + \text{BETA}(3) \diamond 0.25$

YOUR Y FORECAST IS; YFORE= 0.275

THE STANDARD DEVIATION OF YFORE IS; STNDEV= 0.57

TYPE YES FOR ANOTHER FORECAST - NO OTHERWISE.

NO

ALL DONE

APPENDIX A: GENVAR Graphics

As explained previously, GENVAR produces FR80 files whenever the user's model consists of only a polynomial with no additional single-valued terms. If FREDIT (See T. Stevenson, FREDIT REPORT, Edition 1.9, 19 May 1976) is used to process the resulting graphics disk files, the user can put these out in hard copy to an RJET or a 35-mm film processor. Figs. A-1 and A-2 are samples of GENVAR's graphic output.

When comparing the two graphics, note that the error bars associated with each forecast point (0) are noticeably greater than the one-sigma spread about the estimator lines. This reflects additional uncertainties about the future as well as remoteness of the forecast points from the given data points and is especially noticeable in Fig. A-2 where the error bar around the forecast at $X = 2.5$ is considerably greater than that of the point at $X = -0.5$ which is nestled closely between two experimental data points.

Fig. A-1. A sample of GENVAR's graphic output. This is a first-degree polynomial fit of five data points (X's).

Fig. A-2. A sample of GENVAR's graphic output. This is a second-degree polynomial fit of the same five data points shown in Fig. A-1. Note the better fit, indicated by the lower SIGMA value.

APPENDIX B: Source Code Listing

```

* CHAT (300000=,SYMBΔ,URLIB,TV80LIB,ORDERLIB)XME,GENVAR,BIN$,LOD1,Z06,L,L
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C                                PROGRAM GENVAR                                C
C
C                                BY                                C
C
C                                S. DUANE STRATTON                        C
C                                JANUARY   6 ,1977                        C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C THIS PROGRAM USES LINEAR REGRESSION TO FIT A GENERAL LINEAR MODEL,
C BETA*X=Y, TO A SET OF DATA POINTS. THEN, USING THE ESTIMATORS FOR
C THE BETAS, GENVAR CAN BE USED TO MAKE OUTCOME FORECASTS. BOTH THE
C ESTIMATORS AND THE FORECASTS WILL HAVE VARIANCES OR STANDARD DEVIATIONS
C CALCULATED FOR APPROPRIATE GOODNESS OF FIT ANALYSIS.
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C PROGRAM CARD(TAPE59,TAPE6,FOREDATA=TAPE6,TAPE7,EQNSDATA=TAPE7)
C CALL CHANGE(Δ+GENVARΔ)
C COMMON FORM(40),BUFEQN(50)
C COMMON /REPORT/NEEDAINV
C LCM (TVCOML)
C COMMON /TVCOML/ ITBUF(4614)
C DIMENSION XEQN(40,20),YEQN(40),BETA(20),BE(20,20),ARE(20),W(20),
C 1V(20),A(20,20),AIN(20,20),WYE(20),YEST(40),TSTUDENTS(20)
C 2,XTAIN(20)
C DATA FORM/ΔY( )=BETA( 1)*1.00 +BETA( 2) *          +BETA( 3)Δ,
C 1Δ *          +BETA( 4) *          +BETA( 5) *          +BETA( 6)Δ,
C 2Δ *          +BETA( 7) *          +BETA( 8) *          +BETA( 9)Δ,
C 3Δ *          +BETA(10) *          +BETA(11) *          +BETA(12)Δ,
C 4Δ *          +BETA(13) *          +BETA(14) *          +BETA(15)Δ,
C 5Δ *          +BETA(16) *          +BETA(17) *          +BETA(18)Δ,
C 6Δ *          +BETA(19) *          +BETA(20) *          Δ,/
C NEEDHELP=NEEDEQNS=NEWNTH=NOWEQNS=NEEDAINV=0
C WRITE (59,STRT)
C
C STRT FORMAT (15X,ΔPROGRAM ...GENVAR... HAS BEGUN.Δ//)
C RTRY WRITE (59,OPTN)
C OPTN FORMAT (ΔFOR INSTRUCTIONS, TYPE 'HELP'; OTHERWISE,...RETURN...Δ
C 1ΔKEY.Δ//)
C READ (59,Δ(A4)Δ) NEEDHELP
C IF (NEEDHELP.EQ.ΔHELPΔ) CALL HELP
C
C THIS PERMITS THE USER TO WRITE A NEW POLYNOMIAL USING OLD Y/X
C VALUES OR TO USE OLD BETAS FOR NEW FORECASTING.
C
C WRITE (59,FDAT)
C
C FDAT FORMAT (ΔIF NEW TTY Y/X VALUES (INPUT EQUATIONS) ARE NEEDED,Δ/
C 1ΔTYPE 'NEW'; TYPE 'OLD' OTHERWISE -- THEN...RETURN...KEY.Δ//)
C READ (59,EQNS) NEEDEQNS
C EQNS FORMAT (A3)
C IF (NEEDEQNS.EQ.ΔNEWΔ) GO TO NNEW
C IF (NEEDEQNS.NE.ΔNEWΔ.AND.NEEDEQNS.NE.ΔOLDΔ) GO TO RTRY
C DUMB WRITE (59,NPLY)
C NPLY FORMAT (ΔFOR A NEW NTH-ORDER POLYNOMIAL FROM OLD Y/X VALUES INΔ/
C 1Δ'EQNSDATA' FILE, TYPE 'NEW'; TYPE 'OLD' TO COMMENCE FORECASTINGΔ/
C 2ΔUSING OLD DATA FROM FILE 'FOREDATA' -- THEN ...RETURN...KEY.Δ//)
C READ (59,Δ(A3)Δ) NEWNTH
C IF (NEWNTH.NE.ΔNEWΔ.AND.NEWNTH.NE.ΔOLDΔ) GO TO DUMB

```



```

      IF (NEWNTH.EQ.OLD) GO TO NOEQ
C
C      THIS SETS THE NTH ORDER FOR A POLYNOMIAL FIT.
C
      NNEW WRITE (59,POL1)
      POL1 FORMAT (TYPE INTEGER (NTH=1...19) TO SET HIGHEST ORDER TERM/
      1 IN YOUR GENERAL LINEAR MODEL -- THEN...RETURN...KEY.//)
      NTH=0
      CALL GSYMTT(NOWNTH,1,NUM,0,ERR,PROMPT,0)
      NTH=KATI(NOWNTH)
      IOK=NUMB=0
      DO CHEK MM=1,19
      NUMB=NUMB+1
      IF (NTH.EQ.NUMB) IOK=1
      CHEK CONTINUE
      IF (.NOT.IOK) GO TO NNEW
      WRITE (59,POLY) NTH+1,NTH,NTH+2
      POLY FORMAT (FOR EACH EQUATION, THE FIRST X-INPUT SETS THE X-VALUES/
      1 FOR THE ,12, TERMS OF A ,12,-ORDER POLYNOMIAL./
      2 ADDITIONAL X-INPUTS ADD SINGLE-VALUED TERMS TO THE GENERAL/
      3 LINEAR MODEL, STARTING WITH TERM ,12,.//)
      IF (NEWNTH.EQ.NEW) GO TO ENNU
C
C      THIS READS EACH LINEAR EQUATION.
C
      LINE=IEND=NEWLINE=0
      REED LINE=LINE+1
      WRITE (59,INST) LINE
      INST FORMAT (3X,TYPE EQUATION, ,12)
      XEQN(LINE,1)=1.
      READ (59,INPT) YEQN(LINE),(XEQN(LINE,JJ),JJ=2,9)
      INPT FORMAT (10F7.2)
      INOTDONE=0
      DO CONT JJ=2,10
      IF (XEQN(LINE,JJ).NE.0..OR.YEQN(LINE).NE.0.) INOTDONE=1
      CONT CONTINUE
      IF (INOTDONE) GO TO REED
      LINE=LINE-1
C
C      THIS CREATES 'EQNSDATA' TO BE ABLE TO WRITE A NEW POLYNOMIAL USING OLD
C      DATA.
C
      CALL DEVICE(DESTROY, EQNSDATA)
      CALL DEVICE(CREATE, EQNSDATA, 300000)
      CALL DEVICE(OPEN, EQNSDATA, NSIZE)
      REWIND 7
C
C      THIS SETS VALUES INTO FILE 'EQNSDATA'.
C
      WRITE (7) LINE,NTH
      DO PDAT II=1,LINE
      WRITE (7) YEQN(II),(XEQN(II,JJ),JJ=2,9)
      PDAT CONTINUE
      END FILE 7
      AGIN REWIND 7
C
C      THIS CONVERTS XEQN(II,2) TO A POLY OF NTH ORDER AS WELL AS
C      READ OFF OLD EQUATIONS VALUES FROM FILE 'EQNSDATA'.
C
      ENNU IF (NTH.GT.1.OR.NEEDEQNS.EQ.OLD)

```

```

      1 CALL POLYEQNS(LINE,NTH,XEQN,YEQN,NEEDEQNS)
C
C   THIS CALCULATES THE NUMBER OF VARIABLES AND EQUATIONS TO BE USED IN
C   THE LINEAR REGRESSION ROUTINE, MLR.
C
      NUMCOUNTED=NVAR=NEQN=0
      DO VARB JJ=1,20
      INCOLUMN=0
      DO VARA II=1,LINE
      IF (XEQN(II,JJ).NE 0..AND..NOT.INCOLUMN) INCOLUMN=1
VARA CONTINUE
      NUMCOUNTED=NUMCOUNTED+INCOLUMN
VARB CONTINUE
      NVAR=NEQN=NUMCOUNTED
      NM1=NVAR
      IF (NM1.GT.7) NM1=7
      NM2=NVAR-7
      IF (NM2.GT.7) NM2=7
      NM3=NVAR-14
      IF (NVAR.GE.LINE.OR.NVAR.GT.20) WRITE (59,WRNG)
WRNG FORMAT ('ERROR...THE NUMBER OF TERMS IN YOUR GLM EXCEEDS 20 OR#/
1#EQUALS OR EXCEEDS THE NUMBER OF INPUTED EQUATIONS. #//')
      IF (NVAR.GE.LINE.OR.NVAR.GT.20) GO TO RTRY
      IF (NEWLINE) GO TO DOEQ
BOOB WRITE (59,NDEQ)
NDEQ FORMAT ('PRINT EQUATIONS? TYPE YES/NO, THEN...RETURN...KEY.#//')
      READ (59,#(A3)#) NOWEQNS
      IF (NOWEQNS.EQ.#NO #) GO TO AMTX
      IF (NOWEQNS.NE.#YES#.AND.NOWEQNS.NE.#NO #) GO TO BOOB
C
C   THIS WRITES OUT THE EQUATIONS UNDER CONSIDERATION.
C
DOEQ NPRINT= 4+(NVAR-2)*2
      NMOVE= 0*NPRINT
      IF (.NOT.NEWLINE) WRITE (59,PTOT)
PTOT FORMAT ('//,X,#YOUR INPUT EQUATIONS ARE:#//')
      IF (NEWLINE) WRITE (59,PNEW)
PNEW FORMAT ('//,X,#YOUR CORRECTED EQUATION IS:#//')
      LIMIT=.LINE
      IF (NEWLINE) LIMIT=1
      DO WRTE II=1,LIMIT
      CALL SSMOVE(FORM,BUFEQN,0,0,NMOVE)
      IF (NEWLINE) II=NEWLINE
      CALL CONVI(II,BUFEQN,2,2)
      DO RITE JJ=2,NVAR
      CALL CONV(XEQN(II,JJ),BUFEQN,33+(JJ-2)*20,7,2,0)
RITE CONTINUE
      WRITE (59,#(6A10)#) (RIFFQN(III),III=1,NPRINT)
WRTE CONTINUE
C
C   THIS ALLOWS USER TO CORRECT A SINGLE EQUATION IN ERROR BEFORE CALCULATING.
C
      WRITE (59,EQOK)
EQOK FORMAT ('//#IF EQUATIONS OK, TYPE...RETURN...KEY. IF NOT, TYPE#/
1#THE NUMBER OF THE EQUATION (LINE NO.) IN ERROR.#//')
      NEWLINE=0
      CALL GSYMTT(NULINE,1,NUM,0,ERR,PROMPT,0)
      NEWLINE=KATI(NULINE)
      IF (NFWLINE) CALL NEWLINES(NEWLINE,YEQN,XEQN)
      IF (NEWLINE) GO TO AGIN

```

```

C
C   THIS GIVES  $X'X=A$ , WHERE A IS A SQUARE MATRIX.
C
AMTX DO DOTA JJ=1,NVAR
      DO DOTA II=1,NVAR
      SUMA=DOTPROD(XEQN(1,JJ),XEQN(1,II),XEQN(2,JJ),XEQN(2,II),LINE)
      A(JJ,II)=SUMA
DOTA CONTINUE
      NEEDA=0
      DO TEST II=1,NVAR
      DO TEST JJ=1,NVAR
      DIFF=ABSF(A(II,JJ)-A(JJ,II))
      IF (DIFF.GT.1.E-5) NEEDA=1
TEST CONTINUE
      IF (.NOT.NEEDA) GO TO SKIP
C
C   THIS WRITES THE A-MATRIX ON TTY IF AN ERROR IS FOUND.
C
      WRITE (59,MATX)
MATX FORMAT (X,THE A-MATRIX, WHERE  $A=X'X$ , IS: //)
      CALL MATRIX(NVAR,NVAR,A,20,20)
C
C   THIS INVERTS THE A MATRIX.
C
SKIP CALL INVERT(A,AIN,NVAR)
C
C   THIS WRITES THE A-INVERSE MATRIX IF AN ERROR IS FOUND.
C
MISS IF (.NOT.NEEDAINV) GO TO SKYP
      WRITE (59,INVS)
INVS FORMAT (THE A-MATRIX INVERSE IS: //)
      CALL MATRIX(NVAR,NVAR,AIN,20,20)
C
C   THIS GIVES  $X'Y=WYE$ , WHERE WYE IS A VECTOR.
C
SKYP DO DOTY II=1,NVAR
      SUMY=DOTPROD(XEQN(1,II),YEQN(1),XEQN(2,II),YEQN(2),LINE)
      WYE(II)=SUMY
DOTY CONTINUE
C
C   THIS USE MINIMUM LINEAR REGRESSION TO SOLVE FOR THE OUTPUT ESTIMATOR
C   COEFFICIENTS IN THE EQUATION,  $X*BETA=Y$ . TO SOLVE THIS, USING MLR,
C   THE EQUATION  $X'X*BETA=X'Y$  WAS USED, WHICH BY SUBSTITUTION YIELDS,
C    $A*BETA=WYE$ .
C
      CALL MLR(20,NEQN,NVAR,A,WYE,BETA,BE,ARE,W,V)
C
C   THIS DOES THE OUTPUT ESTIMATOR VALUES, YEST.
C
      DO ESTY JJ=1,LINE
      YEST(JJ)=0.
      DO ESTY II=1,NVAR
      YEST(JJ)=YEST(JJ)+BETA(II)*XEQN(JJ,II)
ESTY CONTINUE
C
C   THIS DOES THE SUM OF THE SQUARES OF ERRORS, SSE, TO USE IN DOING
C   THE UNBIASED ESTIMATOR, SIGMA, CALCULATIONS.
C
      SUMSQR=0.
      DO SUMS II=1,LINE

```

```

SUMSQR=SUMSQR+(YEQN(II)-YEST(II))*2
SUMS CONTINUE
SSQR=(SUMSQR/(LINE-NVAR))
SIGMA=SQRTF(SSQR)
C
C THIS WRITES THE BETA ESTIMATES FOR THE ESTIMATOR EQUATION.
C
WRITE (59,ANSR) NVAR
ANSR FORMAT(=YOUR =,12,= ESTIMATOR EQUATION COEFFICIENTS (IN ORDER) =
1 =ARE: =//)
WRITE (59,COEF) NM1,(BETA(JJ),JJ=1,NM1)
COEF FORMAT (* (E11.3))
IF (NVAR.GT.7) WRITE (59,=(*(E11.3))=) NM2,(BETA(JJ),JJ=8,7+NM2)
IF (NVAR.GT.14) WRITE (59,=(*(E11.3))=)
1 NM3,(BETA(JJ),JJ=15,14+NM3)
WRITE (59,=(/)=)
C
C THIS CREATES 'FOREDATA' TO BE ABLE TO FORECAST USING OLD BETAS, ETC.
C
CALL DEVICE(=DESTROY=,=FOREDATA=)
CALL DEVICE(=CREATE=,=FOREDATA=,300000)
REWIND 6
CALL DEVICE(=OPEN=,=FOREDATA=,MSIZE)
C
C THIS WRITES DATA ONTO 'FOREDATA' DISC FILE FOR LATER USE.
C
WRITE (6) NVAR,NTH,LINE,SIGMA,SSQR
WRITE (6) (BETA(JJ),JJ=1,NVAR)
DO INVR II=1,NVAR
WRITE (6) (AIN(II,JJ),JJ=1,NVAR)
INVR CONTINUE
END FILE 6
IF (NEEDEQNS.EQ.=NEW=) WRITE (59,SIGA) SIGMA
SIGA FORMAT (=FOR SIGMA=,=,E11.3,=,=)
IF (NEEDEQNS.EQ.=OLD=) WRITE (59,SIGB) SIGMA
SIGB FORMAT (//=FOR SIGMA=,=,E11.3,=,=)
WRITE (59,SIGX)
SIGX FORMAT (=THE BETA VARIANCES/COVARIANCES ARE: =//)
DO SIGM II=1,NVAR
WRITE (59,VARI) NM1,(SSQR*AIN(II,JJ),JJ=1,NM1)
IF (NVAR.GT.7) WRITE (59,VARI) NM2,(SSQR*AIN(II,JJ),JJ=8,7+NM2)
IF (NVAR.GT.14) WRITE (59,VARI) NM3,(SSQR*AIN(II,JJ),JJ=15,14+NM3)
WRITE (59,=(/)=)
VARI FORMAT (* (E10.2))
SIGM CONTINUE
IF (NEEDEQNS.EQ.=NEW=.OR.=NEWNTH.EQ.=NEW=) GO TO NUEQ
C
C THIS WRITES 'FOREDATA' FILE DATA FOR PARAMETER VALUES VERIFICATION
C OR TO READ DATA FOR FORECAST FROM OLD EQUATIONS.
C
NUEQ CALL DEVICE(=OPEN=,=FOREDATA=,MSIZE)
REWIND 6
READ (6) NVAR,NTH,LINE,SIGMA,SSQR
READ (6) (BETA(II),II=1,NVAR)
DO FILE JJ=1,NVAR
READ (6) (AIN(JJ,II),II=1,NVAR)
FILE CONTINUE
NM1=NVAR
IF (NM1.GT.7) NM1=7
NM2=NVAR-7

```

```

      IF (NM2.GT.7) NM2=7
      NM3=NVAR-14
      CALL POLYEQNS(LINE,NTH,XEQN,YEQN,NEEDEQNS)
      WRITE (59,PLYN) NTH
PLYN  FORMAT (4FOR A LINEAR MODEL WITH A 4,12,4-DEGREE POLYNOMIAL,4)
      WRITE (59,ANSR) NVAR
      WRITE (59,4(* (E11.3))4) NM1,(BETA(JJ),JJ=1,NM1)
      IF (NVAR.GT.7) WRITE (59,4(* (E11.3))4) NM2,(BETA(JJ),JJ=8,7+NM2)
      IF (NVAR.GT.14) WRITE (59,4(* (E11.3))4) NM3,(BETA(JJ),JJ=15,14+NM3)
      WRITE (59,4(/)4)
      WRITE (59,SIGA) SIGMA
      WRITE (59,SIGX)
      DO SGMA II=1,NVAR
      WRITE (59,VARI) NM1,(SSQR*AIN(II,JJ),JJ=1,NM1)
      IF (NVAR.GT.7) WRITE (59,VARI) NM2,(SSQR*AIN(II,JJ),JJ=8,7+NM2)
      IF (NVAR.GT.14) WRITE (59,VARI) NM3,(SSQR*AIN(II,JJ),JJ=15,14+NM3)
      WRITE (59,4(/)4)
SGMA  CONTINUE
C
C      THIS DRAWS ESTIMATOR LINE AND DATA POINTS, WITH SIGMA, FOR POLYNOMIAL
C      ONLY FIT (NO ADDITIONAL SINGLE-VALUED TERMS).
C
NUEQ  IF (NTH+1.EQ.NVAR) CALL GRAPH(BETA,XEQN,YEQN,NTH,SIGA,LINE)
C
C      THIS DOES THE STATISTICAL AND FORECASTING ROUTINES.
C
      IF (.NOT.NEEDAINV.AND.(NEWNTH.EQ.4NEW4.OR.NEEDQNS.EQ.4NEW4))
1 CALL STATS(TSTUDENTS,LINE,NVAR,BETA,SIGA,AIN)
      IF (NEEDAINV) WRITE (59,BADA)
BADA  FORMAT (4A-INVERSE ERROR; T-TEST IS INFEASIBLE.4)
      CALL FORECAST(NTH,NVAR,BETA,SSQR,AIN)
      CALL DEVICE(4CLOSE4,4FOREDATA4)
      CALL DEVICE(4CLOSE4,4EQNSDATA4)
      CALL PLOTE
      CALL QUIT(1)
      END
      END

C
C THIS CALCULATES THE INVERSE OF THE X'X=A MATRIX (AIN). WHEN EACH
C ELEMENT OF AIN IS MULTIPLIED BY SIGMA**2, THE VARIANCE OR COVARIANCE
C OF EACH BETA ESTIMATOR IS DETERMINED. THAT IS, VAR(BETA(I,1))=
C AIN(I,1)*SIGMA**2 AND COV(BETA(I,J))=AIN(I,J)*SIGMA**2; WHERE SIGMA
C IS THE UNBIASED ESTIMATOR OF THE POPULATION STANDARD DEVIATION.
C
      SUBROUTINE INVERT(CM,CMI,NVAR)
      DIMENSION CM(20,20),CMI(20,20),AUG(20,40),TERM(20)
      COMMON /REPORT/NEEDAINV
C
C      THIS DEFINES THE VALUES FOR THE AUGMENTED MATRIX, AUG(I,J).
C
      DO AUGA I=1,NVAR
      DO AUGA J=1,NVAR
      AUG(I,J)=CM(I,J)
AUGA  CONTINUE
      DO AUGB I=1,NVAR
      DO AUGB J=NVAR+1,2*NVAR
      AUG(I,J)=0.0
      IF ((NVAR+1).EQ.J) AUG(I,J)=1.0

```

```

AUGB CONTINUE
C
C   THIS DEFINES THE OPERATIONS TO INVERT CM(I,J).
C
DO ITER M=1,NVAR
PIVOT=AUG(M,M)
IF (PIVOT.EQ.0.) PIVOT=1.E-20
DO ROWS II=1,NVAR
TERM(II)=AUG(II,M)
IF (II.EQ.M) GO TO ROWS
DO KOLS JJ=1,2*NVAR
DYFF=AUG(II,JJ)*PIVOT-TERM(II)*AUG(M,JJ)
AUGTEST=AUG(II,JJ)*PIVOT
IF (AUGTEST.NE.0.) TEST=ABSF(DYFF/AUG(II,JJ)*PIVOT)
IF (TEST.LT.1.E-4) DYFF=AUG(II,JJ)*PIVOT*TEST
AUG(II,JJ)=DYFF/PIVOT
KOLS CONTINUE
ROWS CONTINUE
DO PIVT JJ=1,2*NVAR
AUG(M,JJ)=AUG(M,JJ)/PIVOT
PIVT CONTINUE
ITER CONTINUE
C
C   THIS COPIES THE INVERTED MATRIX FROM THE RIGHT-HAND PARTITION.
C
DO COPY IK=1,NVAR
DO COPY JK=1,NVAR
CMI(IK,JK)=AUG(IK,JK+NVAR)
COPY CONTINUE
C
C   THIS CREATES AN ERROR FLAG IF THE A-INVERSE IS NOT SYMMETRIC
C   OR THE MAIN DIAGONAL ELEMENTS ARE NEGATIVE.
C
NEEDAINV=0
DO EROR II=1,NVAR
DO EROR JJ=1,NVAR
DENOM=CMI(II,JJ)
IF (CMI(II,JJ).EQ.0.) DENOM=1.E-20
DIFF=ABSF(CMI(II,JJ)-CMI(JJ,II))/DENOM
IF (DIFF.GT.1.E-5.OR.CMI(II,II).LT.0.) NEEDAINV=1
EROR CONTINUE
RETURN
END

C
C THIS DOES THE STUDENTS T TEST FOR EACH BETA COEFFICIENT ON THE DIAGONAL
C OF THE VARIANCE/COVARIANCE MATRIX.
C
SUBROUTINE STATS(TSTUDENTS,LYNE,NUMVAR,BETA,SIGS,AYN)
DIMENSION TSTUDENTS(20),BETA(20),AYN(20,20)
MSTK WRITE (59,INST)
INST FORMAT (//FOR A T-STUDENTS TEST OF THE DIAGONAL BETAS, TYPE#/
1#YES, TYPE NO OTHERWISE. THEN PUSH THE ..RETURN.. KEY.#/
2#NOTE...THE NULL HYPOTHESIS IS THAT THE BETA VALUE IS ZERO.#//)
READ (59,INTX) NEEDSTATS
INTX FORMAT (A3)
IF (NEEDSTATS.EQ.#NO #) RETURN
IF (NEEDSTATS.NE.#YES#) GO TO MSTK
NMI=NUMVAR

```

```

        IF (NM1.GT.10) NM1=10
        NM2=NUMVAR-10
        DO STAT II=1,NUMVAR
        TSTUDENTS(II)=BETA(II)/(SIGS*SQRTF(AYN(II,II)))
STAT CONTINUE
        WRITE (59,TST1) LYNE=NUMVAR
TST1 FORMAT ('FOR ',12,'-DEGREES OF FREEDOM, /
1 'THE STUDENTS, T-TESTS FOR THE DIAGONAL BETAS ARE: /')
        WRITE (59,('F6.3,X')) NM1,(TSTUDENTS(II),II=1,NM1)
        IF (NUMVAR.GT.10) WRITE (59,('F6.3,X'))
1 NM2,(TSTUDENTS(II),II=NM1+1,NM2)
        RETURN
        END

C
C THIS DOES A FORECASTED OUTCOME, Y, BASED ON THE BETA ESTIMATES.
C
        SUBROUTINE FORECAST(NTH,NVAR,BEDA,ESSQR,AINV)
        COMMON FORM(40),BUFEQN(50)
        DIMENSION XFORE(40,20),BEDA(20),AINV(20,20),XTAIN(20)
GOOF WRITE (59,FORE)
FORE FORMAT ('//IF YOU WISH TO MAKE AN OUTPUT FORECAST, TYPE /
1 'YES; NO OTHERWISE -- THEN ...RETURN...KEY. /')
        READ (59,GOON) NEEDFORE
GOON FORMAT (A3)
        IF (NEEDFORE.EQ.'NO ') RETURN
        IF (NEEDFORE.NE.'YES ') GO TO GOOF

C
C THIS DOES THE FORECASTED OUTPUT, GIVEN THE X-VALUES AND BEDA ESTIMATES.
C
REPT WRITE (59,OBSV)
OBSV FORMAT ('TYPE X-VALUES, FORMAT 9F7.2. /')
        XFORE(1,1)=1.00
        READ (59,VALU) (XFORE(1,JJ),JJ=2,9)
VALU FORMAT (10F7.2)
        CALL POLYNOMIAL(1,NTH,XFORE)
        SUM=BEDA(1)
        DO YPRE JJ=2,NVAR
        SUM=SUM+BEDA(JJ)*XFORE(1,JJ)
        YPRE CONTINUE

C
C THIS DOES THE STANDARD DEVIATION OF ERROR=(Y-YFORE).
C
        SUMX=0.
        DO DOTX JJ=1,NVAR
        SUMX=DOTPROD(XFORE(1,1),AINV(1,JJ),XFORE(1,2),AINV(2,JJ),NVAR)
        XTAIN(JJ)=SUMX
DOTX CONTINUE
        SUMY=DOTPROD(XTAIN(1),XFORE(1,1),XTAIN(2),XFORE(1,2),NVAR)

C
C NOTE...VAR(ERROR)=VAR(Y)+VAR(YFORE), THEREFORE, THE FOLLOWING:
C
        VARIANCE=ESSQR*(1.+SUMY)
        STNDEV=SQRTF(VARIANCE)
        IF (NTH+1.EQ.NVAR) CALL GRAPH(BEDA,XFORE,SUM,NTH,STNDEV,1)

C
C THIS WRITES THE FORECAST EQUATION ON TTY.
C
        II=1

```

```

      NPRINT=4+(NVAR-2)*2
      NMOVE=10*NPRINT
      CALL SSMOVE(FORM,BUFEQN,0,0,NMOVE)
      CALL CONVI(11,BUFEQN,2,2)
      DO RITE JJ=2,NVAR
      CALL CONV(XFORE(11,JJ),BUFEQN,33+(JJ-2)*20,7,2,0)
RITE CONTINUE
      WRITE (59,*(6A10*)) (BUFEQN(111),111=1,NPRINT)
      WRITE (59,PRED) SUM,STNDEV
PRED FORMAT (//YOUR Y FORECAST IS, YFORE=*,E13.5/
1*THE STANDARD DEVIATION OF YFORE IS, STNDEV=*,E13.5//)
EROR WRITE (59,OVER)
OVER FORMAT (*TYPE YES FOR ANOTHER FORECAST - NO OTHERWISE.*/)
      READ (59,*(A3*)) NEEDMORE
      IF (NEEDMORE.EQ.*YES*) GO TO REPT
      IF (NEEDMORE.NE.*NO *) GO TO EROR
      RETURN
      END

C
C THIS WRITES THE POLYNOMIAL, YEQN(M)=BETA(1)*XEQN(1)+...+BETA(N)*XEQN(N)**N-1.
C
      SUBROUTINE POLYEQNS(LNE,N,XPOLY,YPOLY,NEDEQNS)
      DIMENSION XPOLY(40,20),YPOLY(40),XOLD(40,20),YOLD(40)
C
C THIS READS OLD Y/X VALUES FOR NEW POLYNOMIAL IF NEEDED.
C
      IF (NEDEQNS.EQ.*NEW*) GO TO NNEW
      CALL DEVICE(*OPEN*,*EQNSDATA*,NSIZE)
      REWIND 7
      READ (7) LINOLD,NOLD
      DO RSET II=1,LINOLD
      XPOLY(II,1)=1.00
      READ (7) YOLD(II),(XOLD(II,JJ),JJ=2,9)
      XPOLY(II,2)=XOLD(II,2)
      YPOLY(II)=YOLD(II)
C
C THIS EXPANDS OR CONTRACTS THE GLM SINGLE-VALUED TERMS TO ACCOMODATE
C THE POLYNOMIAL.
C
      DO RSET JJ=3,9
      JJNEW=JJ-(NOLD-N)
      IF (JJNEW.GT.20) JJNEW=20
      XPOLY(II,JJNEW)=XOLD(II,JJ)
RSET CONTINUE
      LNE=LINOLD
C
C THIS DOES THE POLYNOMIAL POWERS 1 TO N.
C
      ENTRY POLYNOMIAL(LNE,N,XPOLY)
NNEW DO POWR II=1,LNE
      POLYTERM=XPOLY(II,2)
      DO POWR JJ=1,N
      XPOLY(II,JJ+1)=0.
      XPOLY(II,JJ+1)=POLYTERM**JJ
POWR CONTINUE
      RETURN
      END

```



```

C
C THIS ALLOWS USER TO CORRECT AN INPUT EQUATION BEFORE CALCULATIONS BEGIN.
C
      SUBROUTINE NEWLINES(NEWLINE,YNEW,XNEW)
      DIMENSION YNEW(40),XNEW(40,20)
      CALL DEVICE(OPEN, EQNSDATA, NSIZE)
      REWIND 7
      READ (7) LINE, NTH
      DO NUEQ II=1, LINE
      READ (7) YNEW(II), (XNEW(II, JJ), JJ=2, 9)
NUEQ CONTINUE
C
C THIS WRITES CORRECTED EQUATION INTO 'EQNSDATA' FILE.
C
      REWIND 7
      WRITE (7) LINE, NTH
      DO RWRT II=1, NEWLINE-1
      IF (NEWLINE.NE.1) WRITE (7) YNEW(II), (XNEW(II, JJ), JJ=2, 9)
RWRT CONTINUE
      WRITE (59, NULN) NEWLINE
NULN FORMAT (PRE-TYPE EQUATION, 12)
      READ (59, (10F7.2)) YNEW(NEWLINE), (XNEW(NEWLINE, JJ), JJ=2, 9)
      WRITE (7) YNEW(NEWLINE), (XNEW(NEWLINE, JJ), JJ=2, 9)
      DO FINE II=NEWLINE+1, LINE
      IF (NEWLINE.NE.LINE) WRITE (7) YNEW(II), (XNEW(II, JJ), JJ=2, 9)
FINE CONTINUE
      END FILE 7
      RETURN
      END

C
C THIS DRAWS AN X/Y GRAPHIC WITH ONE SIGMA SPREADS AROUND THE ESTIMATORS.
C
      SUBROUTINE GRAPH(BCOF, XEQ, YEQ, N, S, LN)
      DIMENSION XEQ(40, 20), YEQ(40), SMINUS(21), SPLUS(21)
      1, YDRA(21), XDRA(21), XPT(2), YPT(2), XMAP(40), YMAP(40), YES(21)
      2, XES(40, 20), BCOF(20)
      IF (11.GE.22) GO TO FORE

C
C THIS PERMITS THE USER TO EXAMINE A POLYNOMIAL FIT ON THE TMD5 SCREEN.
C
      WRITE (59, INTV)
      INTV FORMAT (//TV PICTURE? TYPE YES OR NO, THEN...RETURN...KEY.#//)
      NEEDTV=0
      READ (59, (A3)) NEEDTV
      IF (NEEDTV.EQ.#NO #) GO TO NOTV
      CALL TVID(0, 0, 2)

C
C THIS OPENS THE FR80 DEVICES AND FILES.
C
      NOTV CALL KEEP80(1, 3)
      CALL FR80ID(AXEROX+FILM, 0, 2)

C
C THIS SETS X AND Y MAPPING VALUES BASED ON X AND Y INPUTS.
C
      DO MAPR II=1, LN
      YMAP(II)=YEQ(II)
      XMAP(II)=XEQ(II, 2)

```

```

MAPR CONTINUE
C
C   THIS SETS THE PICTURE FRAME LIMITS.
C
XMIN=XMINES=AMINAF(XMAP,1,LN)
XMAX=AMAXAF(XMAP,1,LN)
CORD=ABSF(XMAX-XMIN)
XINC=.05*CORD
XMIN=XMIN-.25*CORD
XMAX=XMAX+.75*CORD
YMIN=AMINAF(YMAP,1,LN)
YMAX=AMAXAF(YMAP,1,LN)
CORD=ABSF(YMAX-YMIN)
YMIN=YMIN-CORD
YMAX=YMAX+CORD
CALL MAPX(5,XMIN,XMAX,YMIN,YMAX,.2,1,.2,1.)
C
C   THIS WILL LABEL THE GRAPHIC.
C
CALL SETCH(28.,30.,1,0,2,0,0)
WRITE (100,LBL3) S
LBL3 FORMAT (□ SIGMA=□,E11.3)
CALL SETCH(28.,4.,1,0,2,0,0)
WRITE (100,LBL1) N
LBL1 FORMAT (□ FORECAST/DATA X-INPUTS □/□FOR □,12,□-DEGREE POLYNOMIAL□)
CALL SETCH(4.,28.,1,0,2,1,0)
WRITE (100,LBL2)
LBL2 FORMAT (□FORECAST/DATA Y-OUTPUTS□)
C
C   THIS DOES 21 Y/X POINTS FOR DRAWING THE ESTIMATOR LINE AND PLUS/MINUS
C   ONE SIGMA.
C
XES(1,1)=1.00
XES(1,2)=XMINES
DO XLIN 11=2,21
XES(11,1)=1.00
XES(11,2)=XES(11-1,2)+XINC
XLIN CONTINUE
C
C   THIS DOES HIGHER ORDER X VALUES FOR ESTIMATOR LINE.
C
CALL POLYNOMIAL(21,N,XES)
C
C   THIS DOES THE ESTIMATOR LINE Y VALUES.
C
DO SIGM 11=1,21
YES(11)=0.0
DO YLIN 11=1,N+1
YES(11)=YES(11)+BCOF(11)*XES(11,11)
YLIN CONTINUE
IOUT=0
SPLUS(11)=YES(11)+S
SMINUS(11)=YES(11)-S
XDRA(11)=XES(11,2)
YDRA(11)=YES(11)
IF (YDRA(11).LE.YMIN.AND..NOT.IOUT) XOUT=XDRA(11-1)
IF (YDRA(11).LE.YMIN.AND..NOT.IOUT) YOUT=YDRA(11-1)
IF (YDRA(11).GT.YMIN) GO TO SIGM
IOUT=1
SPLUS(11)=YOUT+S

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      SMINUS(1)=YOUT-S
      XDRA(1)=XOUT
      YDRA(1)=YOUT
SIGM CONTINUE
C
C   THIS DRAWS THE DATA POINTS AND THE ESTIMATOR LINES.
C
      CALL TRACEP(XDRA,SPLUS,21)
      CALL TRACEP(XDRA,SMINUS,21)
      CALL TRACE(XDRA,YDRA,21)
      CALL SETPCH(1,1,2)
      CALL POINTC(□X□,XMAP,YMAP,LN)
      CALL PLOTEA
      RETURN
C
C   THIS SETS THE PLUS/MINUS SIGMA VALUES FOR FORECAST PLOTTING.
C
FORE SPLUS(1)=YEQ(1)+S
      SMINUS(1)=YEQ(1)-S
      XFOR=XEQ(1,2)
C
C   THIS DRAWS THE FORECASTED POINTS AND THEIR ERROR BARS.
C
      CALL SETPCH(1,1,2)
      CALL POINTC(□O□,XFOR,YEQ,1)
      CALL POINTC(□=□,XFOR,SPLUS,1)
      CALL POINTC(□=□,XFOR,SMINUS,1)
      YPT(1)=SPLUS(1)
      YPT(2)=SMINUS(1)
      XPT(1)=XPT(2)=XFOR
      CALL TRACEP(XPT,YPT,2)
      CALL PLOTEA
      RETURN
      END
C
C THIS PROVIDES A HELP PACKAGE FOR THE UNINITIATED USER.
C
      SUBROUTINE HELP
      WRITE (59,INTR)
      INTR FORMAT (□IN THE LINEAR, MATRIX EQUATION, BETA*X=Y (Y=DEPENDENT/□/
1□X=INDEPENDENT), GENVAR SOLVES FOR ESTIMATOR COEFFICIENTS, BETA.□/
2□IT THEN USES THE BETA VALUES TO FORECAST Y ESTIMATES, GIVEN NEW□/
3□X VALUES. STANDARD DEVIATIONS, FOR ERROR BAR CALCULATIONS,□/
4□ARE GENERATED FOR EACH Y-FORECAST.□//)
      WRITE (59,BEGN)
      DEGN FORMAT(□WHEN ASKED TO TYPE YOUR Y AND X VALUES, USE FORMAT,□/
1□(10F7.2). AFTER THE PROMPT 'TYPE EQUATION' AND THERE ARE□/
2□NO MORE Y/X VALUES TO BE ENTERED, TYPE ...RETURN... KEY TO SHOW□/
3□THAT CALCULATIONS CAN BEGIN. THE FIRST F7.2 FIELD TAKES□/
4□THE Y VALUE OF EACH LINE; THE REMAINING 9 F7.2 FIELDS TAKE□/
5□THE X VALUES.□//)
      WRITE (59,EQN1)
      EQN1 FORMAT (□CAUTION...THE NUMBER OF X VARIABLES, NVAR, PLUS 1, MUST□/
1□BE LESS THAN THE NUMBER OF INPUT LINES, LINE (NVAR+1,LT.LINE).□/
2□NOTE...XEQN(1), ASSOCIATED WITH BETA(1), ALWAYS = 1.00 AND SHOULD□/
3□NOT...NOT...BE ENTERED AS AN X-VALUE AT ANYTIME. THUS, EACH□/
4□EQUATION IS AS: Y(1)=BETA(1)+BETA(2)*X(2)+BETA(3)*X(3)+...□/
5□NOTE...THE NUMBER OF INPUT LINES MUST NOT EXCEED FORTY (40).□//)

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      WRITE (59,EQN2)
EQN2 FORMAT (1)GENVAR CREATES 3 DATA FILES FOR LATER USE IF DESIRED.(2/
1)FOREDATA' CONTAINS DATA BY WHICH FORECASTING CAN BE DONE USING(2/
2)PREVIOUSLY GENERATED BETAS, ETC. 'EQNSDATA' IS USED TO CHANGE(2/
3)THE ORDER OF A POLYNOMIAL WHILE USING THE Y/X INPUT DATA FROM(2/
4)A PREVIOUS RUN (GOOD FOR BEST FITTING GIVEN DATA POINTS). AN(2/
5)FR80 FILE IS ALSO CREATED IF THE GLM HAS ONLY A POLYNOMIAL.(2//)
      RETURN
      END

```

```

C
C THIS PRINTS A MATRIX ARRAY ON THE TTY.
C

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      SUBROUTINE MATRIX(NROWS,NOVAR,VAR,IP,JP)
      DIMENSION VAR(IP,JP)
      NM1=NOVAR
      IF (NM1.GT.5) NM1=5
      NM2=NOVAR-5
      IF (NM2.GT.5) NM2=5
      NM3=NOVAR-10
      IF (NM3.GT.5) NM3=5
      NM4=NOVAR-15
      IF (NM4.GT.5) NM4=5
      NM5=NOVAR-20
      IF (NM5.GT.5) NM5=5
      NM6=NOVAR-25
      IF (NM6.GT.5) NM6=5
      NM7=NOVAR-30
      IF (NM7.GT.5) NM7=5
      NM8=NOVAR-35
      DO AMAT II=1,NROWS
      WRITE (59,(*(E14.6)))(NM1,(VAR(II,JJ),JJ=1,NM1)
      IF (NOVAR.GT.5) WRITE (59,(*(E14.6)))(
1 NM2,(VAR(II,JJ),JJ=6,5+NM2)
      IF (NOVAR.GT.10) WRITE (59,(*(E14.6)))(
1 NM3,(VAR(II,JJ),JJ=11,10+NM3)
      IF (NOVAR.GT.15) WRITE (59,(*(E14.6)))(
1 NM4,(VAR(II,JJ),JJ=16,15+NM4)
      IF (NOVAR.GT.20) WRITE (59,(*(E14.6)))(
1 NM5,(VAR(II,JJ),JJ=21,20+NM5)
      IF (NOVAR.GT.25) WRITE (59,(*(E14.6)))(
1 NM6,(VAR(II,JJ),JJ=26,25+NM6)
      IF (NOVAR.GT.30) WRITE (59,(*(E14.6)))(
1 NM7,(VAR(II,JJ),JJ=31,30+NM7)
      IF (NOVAR.GT.35) WRITE (59,(*(E14.6)))(
1 NM8,(VAR(II,JJ),JJ=36,35+NM8)
      WRITE (59,(/))
      AMAT CONTINUE
      RETURN
      END

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JTS/gw/mg/mla

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