AD-A178 545 AN ALGORITHM FOR THE COMPUTATION OF GENERALIZED LIKELIHOOD OR SELF-CRITIC..(U) RENSSELAUER POLYTECHNIC INST TROY NY SCHOOL OF MANAGEMENT T A DELAHANTY ET AL. 1986 WP-37-86-P26 ARO-18072.20-MA 1/1

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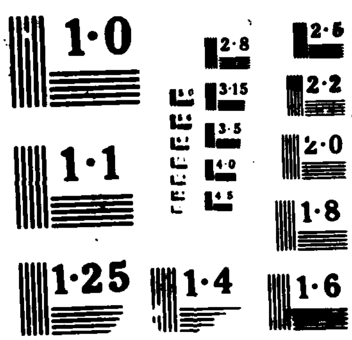
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School of Management

Working Paper No. 37-86-P26

AN ALGORITHM FOR THE COMPUTATION OF GENERALIZED LIKELIHOOD OR SELF-CRITICAL ESTIMATORS FOR BINARY DATA

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* Research sponsored in part by U.S. Army Research Office Contract DAAG29-81-K-0110.

Documentation for Self-Critical Binary Program

1. Purpose

Subroutine BINARY is an implementation of the self-critical estimation procedure of Paulson, Presser and Lawrence (1983). The logistic, Gaussian or Type I extreme value distribution may be selected as tolerance distribution. Estimates are expressed in location-scale form on entry and exit, but results may be printed out in regression form, location-scale form, or in both forms (see Section 3 for a description of the two parametrizations). It is possible to hold location parameters constant during the estimation procedure. Estimation is accomplished by a Newton-Raphson method.

2. Specification (FORTRAN)

```
SUBROUTINE BINARY (N, IX, X, IA, NPAR, ISUB, ISTART, IDEP, IDIST, C,
RELTOL, ABSTOL, MAXIT, IPRINT, IFLAG, BETA, XLOGL, ICOV, COV, LMEM,
MEMORY, IFAULT)
```

3. Description

The routine is applicable to the following modeling situation: For $i = 1, \ldots, n$ (n is the sample size), let v_i be the stress variable, a_i a zero-one indicator of withstand or failure, and $X_i = (x_{1i}, \ldots, x_{pi})^T$ a column vector of covariates. A constant is incorporated as a covariate identically equal to unity. The case $p=0$ is possible, but should be rare.

The tolerance distribution and density, $F(v_i)$ and $f(v_i)$ respectively, depend on the covariates, a scale parameter σ, and a vector of location parameters $\beta = (\beta_1, \ldots, \beta_p)^T$ as follows, where

$$u_i = \frac{(v_i - \beta' X_i)}{\sigma};$$

- logistic, $$F(v_i) = \frac{\exp(u_i)}{(1+\exp(u_i)},$$

$$f(v_i) = \frac{1}{|\sigma|} \frac{\exp(u_i)}{(1+\exp(u_i))^2};$$

- Gaussian, $$F(v_i) = \Phi(u_i)$$

(Φ is the standard Normal distribution function),

$$f(v_i) = \frac{1}{|\sigma|\sqrt{2\pi}} \exp(-\tfrac{1}{2} u_i^2);$$

- extreme value, $$F(v_i) = 1 - \exp(-\exp(u_i)),$$

$$f(v_i) = \frac{1}{|\sigma|} \exp(u_i - \exp(u_i)).$$

In principle, it is possible for σ to be negative, but this contradicts the physical notion of a stress variable.

In the method of maximum likelihood, parameters θ are estimated by maximizing the log likelihood,

$$L(\theta) = \sum_{i=1}^{n} [a_i \log F(v_i) + (1-a_i) \log S(v_i)],$$

where $S = 1-F$. The self-critical procedure depends on a user-specified quantity c, and estimates θ by solving the system

$$\sum_{i=1}^{n} f^c(v_i)\left[a_i \frac{\partial}{\partial\theta} \log F(v_i) + (1-a_i) \frac{\partial}{\partial\theta} \log S(v_i)\right] = 0.$$

When $c = 0$, maximum likelihood estimates are obtained. As c increases from zero, increasingly robust estimators result. The sensitivity of parameter estimates to departures from model assumptions can be examined by starting with $c = 0$ and refitting the model for increasing values of c. Negative values of c seem less useful.

4. Numerical Method

For the purpose of estimation, the routine (internally) reparameterizes the problem in a "regression" form. In this parameterization, $F(\cdot)$ depends on

$$w_i = \alpha v_i + \mu' X_i$$

instead of

$$u_i = \frac{v_i - \beta' X_i}{\sigma} .$$

The reparameterization offers two advantages:

1) Computation of the necessary partial derivatives is simple;

2) For maximum likehood estimation with a logistic tolerance distribution, it can be shown that the regression parameterization results in a concave maximization problem. We anticipate that it will have fairly good properties in the more complicated cases.

It has a disadvantage in terms of potential ill-conditioning of the Hessian (or Jacobian) matrix, so that the input data should be sensibly scaled (see Section 11). Parameters are assumed to be expressed in the easier to understand location-scale form on entry, and are transformed back to location-scale form on exit, so the user need not worry about details of reparameterization.

Let

$$S_{\theta i} = f^C(v_i)\left[a_i \frac{\partial}{\partial\theta} \log F(v_i) + (1-a_i) \frac{\partial}{\partial\theta} \log S(v_i)\right] .$$

The gradient used in Newton-Raphson iteration has θ^{th} component $g_\theta = n^{-1}\sum_{i=1}^{n} S_{\theta i}$, and the Hessian has (θ, θ') component $H_{\theta\theta'} = n^{-1}\sum_{i=1}^{n} \frac{\partial}{\partial\theta'} S_{\theta i}$, (the scaling by n^{-1} should be helpful when n is large).

When $c = 0$, the estiamted asymptotic covariance matrix of the estimators is $n^{-1}(-H)^{-1}$, while when $c \neq 0$ it is $n^{-1}H^{-1}VH^{-1}$, where V has (θ,θ') component $V_{\theta\theta'} = n^{-1} \sum_{i=1}^{n} S_{\theta i}S_{\theta' i}$. The estimated asymptotic covariance matrix is expressed in location-scale form by pre- and post-multiplying it by the Jacobian of the underlying parameter transformation.

Newton-Raphson iteration converges when

$$\max_i \left| \theta^{(k)} - \theta_i^{(k-1)} \right| < \text{ABSTOL}$$

and

$$\max_i \left| \frac{\theta_i^{(k)}}{\theta^{(k-1)}} \right| < \text{RELTOL},$$

where superscripts represent iteration numbers and ABSTOL and RELTOL are user-supplied. The user also specifies a maximum allowable number MAXIT of iterations.

Solution of linear equations and matrix inversion is accomplished by subroutines DECOMP and SOLVE, taken from Forsythe, Malcolm and Moler (1977). These routines are of high numerical quality, and provide an estimate of the condition number of the input matrix, which is often useful. In the interest of portability, iterative improvement is not used.

5. Parameters

5.1 Input Parameters

N - INTEGER
Sample size. Unchanged on exit.

IX - INTEGER
Row dimension of data matrix X. Unchanged on exit.

X - REAL array of DIMENSION (IX, q), where $q \geq N$. Data matrix containing the dependent (stress) variable and all covariates. Each column corresponds to one observation. If parameters are held fixed, values of the dependent variable will be changed, but their input values restored.
Unchanged on exit.

IA - INTEGER array of DIMENSION N.
Withstand or failure is indicated for observation I according as IA(I) = 0 or IA(I) ≠ 0.
Unchanged on exit.

NPAR - INTEGER.
Number of parameters in the model.
Unchanged on exit.

ISUB - INTEGER array of DIMENSION (NPAR).
Indicates rows of data matrix X corresponding to parameters (the scale parameter is taken to correspond to the dependent variable). For instance, if ISUB(3) = 5, the third parameter corresponds to the fifth row of X.
Unchanged on exit.

ISTART - INTEGER array of DIMENSION (NPAR).
Indicates the status of parameters in the model, and whether a starting value is to be supplied.
If ISTART(I) is equal to
0, BETA(I) is to be estimated, and its input value is to be disregarded;
1, BETA(I) is to be estimated, and its input value is to be used as starting value;
2, BETA(I) is to be held constant at its input value.
(See Section 11.2 for comments on starting values; the scale of parameter is not allowed to be held constant.)
Unchanged on exit.

IDEP - INTEGER.
Row of dependent (stress) variable in X.
Unchanged on exit.

IDIST - INTEGER.
Indicates the tolerance distribution desired.
If IDIST equals
1, logistic distribution will be used;
2, Gaussian distribution will be used;
3, extreme value distribution will be used.
Unchanged on exit.

C - DOUBLE PRECISION
User-supplied constant for self-critical estimation.
Unchanged on exit.

RELTOL - DOUBLE PRECISION.
Relative convergence tolerance for Newton-Raphson iteration (see Section 4).
Unchanged on exit.

MAXIT - INTEGER.
Maximum allowable number of Newton-Raphson iteration.
Unchanged on exit.

IPRINT - INTEGER.
Output unit number. If IPRINT $\leq$ 0, no output will be produced. If IPRINT > 0, standard output will be produced on logical output unit IPRINT.
Unchanged on exit.

IFLAG - INTEGER.
Indicator for form of output.
If IFLAG < 0, the standard output summary will be in regression form. If IFLAG = 0, output summaries will be produced for both regression and location-scale parameterizations. If IFLAG > 0, the standard output summary will be in location-scale form. (See Section 11.3).
Unchanged on exit.

5.2 Input/Output (and associated dimension) Parameters.

BETA - DOUBLE PRECISION array of DIMENSION (NPAR).
On entry, contains starting values as specified by ISTART.
On exit, contains parameter estimates, in location scale form.

XLOGL - DOUBLE PRECISION.
On exit, contains the log likelihood if c = 0 (maximum likelihood estimation), and zero otherwise.

ICOV - INTEGFR.
Row dimenision for COV.
Unchanged on exit.

COV - DOUBLE PRECISION array of DIMENSION (ICOV, q), where q $\geq$ NPAR.
On exit, estimated asymptotic covariance information for the parameters. The diagnal contains standard errors, the strict lower triangle correlations, and the strict upper triangle covariances. If a parameter is held constant, all corresponding entries are zero. The covariance matrix will be for the location-scale parameterization rulers IFLAG < 0, when it will be in regression form. See Section 11.3.

5.3 Workspace (and associated dimension) parameters

LMEM - INTEGER.
Length of work array MEMORY, as declared in calling program unit.
LMEM ≥ NPAR + 4*NACT*(1+NACT) + 2*max(NFIX, 2*NACT), where NACT is the number of parameters estimated and NFIX = NPAR-NACT is the number of parameters held constant.
Unchanged on exit.

MEMORY - INTEGER array of DIMENSION (LMEM).
Used as workspace.

5.4 Diagnostic Parameter

IFAULT - INTEGER.
Unless the routine finds an error or gives a warning, IFAULT will be 0 on exit. See Section 6.

6. Error Indications and Warnings

Errors or warnings specified by the routine:

IFAULT < 0 If IFAULT = -I, I > 0, then an arithmetic exception was about to occur on observation I, while computing partial derivatives. This failure should be rare. If the data have been sensibly scaled, and the starting values are not too bad (see Sections 11.1-11.2), the probable cause is a data error. The routine stops as soon as the error is detected, and output parameter values are not of interest.

IFAULT = 1 Input parameter outside expected range. This failure will occur if, on entry, N < 1, NPAR < 1, IX < NPAR, ICOV < NPAR, RELTOL ≤ 0, ABSTOL < 0, MAXIT < 1, IDIST < 1, IDIST > 3, IFLAG ≤ 0 and IPRINT ≤ 0 (see Section 11.3), ISTART(I) < 0 or ISTART(I) > 2 for some I, ISTART(I) = 2 for all I, ISUB(I) ≠ IDEP for all I, or ISUB(I) = IDEP and ISTART(I) = 2 for some I. (The last restriction means that the scale parameter cannot be held constant.) The routine stops without doing any calculations.

IFAULT = 2 Insufficient workspace. This failure will occur if, on entry, LMEM < NPAR + 4*NACT*(1+NACT) + 2*MAX(NFIX,2*NACT), where NACT is the number of parameters estimated (ISTART(I) < 2), and NFIX = NPAR - NACT is the number of parameters held constant (ISTART(I) = 2). The routine stops without doing any calculations.

IFAULT = 3 The Hessian matrix has become numerically singular during Newton-Raphson iteration. The routine transforms estimates to location-scale form, restores values of the dependent variable if parameters were held fixed, and stops. Output parameter values are not generally of interest.

IFAULT = 4 The Newton-Raphson iteration did not converge to within RELTOL and ABSTOL in the specified MAXIT iterations. The routine transforms estimates to location-scale form, restores values of the dependent variable if parameters were held fixed, and stops. Output parameter values are not generally of interest.

7. Auxiliary Routines

SUBROUTINE PREPAR(IX, N, X, NPAR, BETA, ISUB, ISTART, NACT, IACT, IMAP, PAR, NFIX, IFIXED, IDEP, WORK)

Prepares for iteration by setting up some indexing and working arrays, subtracting the effects of fixed parameters from the dependent variable, and setting initial active parameter values in regression form.

SUBROUTINE NEWTON(C, MAXIT, RELTOL, ABSTOL, DIFFER, XLOGL, NACT, IACT, PAR, IPIVOT, HESS, HESFAC, N, IX, X, IA, IPRINT, LWORK, WORK, IFAULT)

Carries out the Newton-Raphson iteration.

SUBROUTINE VARIAB(C, XLOGL, REGRES, DIFFER, VROUT, NACT, IACT, IMAP, PAR, IPIVOT, HESS, HESFAC, ICOV, NPAR, COV, DET, N, IX, X, IA, WORK)

Computes the estimated asymptotic covariance matrix, transforms it to location-scale form if requested, and computes correlations and standard errors.

SUBROUTINE EXPOST(REGRES, IDEP, NPAR, BETA, ISTART, NACT, PAR, IMAP, N, IX, X, NFIX, IFIXED, WORK)

Sets the output vector BETA, transforms to location-scale form if requested. If location-scale form is requeted and parameters were held fixed, restore initial values of dependent variable.

SUBROUTINE RESULT (C, REGRES, IPRINT, IDIST, N, IDEP, NACT, NFIX, XLOGL, NPAR, BETA, ISUB, ISTART, ICOV, COV, DET)

Produces a standard output summary on logical output unit IPRINT.

The following routines are specific to particular tolerance distributions, and are declared EXTERNAL in BINARY. The first three, prefixed D, are passed to NEWTON and VARIAB. The next three, prefixed V, are passed to VARIAB.

```
SUBROUTINE DLOGBN(C, OBJECT, NACT, IACT, PAR, GRAD, HESS, N, IX, X,
IA,, IFAULT)
SUBROUTINE DGAUBN ( ———— " ————)
SUBROUTINE DEXVBN ( ———— " ————)
```

Compute gradient and Hessian for logistic, Gaussian and extreme value models, resp.

```
SUBROUTINE VLOGBN(C, NACT, IACT, PAR, V, N, IX, X, IA)
SUBROUTINE VGAUBN(———— " ————)
SUBROUTINE VEXUBN(———— " ————)
```

Compute V factor of estimated asymptotic covariance matrix for logistic, Guassian and extreme value models, resp.

The following procedures perform general numerical tasks. They have been included in the interest of portability, although equivalents exist on many computer systems.

```
SUBROUTINE DECOMP(NDIM, N, A, UL, COND, IPUT, WORK)
SUBROUTINE SOLVE(NDIM, N, A, B, X, IPUT)
```

DECOMP decomposes a matrix into LU factors and estimates its condition. SOLVE solves a linear system, using the results of DECOMP. These routines are in Forsythe, Malcolm and Moler (1977), but the present versions include an extra argument so that A and B need not be overwritten.

```
SUBROUTINE DMXMLT(A, IA, N1, B, IB, N2, C, IC, N3, WORK, LWORK,
IFLAG, IFAULT)
```

Double precision matrix multiplication -
A(N1 x N3) = B(N1 x N2) * C(N2 x N3), where B is overwritten if IFLAG < 0 and c is overwritten if IFLAG > 0.

DOUBLE PRECISION FUNCTION ALNORM (X, UPPER)
Algorithm as 66 (Hill, 1973) to compute tail areas of the standard Normal curve.

DOUBLE PRECISION FUNCTION RMILLS(X)
Computes Z(x)/Q(x), the reciprocal of Mills' ratio, where x is a standard Normal variate. This procedure is based on procedures by Hill (1973) and Adams (1969).

8. References

Adams, A.G. (1969). Algorithm 39. Areas under the normal curve. Computer J., 12, 197-198.

Forsythe, G.E. Malcolm, M.A. and Moler, C.B. (1977). Computer Methods for Mathematical Computations. Englewood Cliffs, New Jersey: Prentice-Hall.

Hill, I.D. (1973). Algorithm AS 66. The normal integral. Applied Statistics, 22, 424-427.

Paulson, A.S., Presser, M.A. and Lawrence, C.E. (1983). Self-critical, and robust, procedures for the analysis of binary data. Operations Research and Statistics Report No. 37-83-P1, Department of Operations Research and Statistics, Rensselaer Polytechnic Institute.

9. Storage

There are no internally declared arrays.

10. Precision, Machine Dependent Constants

The routein was developed on an IBM computers. The data matrix is single precision to conserve storage. To convert to single precision, take the following steps, with the exception noted below:

1) Change all DOUBLE PRECISION declarations to REAL;
2) Replace references to double precision FORTRAN library functions with single precision versions, e.g., EXP replaces DEXP;
3) Replace double precision constants by their single precision versions, e.g., 1.0 replaces 1.0D0.

Note: In routines PREPAR and EXPOST, the dependent variable is adjusted for the effect of fixed parameters. These adjustements must be calculated in double precision to avoid a loss of significant digits in X which could affect subsequent computations.

Procedures DLOGBN, VLOGBN, DGAUBN, VGAUBN, DEXUBN, VEXUBN, DECOMP, ALNORM and RMILLS use machine-dependent constants whose vlaues are set in DATA statements. These constants may have to be altered for some computers. They are pointed out by comments in the program units.

11. Further Comments

11.1 Scaling, conditioning of Hessian matrix

The user should be aware of potential problems of ill-conditioning. Because a regression-type parameterization is used, calculation of the Hessian matrix involves operations similar to the formation of $X^T X$, where X is the data matrix. Unfortunately, the resulting Hessian is often rather ill-conditioned. If IPRINT > 0, an estimate of the Hessian's condition number is printed out at each iteration. Roughly speaking, a condition number in excess of 10^7 is worrisome, although condition numbers in excess of 10^{10} can be tolerated when working in double precision on an IBM 3081. The user can and should avoid potentially excessive ill-conditioning by scaling the data matrix X before calling the routine.

Although it is not known how to optimally scale a problem, it seems that a nearly ideal scaling will be achieved if nonconstant variables are transformed to the range [-1, 1], centered at zero. However, such precise scaling if often tedious. It seems most important to "equilibrate" the data matrix so that all variables have roughly the same (moderate) magnitude. Such equilibration is often simply accomplished by dividing by suitable powers of 10, e.g., expressing voltages in megavolts instead of kilovolts. Centering the variables will further reduce the condition number. One often centers covariates anyway, so that the "intercept" parameter has a clear interpretation.

11.2. Starting values

Since Newton-Raphson procedure is employed, starting values are important. If no starting values are supplied by the user (ISTART(I) = 0 for all I), the routine will use unity for the scale parameter and zero for all location parameters. These starting values will not be acceptable unless the dependent variable has been centered and scaled. It is recommended that the user employ the mean and standard deviation of the dependent variable as starting values for the "intercept" parameter (if any) and scale parameter, respectively. If the model is sequentially refit with different values of c, it is recommended that estimates from the most recent call be used as starting values for the next call.

11.3 Output Flags

Because the routine will generally be called sequentially with different values of c, it is most convenient to always express entry and exit parameter values in the same form. The location-scale form is used, because that form affords the clearest interpretation. An inconsistency arises of IFLAG < 0, for them the output estimates are in location-scale form, but the convariance matrix is in regression form. Thus, if the user wants to make separate use of the output parameters of BINARY, the routine should be called with IFLAG ≥ 0.

It is recommended that the routine be called with IPRINT > 0. If IFLAG ≤ 0, the requirement IPRINT > 0 is enforced. (When IFLAG < 0, the requirement is in keeping with the inconsistency mentioned above.) The standard output summary should be sufficient for most applications. For the maximum flexibility in output and interpretation of results, call BINARY with IPRINT > 0, IFLAG = 0.

12. Example

The following program illustrates the use of BINARY, and the standard output produced when IPRING > 0 and IFLAG = 0.

```fortran
C*********************************************************************
C        (OPTIONALLY ROBUST) BINARY DATA ESTIMATION ROUTINE.
C        LOGISTIC, EXTREME VALUE, OR GAUSSIAN TOLERANCE DISTRIBUTION
C        CAN BE USED.  PARAMETERS ON INPUT/OUTPUT ARE IN LOCATION-
C        SCALE FORM, BUT ESTIMATION IS CARRIED OUT USING A
C        REGRESSION-TYPE REPARAMETERIZATION.  IF PRINTOUT IS DESIRED
C        (IPRINT .GT. O), RESULTS CAN BE PRINTED OUT IN REGRESSION
C        FORM, LOCATION-SCALE FORM, OR BOTH.  ARGUMENT IFLAG
C        SPECIFIES THE OUTPUT DESIRED.
C        FAILURE CODES -
C                IFAULT = 1 - INPUT ERROR
C                IFAULT = 2 - INSUFFICIENT WORKSPACE SUPPLIED
C                IFAULT = 3 - HESSIAN MATRIX IS NUMERICALLY SINGULAR
C                IFAULT = 4 - NO CONVERGENCE IN MAXIT ITERATIONS
C                IFAULT = -I - AN EXCEPTION WAS ABOUT TO OCCUR WHILE
C                              PROCESSING THE I TH OBSERVATION
C*********************************************************************
      SUBROUTINE BINARY(N, IX, X, IA, NPAR, ISUB, ISTART, IDEP, IDIST,
     1           C, RELTOL, ABSTOL, MAXIT, IPRINT, IFLAG, BETA, XLOGL,
     2           ICOV, COV, LMEM, MEMORY, IFAULT)
C        EXTERNAL PROCEDURES FOR PARTICULAR TOLERANCE DISTRIBUTIONS
      EXTERNAL DLOGBN, DGAUBN, DEXVBN, VLOGBN, VGAUBN, VEXVBN
C        ARGUMENTS
      INTEGER N, IX, IA(N), NPAR, ISUB(NPAR), ISTART(NPAR), IDEP, IDIST,
     1        MAXIT, IPRINT, IFLAG, ICOV, LMEM, MEMORY(LMEM), IFAULT
      REAL X(IX,N)
      DOUBLE PRECISION C, RELTOL, ABSTOL, BETA(NPAR), XLOGL,
     1       COV(ICOV,NPAR)
C        LOCAL SCALARS
      LOGICAL REGRES
      INTEGER NACT, NFIX, IND, IND1, MIACT, MIFIX, MIMAP, MIPVT, MPAR,
     1        MHESS, MHFAC, MWORK
      DOUBLE PRECISION DET, ZERO
C        CONSTANTS
      DATA ZERO /0.0D0/
C
C        CHECK FOR INPUT ERRORS
      IFAULT = 1
      IF (N .LT. 1 .OR. NPAR .LT. 1 .OR. IX .LT. NPAR .OR. ICOV .LT.
     1       NPAR) RETURN
      IF (RELTOL .LE. ZERO .OR. ABSTOL .LE. ZERO .OR. MAXIT .LT. 1)
     1       RETURN
      IF (IDIST .LT. 1 .OR. IDIST .GT. 3) RETURN
      IF (IFLAG .LE. O .AND. IPRINT .LE. O) RETURN
C
C        MEMORY MANAGEMENT, POSSIBLE RELATED INPUT ERRORS.  CHECK
C        ISUB(*), ISTART(*) VECTORS, COUNT ACTIVE PARAMETERS.
C        NOTE SCALE PARAMETER CANNOT BE FIXED.
      NACT = O
      IND1 = O
      DO 10 I = 1, NPAR
        IND = ISUB(I)
        IF (IND .LT. 1 .OR. IND .GT. IX) RETURN
        IF (IND .EQ. IDEP) IND1 = I
        IND = ISTART(I)
        IF (IND .LT. O .OR. IND .GT. 2) RETURN
        IF (IND .NE. 2) NACT = NACT + 1
   10 CONTINUE
      IF (NACT .EQ. O .OR. IND1 .EQ. O) RETURN
      IF (ISTART(IND1) .EQ. 2) RETURN
```

```
      NFIX = NPAR - NACT
C
C        CHECK IF WORKSPACE SIZE IS ADEQUATE, ALLOCATE IT
      IFAULT = 2
      IND = 2 * NACT
      IND1 = IND * NACT
      IF (LMEM .LT. NPAR + 2*NACT + IND + 2*IND1 + MAXO(2*NFIX,2*IND))
     1      RETURN
      MIACT = 1
      MIFIX = MIACT + NACT
      MIMAP = MIACT + NPAR
      MIPVT = MIMAP + NACT
      MPAR = MIPVT + NACT
      MHESS = MPAR + IND
      MHFAC = MHESS + IND1
      MWORK = MHFAC + IND1
C
C        PREPARE FOR ESTIMATION - SET UP SUBSCRIPT ARRAYS AND
C        STARTING VALUES FOR ACTIVE PARAMETERS, SUBTRACT EFFECT OF
C        FIXED PARAMETERS FROM DEPENDENT VARIABLE
      CALL PREPAR(IX, N, X, NPAR, BETA, ISUB, ISTART, NACT,
     1    MEMORY(MIACT), MEMORY(MIMAP), MEMORY(MPAR), NFIX,
     2    MEMORY(MIFIX), IDEP, MEMORY(MWORK))
C
C        NEWTON-RAPHSON ITERATION WITH EXTERNAL ROUTINE PASSED FOR
C        FIRST AND SECOND PARTIALS
      IF (IDIST .EQ. 1) CALL NEWTON(C, MAXIT, RELTOL, ABSTOL, DLOGBN,
     1    XLOGL, NACT, MEMORY(MIACT), MEMORY(MPAR), MEMORY(MIPVT),
     2    MEMORY(MHESS), MEMORY(MHFAC), N, IX, X, IA, IPRINT, 2*NACT,
     3    MEMORY(MWORK), IFAULT)
      IF (IDIST .EQ. 2) CALL NEWTON(C, MAXIT, RELTOL, ABSTOL, DGAUBN,
     1    XLOGL, NACT, MEMORY(MIACT), MEMORY(MPAR), MEMORY(MIPVT),
     2    MEMORY(MHESS), MEMORY(MHFAC), N, IX, X, IA, IPRINT, 2*NACT,
     3    MEMORY(MWORK), IFAULT)
      IF (IDIST .EQ. 3) CALL NEWTON(C, MAXIT, RELTOL, ABSTOL, DEXVBN,
     1    XLOGL, NACT, MEMORY(MIACT), MEMORY(MPAR), MEMORY(MIPVT),
     2    MEMORY(MHESS), MEMORY(MHFAC), N, IX, X, IA, IPRINT, 2*NACT,
     3    MEMORY(MWORK), IFAULT)
C
C        ERROR HANDLING IF NEWTON-RAPHSON PROCEDURE FAILS.
C        ON ERROR, PRINT OUT MESSAGE IF IPRINT .GT. O, SET UP
C        THE FINAL CALL TO EXPOST().
      IF (IFAULT .EQ. O) GO TO 30
      REGRES = .FALSE.
      IF (IPRINT .LE. O) GO TO 50
      IF (IFAULT .GT. O) GO TO 20
      IND = -IFAULT
      WRITE (IPRINT,60) IND
      GO TO 50
   20 IFAULT = IFAULT + 1
      IF (IFAULT .EQ. 3) WRITE (IPRINT,70)
      IF (IFAULT .EQ. 4) WRITE (IPRINT,80) MAXIT
      GO TO 50
C
C        COMPUTE APPROXIMATE ASYMPTOTIC COVARIANCE MATRIX.
C        REGRES IS A FLAG FOR WHETHER OR NOT TO SET UP OUTPUT IN
C        REGRESSION FORM.  STATEMENT 30, THE FIRST BRANCH POINT,
C        SETS UP REGRES FOR FIRST OUTPUT (IF REGRESSION AND
C        LOCATION-SCALE BOTH REQUESTED, REGRESSION GOES FIRST).
C        STATEMENT 40, THE SECOND BRANCH POINT, IS FOR REPEAT
```

```
C        CALL (ALWAYS LOCATION-SCALE)                                   BINA0121
   30 REGRES = IFLAG .LE. 0                                             BINA0122
   40 IF (IDIST .EQ. 1) CALL VARIAB(C, XLOGL, REGRES, DLOGBN, VLOGBN,   BINA0123
     1     NACT, MEMORY(MIACT), MEMORY(MIMAP), MEMORY(MPAR),            BINA0124
     2     MEMORY(MIPVT), MEMORY(MHESS), MEMORY(MHFAC), ICOV, NPAR, COV,BINA0125
     3     DET, N, IX, X, IA, MEMORY(MWORK))                            BINA0126
      IF (IDIST .EQ. 2) CALL VARIAB(C, XLOGL, REGRES, DGAUBN, VGAUBN,   BINA0127
     1     NACT, MEMORY(MIACT), MEMORY(MIMAP), MEMORY(MPAR),            BINA0128
     2     MEMORY(MIPVT), MEMORY(MHESS), MEMORY(MHFAC), ICOV, NPAR, COV,BINA0129
     3     DET, N, IX, X, IA, MEMORY(MWORK))                            BINA0130
      IF (IDIST .EQ. 3) CALL VARIAB(C, XLOGL, REGRES, DEXVBN, VEXVBN,   BINA0131
     1     NACT, MEMORY(MIACT), MEMORY(MIMAP), MEMORY(MPAR),            BINA0132
     2     MEMORY(MIPVT), MEMORY(MHESS), MEMORY(MHFAC), ICOV, NPAR, COV,BINA0133
     3     DET, N, IX, X, IA, MEMORY(MWORK))                            BINA0134
C                                                                       BINA0135
C        ARRANGE ESTIMATED PARAMETERS IN BETA(*) FOR OUTPUT.            BINA0136
C        IF LOCATION-SCALE FORM, TRANSFORM PARAMETERS AND POSSIBLY      BINA0137
C        RESTORE DEPENDENT VARIABLE TO VALUE ON ENTRY.                  BINA0138
   50 CALL EXPOST(REGRES, IDEP, NPAR, BETA, ISTART, NACT, MEMORY(MPAR), BINA0139
     1     MEMORY(MIMAP), N, IX, X, NFIX, MEMORY(MIFIX), MEMORY(MWORK)) BINA0140
C                                                                       BINA0141
C        IF NEWTON-RAPHSON FAILED, GOODBYE.                             BINA0142
      IF (IFAULT .NE. 0) RETURN                                         BINA0143
C                                                                       BINA0144
C        PRODUCE STANDARD OUTPUT IF REQUESTED.                          BINA0145
      IF (IPRINT .GT. 0) CALL RESULT(C, REGRES, IPRINT, IDIST, N, IDEP, BINA0146
     1     NACT, NFIX, XLOGL, NPAR, BETA, ISUB, ISTART, ICOV, COV, DET) BINA0147
C                                                                       BINA0148
C        IF OUTPUT DESIRED IN BOTH REGRESSION AND LOCATION-SCALE        BINA0149
C        FORMS, LOOP BACK, ELSE EXIT                                    BINA0150
      REGRES = .NOT. REGRES                                             BINA0151
      IF ( .NOT. REGRES .AND. IFLAG .EQ. 0) GO TO 40                    BINA0152
C                                                                       BINA0153
C        IF ONLY REGRESSION FORM OUTPUT WAS REQUESTED, AN EXTRA         BINA0154
C        CALL TO EXPOST() IS NEEDED TO RESTORE LOCATION-SCALE FORM      BINA0155
      IF (IFLAG .LT. 0) CALL EXPOST(REGRES, IDEP, NPAR, BETA, ISTART,   BINA0156
     1     NACT, MEMORY(MPAR), MEMORY(MIMAP), N, IX, X, NFIX,           BINA0157
     2     MEMORY(MIFIX), MEMORY(MWORK))                                BINA0158
C                                                                       BINA0159
   60 FORMAT ('OFAILURE - EXCEPTION ON OBSERVATION NO.', I5)            BINA0160
   70 FORMAT ('OFAILURE - HESSIAN MATRIX IS NUMERICALLY SINGULAR')      BINA0161
   80 FORMAT ('OWARNING - NO CONVERGENCE IN', I4, ' ITERATIONS - POSSIBLBINA0162
     1E FAILURE')                                                       BINA0163
      RETURN                                                            BINA0164
      END                                                               BINA0165
C***********************************************************************PREP0001
C        PREPARE FOR ANALYSIS BY SETTING UP THE FOLLOWING ARRAYS -      PREP0002
C             IACT(*) - X(*,*) ROWS FOR ACTIVE PARAMETERS               PREP0003
C             IFIXED(*) - X(*,*) ROWS FOR FIXED PARAMETERS              PREP0004
C             IMAP(*) - POSITIONS IN BETA(*) OF ACTIVE PARAMETERS       PREP0005
C             PAR(*) - INITIAL VALUES OF ACTIVE PARAMETERS IN           PREP0006
C                        REGRESSION FORM                                PREP0007
C        ALSO SUBTRACT EFFECTS OF FIXED PARAMETERS FROM DEPENDENT       PREP0008
C        VARIABLE, USING WORK(*)                                        PREP0009
C        NOTE - DEPENDENT VARIABLE (SCALE) PARAMETER IS ALWAYS          PREP0010
C               PLACED FIRST IN PAR(*), FOR CONVENIENCE LATER           PREP0011
C***********************************************************************PREP0012
      SUBROUTINE PREPAR(IX, N, X, NPAR, BETA, ISUB, ISTART, NACT, IACT, PREP0013
     1            IMAP, PAR, NFIX, IFIXED, IDEP, WORK)                  PREP0014
C        ARGUMENTS                                                      PREP0015
```

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      INTEGER IX, N, NPAR, ISUB(NPAR), ISTART(NPAR), NACT, IACT(NACT),  PREP0016
     1        IMAP(NACT), NFIX, IFIXED(1), IDEP                         PREP0017
      REAL X(IX,N)                                                      PREP0018
      DOUBLE PRECISION BETA(NPAR), PAR(NACT), WORK(1)                   PREP0019
C        LOCAL SCALARS                                                  PREP0020
      INTEGER IND, IND1, LACT, ISCALE                                   PREP0021
      DOUBLE PRECISION TEMP, ZERO, ONE                                  PREP0022
      DATA ZERO, ONE /0.0D0, 1.0D0/                                     PREP0023
C                                                                       PREP0024
C        SET UP IACT(*), IFIXED(*), IMAP(*)                             PREP0025
      LACT = 0                                                          PREP0026
      IND = 0                                                           PREP0027
      ISCALE = 0                                                        PREP0028
      DO 20 I = 1, NPAR                                                 PREP0029
        IF (ISTART(I) .EQ. 2) GO TO 10                                  PREP0030
        LACT = LACT + 1                                                 PREP0031
        IMAP(LACT) = I                                                  PREP0032
        IND1 = ISUB(I)                                                  PREP0033
        IACT(LACT) = IND1                                               PREP0034
        IF (IND1 .EQ. IDEP) ISCALE = I                                  PREP0035
        GO TO 20                                                        PREP0036
   10   IND = IND + 1                                                   PREP0037
        IFIXED(IND) = ISUB(I)                                           PREP0038
        WORK(IND) = BETA(I)                                             PREP0039
   20 CONTINUE                                                          PREP0040
C                                                                       PREP0041
C        SWITCH PLACES SO SCALE IS FIRST ACTIVE PARAMETER               PREP0042
      IND = IACT(1)                                                     PREP0043
      IACT(1) = IACT(ISCALE)                                            PREP0044
      IACT(ISCALE) = IND                                                PREP0045
      IND = IMAP(1)                                                     PREP0046
      IMAP(1) = IMAP(ISCALE)                                            PREP0047
      IMAP(ISCALE) = IND                                                PREP0048
C                                                                       PREP0049
C        MAIN LOOP OVER SAMPLE IF PARAMETERS ARE FIXED, TO ADJUST       PREP0050
C        DEPENDENT VARIABLE (TO BE RESET ON EXIT FROM BINARY())         PREP0051
      IF (NFIX .EQ. 0) GO TO 50                                         PREP0052
      DO 40 I = 1, N                                                    PREP0053
C                                                                       PREP0054
C        THE FOLLOWING INNER PRODUCT MUST BE ACCUMULATED IN DOUBLE      PREP0055
C        PRECISION...                                                   PREP0056
        TEMP = DBLE(X(IDEP,I))                                          PREP0057
        DO 30 J = 1, NFIX                                               PREP0058
          IND = IFIXED(J)                                               PREP0059
          TEMP = TEMP - WORK(J) * X(IND,I)                              PREP0060
   30   CONTINUE                                                        PREP0061
        X(IDEP,I) = SNGL(TEMP)                                          PREP0062
C                                                                       PREP0063
   40 CONTINUE                                                          PREP0064
C                                                                       PREP0065
C        SET STARTING VALUES                                            PREP0066
   50 DO 60 I = 1, NPAR                                                 PREP0067
   60 PAR(I) = ZERO                                                     PREP0068
      TEMP = ONE                                                        PREP0069
      IND = IMAP(1)                                                     PREP0070
      IF (ISTART(IND) .EQ. 1 .AND. BETA(IND) .NE. ZERO) TEMP = BETA(IND)PREP0071
      PAR(1) = ONE / TEMP                                               PREP0072
      IF (NACT .EQ. 1) RETURN                                           PREP0073
      DO 70 I = 2, NACT                                                 PREP0074
        IND = IMAP(I)                                                   PREP0075
```

```
      IF (ISTART(IND)  EQ  1) PAR(I) = -BETA(IND) / TEMP
   70 CONTINUE
C
      RETURN
      END
C***********************************************************************
C        NEWTON-RAPHSON ITERATION
C        FAILURE CODES -
C        IFAULT = 1 - INSUFFICIENT WORKSPACE (LESS THAN 2 * NACT
C                     LOCATIONS)
C        IFAULT = 2 - THE HESSIAN MATRIX IS NUMERICALLY SINGULAR
C        IFAULT = 3 - CONVERGENCE HAS NOT OCCURRED IN MAXIT ITNS
C        IFAULT = -I - AN EXCEPTION WAS ABOUT TO OCCUR WHILE
C                      PROCESSING THE I TH OBSERVATION IN DIFFER()
C***********************************************************************
      SUBROUTINE NEWTON(C, MAXIT, RELTOL, ABSTOL, DIFFER, XLOGL, NACT,
     1           IACT, PAR, IPIVOT, HESS, HESFAC, N, IX, X, IA, IPRINT,
     2           LWORK, WORK, IFAULT)
C        ARGUMENTS - DIFFER IS EXTERNAL ROUTINE FOR PARTIALS
      INTEGER MAXIT, NACT, IACT(NACT), IPIVOT(NACT), N, IX, IA(N),
     1        IPRINT, LWORK, IFAULT
      REAL X(IX,N)
      DOUBLE PRECISION C, RELTOL, ABSTOL, XLOGL, PAR(NACT),
     1        HESS(NACT,NACT), HESFAC(NACT,NACT), WORK(LWORK)
C        LOCAL SCALARS
      INTEGER ITER, IND
      DOUBLE PRECISION GNORM, COND, ABSERR, RELERR, TEMP, XNEW, ZERO,
     1        ONE
      DATA ZERO, ONE /0.0D0, 1.0D0/
C
      IFAULT = 1
      IF (LWORK  LT  2*NACT) RETURN
      IFAULT = 0
      IND = NACT + 1
      ITER = 0
      IF (IPRINT  GT  0) WRITE (IPRINT,50) C, MAXIT, RELTOL, ABSTOL
C
C        LOOPING POINT FOR ITERATION   THE FIRST NACT LOCATIONS OF
C        WORK(*) ARE USED FOR GRADIENT/INCREMENT, WHILE THE NEXT
C        NACT LOCATIONS ARE WORKSPACE FOR DECOMP
   10 ITER = ITER + 1
      CALL DIFFER(C, XLOGL, NACT, IACT, PAR, WORK(1), HESS, N, IX, X,
     1      IA, IFAULT)
      IF (IFAULT  LT  0) RETURN
C
C        FACTOR THE HESSIAN INTO L * U, CHECK IF SINGULAR
      CALL DECOMP(NACT, NACT, HESS, HESFAC, COND, IPIVOT, WORK(IND))
      IF (COND + ONE  NE  COND) GO TO 20
      IFAULT = 2
      RETURN
C
C        SOLVE THE SYSTEM HESS * INCREMENT = -GRADIENT,
C        OVERWRITING GRADIENT
   20 GNORM = ZERO
      DO 30 I = 1, NACT
        TEMP = WORK(I)
        WORK(I) = -TEMP
        GNORM = GNORM + TEMP * TEMP
   30 CONTINUE
      GNORM = DSQRT(GNORM)
```

```
      CALL SOLVE(NACT, NACT, HESFAC, WORK, WORK, IPIVOT)
C
C        INCREMENT PARAMETERS, COMPUTE CONVERGENCE CRITERIA
      RELERR = ZERO
      ABSERR = ZERO
      DO 40 I = 1, NACT
        TEMP = WORK(I)
        ABSERR = DMAX1(ABSERR,DABS(TEMP))
        XNEW = PAR(I) + TEMP
        PAR(I) = XNEW
        IF (ONE + XNEW .NE. ONE) TEMP = TEMP / XNEW
        RELERR = DMAX1(RELERR,DABS(TEMP))
   40 CONTINUE
      IF (IPRINT .GT. 0) WRITE (IPRINT,60) ITER, GNORM, RELERR, ABSERR,
     1COND
C
C        CHECK CONVERGENCE, SET FAILURE CODE IF NONE
      IF (RELERR .LT. RELTOL .AND. ABSERR .LT. ABSTOL) RETURN
      IF (ITER .LT. MAXIT) GO TO 10
      IFAULT = 3
C
   50 FORMAT ('1   C        MAX ITNS  REL TOLER  ABS TOLER'/D11.3, I9,
     1        2D11.2)
   60 FORMAT ('0 ITN   GRAD NORM  REL CHANGE  ABS CHANGE'/I5, 3D12.2, /,
     1        ' ESTIMATED CONDITION NUMBER OF HESSIAN IS', D10.2)
      RETURN
      END
C*********************************************************************
C        COMPUTATIONS FOR VARIABILITY OF THE ESTIMATORS
C        ESTIMATE ASYMPTOTIC COVARIANCE MATRIX, TRANSFORM IT FROM
C        REGRESSION TO LOCATION-SCALE FORM, COMPUTE ASYMPTOTIC
C        CORRELATIONS AND STD. ERRORS
C*********************************************************************
      SUBROUTINE VARIAB(C, XLOGL, REGRES, DIFFER, VROUT, NACT, IACT,
     1           IMAP, PAR, IPIVOT, HESS, HESFAC, ICOV, NPAR, COV, DET,
     2           N, IX, X, IA, WORK)
C        ARGUMENTS - DIFFER AND VROUT ARE SUBROUTINES
      LOGICAL REGRES
      INTEGER NACT, IACT(NACT), IMAP(NACT), IPIVOT(NACT), ICOV, NPAR, N,
     1        IX, IA(N)
      REAL X(IX,N)
      DOUBLE PRECISION C, XLOGL, PAR(NACT), HESS(NACT,NACT),
     1        HESFAC(NACT,NACT), COV(ICOV,NPAR), DET, WORK(NACT)
C        LOCAL SCALARS
      LOGICAL FLAG
      INTEGER IND, IND1, IND2
      DOUBLE PRECISION ALPHA, ALPHA2, TEMP, TEMP1, ZERO, ONE, SMALL
C        MACHINE-DEPENDENT CONSTANT - SMALL SET SO THAT DEXP(X)
C        WILL CAUSE EXCEPTION IF X .LT. SMALL
      DATA ZERO, ONE, SMALL /0.0D0, 1.0D0, -180.0D0/
C
C        CALCULATE HESSIAN AT OPTIMAL POINT AND FACTOR IT
C        (THIS MAY BE WASTEFUL IN SOME CASES, BUT IT AVOIDS
C        SOME LOGICAL COMPLICATIONS.)  WORK(*) USED AS SCRATCH
C        THE HESSIAN IS ASSUMED NONSINGULAR, AS IT SHOULD BE IF
C        THIS POINT IS REACHED.  FACTORIZATION TO HESFAC(*,*)
      CALL DIFFER(C, XLOGL, NACT, IACT, PAR, WORK, HESS, N, IX, X, IA,
     1     IND)
      CALL DECOMP(NACT, NACT, HESS, HESFAC, TEMP, IPIVOT, WORK)
C
```

```
C        INVERT NEGATIVE OF HESSIAN, USING IPIVOT(*) AND                 VARI0034
C        FACTORIZATION IN HESFAC(*,*). PLACE INVERSE IN HESS(*,*)        VARI0035
      DO 20 J = 1, NACT                                                  VARI0036
        DO 10 I = 1, NACT                                                VARI0037
   10   HESS(I,J) = ZERO                                                 VARI0038
        HESS(J,J) = -ONE                                                 VARI0039
        CALL SOLVE(NACT, NACT, HESFAC, HESS(1,J), HESS(1,J), IPIVOT)     VARI0040
   20 CONTINUE                                                           VARI0041
      IF (C .EQ. ZERO) GO TO 30                                          VARI0042
C                                                                        VARI0043
C        SECTION FOR ROBUST ANALYSIS -                                   VARI0044
C        PLACE PRODUCT (H INVERSE) * V * (H INVERSE) IN HESS(*,*)        VARI0045
C        FIRST COMPUTE V(*,*), PLACE IN COV(*,*)                         VARI0046
      CALL VROUT(C, NACT, IACT, PAR, COV, N, IX, X, IA)                  VARI0047
C                                                                        VARI0048
C        MULTIPLY HESS * COV, OVERWRITING COV(*,*)                       VARI0049
      CALL DMXMLT(COV, NACT, NACT, HESS, NACT, NACT, COV, NACT, NACT,    VARI0050
     1      WORK, NACT, 1, IND)                                          VARI0051
C                                                                        VARI0052
C        MULTIPLY COV * HESS, OVERWRITING HESS(*,*)                      VARI0053
      CALL DMXMLT(HESS, NACT, NACT, COV, NACT, NACT, HESS, NACT, NACT,   VARI0054
     1      WORK, NACT, 1, IND)                                          VARI0055
C                                                                        VARI0056
C        ALL VALUES OF C - IF LOCATION-SCALE FORM, TRANSFORM             VARI0057
C        THE COVARIANCE MATRIX.                                          VARI0058
   30 IF (REGRES) GO TO 80                                               VARI0059
      ALPHA = PAR(1)                                                     VARI0060
      ALPHA2 = ALPHA * ALPHA                                             VARI0061
      FLAG = NACT .EQ. 1                                                 VARI0062
C                                                                        VARI0063
C        LEFT-MULTIPLY HESS(*,*) BY JACOBIAN, RESULT TO HESFAC(*,*)      VARI0064
      DO 50 J = 1, NACT                                                  VARI0065
        TEMP = HESS(1,J) / ALPHA2                                        VARI0066
        HESFAC(1,J) = -TEMP                                              VARI0067
        IF (FLAG) GO TO 50                                               VARI0068
        DO 40 I = 2, NACT                                                VARI0069
   40   HESFAC(I,J) = PAR(I) * TEMP - HESS(I,J) / ALPHA                  VARI0070
   50 CONTINUE                                                           VARI0071
C                                                                        VARI0072
C        RIGHT-MULTIPLY HESFAC(*,*) BY TRANSPOSE OF JACOBIAN,            VARI0073
C        RESULT TO HESS(*,*)                                             VARI0074
      DO 70 I = 1, NACT                                                  VARI0075
        TEMP = HESFAC(I,1) / ALPHA2                                      VARI0076
        HESS(I,1) = -TEMP                                                VARI0077
        IF (FLAG) GO TO 70                                               VARI0078
        DO 60 J = 2, NACT                                                VARI0079
   60   HESS(I,J) = PAR(J) * TEMP   HESFAC(I,J) / ALPHA                  VARI0080
   70 CONTINUE                                                           VARI0081
C                                                                        VARI0082
C        BOTH PARAMETERIZATIONS - DIVIDE COVARIANCE MATRIX BY            VARI0083
C        SAMPLE SIZE                                                     VARI0084
   80 TEMP = DBLE(FLOAT(N))                                              VARI0085
      DO 90 J = 1, NACT                                                  VARI0086
        DO 90 I = 1, J                                                   VARI0087
          HESS(I,J) = HESS(I,J) / TEMP                                   VARI0088
          HESS(J,I) = HESS(I,J)                                          VARI0089
   90 CONTINUE                                                           VARI0090
C                                                                        VARI0091
C        FIND DETERMINANT OF COVARIANCE MATRIX - FACTOR IT,              VARI0092
C        RESETTING IPIVOT(*) AND HESFAC(*,*)                             VARI0093
```

```
      CALL DECOMP(NACT, NACT, HESS, HESFAC, TEMP, IPIVOT, WORK)
      DET = ZERO
      IF (TEMP + ONE .EQ. TEMP) GO TO 110
      IND = IPIVOT(NACT)
      DO 100 I = 1, NACT
        TEMP1 = HESFAC(I,I)
        IF (TEMP1 .LT. ZERO) IND = -IND
        DET = DET + DLOG(DABS(TEMP1))
  100 CONTINUE
C
C          TAKE THE NACT ROOT OF DETERMINANT.  SET DET TO ZERO
C          IF IT UNDERFLOWS OR IS NEGATIVE.
      DET = DET / DBLE(FLOAT(NACT))
      IF (DET .LT. SMALL .OR. IND .LT. 0) DET = ZERO
      IF (DET .GE. SMALL .AND. IND .GT. 0) DET = DEXP(DET)
C
C          MOVE CONTENTS OF HESS(*,*) TO UPPER TRIANGLE OF COV(*,*)
  110 DO 120 J = 1, NPAR
        DO 120 I = 1, NPAR
  120 COV(I,J) = ZERO
      DO 130 I = 1, NACT
        IND = IMAP(I)
        DO 130 J = I, NACT
          IND1 = IMAP(J)
          IND2 = MINO(IND,IND1)
          IND1 = MAXO(IND,IND1)
          COV(IND2,IND1) = HESS(I,J)
  130 CONTINUE
C
C          PUT STD ERRORS ON DIAG OF COV(*,*), CORRELATIONS BELOW
      DO 150 I = 1, NPAR
        TEMP = COV(I,I)
        IF (TEMP .EQ. ZERO) GO TO 150
        TEMP = DSQRT(TEMP)
        COV(I,I) = TEMP
        IF (I .EQ. 1) GO TO 150
        IND = I - 1
        DO 140 J = 1, IND
          TEMP1 = COV(J,J)
          IF (TEMP1 .NE. ZERO) COV(I,J) = COV(J,I) / (TEMP*TEMP1)
  140   CONTINUE
  150 CONTINUE
C
      RETURN
      END
C*********************************************************************
C          EX POST ADJUSTMENTS BEFORE EXIT
C          PUT OPTIMAL PARAMETERS IN BETA(*).  IF LOCATION-SCALE
C          FORM, TRANSFORM THE PARAMETERS AND RESTORE DEPENDENT
C          VARIABLE TO INITIAL VALUES IF PARAMETERS WERE FIXED.
C*********************************************************************
      SUBROUTINE EXPOST(REGRES, IDEP, NPAR, BETA, ISTART, NACT, PAR,
     1                  IMAP, N, IX, X, NFIX, IFIXED, WORK)
C          ARGUMENTS
      LOGICAL REGRES
      INTEGER IDEP, NPAR, ISTART(NPAR), NACT, IMAP(NACT), N, IX, NFIX,
     1        IFIXED(1)
      REAL X(IX,N)
      DOUBLE PRECISION BETA(NPAR), PAR(NACT), WORK(1)
C          LOCAL SCALARS
```

```
      INTEGER IND
      DOUBLE PRECISION TEMP, ONE
      DATA ONE /1 ODO/
C
C        INSERT WORKING PARAMETERS PAR(*) IN BETA(*), IN THE
C        SUITABLE FORM.
      TEMP = PAR(1)
      IND = IMAP(1)
      IF (REGRES) BETA(IND) = TEMP
      IF ( NOT  REGRES) BETA(IND) = ONE / TEMP
      IF (NACT  EQ. 1) GO TO 20
      DO 10 I = 2, NACT
        IND = IMAP(I)
        IF (REGRES) BETA(IND) = PAR(I)
        IF ( NOT. REGRES) BETA(IND) = -PAR(I) / TEMP
   10 CONTINUE
C
C        IF LOCATION-SCALE FORM AND PARAMETERS WERE HELD FIXED,
C        RESTORE DEPENDENT VARIABLE
   20 IF (REGRES  OR  NFIX .EQ. O) RETURN
      IND = O
      DO 30 I = 1, NPAR
        IF (ISTART(I)  NE  2) GO TO 30
        IND = IND + 1
        WORK(IND) = BETA(I)
   30 CONTINUE
      DO 50 I = 1, N
C
C        THE FOLLOWING INNER PRODUCT MUST BE ACCUMULATED IN DOUBLE
C        PRECISION
        TEMP = DBLE(X(IDEP,I))
        DO 40 J = 1, NFIX
          IND = IFIXED(J)
          TEMP = TEMP + WORK(J) * X(IND,I)
   40   CONTINUE
        X(IDEP,I) = SNGL(TEMP)
C
   50 CONTINUE
C
      RETURN
      END
C**********************************************************************
C        PRINT OUT TYPICAL OUTPUT SUMMARY ON OUTPUT UNIT IPRINT
C**********************************************************************
      SUBROUTINE RESULT(C, REGRES, IPRINT, IDIST, N, IDEP, NACT, NFIX,
     1           XLOGL, NPAR, BETA, ISUB, ISTART, ICOV, COV, DET)
C        ARGUMENTS
      LOGICAL REGRES
      INTEGER IPRINT, IDIST, N, IDEP, NACT, NFIX, NPAR, ISUB(NPAR),
     1        ISTART(NPAR), ICOV
      DOUBLE PRECISION C, XLOGL, BETA(NPAR), COV(ICOV,NPAR), DET
C        LOCAL SCALARS
      LOGICAL MLE
      INTEGER IND
      DOUBLE PRECISION TSTAT, ZERO
      DATA ZERO /O ODO/
C
C        BASIC HEADINGS
      MLE = C  EQ  ZERO
      IF (MLE) WRITE (IPRINT,40)
```

```
C        FAILURE CODE - IFAULT = -I - AN EXCEPTION WAS ABOUT TO
C                OCCUR WHILE PROCESSING THE I TH OBSERVATION
C*********************************************************************
      SUBROUTINE DLOGBN(C, OBJECT, NACT, IACT, PAR, GRAD, HESS, N, IX,
     1           X, IA, IFAULT)
C        ARGUMENTS
      INTEGER NACT, IACT(NACT), N, IX, IA(N), IFAULT
      REAL X(IX,N)
      DOUBLE PRECISION C, OBJECT, PAR(NACT), GRAD(NACT), HESS(NACT,NACT)
C        LOCAL SCALARS
      LOGICAL MLE
      INTEGER IND
      DOUBLE PRECISION EXTRA, F, S, G, FC, EITHER, DDENS, XJI, ZERO,
     1       ONE, BIG
C        MACHINE-DEPENDENT CONSTANT - BIG ROUGHLY CHOSEN SO THAT
C        DEXP(X) WILL CAUSE EXCEPTION IF /X/ .GT. BIG
      DATA ZERO, ONE, BIG /0.0D0, 1.0D0, 174.0D0/
C
      IFAULT = 0
      MLE = ONE + C .EQ. ONE
      EXTRA = ONE / PAR(1)
      OBJECT = ZERO
      DO 10 J = 1, NACT
        GRAD(J) = ZERO
        DO 10 I = J, NACT
          HESS(I,J) = ZERO
   10 CONTINUE
C
C        MAIN LOOP OVER SAMPLE
      DO 90 I = 1, N
        FC = ZERO
        DO 20 J = 1, NACT
          IND = IACT(J)
          FC = FC + PAR(J) * X(IND,I)
   20   CONTINUE
        IF (DABS(FC) .GT. BIG) GO TO 110
        FC = DEXP(FC)
        S = ONE + FC
        F = FC / S
        S = ONE / S
        G = F * S
        IF (IA(I) .EQ. 0) GO TO 30
        EITHER = S
        XJI = F
        GO TO 40
   30   EITHER = -F
        XJI = S
   40   IF (MLE) GO TO 50
        FC = G ** C
        GO TO 60
   50   OBJECT = OBJECT + DLOG(XJI)
        FC = ONE
C
C        LOOP TO INCREMENT GRADIENT AND HESSIAN UPPER TRIANGLE
   60   EITHER = FC * EITHER
        G = FC * G
        FC = C * EITHER
        DO 80 J = 1, NACT
          IND = IACT(J)
          XJI = DBLE(X(IND,I))
```

```
      IF ( NOT  MLE) WRITE (IPRINT,50) C                                RESU0020
      IF (IDIST  EQ  1) WRITE (IPRINT,60)                               RESU0021
      IF (IDIST  EQ  2) WRITE (IPRINT,70)                               RESU0022
      IF (IDIST  EQ  3) WRITE (IPRINT,80)                               RESU0023
      WRITE (IPRINT,90) N, NPAR, NACT, NFIX                             RESU0024
      IF (REGRES) WRITE (IPRINT,100)                                    RESU0025
      IF ( NOT  REGRES) WRITE (IPRINT,110)                              RESU0026
C                                                                       RESU0027
C         PARAMETER ESTIMATES                                           RESU0028
      WRITE (IPRINT,120)                                                RESU0029
      DO 20 I = 1, NPAR                                                 RESU0030
        IND = ISUB(I)                                                   RESU0031
        IF (ISTART(I)  LT  2) GO TO 10                                  RESU0032
        WRITE (IPRINT,130) I, IND, BETA(I)                              RESU0033
        GO TO 20                                                        RESU0034
   10   TSTAT = BETA(I) / COV(I,I)                                      RESU0035
        IF (IND  EQ  IDEP) WRITE (IPRINT,140) I, IND, BETA(I), COV(I,I),RESU0036
     1  TSTAT                                                           RESU0037
        IF (IND  NE  IDEP) WRITE (IPRINT,150) I, IND, BETA(I), COV(I,I),RESU0038
     1  TSTAT                                                           RESU0039
   20 CONTINUE                                                          RESU0040
C                                                                       RESU0041
C         ASYMPTOTIC QUANTITIES                                         RESU0042
      IF (MLE) WRITE (IPRINT,160) XLOGL                                 RESU0043
      IF (DET  LE  ZERO) WRITE (IPRINT,170)                             RESU0044
      IF (DET  GT  ZERO) WRITE (IPRINT,180) NACT, DET                   RESU0045
      WRITE (IPRINT,190)                                                RESU0046
      DO 30 I = 1, NPAR                                                 RESU0047
   30 WRITE (IPRINT,200) (COV(I,J),J=1,I)                               RESU0048
C                                                                       RESU0049
   40 FORMAT ('1MAXIMUM LIKELIHOOD BINARY ANALYSIS')                    RESU0050
   50 FORMAT ('1SELF-CRITICAL BINARY ANALYSIS, C =', D11 3)             RESU0051
   60 FORMAT ('OLOGISTIC TOLERANCE DISTRIBUTION')                       RESU0052
   70 FORMAT ('OGAUSSIAN TOLERANCE DISTRIBUTION')                       RESU0053
   80 FORMAT ('OEXTREME VALUE TOLERANCE DISTRIBUTION')                  RESU0054
   90 FORMAT ('OANALYSIS OF', I6, ' CASES AND', I4, ' VARIABLES'/'O',   RESU0055
     1        I4, ' PARAMETERS WERE ESTIMATED AND', I4,                 RESU0056
     2        ' WERE HELD CONSTANT', 2(/,'O'))                          RESU0057
  100 FORMAT ('OPARAMETERS ARE EXPRESSED IN REGRESSION FORM'/'O')       RESU0058
  110 FORMAT ('OPARAMETERS ARE EXPRESSED IN LOCATION-SCALE FORM'/'O')   RESU0059
  120 FORMAT ('     I  VAR', 8X, 'BETA(I)', 6X, 'STD  ERR ', 9X,        RESU0060
     1        'T STAT', 5X, 'STATUS')                                   RESU0061
  130 FORMAT (2I5, D15 7, 35X, 'FIXED LOCATION')                        RESU0062
  140 FORMAT (2I5, 3D15 7, 5X, 'ESTIMATED SCALE')                       RESU0063
  150 FORMAT (2I5, 3D15 7, 5X, 'ESTIMATED LOCATION')                    RESU0064
  160 FORMAT (2(/,'O'), /, ' THE LOG LIKELIHOOD IS', D16 8)             RESU0065
  170 FORMAT (2(/,'O'), /, ' THE ESTIMATED ASYMPTOTIC COVARIANCE',      RESU0066
     1        ' MATRIX IS NOT POSITIVE DEFINITE')                       RESU0067
  180 FORMAT (2(/,'O'), /, ' THE', I4, ' ROOT OF THE DETERMINANT ',     RESU0068
     1        'OF THE ESTIMATED'/' ASYMPTOTIC COVARIANCE MATRIX IS',    RESU0069
     2        D16 8)                                                    RESU0070
  190 FORMAT (/, 'OESTIMATED ASYMPTOTIC STD  ERRORS (ON DIAGONAL)',     RESU0071
     1        ', CORRELATIONS (BELOW DIAGONAL)'/' ')                    RESU0072
  200 FORMAT (10D12 4)                                                  RESU0073
      RETURN                                                            RESU0074
      END                                                               RESU0075
C***********************************************************************DLOG0001
C         FIRST AND SECOND PARTIAL DERIVATIVES FOR LOGISTIC BINARY,     DLOG0002
C         REGRESSION PARAMETERIZATION   PARTIALS ARE SCALED BY          DLOG0003
C         SAMPLE SIZE                                                   DLOG0004
```

```
          DDENS = XJI * EITHER                                          DLOG0065
          GRAD(J) = GRAD(J) + DDENS                                     DLOG0066
          DDENS = XJI * (S - F)                                         DLOG0067
          IF (J .EQ. 1) DDENS = DDENS + EXTRA                           DLOG0068
          DDENS = DDENS * FC - G * XJI                                  DLOG0069
          DO 70 K = J, NACT                                             DLOG0070
            IND = IACT(K)                                               DLOG0071
            HESS(K,J) = HESS(K,J) + X(IND,I) * DDENS                    DLOG0072
   70     CONTINUE                                                      DLOG0073
   80   CONTINUE                                                        DLOG0074
   90 CONTINUE                                                          DLOG0075
C                                                                       DLOG0076
C        SCALE GRADIENT AND HESSIAN BY SAMPLE SIZE                      DLOG0077
      EXTRA = DBLE(FLOAT(N))                                            DLOG0078
      DO 100 J = 1, NACT                                                DLOG0079
        GRAD(J) = GRAD(J) / EXTRA                                       DLOG0080
        DO 100 I = J, NACT                                              DLOG0081
          HESS(I,J) = HESS(I,J) / EXTRA                                 DLOG0082
          HESS(J,I) = HESS(I,J)                                         DLOG0083
  100 CONTINUE                                                          DLOG0084
      IFAULT = 0                                                        DLOG0085
      RETURN                                                            DLOG0086
C                                                                       DLOG0087
C        ERROR EXIT                                                     DLOG0088
  110 IFAULT = -1                                                       DLOG0089
C                                                                       DLOG0090
      RETURN                                                            DLOG0091
      END                                                               DLOG0092
C***********************************************************************VLOG0001
C        COMPUTE V(*,*) FACTOR FOR ASYMPTOTIC COVARIANCE MATRIX,        VLOG0002
C        LOGISTIC BINARY.  CALLED ONLY WHEN C .NE. 0                    VLOG0003
C***********************************************************************VLOG0004
      SUBROUTINE VLOGBN(C, NACT, IACT, PAR, V, N, IX, X, IA)            VLOG0005
C        ARGUMENTS                                                      VLOG0006
      INTEGER NACT, IACT(NACT), N, IX, IA(N)                            VLOG0007
      REAL X(IX,N)                                                      VLOG0008
      DOUBLE PRECISION C, PAR(NACT), V(NACT,NACT)                       VLOG0009
C        LOCAL SCALARS                                                  VLOG0010
      INTEGER IND                                                       VLOG0011
      DOUBLE PRECISION FC, S, F, EITHER, TEMP, ZERO, ONE, BIG           VLOG0012
C        MACHINE-DEPENDENT CONSTANT - BIG ROUGHLY CHOSEN SO THAT        VLOG0013
C        DEXP(X) WILL CAUSE EXCEPTION IF /X/ .GT. BIG                   VLOG0014
      DATA ZERO, ONE, BIG /0.0D0, 1.0D0, 174.0D0/                       VLOG0015
C                                                                       VLOG0016
C        SET UPPER TRIANGLE OF V(*,*) TO 0                              VLOG0017
      DO 10 J = 1, NACT                                                 VLOG0018
        DO 10 I = J, NACT                                               VLOG0019
   10 V(I,J) = ZERO                                                     VLOG0020
C                                                                       VLOG0021
C        MAIN LOOP OVER SAMPLE                                          VLOG0022
      DO 50 I = 1, N                                                    VLOG0023
        FC = ZERO                                                       VLOG0024
        DO 20 J = 1, NACT                                               VLOG0025
          IND = IACT(J)                                                 VLOG0026
          FC = FC + PAR(J) * X(IND,I)                                   VLOG0027
   20   CONTINUE                                                        VLOG0028
        IF (DABS(FC) .GE. BIG) GO TO 50                                 VLOG0029
        FC = DEXP(FC)                                                   VLOG0030
        S = ONE + FC                                                    VLOG0031
        F = FC / S                                                      VLOG0032
```

```
      S = ONE / S                                                       VLOG0033
      FC = (F*S) ** C                                                   VLOG0034
      EITHER = S                                                        VLOG0035
      IF (IA(I) .EQ. 0) EITHER = F                                      VLOG0036
      EITHER = (EITHER*FC) ** 2                                         VLOG0037
C                                                                       VLOG0038
C        INCREMENT TERM OF V(*,*)                                       VLOG0039
      DO 40 J = 1, NACT                                                 VLOG0040
        IND = IACT(J)                                                   VLOG0041
        TEMP = EITHER * X(IND,I)                                        VLOG0042
        DO 30 K = J, NACT                                               VLOG0043
          IND = IACT(K)                                                 VLOG0044
          V(K,J) = V(K,J) + TEMP * X(IND,I)                             VLOG0045
   30   CONTINUE                                                        VLOG0046
   40 CONTINUE                                                          VLOG0047
   50 CONTINUE                                                          VLOG0048
C                                                                       VLOG0049
C        DIVIDE V(*,*) BY SAMPLE SIZE, FILL OUT                         VLOG0050
      TEMP = DBLE(FLOAT(N))                                             VLOG0051
      DO 60 J = 1, NACT                                                 VLOG0052
        DO 60 I = J, NACT                                               VLOG0053
          V(I,J) = V(I,J) / TEMP                                        VLOG0054
          V(J,I) = V(I,J)                                               VLOG0055
   60 CONTINUE                                                          VLOG0056
C                                                                       VLOG0057
      RETURN                                                            VLOG0058
      END                                                               VLOG0059
C***********************************************************************DGAU0001
C        FIRST AND SECOND PARTIAL DERIVATIVES FOR BINARY GAUSSIAN,      DGAU0002
C        REGRESSION PARAMETERIZATION.  PARTIALS ARE SCALED BY           DGAU0003
C        SAMPLE SIZE                                                    DGAU0004
C        FAILURE CODE - IFAULT = -I - AN EXCEPTION WAS ABOUT TO         DGAU0005
C                OCCUR WHILE PROCESSING THE I TH OBSERVATION            DGAU0006
C***********************************************************************DGAU0007
      SUBROUTINE DGAUBN(C, OBJECT, NACT, IACT, PAR, GRAD, HESS, N, IX,  DGAU0008
     1            X, IA, IFAULT)                                        DGAU0009
C        ARGUMENTS                                                      DGAU0010
      INTEGER NACT, IACT(NACT), N, IX, IA(N), IFAULT                    DGAU0011
      REAL X(IX,N)                                                      DGAU0012
      DOUBLE PRECISION C, OBJECT, PAR(NACT), GRAD(NACT), HESS(NACT,NACT)DGAU0013
C        LOCAL SCALARS                                                  DGAU0014
      LOGICAL MLE                                                       DGAU0015
      INTEGER IND                                                       DGAU0016
      DOUBLE PRECISION EXTRA, DOT, DOTMIN, FC, CBY2, RATIO, EITHER,     DGAU0017
     1       HTERM, XJ1, DDENS, ZERO, ONE, TWO, BIG                     DGAU0018
C        FUNCTIONS CALLED                                               DGAU0019
      DOUBLE PRECISION ALNORM, RMILLS                                   DGAU0020
C        MACHINE-DEPENDENT CONSTANT - BIG ROUGHLY CHOSEN SO THAT        DGAU0021
C        DEXP(X) WILL CAUSE EXCEPTION IF /X/ .GT. BIG                   DGAU0022
      DATA ZERO, ONE, TWO, BIG /0.0D0, 1.0D0, 2.0D0, 174.0D0/           DGAU0023
C                                                                       DGAU0024
      IFAULT = 0                                                        DGAU0025
      MLE = ONE + C .EQ. ONE                                            DGAU0026
      EXTRA = ONE / PAR(1)                                              DGAU0027
      CBY2 = C / TWO                                                    DGAU0028
      OBJECT = ZERO                                                     DGAU0029
      DO 10 J = 1, NACT                                                 DGAU0030
        GRAD(J) = ZERO                                                  DGAU0031
        DO 10 I = J, NACT                                               DGAU0032
          HESS(I,J) = ZERO                                              DGAU0033
```

```
   10 CONTINUE
C
C         MAIN LOOP OVER SAMPLE
      DO 90 I = 1, N
        DOT = ZERO
        DO 20 J = 1, NACT
          IND = IACT(J)
          DOT = DOT + PAR(J) * X(IND,I)
   20   CONTINUE
        DOTMIN = -DOT
        IF (IA(I) .EQ. 0) GO TO 30
        RATIO = RMILLS(DOTMIN)
        EITHER = RATIO
        GO TO 40
   30   RATIO = RMILLS(DOT)
        DOT = DOTMIN
        EITHER = -RATIO
   40   IF (MLE) GO TO 50
        XJI = CBY2 * DOT * DOT
        IF (DABS(XJI) .GT. BIG) GO TO 110
        FC = DEXP(-XJI)
        GO TO 60
   50   FC = ONE
        XJI = ALNORM(DOT, .FALSE. )
        IF (XJI .EQ. ZERO) GO TO 110
        OBJECT = OBJECT + DLOG(XJI)
C
C         INCREMENT GRADIENT AND HESSIAN
   60   EITHER = FC * EITHER
        HTERM = -FC * RATIO * (DOT + RATIO)
        FC = C * EITHER
        DO 80 J = 1, NACT
          IND = IACT(J)
          XJI = DBLE(X(IND,I))
          GRAD(J) = GRAD(J) + XJI * EITHER
          DDENS = XJI * DOTMIN
          IF (J .EQ. 1) DDENS = DDENS + EXTRA
          DDENS = DDENS * FC + XJI * HTERM
          DO 70 K = J, NACT
            IND = IACT(K)
            HESS(K,J) = HESS(K,J) + X(IND,I) * DDENS
   70     CONTINUE
   80   CONTINUE
   90 CONTINUE
C
C         SCALE GRADIENT AND HESSIAN BY SAMPLE SIZE
      EXTRA = DBLE(FLOAT(N))
      DO 100 J = 1, NACT
        GRAD(J) = GRAD(J) / EXTRA
        DO 100 I = J, NACT
          HESS(I,J) = HESS(I,J) / EXTRA
          HESS(J,I) = HESS(I,J)
  100 CONTINUE
      IFAULT = 0
      RETURN
C
C         ERROR EXIT
  110 IFAULT = -I
C
      RETURN
```

```
      END                                                               DGAU0094
C***********************************************************************VGAU0001
C        COMPUTE V(*,*) FACTOR FOR ASYMPTOTIC COVARIANCE MATRIX,        VGAU0002
C        GAUSSIAN BINARY.  CALLED ONLY WHEN C .NE. 0                    VGAU0003
C***********************************************************************VGAU0004
      SUBROUTINE VGAUBN(C, NACT, IACT, PAR, V, N, IX, X, IA)            VGAU0005
C        ARGUMENTS                                                      VGAU0006
      INTEGER NACT, IACT(NACT), N, IX, IA(N)   .                        VGAU0007
      REAL X(IX,N)                                                      VGAU0008
      DOUBLE PRECISION C, PAR(NACT), V(NACT,NACT)                       VGAU0009
C        LOCAL SCALARS                                                  VGAU0010
      INTEGER IND                                                       VGAU0011
      DOUBLE PRECISION F2C, TEMP, EITHER, ZERO, BIG                     VGAU0012
C        FUNCTION CALLED                                                VGAU0013
      DOUBLE PRECISION RMILLS                                           VGAU0014
C        MACHINE-DEPENDENT CONSTANT - BIG ROUGHLY CHOSEN SO THAT        VGAU0015
C        DEXP(X) WILL CAUSE EXCEPTION IF /X/ .GT. BIG                   VGAU0016
      DATA ZERO, BIG /0.0D0, 174.0D0/                                   VGAU0017
C                                                                       VGAU0018
C        SET UPPER TRIANGLE OF V(*,*) TO ZERO                           VGAU0019
      DO 10 J = 1, NACT                                                 VGAU0020
        DO 10 I = J, NACT                                               VGAU0021
   10 V(I,J) = ZERO                                                     VGAU0022
C                                                                       VGAU0023
C        MAIN LOOP OVER SAMPLE                                          VGAU0024
      DO 70 I = 1, N                                                    VGAU0025
        F2C = ZERO                                                      VGAU0026
        DO 20 J = 1, NACT                                               VGAU0027
          IND = IACT(J)                                                 VGAU0028
          F2C = F2C + PAR(J) * X(IND,I)                                 VGAU0029
   20   CONTINUE                                                        VGAU0030
        TEMP = C * F2C * F2C                                            VGAU0031
        IF (DABS(TEMP) .GE. BIG) GO TO 70                               VGAU0032
        IF (IA(I) .EQ. 0) GO TO 30                                      VGAU0033
        EITHER = RMILLS(-F2C)                                           VGAU0034
        GO TO 40                                                        VGAU0035
   30   EITHER = RMILLS(F2C)                                            VGAU0036
   40   F2C = DEXP(-TEMP) * EITHER * EITHER                             VGAU0037
        DO 60 J = 1, NACT                                               VGAU0038
          IND = IACT(J)                                                 VGAU0039
          TEMP = F2C * X(IND,I)                                         VGAU0040
          DO 50 K = J, NACT                                             VGAU0041
            IND = IACT(K)                                               VGAU0042
            V(K,J) = V(K,J) + TEMP * X(IND,I)                           VGAU0043
   50     CONTINUE                                                      VGAU0044
   60   CONTINUE                                                        VGAU0045
   70 CONTINUE                                                          VGAU0046
C                                                                       VGAU0047
C        DIVIDE V(*,*) BY SAMPLE SIZE, FILL OUT                         VGAU0048
      TEMP = DBLE(FLOAT(N))                                             VGAU0049
      DO 80 J = 1, NACT                                                 VGAU0050
        DO 80 I = J, NACT                                               VGAU0051
          V(I,J) = V(I,J) / TEMP                                        VGAU0052
          V(J,I) = V(I,J)                                               VGAU0053
   80 CONTINUE                                                          VGAU0054
C                                                                       VGAU0055
      RETURN                                                            VGAU0056
      END                                                               VGAU0057
C***********************************************************************DEXV0001
C        FIRST AND SECOND PARTIAL DERIVATIVES FOR BINARY EXTREME        DEXV0002
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```
C         VALUE, REGRESSION PARAMETERIZATION.  PARTIALS ARE SCALED
C         BY SAMPLE SIZE.
C         FAILURE CODE - IFAULT = -I - AN EXCEPTION WOULD HAVE
C                OCCURRED WHEN PROCESSING THE I TH OBSERVATION
C*****************************************************************
      SUBROUTINE DEXVBN(C, OBJECT, NACT, IACT, PAR, GRAD, HESS, N, IX,
     1           X, IA, IFAULT)
C         ARGUMENTS
      INTEGER NACT, IACT(NACT), N, IX, IA(N), IFAULT
      REAL X(IX,N)
      DOUBLE PRECISION C, OBJECT, PAR(NACT), GRAD(NACT), HESS(NACT,NACT)
C         LOCAL SCALARS
      LOGICAL MLE
      INTEGER IND
      DOUBLE PRECISION EXTRA, DOT, EXPON, DENFAC, EXPEXP, FC, EITHER,
     1      HTERM, ZERO, ONE, BIG, BIG1
C         MACHINE-DEPENDENT CONSTANTS - BIG ROUGHLY CHOSEN SO THAT
C         DEXP(X) WILL CAUSE EXCEPTION IF /X/ .GT. BIG, BIG1 SUCH
C         THAT 1.0D0 / DEXP(DEXP(X)) .NE. 1.0D0 IF X .GT. BIG1
      DATA ZERO, ONE, BIG, BIG1 /0.0D0, 1.0D0, 174.0D0, -36.2D0/
C
      IFAULT = 0
      MLE = ONE + C .EQ. ONE
      EXTRA = ONE / PAR(1)
      OBJECT = ZERO
      DO 10 J = 1, NACT
        GRAD(J) = ZERO
        DO 10 I = J, NACT
          HESS(I,J) = ZERO
   10 CONTINUE
C
C         MAIN LOOP OVER SAMPLE
      DO 90 I = 1, N
        DOT = ZERO
        DO 20 J = 1, NACT
          IND = IACT(J)
          DOT = DOT + PAR(J) * X(IND,I)
   20   CONTINUE
        IF (DABS(DOT) .GE. BIG) GO TO 110
        EXPON = DEXP(DOT)
        DENFAC = ONE - EXPON
        IF (IA(I) .EQ. 0) GO TO 40
C
C         FAILURE TERM, IA(I) = 1
        IF (EXPON .GE. BIG .OR. DOT .LE. BIG1) GO TO 110
        EXPEXP = DEXP(EXPON)
        DOT = ONE - ONE / EXPEXP
        FC = EXPON / EXPEXP
        EITHER = FC / DOT
        HTERM = EITHER * (DENFAC - EITHER)
        IF (MLE) GO TO 30
        FC = FC ** C
        GO TO 60
   30   FC = ONE
        OBJECT = OBJECT + DLOG(DOT)
        GO TO 60
C
C         NON FAILURE TERM, IA(I) = 0
   40   EITHER = -EXPON
        HTERM = EITHER
```

```
      IF (MLE) GO TO 50                                                 DEXV0063
      FC = C * (DOT - EXPON)                                            DEXV0064
      IF (DABS(FC)  GE  BIG) GO TO 110                                  DEXV0065
      FC = DEXP(FC)                                                     DEXV0066
      GO TO 60                                                          DEXV0067
   50 FC = ONE                                                          DEXV0068
      OBJECT = OBJECT + EITHER                                          DEXV0069
C                                                                       DEXV0070
C        LOOP TO INCREMENT THE DERIVATIVES                              DEXV0071
   60 EITHER = FC * EITHER                                              DEXV0072
      HTERM = FC * HTERM                                                DEXV0073
      FC = C * EITHER                                                   DEXV0074
      DO 80 J = 1, NACT                                                 DEXV0075
        IND = IACT(J)                                                   DEXV0076
        DOT = DBLE(X(IND,I))                                            DEXV0077
        GRAD(J) = GRAD(J) + DOT * EITHER                                DEXV0078
        EXPON = DOT * DENFAC                                            DEXV0079
        IF (J  EQ  1) EXPON = EXPON + EXTRA                             DEXV0080
        EXPON = FC * EXPON + DOT * HTERM                                DEXV0081
        DO 70 K = J, NACT                                               DEXV0082
          IND = IACT(K)                                                 DEXV0083
          HESS(K,J) = HESS(K,J) + X(IND,I) * EXPON                      DEXV0084
   70   CONTINUE                                                        DEXV0085
   80 CONTINUE                                                          DEXV0086
   90 CONTINUE                                                          DEXV0087
C                                                                       DEXV0088
C        SCALE PARTIALS BY SAMPLE SIZE, NORMAL EXIT                     DEXV0089
      EXTRA = DBLE(FLOAT(N))                                            DEXV0090
      DO 100 J = 1, NACT                                                DEXV0091
        GRAD(J) = GRAD(J) / EXTRA                                       DEXV0092
        DO 100 I = J, NACT                                              DEXV0093
          HESS(I,J) = HESS(I,J) / EXTRA                                 DEXV0094
          HESS(J,I) = HESS(I,J)                                         DEXV0095
  100 CONTINUE                                                          DEXV0096
      RETURN                                                            DEXV0097
C                                                                       DEXV0098
C        ERROR EXIT - EXCEPTIONS                                        DEXV0099
  110 IFAULT = -I                                                       DEXV0100
C                                                                       DEXV0101
      RETURN                                                            DEXV0102
      END                                                               DEXV0103
C***********************************************************************VEXV0001
C        COMPUTE V(*,*) FACTOR FOR ASYMPTOTIC COVARIANCE MATRIX,        VEXV0002
C        BINARY EXTREME VALUE   CALLED ONLY WHEN C  NE  O               VEXV0003
C***********************************************************************VEXV0004
      SUBROUTINE VEXVBN(C, NACT, IACT, PAR, V, N, IX, X, IA)            VEXV0005
C        ARGUMENTS                                                      VEXV0006
      INTEGER NACT, IACT(NACT), N, IX, IA(N)                            VEXV0007
      REAL X(IX,N)                                                      VEXV0008
      DOUBLE PRECISION C, PAR(NACT), V(NACT,NACT)                       VEXV0009
C        LOCAL SCALARS                                                  VEXV0010
      INTEGER IND                                                       VEXV0011
      DOUBLE PRECISION DOT, EXPON, FC, ZERO, ONE, BIG, BIG1             VEXV0012
C        MACHINE-DEPENDENT CONSTANTS   BIG ROUGHLY CHOSEN SO THAT       VEXV0013
C        DEXP(X) WILL CAUSE EXCEPTION IF /X/  GT  BIG, BIG1 SUCH        VEXV0014
C        THAT 1 ODO / DEXP(DEXP(X))  NE  1 ODO IF X  GT  BIG1           VEXV0015
      DATA ZERO, ONE, BIG, BIG1 /O ODO, 1 ODO, 174 ODO, -36 2DO/        VEXV0016
C                                                                       VEXV0017
C        SET UPPER TRIANGLE OF V(*,*) TO ZERO                           VEXV0018
      DO 10 J = 1, NACT                                                 VEXV0019
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      DO 10 I = J, NACT                                                 VEXV0020
   10 V(I,J) = ZERO                                                     VEXV0021
C                                                                       VEXV0022
C        MAIN LOOP OVER SAMPLE                                          VEXV0023
      DO 70 I = 1, N                                                    VEXV0024
        DOT = ZERO                                                      VEXV0025
        DO 20 J = 1, NACT                                               VEXV0026
          IND = IACT(J)                                                 VEXV0027
          DOT = DOT + PAR(J) * X(IND,I)                                 VEXV0028
   20   CONTINUE                                                        VEXV0029
        IF (DABS(DOT) .GE. BIG) GO TO 70                                VEXV0030
        EXPON = DEXP(DOT)                                               VEXV0031
        IF (IA(I) .EQ. 0) GO TO 30                                      VEXV0032
        IF (DOT .LT. BIG1) GO TO 70                                     VEXV0033
        FC = DEXP(EXPON)                                                VEXV0034
        DOT = ONE - ONE / FC                                            VEXV0035
        FC = EXPON / FC                                                 VEXV0036
        EXPON = FC / DOT                                                VEXV0037
        FC = EXPON * FC ** C                                            VEXV0038
        GO TO 40                                                        VEXV0039
   30   FC = C * (DOT - EXPON)                                          VEXV0040
        IF (DABS(FC) .GT. BIG) GO TO 70                                 VEXV0041
        FC = EXPON * DEXP(FC)                                           VEXV0042
C                                                                       VEXV0043
C        SUMMANDS FOR V(*,*)                                            VEXV0044
   40   FC = FC * FC                                                    VEXV0045
        DO 60 J = 1, NACT                                               VEXV0046
          IND = IACT(J)                                                 VEXV0047
          DOT = FC * X(IND,I)                                           VEXV0048
          DO 50 K = J, NACT                                             VEXV0049
            IND = IACT(K)                                               VEXV0050
            V(K,J) = V(K,J) + DOT * X(IND,I)                            VEXV0051
   50     CONTINUE                                                      VEXV0052
   60   CONTINUE                                                        VEXV0053
   70 CONTINUE                                                          VEXV0054
C                                                                       VEXV0055
C        DIVIDE V(*,*) BY SAMPLE SIZE, FILL OUT                         VEXV0056
      DOT = DBLE(FLOAT(N))                                              VEXV0057
      DO 80 J = 1, NACT                                                 VEXV0058
        DO 80 I = J, NACT                                               VEXV0059
          V(I,J) = V(I,J) / DOT                                         VEXV0060
          V(J,I) = V(I,J)                                               VEXV0061
   80 CONTINUE                                                          VEXV0062
C                                                                       VEXV0063
      RETURN                                                            VEXV0064
      END                                                               VEXV0065
C***********************************************************************DMXM0001
C        DOUBLE PRECISION MATRIX MULTIPLICATION                         DMXM0002
C        X(N1 BY N3) = Y(N1 BY N2) * Z(N2 BY N3)                        DMXM0003
C        THREE OPTIONS -                                                DMXM0004
C              IFLAG = 0 - X, Y, AND Z ARE DISTINCT                     DMXM0005
C              IFLAG .LT. 0 - X, Y OVERLAP, CORNER OF Y OVERWRITTEN     DMXM0006
C              IFLAG .GT. 0 - X, Z OVERLAP, CORNER OF Z OVERWRITTEN     DMXM0007
C***********************************************************************DMXM0008
      SUBROUTINE DMXMLT(X, IX, N1, Y, IY, N2, Z, IZ, N3, WORK, LWORK,   DMXM0009
     1          IFLAG, IFAULT)                                          DMXM0010
C        ARGUMENTS                                                      DMXM0011
      INTEGER IX, N1, IY, N2, IZ, N3, LWORK, IFLAG, IFAULT              DMXM0012
      DOUBLE PRECISION X(IX,N3), Y(IY,N2), Z(IZ,N3), WORK(LWORK)        DMXM0013
C        LOCAL SCALARS                                                  DMXM0014
```

```
      DOUBLE PRECISION TEMP, ZERO                                       DMXM0015
      DATA ZERO /0 0D0/                                                 DMXM0016
C                                                                       DMXM0017
C        ERROR EXITS                                                    DMXM0018
      IFAULT = 1                                                        DMXM0019
      IF (MIN0(N1,N2,N3) .LT. 1 .OR. MIN0(IX,IY) .LT. N1 .OR. IZ .LT.   DMXM0020
     1       N2) RETURN                                                 DMXM0021
      IFAULT = 2                                                        DMXM0022
      IF (IFLAG .LT. 0 .AND. (N3 .GT. N2 .OR. LWORK .LT. N3))           DMXM0023
     1       RETURN                                                     DMXM0024
      IFAULT = 3                                                        DMXM0025
      IF (IFLAG .GT. 0 .AND. (N1 .GT. IZ .OR. LWORK .LT. N1))           DMXM0026
     1       RETURN                                                     DMXM0027
      IFAULT = 0                                                        DMXM0028
      IF (IFLAG .NE. 0) GO TO 30                                        DMXM0029
C                                                                       DMXM0030
C        STRAIGHTFORWARD, NO OVERWRITING                                DMXM0031
      DO 20 I = 1, N1                                                   DMXM0032
        DO 20 J = 1, N3                                                 DMXM0033
          TEMP = ZERO                                                   DMXM0034
          DO 10 K = 1, N2                                               DMXM0035
   10     TEMP = TEMP + Y(I,K) * Z(K,J)                                 DMXM0036
          X(I,J) = TEMP                                                 DMXM0037
   20 CONTINUE                                                          DMXM0038
      RETURN                                                            DMXM0039
C                                                                       DMXM0040
C        CORNER OF MATRIX Z IS OVERWRITTEN                              DMXM0041
   30 IF (IFLAG .LT. 0) GO TO 80                                        DMXM0042
      DO 70 J = 1, N3                                                   DMXM0043
        DO 50 I = 1, N1                                                 DMXM0044
          TEMP = ZERO                                                   DMXM0045
          DO 40 K = 1, N2                                               DMXM0046
   40     TEMP = TEMP + Y(I,K) * Z(K,J)                                 DMXM0047
          WORK(I) = TEMP                                                DMXM0048
   50   CONTINUE                                                        DMXM0049
        DO 60 I = 1, N1                                                 DMXM0050
   60   X(I,J) = WORK(I)                                                DMXM0051
   70 CONTINUE                                                          DMXM0052
      RETURN                                                            DMXM0053
C                                                                       DMXM0054
C        CORNER OF MATRIX Y IS OVERWRITTEN                              DMXM0055
   80 DO 120 I = 1, N1                                                  DMXM0056
        DO 100 J = 1, N3                                                DMXM0057
          TEMP = ZERO                                                   DMXM0058
          DO 90 K = 1, N2                                               DMXM0059
   90     TEMP = TEMP + Y(I,K) * Z(K,J)                                 DMXM0060
          WORK(J) = TEMP                                                DMXM0061
  100   CONTINUE                                                        DMXM0062
        DO 110 J = 1, N3                                                DMXM0063
  110   X(I,J) = WORK(J)                                                DMXM0064
  120 CONTINUE                                                          DMXM0065
C                                                                       DMXM0066
      RETURN                                                            DMXM0067
      END                                                               DMXM0068
C***********************************************************************ALN00001
C        DOUBLE PRECISION VERSION OF ALGORITHM AS 66, APPLIED           ALN00002
C        STATISTICS (1973), VOL. 22, NO. 3                              ALN00003
C        EVALUATES THE TAIL AREA OF THE STANDARD NORMAL CURVE           ALN00004
C        FROM X TO INFINITY IF UPPER IS .TRUE. OR FROM                  ALN00005
C        MINUS INFINITY TO X IF UPPER IS .FALSE.                        ALN00006
```

```
C***********************************************************************
      DOUBLE PRECISION FUNCTION ALNORM(X,UPPER)
C        ARGUMENTS
      LOGICAL UPPER
      DOUBLE PRECISION X
C        LOCAL SCALARS
      LOGICAL UP
      DOUBLE PRECISION LTONE, UTZERO, ZERO, HALF, ONE, CON, Z, Y
C        MACHINE-DEPENDENT CONSTANTS - LTONE = (N + 9) / 3, WHERE
C        N IS NO. OF DECIMAL DIGITS IN DOUBLE PRECISION NUMBER,
C        UTZERO SUCH THAT DEXP(-X*X/2.0D0) WILL CAUSE AN EXCEPTION
C        IF X .GT. UTZERO.
C     .  CONSTANTS IN EXPRESSIONS ARE AS IN AS 66.
      DATA LTONE, UTZERO, ZERO, HALF, ONE, CON /8.0D0, 18.65D0, 0.0D0,
     1     0.5D0, 1.0D0, 1.28D0/
C
      UP = UPPER
      Z = X
      IF (Z .GE. ZERO) GO TO 10
      UP = .NOT. UP
      Z = -Z
   10 IF (Z .LE. LTONE .OR. UP .AND. Z .LE. UTZERO) GO TO 20
      ALNORM = ZERO
      GO TO 40
   20 Y = HALF * Z * Z
      IF (Z .GT. CON) GO TO 30
C
      ALNORM = HALF - Z * (0.398942280444D0-0.399903438504D0*Y/(Y + 5.
     175885480458D0-29.821355780800/(Y + 2.62433121679D0+48.
     26959930692D0/(Y + 5.92885724438D0))))
      GO TO 40
C
   30 ALNORM = 0.398942280385D0 * DEXP(-Y) / (Z - 3.8052D-8 + 1.
     100000615302D0/(Z + 3.98064794D-4 + 1.98615381364D0/(Z - 0.
     215167911663500+5.29330324926D0/(Z + 4.83859128080D0-15.
     31508972451D0/(Z + 0.742380924027D0+30.789933034D0/(Z + 3.
     4990194170110D0))))))
C
   40 IF ( .NOT. UP) ALNORM = ONE - ALNORM
C
      RETURN
      END
C***********************************************************************
C        RECIPROCAL OF MILLS RATIO, Z(X) / Q(X), X A STANDARD NORMAL
C        VARIATE.  BASED ON FUNCTION ALNORM(), ALGORITHM AS 66.
C***********************************************************************
      DOUBLE PRECISION FUNCTION RMILLS(X)
C        ARGUMENTS
      DOUBLE PRECISION X
C        LOCAL SCALARS
      LOGICAL UP
      DOUBLE PRECISION Z, Y, LTONE, UTZERO, ZERO, HALF, ONE, CON, FPI1,
     1     FPI2
C        MACHINE-DEPENDENT CONSTANTS - LTONE = (N + 9) / 3, WHERE
C        N IS NO. OF DECIMAL DIGITS IN DOUBLE PRECISION NUMBER,
C        UTZERO SUCH THAT DEXP(-X*X/2.0D0) WILL CAUSE AN EXCEPTION
C        IF X .LT. UTZERO.
C        FPI1 = SQRT(2/PI), FPI2 = 1/SQRT(2*PI)
C        CONSTANTS IN EXPRESSIONS ARE AS IN AS 66.
      DATA LTONE, UTZERO, ZERO, HALF, ONE, CON, FPI1, FPI2 /8.0D0,
```

```
     1     -18.65D0, 0.0D0, 0.5D0, 1.0D0, 1.28D0, 7.9788456080286536D-1,RMIL0019
     2     3.9894228040143268D-1/                                        RMIL0020
C                                                                        RMIL0021
C        TRIVIAL CASES                                                   RMIL0022
      IF (X .NE. ZERO) GO TO 10                                          RMIL0023
      RMILLS = FPI1                                                      RMIL0024
      RETURN                                                             RMIL0025
   10 IF (X .GT. UTZERO) GO TO 20                                        RMIL0026
      RMILLS = ZERO                                                      RMIL0027
      RETURN                                                             RMIL0028
C                                                                        RMIL0029
C        USUAL SITUATION                                                 RMIL0030
   20 UP = .TRUE.                                                        RMIL0031
      Z = X                                                              RMIL0032
      IF (Z .GE. ZERO) GO TO 30                                          RMIL0033
      UP = .FALSE.                                                       RMIL0034
      Z = -Z                                                             RMIL0035
   30 Y = HALF * Z * Z                                                   RMIL0036
      IF (Z .GT. CON) GO TO 50                                           RMIL0037
C                                                                        RMIL0038
C        CENTRAL PORTION - 0 .LT. ABS(X) .LT. 1.28                       RMIL0039
      RMILLS = Z * (0.398942280444D0-0.399903438504D0*Y/(Y + 5.          RMIL0040
     1758854804580D0-29.8213557808D0/(Y + 2.62433121679D0+48.            RMIL0041
     26959930692D0/(Y + 5.92885724438D0))))                              RMIL0042
      Y = FPI2 * DEXP(-Y)                                                RMIL0043
      IF (UP) GO TO 40                                                   RMIL0044
      RMILLS = Y / (HALF + RMILLS)                                       RMIL0045
      RETURN                                                             RMIL0046
   40 RMILLS = Y / (HALF - RMILLS)                                       RMIL0047
      RETURN                                                             RMIL0048
C                                                                        RMIL0049
C        OUTER PORTION - ABS(X) .GE. 1.28                                RMIL0050
   50 IF (UP .OR. Z .LE. LTONE) GO TO 60                                 RMIL0051
C                                                                        RMIL0052
C        SPECIAL CASE - LOWER TAIL AND Q ESSENTIALLY 1                   RMIL0053
      RMILLS = FPI2 * DEXP(-Y)                                           RMIL0054
      RETURN                                                             RMIL0055
C                                                                        RMIL0056
C        USUAL SITUATION                                                 RMIL0057
   60 RMILLS = (Z - 3.8052D-8 + 1.00000615302D0/(Z + 3.98064794D-4 + 1.  RMIL0058
     1986153813664D0/(Z - 0.151679116635D0+5.29330324926D0/(Z + 4.       RMIL0059
     28385912808D0-15.150897245 1D0/(Z + 0.742380924027D0+30.789933034D0/RMIL0060
     3(Z + 3.99019417011D0))))))                                         RMIL0061
C                                                                        RMIL0062
      IF (UP) RETURN                                                     RMIL0063
      Y = FPI2 * DEXP(-Y)                                                RMIL0064
      RMILLS = Y / (ONE - Y/RMILLS)                                      RMIL0065
C                                                                        RMIL0066
      RETURN                                                             RMIL0067
      END                                                                RMIL0068
```

```
C****************************************************************
C        SAMPLE MAIN PROGRAM AND INPUT SUBROUTINE FOR SELF-CRITICAL
C        BINARY ESTIMATION.  IT IS RECOMMENDED THAT BINARY() AND
C        ITS AUXILIARY PROCEDURES BE COMPILED AND PLACED IN AN
C        OBJECT CODE LIBRARY, SO THE USER CAN CALL BINARY() FROM
C        ARBITRARY PROGRAMS.
C****************************************************************
      INTEGER N, IX, IA(750), NPAR, ISUB(10), ISTART(10), IDEP, IDIST,
     1        MAXIT, IPRINT, IFLAG, ICOV, LMEM, MEMORY(490), IFAULT, NC,
     2        NMAX, NCMAX, IREAD
      REAL X(10,750)
      DOUBLE PRECISION C(5), RELTOL, ABSTOL, BETA(10), XLOGL, COV(10,10)
C
C        DIMENSION SPECIFICATIONS FOR ARRAYS.
C        THIS MAIN PROGRAM CAN HANDLE UP TO 750 OBSERVATIONS,
C        WITH UP TO 10 PARAMETERS AND 5 DIFFERENT VALUES OF
C        C FOR ESTIMATION.
      DATA IX, ICOV, LMEM, NMAX, NCMAX /10, 10, 490, 750, 5/
C
C        BASIC INFORMATION TO PASS TO BINARY() - IPRINT STANDS
C        FOR LOGICAL OUTPUT UNIT 6
      DATA MAXIT, RELTOL, ABSTOL, IPRINT, IFLAG /15, 1.0D-7, 1.0D-7, 6,
     1   0/
C
C        IREAD IS LOGICAL INPUT UNIT 5
      DATA IREAD /5/
C
C        SPECIFY EVERYTHING BY HAND IN SUBROUTINE INPUT - ARRAY
C        MEMORY(*) PASSED AS WORKSPACE
      CALL INPUT(IX, N, NMAX, X, IA, NPAR, BETA, ISUB, ISTART, NC,
     1   NCMAX, C, IDEP, IDIST, MEMORY, IREAD, IPRINT, IFAULT)
      IF (IFAULT .EQ. 0) GO TO 10
      IF (IFAULT .EQ. 1) WRITE (IPRINT,50) N, NMAX
      IF (IFAULT .EQ. 2) WRITE (IPRINT,60) NPAR, IX
      IF (IFAULT .EQ. 3) WRITE (IPRINT,70) NC, NCMAX
      WRITE (IPRINT,80)
      STOP
C
C        LOOP OVER THE VALUES OF C REQUESTED FOR ESTIMATION
   10 DO 40 I = 1, NC
        CALL BINARY(N, IX, X, IA, NPAR, ISUB, ISTART, IDEP, IDIST, C(I),
     1        RELTOL, ABSTOL, MAXIT, IPRINT, IFLAG, BETA, XLOGL, ICOV,
     2        COV, LMEM, MEMORY, IFAULT)
        IF (IFAULT .EQ. 0) GO TO 20
        WRITE (IPRINT,90) IFAULT
        STOP
   20   IF (I .GT. 1) GO TO 40
C
C        AFTER THE FIRST ESTIMATION, SET ISTART(*) TO 1, SO
C        LATEST ESTIMATES CAN BE USED AS STARTING VALUES
        DO 30 J = 1, NPAR
   30   ISTART(J) = 1
C
   40 CONTINUE
C
   50 FORMAT ('OERROR - SAMPLE SIZE OF', I10, ' EXCEEDS DIMENSION OF',
     1        I10)
   60 FORMAT ('OERROR - ', I3, ' PARAMETERS EXCEEDS DIMENSION OF', I3)
   70 FORMAT ('OERROR - ', I3, ' C VALUES EXCEEDS DIMENSION OF', I3)
   80 FORMAT ('ORECOMPILE MAIN PROGRAM WITH NEW DIMENSIONS')
```

```
   90 FORMAT ('OESTIMATION PROCEDURE HAS FAILED - IFAULT =', I6)
      STOP
      END
C*********************************************************************
C          CRUDE INPUT ROUTINE   SETS ESTIMATION CONTROL PARAMETERS
C          EXPLICITLY, INSTEAD OF READING THEM IN
C*********************************************************************
      SUBROUTINE INPUT(IX, N, NMAX, X, IA, NPAR, BETA, ISUB, ISTART, NC,
     1             NCMAX, C, IDEP, IDIST, WORK, IREAD, IPRINT, IFAULT)
C          ARGUMENTS
      INTEGER IX, N, NMAX, IA(1), NPAR, ISUB(1), ISTART(1), NC, NCMAX,
     1        IDEP, IDIST, IPRINT, IFAULT
      REAL X(IX,1), WORK(1)
      DOUBLE PRECISION BETA(1), C(1)
C          LOCAL TYPE DECLARATION
      LOGICAL FLAG
C
C          SET DETAILS OF PROBLEM SIZE
      N = 680
      NPAR = 5
      NC = 4
C
C          CHECK FOR SIZE ERRORS
      IFAULT = 1
      IF (N  GT  NMAX) RETURN
      IFAULT = 2
      IF (NPAR  GT  IX) RETURN
      IFAULT = 3
      IF (NC  GT  NCMAX) RETURN
      IFAULT = 0
C
C          MODELING DETAILS
C          DEPENDENT VARIABLE IN FIRST ROW
      IDEP = 1
C          CONSTANT IN SECOND ROW
      ICONST = 2
C          GAUSSIAN TOLERANCE DISTRIBUTION
      IDIST = 2
C          VALUES OF C FOR SELF-CRITICAL
      C(1) = 0 0D0
      C(2) = 0 1D0
      C(3) = 0 2D0
      C(4) = 0 3D0
C
C          INITIALIZE AVERAGES TO 0
      YBAR = 0 0
      YSE = 0 0
      DO 10 I = 1, NPAR
   10 WORK(I) = 0 0
C
C          LOOP OVER SAMPLE TO READ IN DATA
      FLAG = NPAR  LE  2
      DO 40 I = 1, N
        READ (IREAD,20) VC, IA(I), ALPHA, S
   20   FORMAT (F10 0, I2, 2F8 0)
C
C          EXPRESS S IN METERS, SCALE VC
        VC = ALOG(VC/1000 0)
        S = 0 3048 * EXP(S)
C
```

```
C        FILL THE DATA MATRIX - CONSTANT IN SECOND ROW                   INPU0058
        X(IDEP,I) = VC                                                   INPU0059
        X(ICONST,I) = 1 O                                                INPU0060
        X(3,I) = ALPHA                                                   INPU0061
        X(4,I) = S                                                       INPU0062
        X(5,I) = ALPHA * S                                               INPU0063
C                                                                        INPU0064
C        UPDATE MEAN AND STD ERROR OF DEPENDENT VARIABLE IN A            INPU0065
C        WAY WHICH DOESNT LOSE SIGNIFICANT FIGURES                       INPU0066
        TEMP = VC - YBAR                                                 INPU0067
        YBAR = YBAR + TEMP / FLOAT(I)                                    INPU0068
        YSE = YSE + TEMP * (VC - YBAR)                                   INPU0069
C                                                                        INPU0070
C        INCREMENT COVARIATE AVERAGES (3D ROW AND UP)                    INPU0071
        IF (FLAG) GO TO 40                                               INPU0072
        DO 30 J = 3, NPAR                                                INPU0073
   30   WORK(J) = WORK(J) + X(J,I)                                       INPU0074
C                                                                        INPU0075
   40 CONTINUE                                                           INPU0076
C                                                                        INPU0077
C        SET ISUB(*) AND ISTART(*), PROVIDING STARTING VALUES            INPU0078
C        FOR INTERCEPT AND SCALE                                         INPU0079
      DO 50 I = 1, NPAR                                                  INPU0080
        ISUB(I) = I                                                      INPU0081
        ISTART(I) = O                                                    INPU0082
   50 CONTINUE                                                           INPU0083
      TEMP = FLOAT(N)                                                    INPU0084
      YSE = SQRT(YSE/TEMP)                                               INPU0085
      ISTART(IDEP) = 1                                                   INPU0086
      BETA(IDEP) = DBLE(YSE)                                             INPU0087
      ISTART(ICONST) = 1                                                 INPU0088
      BETA(ICONST) = DBLE(YBAR)                                          INPU0089
C                                                                        INPU0090
C        WRITE OUT INFORMATION ON STD. ERROR AND AVERAGES                INPU0091
      WRITE (IPRINT,60) YBAR, YSE                                        INPU0092
   60 FORMAT ('1DEPENDENT (STRESS) VARIABLE'/'OMEAN =', E14.6,           INPU0093
     1        ' STANDARD DEVIATION =', E14.6)                            INPU0094
      IF (FLAG) RETURN                                                   INPU0095
      WRITE (IPRINT,70)                                                  INPU0096
   70 FORMAT ('OCOVARIATES HAVE BEEN CENTERED BY THEIR MEANS'/           INPU0097
     1        'OVARIABLE', 10X, 'MEAN')                                  INPU0098
      DO 90 I = 3, NPAR                                                  INPU0099
        WORK(I) = WORK(I) / TEMP                                         INPU0100
        WRITE (IPRINT,80) ISUB(I), WORK(I)                               INPU0101
   80   FORMAT ('O', I8, E14.6)                                          INPU0102
   90 CONTINUE                                                           INPU0103
C                                                                        INPU0104
C        SUBTRACT MEANS FROM COVARIATES                                  INPU0105
      DO 110 I = 1, N                                                    INPU0106
        DO 100 J = 3, NPAR                                               INPU0107
  100   X(J,I) = X(J,I) - WORK(J)                                        INPU0108
  110 CONTINUE                                                           INPU0109
C                                                                        INPU0110
      RETURN                                                             INPU0111
      END                                                                INPU0112
```

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AD-A172 545

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARO-3	2. GOVT ACCESSION NO. N/A	3. RECIPIENT'S CATALOG NUMBER N/A
4. TITLE (and Subtitle) An Algorithm for the Computation of Generalized Likelihood or Self-Critical Estimators for Binary Data		5. TYPE OF REPORT & PERIOD COVERED Working Paper
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) T.A. Delehanty A.S. Paulson		8. CONTRACT OR GRANT NUMBER(s) DAAG29-81-K-0110
9. PERFORMING ORGANIZATION NAME AND ADDRESS Rensselaer Polytechnic Institute Troy, New York 12180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office Post Office Box 12211 Research Triangle Park, NC 27709		12. REPORT DATE
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

NA

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

binary data, extreme value distribution, logistic distribution, Gaussian distribution, generalized likelihood, model-critical analysis, regression models, parametric proportional hazard models

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This paper describes the computational algorithms for computing generalized likelihood estimators for parametric proportional hazards models.

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DTIC