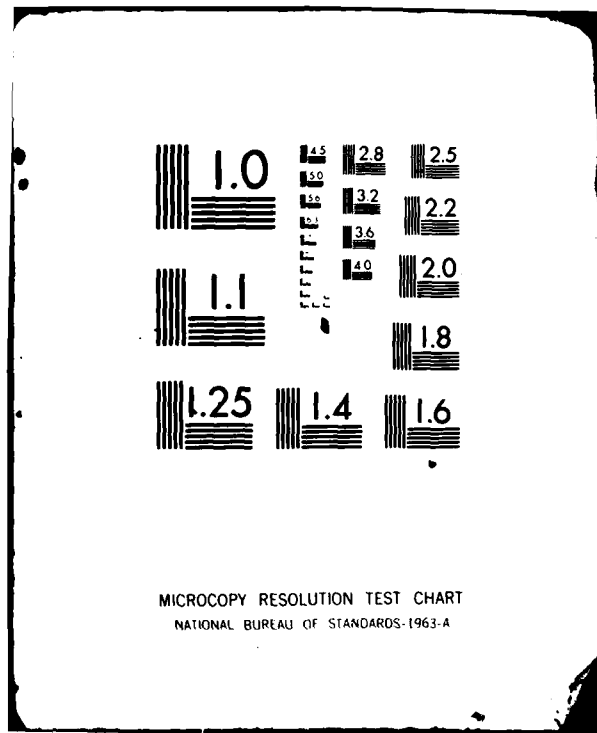


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# TESTING FOR STRUCTURAL CHANGE BY D-METHODS IN SWITCHING SIMULTANEOUS EQUATIONS MODELS

Lung-Fei Lee  
G. S. Maddala  
R. P. Trost

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Lung-Fei Lee  
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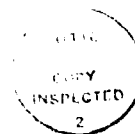
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TESTING FOR STRUCTURAL CHANGE BY  
D-METHODS IN SWITCHING SIMULTANEOUS EQUATIONS MODELS\*

Lung-fei Lee, University of Minnesota  
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and R. P. Trost, Center for Naval Analyses

1. Introduction

Goldfeld and Quandt (1972) considered a switching regression model with two regimes:

$$y_i = a_1 + b_1 x_i + u_{1i} \quad (1)$$

$$y_i = a_2 + b_2 x_i + u_{2i} \quad (2)$$

$$u_{1i} \sim IN(0, \sigma_1^2) \text{ and } u_{2i} \sim IN(0, \sigma_2^2)$$

They assume that there is an identifiable variable  $Z_i$  such that if  $Z_i < Z_0$  then the observations are generated by (1) and if  $Z_i \geq Z_0$  then the observations are generated by (2). They then define the step function

$$D(Z_i) = 1 \text{ if } Z_i < Z_0 \\ = 0 \text{ if } Z_i \geq Z_0 \quad (3)$$

Later, instead of considering the step function, they consider  $D(Z_i)$  to be a cumulative normal given by

$$D(Z_i) = 1 \text{ if } Z_i < Z_0 + \epsilon_i \\ = 0 \text{ if } Z_i \geq Z_0 + \epsilon_i$$

where  $\epsilon_i \sim IN(0, 1)$ .

The model considered by Goldfeld and Quandt is an exogenous switching model because  $\epsilon_i$  is assumed to be independent of  $u_{1i}$  and  $u_{2i}$ . Goldfeld and Quandt (1973) give an extension of the switching regression model to simultaneous equations systems but the extension is still in the framework of exogenous switching.

Maddala and Nelson (1975) discuss extensions of the Goldfeld-Quandt switching regression model to the case of endogenous switching. Many of the practical problems one encounters - disequilibrium models, selectivity models etc., are all switching regression models with endogenous switching. The present paper extends the D-method suggested by Goldfeld and Quandt to switching simultaneous equations systems with endogenous switching.

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There have been previous discussions of structural change by Heckman (1976b) in models with endogenous switching. However, the type of model we discuss has not been considered by him. What he considers is a shift in the constant term (a structural shift) and not shifts in all the coefficients as we do.

What the D-method does is to combine the equations in the two regimes into a single equation. This will enable us to apply tests for equality of specific coefficients in the two regimes. The alternative to this procedure would be to use a likelihood ratio test every time the significance of a particular coefficient needs to be tested. Thus, the D-method has the advantage of computational simplicity. In this paper we suggest instrumental variable methods to estimate the parameters of the combined equation. Following the methods used by Amemiya (1978), we derive the asymptotic covariance matrix (in the appendix) and present an empirical example illustrating the use of the suggested method.

2. The Switching Simultaneous Equation System

The general model we consider in this paper is the following:

$$I_i = x_i' \delta - \epsilon_i^* \quad (4)$$

$$\text{Regime 1: } B_1 Y_{1i} + \Gamma_1 Z_{1i} \\ = \epsilon_{1i} \text{ if } I_i > 0 \quad (5)$$

$$\text{Regime 2: } B_2 Y_{2i} + \Gamma_2 Z_{2i} \\ = \epsilon_{2i} \text{ if } I_i \leq 0 \quad (6)$$

The residuals  $\epsilon_1$ ,  $\epsilon_2$ , and  $\epsilon^*$  have a multivariate normal distribution with mean vector 0 and covariance matrix

$$\Sigma = \begin{pmatrix} \Sigma_{11} & \Sigma_{12} & \Sigma_{1*} \\ & \Sigma_{22} & \Sigma_{2*} \\ & & 1 \end{pmatrix}$$

Define the dummy variable

$$D_i = 1 \text{ if } I_i > 0 \\ = 0 \text{ if } I_i \leq 0$$

Without loss of generality, let us consider the first equation in the two regimes and assume that the endogenous variables occurring in both are the same. Let the observed endogenous variables be

$$y_{ji}^* = y_{1ji} \quad \text{if } D_i = 1 \\ = y_{2ji} \quad \text{if } D_i = 0 \quad (7)$$

Let us write the first equation in the two regimes as

$$y_{11i} = \beta_{112}y_{12i} + \beta_{113}y_{13i} + \dots \\ + \beta_{11p}y_{1pi} + \gamma_{11}z_i + \epsilon_{11i} \quad (8)$$

and

$$y_{21i} = \beta_{212}y_{22i} + \beta_{213}y_{23i} + \dots \\ + \beta_{21p}y_{2pi} + \gamma_{21}z_i + \epsilon_{21i} \quad (9)$$

These two equations can be combined into a single equation and written as:

$$y_{1i}^* = D_i y_{2i}^* (\beta_{112} - \beta_{212}) + \dots \\ + D_i y_{pi}^* (\beta_{11p} - \beta_{21p}) \\ + Y_{2i}^* \beta_{212} + \dots + Y_{pi}^* \beta_{21p} \\ + D_i z_i (\gamma_{11} - \gamma_{21}) + z_i \gamma_{21} \\ + D_i \epsilon_{11i} + (1 - D_i) \epsilon_{21i} \quad (10)$$

Let us define

$$\phi_i = \phi(x_i' \delta)$$

and

$$\phi_i = \phi(x_i' \delta) \quad (11)$$

where  $x_i$  is the  $i$ th observation of  $x$   $\phi_i$  the standard normal density  $i=1, 2, \dots, N$  evaluated at  $x_i' \delta$  and  $\Phi_i$  is the cumulative normal:

$$\phi_i = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x_i' \delta} e^{-u^2/2} du$$

Note that  $E(\epsilon_{11i} | I_i > 0) = -\sigma_{\epsilon 11}^* \frac{\phi_i}{\Phi_i}$

where  $\sigma_{\epsilon 11}^* = \text{Cov}(\epsilon_{11}, \epsilon^*)$

Similarly  $E(\epsilon_{21i} | I_i \leq 0) = \sigma_{\epsilon 21}^* \frac{\phi_i}{1 - \Phi_i}$

where  $\sigma_{\epsilon 21}^* = \text{Cov}(\epsilon_{21}, \epsilon^*)$

Hence, the composite residual in (10) has the expectation

$$E[D_i \epsilon_{11i} + (1 - D_i) \epsilon_{21i}] = \\ (\sigma_{\epsilon 21}^* - \sigma_{\epsilon 11}^*) \phi_i$$

Equation (10) can now be written as

$$y_{1i}^* = D_i y_{2i}^* (\beta_{112} - \beta_{212}) + \dots \\ + D_i y_{pi}^* (\beta_{11p} - \beta_{21p}) + Y_{2i}^* \beta_{212} + \dots \\ + Y_{pi}^* \beta_{21p} + \phi_i z_i (\gamma_{11} - \gamma_{21}) + z_i \gamma_{21} \\ + \phi_i (\sigma_{\epsilon 21}^* - \sigma_{\epsilon 11}^*) + \xi_{1i} \quad (12)$$

where  $E(\xi_{1i}) = 0$ .

### 3. Estimation Under D-Methods

To estimate equation (12) and develop valid statistical tests we will extend the two-stage estimations method that Heckman (1976a) suggested. First, we get an estimate  $\hat{\delta}$  of  $\delta$  by probit maximum likelihood applied to equation (4).

Second, we estimate the reduced form equations for the endogenous variables in (8) and (9) by the following two stage method.

The reduced form equation for  $y_{1ji}$  can be written as

$$y_{1ji} = z_i \pi_{1j} + v_{1ji} \quad (13)$$

Since  $E(v_{1ji} | I_i > 0) = -\sigma_{ij}^* \frac{\phi_i}{\Phi_i}$

where  $\sigma_{ij}^* = \text{Cov}(v_{1j}, \epsilon^*)$

We can write (13) as

$$D_i y_{1ji} = \phi_i z_i \pi_{1j} - \sigma_{1j}^* \phi_i + \eta_{1ji} \quad (14)$$

where  $E(\eta_{1ji}) = 0$ .

We estimate equation (14) by ordinary least squares substituting  $\hat{\phi}_i$  and  $\hat{\phi}_i$  for  $\phi_i$  and  $\phi_i$  respectively.

Here  $\hat{\phi}_i$  and  $\hat{\phi}_i$  are the same as  $\phi_i$  and  $\phi_i$  with  $\hat{\delta}$  substituted for  $\delta$ . This two-stage estimation gives us consistent estimates  $\hat{\pi}_{1j}$  and  $\hat{\sigma}_{1j}^*$ , and we can construct the instrumental variable

$$D_i y_{1ji} = \hat{\phi}_i z_i \hat{\pi}_{1j} - \hat{\sigma}_{1j}^* \hat{\phi}_i \quad (15)$$

From the reduced form equations for  $y_{1ji}$  and  $y_{2ji}$ , one has

$$y_{ji}^* = \phi_i z_i \pi_{1j} + (1 - \phi_i) z_i \pi_{2j} + \\ (\sigma_{2j}^* - \sigma_{1j}^*) \phi_i + v_{ji}$$

where  $E(v_{ji}) = 0$  (16)

We estimate equation (16) by ordinary least squares substituting  $\hat{\phi}_i$  and  $\hat{\phi}_i$  for  $\phi_i$  and  $\phi_i$  to get consistent estimates  $\hat{\pi}_{1j}$ ,  $\hat{\pi}_{2j}$  and  $\hat{\sigma}_{2j}^* - \hat{\sigma}_{1j}^*$ .

Now we construct instrumental variables for  $y_{ji}^*$  in (12) as follows

$$\hat{y}_{ji}^* = \hat{\phi}_i z_i \hat{\pi}_{1j} + (1 - \hat{\phi}_i) z_i \hat{\pi}_{2j} + \hat{\phi}_i \hat{\pi}_{2j}^{-j} \hat{\pi}_{1j}^* \quad (17)$$

With these instrumental variables constructed, one can estimate the structural coefficients from the following modified equations:

$$\begin{aligned} y_{1i}^* &= D_i y_{2i}^* (\beta_{112} - \beta_{212}) + \dots \\ &+ D_i y_{pi}^* (\beta_{11p} - \beta_{21p}) \\ &+ y_{2i}^* \beta_{212} + \dots + y_{pi}^* \beta_{21p} \\ &+ \hat{\phi}_i z_i (y_{11} - y_{21}) + z_i y_{21} \\ &+ \hat{\phi}_i (\sigma_{\epsilon 21} - \sigma_{\epsilon 11}) + \eta_{1i} \end{aligned} \quad (18)$$

$$\begin{aligned} \text{where } \eta_{1i} &= \xi_{1i} + (D_i - \hat{\phi}_i) z_i (y_{11} - y_{21}) \\ &+ (\hat{\phi}_i - \hat{\phi}_i) z_i (y_{11} - y_{21}) \\ &+ (\hat{\phi}_i - \hat{\phi}_i) (\sigma_{\epsilon 21} - \sigma_{\epsilon 11}) \end{aligned} \quad (19)$$

$$\begin{aligned} \text{and } \xi_{1i} &= D_i \epsilon_{11i} + (1 - D_i) \epsilon_{21i} \\ &- (\sigma_{\epsilon 21} - \sigma_{\epsilon 11}) \hat{\phi}_i \end{aligned} \quad (20)$$

In matrix notation, let

$$\begin{aligned} W &= \{Dy_2^*, Dy_3^*, \dots, Dy_p^*, \\ &y_2^*, \dots, y_p^*, \hat{\phi}z, z, \hat{\phi}\} \end{aligned} \quad (21)$$

$$\begin{aligned} \text{and } \theta' &= (\beta_{112} - \beta_{212}, \dots, \beta_{11p} - \beta_{21p}, \beta_{212}, \\ &\dots, \beta_{21p}, y_{11} - y_{21}, \\ &y_{21}, \sigma_{\epsilon 21} - \sigma_{\epsilon 11}) \end{aligned}$$

$$\begin{aligned} \text{Also let } \hat{W} &= \{\hat{Dy}_2^*, \hat{Dy}_3^*, \dots, \hat{Dy}_p^*, \hat{y}_2^*, \dots, \\ &\hat{y}_p^*, \hat{\phi}z, z, \hat{\phi}\} \end{aligned}$$

Then, the instrumental variable estimator of  $\theta$  is

$$\hat{\theta} = (\hat{W}, W)^{-1} \hat{W}' y_1^* \quad (22)$$

It can be shown that in this case given the way the instrumental variables are constructed as defined by equations (17) and (15), the instrumental variable estimator is the same as the two-stage squares estimator so that

$$\hat{\theta} = (\hat{W}' \hat{W})^{-1} \hat{W}' y_1^* \quad (22a)$$

The instrumental variable estimator can be easily shown to be consistent. The asymptotic covariance matrix of this estimator is derived in the appendix. It is the last expression in the appendix. Since it involves the definitions of several expressions, it is not repeated here.

#### 4. An Empirical Illustration

The example we consider is the estimation of the effects of college education on earnings based on the project

TALENT data. More detailed discussion of the data and their use in this problem can be found in Kenny (1977) and Kenny et al. (1979). We will here summarize all the salient features of the data and the model relevant for our discussion of the D-method.

Let S = years of college education  
E = earnings  
X, Z<sub>1</sub>, Z<sub>2</sub> are sets of (possibly overlapping) exogenous variables defined in Table 1.

The switching simultaneous equation system we consider is the following:

$$I = X\delta - \epsilon^* \quad (23)$$

$$S = Z_1 \beta_1 = \epsilon_{11} \quad \text{iff } I > 0 \quad (24)$$

$$E = \gamma S + Z_2 \beta_2 + \epsilon_{12} \quad (25)$$

$$S = 0 \quad \text{otherwise} \quad (26)$$

$$E = Z_2 \beta_3 + \epsilon_{22}$$

I is an indicator function such that if I > 0, the individual goes to college and if I < 0 the individual does not go to college.

The variables in the choice function and the schooling equation, i.e., variables in the sets X and Z<sub>1</sub> are: Rural, Split, MATH, MOCWAG, EDMAL, EDFEM, CHIL. (defined in Table 1).

The variables affecting the earnings functions, i.e., the variables in the set Z<sub>2</sub> are: Rural, MATH, Marital Status and HC (defined in Table 1).

The variable S has been coded as follows:

0 for those with no college education  
4.0 for Bachelor's degree  
5.5 for Master's degree  
6.0 for six years college  
8.0 for Ph.D.

with numbers between 0 and 4 for those without bachelor's degree depending on when they dropped out of the 4 year program.

We will briefly discuss the reasoning behind the choice of the variables in the sets X, Z<sub>1</sub>, Z<sub>2</sub>.

First, regarding the variables X and Z<sub>1</sub> affecting the choice of whether or not to go to college and the years spent in college, high school students coming from rural areas are less likely to go to college or spend more years in college. Hence we included the 'Rural' as a dummy variable. If children are viewed as a

good whose returns are specific to marriage, then divorce would lower the demand for child's educational attainment. Hence we included the variable 'Split' as an explanatory variable and its coefficient is expected to be negative. The variable MATH measures both inherited and achieved cognitive skills. Those with higher MATH scores may learn more rapidly than others and hence may find it optimal to get a higher degree. The variables MOCWAG, EDMAL and EDFEM need no justification. We included the variable CHIL because an increase in the number of children in the parents' household increases the total cost of schooling for the family leading to a reduction in the number of years spent in school.

As for the variables  $Z_2$  affecting the earnings functions, the variable Rural is a crude proxy for cost of living. Individuals who grew up in rural areas, where cost of living (and thus wages) is low, are more likely to live in rural areas than others. The variable MATH measures cognitive achievement and hence should be positively correlated with wages. The variable Marital Status is expected to be positively correlated with wages if we argue that married people have greater responsibilities and hence are likely to work harder. Another argument is that the marriage market may recognize that some men are better 'prospects' (have higher expected wages) than others. Finally the variable HC is used as a proxy for on the job experience. As the number of jobs held (i.e., HC) increases, the amount spent with the current firm is likely to decrease. Hence HC is expected to be negatively correlated with earnings.

Table 2 presents estimates of the parameters  $\delta$  in equation (23). All the coefficients have the expected signs. Table 3 presents the maximum likelihood estimates of the parameters in equations (24), (25) and (26). Table 4 presents estimates of the parameters of the earnings functions obtained by the D-method described in this paper. The standard errors have been computed from the formula in the appendix.

Our objective in using the D-method is to test which coefficients in the earnings functions are significantly different between the two groups - those with college education and those without. The equations in Table 4 suggest that it is only variables HC and MATH that are significantly different; 'Marital Status' and 'Rural' are not.

The example we have used here as an illustration for the D-method is one where maximum likelihood estimation is feasible. There would, however, be many

practical instances where the use of maximum likelihood procedures would be ruled out because of the large size of the model (one example is the model considered by Nelson and Olson [1978]). In such cases the D-method suggested in this paper would be useful to apply tests of significance for equality of coefficients between the two regimes.

## 5. Conclusions

The paper presents an extension of the Goldfeld-Quant D-method to switching simultaneous equation systems with endogenous switching. The method is useful to apply tests for equality of coefficients across regimes in switching simultaneous equation systems with selectivity. The paper derives the valid instrumental variables to use in this situation, the asymptotic covariance matrix of the suggested estimator and gives an empirical illustration.

## REFERENCES

- Amemiya, T. (1978) - "The Estimation of a Simultaneous Equation Generalized Probit Model," Econometrica, Vol. 46, No. 5, pp. 1193-1205.
- Goldfeld, S.M. and R. E. Quandt (1972) - Nonlinear Methods in Econometrics (Amsterdam, North Holland Publishing Co.).
- Goldfeld, S. M. and R. E. Quandt (1973) - "The Estimation of Structural Shifts by Switching Regressions," Annals of Economic and Social Measurement, Vol. 2, No. 4, pp. 475-486.
- Heckman, J. J. (1976a) - "The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimation for Such Models." Annals of Economic and Social Measurement, Vol. 5, No. 4, 475-492.
- Heckman, J. J. (1976b) - "Simultaneous Equations Models with Continuous and Discrete Endogenous Variables and Structural Shifts," in Goldfeld and Quandt (Eds), Studies in Non-linear Estimation (Ballinger Publishing Co.).
- Kenny, L. W. (1977) - "The Demand for Child Quality and for Educational Inputs, the Production of Child Quality and Related Topics," unpublished doctoral dissertation, University of Chicago.
- Kenny, L. W., Lung-fei Lee, G. S. Maddala and R. P. Trost (1979) - "Returns to College Education: An Investigation of Self-Selection Bias Based on the Project Talent Data," International Economic Review, Vol. 20, No. 3.

REFERENCES  
(continued)

Maddala, G. S. and F. D. Nelson (1975) - "Switching Regression Models with Exogenous and Endogenous Switching" - American Statistical Association Proceedings of the Business and Economic Statistics Section, December 1975, pp. 423-426.

Nelson, F. D. and L. Olson (1978) - "Specification and Estimation of a Simultaneous Equations Model with Limited Dependent Variables," International Economic Review, Vol. 19, No. 3, 695-709.

APPENDIX

In this appendix we will derive the covariance matrix of the two-stage least squares estimator (22a).

We have

$$(\theta - \hat{\theta}) = (\hat{W}'\hat{W})^{-1} \hat{W}'\eta_1$$

where  $\eta_{1i}$ , the  $i$ th component of  $\eta_1$  is given by equation (19). Let us first define the  $N \times N$  diagonal matrices

$$B = \text{Diag} [\phi_1, \phi_2, \dots, \phi_N] \quad (1')$$

$$C = \text{Diag} [\phi_1, \phi_2, \dots, \phi_N] \quad (2')$$

$$F = \text{Diag} [x_1'\delta, x_2'\delta, \dots, x_N'\delta] \quad (3')$$

$$H = \text{Diag} [z_1'(1-\gamma_{21}), \dots, z_N'(1-\gamma_{21})] \quad (4')$$

$$V = \text{Diag} [\phi_1(1-\phi_k), \dots, \phi_N(1-\phi_N)] \quad (5')$$

$$\hat{\Lambda} = \text{Diag} \left[ \frac{\phi_1^2}{\phi_1(1-\phi_1)}, \dots, \frac{\phi_N^2}{\phi_N(1-\phi_N)} \right] \quad (6')$$

and

$$\hat{\Lambda}_1 = \text{Diag} \left[ \frac{\phi_1}{\phi_1(1-\phi_1)}, \dots, \frac{\phi_N}{\phi_N(1-\phi_N)} \right] \quad (7')$$

Actually  $\hat{\Lambda} = C^2V^{-1}$  and  $\hat{\Lambda}_1 = CV^{-1}$  but we have defined these two diagonal matrices separately for convenience.

Also let  $X$  be the  $N \times L$  matrix of observations on  $x_i$ , i.e.

$$\begin{bmatrix} X = & x_1' \\ & x_2' \\ & \vdots \\ & x_N' \end{bmatrix} \quad (8')$$

Finally define

$$G = H - [H + (\sigma_{\epsilon 11*} - \sigma_{\epsilon 21*})F] \quad (9')$$

$$CX(X'\hat{\Lambda}X)^{-1}X'\hat{\Lambda}_1$$

Now from equation (19), we have

$$\begin{aligned} \hat{\theta} - \theta &= (\hat{W}'\hat{W})^{-1} \hat{W}'\eta_1 \\ &= (\hat{W}'\hat{W})^{-1} \hat{W}' [\hat{s}_1 + H(D-\hat{\phi}) - H(\hat{\phi}-\phi)] \\ &\quad + (\sigma_{\epsilon 11*} - \sigma_{\epsilon 21*})(\hat{\phi}-\phi) \end{aligned} \quad (10')$$

where  $\hat{s}_1, D, \hat{\phi}, \phi, \hat{\phi}_i$  are all column vectors with their  $i$ -th elements  $\hat{s}_{1i}, D_i, \hat{\phi}_i, \phi_i, \hat{\phi}_i, \phi_i$  respectively.

Expanding  $\hat{\phi}_i$  and  $\phi_i$  up to the first power of  $(\hat{\phi}-\phi)$  we get

$$\hat{\phi}_i = \phi_i + \left[ \frac{\partial \phi_i}{\partial \delta} \right]' (\hat{\phi}-\phi) = \phi_i + \phi_i x_i' (\hat{\phi}-\phi)$$

$$\text{Hence } (\hat{\phi}-\phi) = CX (\hat{\phi}-\phi) \quad (11')$$

Similarly

$$\hat{\phi} - \phi = -FCX (\hat{\phi}-\phi) \quad (12')$$

Hence we have <sup>2</sup> from equation (10')

$$\begin{aligned} \hat{\theta} - \theta &= (\hat{W}'\hat{W})^{-1} [\hat{s}_1 + H(D-\phi)] \\ &\quad - HCX (\hat{\phi}-\phi) - (\sigma_{\epsilon 11*} - \sigma_{\epsilon 21*})FCX (\hat{\phi}-\phi) \end{aligned} \quad (13')$$

Now what we will do is express  $(\hat{\phi}-\phi)$  in terms of  $(D-\phi)$  so that all we have to get is  $\text{Var}(\hat{s}_1), \text{Var}(D-\phi)$  and  $\text{Cov}(\hat{s}_1, D-\phi)$ .

Following Amemiya (1977) we can write

$$(\hat{\phi}-\phi) \stackrel{A}{=} (X'\hat{\Lambda}X)^{-1} X'\hat{\Lambda}_1(D-\phi) \quad (14')$$

Substituting this in (13') we have

$$(\hat{\theta}-\theta) \stackrel{A}{=} (\hat{W}'\hat{W})^{-1} \hat{W}' [\hat{s}_1 + G(D-\phi)] \quad (15')$$

where  $G$  is defined in (9').

From equation (20) in the text, we have

$$\begin{aligned} \hat{s}_{1i} &= \epsilon_{21i} + D_i (\epsilon_{11i} - \epsilon_{21i}) \\ &\quad - (\sigma_{\epsilon 21*} - \sigma_{\epsilon 11*})\phi_i \end{aligned}$$

Hence  $\text{Var}(\hat{s}_{1i}) = E(\hat{s}_{1i}^2)$

$$\begin{aligned} &= \sigma_{21}^2 + (\sigma_{11}^2 - \sigma_{21}^2)\phi_i \\ &\quad + (\sigma_{\epsilon 21*}^2 - \sigma_{\epsilon 11*}^2)(x_i'\delta)\phi_i \\ &\quad - (\sigma_{\epsilon 21*} - \sigma_{\epsilon 11*})^2 \phi_i^2 \end{aligned}$$

Or  $\text{Var}(\hat{s}_1) = \sigma_{\epsilon 21}^2 I_N + (\sigma_{\epsilon 11}^2 - \sigma_{\epsilon 21}^2) B$

$$\begin{aligned} &\quad + (\sigma_{\epsilon 21*}^2 - \sigma_{\epsilon 11*}^2) FC \\ &\quad - (\sigma_{\epsilon 21*} - \sigma_{\epsilon 11*})^2 C^2 \end{aligned} \quad (16')$$

$\text{Var}(D-\phi) = V$  where  $V$  is defined in (5') and hence  $\text{Var}[G(D-\phi)] = GVG'$  (17')

Finally,  $E(\hat{\beta}_1(D-\phi)') = -\sigma_{\epsilon 11} C$   
 $+ (\sigma_{\epsilon 11} - \sigma_{\epsilon 21}) BC$  (18')

Hence, collecting the expressions (16'), (17'), and (18') we have

$$\begin{aligned} \text{Var}(\hat{\theta}-\theta) &= (\hat{W}'\hat{W})^{-1}\hat{W}'[\sigma_{\epsilon 21}^2 I_N \\ &+ (\sigma_{\epsilon 21}^2 I_N + (\sigma_{\epsilon 11} - \sigma_{\epsilon 21})^2) B \\ &+ (\sigma_{\epsilon 21}^2 - \sigma_{\epsilon 11}^2) FC \\ &- (\sigma_{\epsilon 21} - \sigma_{\epsilon 11})^2 C^2 + \text{GVG}' \\ &- \sigma_{\epsilon 11} (CG'+GC) \\ &+ (\sigma_{\epsilon 11} - \sigma_{\epsilon 21}) (BCG'+GCB)] \\ &\hat{W} (\hat{W}'\hat{W})^{-1} \end{aligned}$$

where the expressions B, C, F, G etc. are all defined in equation (1') to (8').

FOOTNOTES:

<sup>1</sup>Richard Quandt kindly pointed out to us that there is an algebraic error in equation (3.8), p. 425 of the Maddala-Nelson paper. The two denominators in  $\phi$  should be  $(\gamma_2^2 \sigma_2^2 + \sigma_3^2)^{1/2}$  and  $(\gamma_1^2 \sigma_1^2 + \sigma_3^2)^{1/2}$  instead of  $(\sigma_2^2 + \sigma_3^2)^{1/2}$  and  $(\sigma_1^2 + \sigma_3^2)^{1/2}$  respectively.

<sup>2</sup>In the discussion that follows, the notation  $\bar{A}$  means that the two expressions have the asymptotic distributions.

TABLE 1  
LIST OF VARIABLES

|       |  |
|-------|--|
| E     | = Natural logarithm of the hourly wage (in cents) in 1971  |
| S     | = Years of college education in 1971   |
| MATH  | = Score on a composite of mathematics achievement tests in 1960  |
| SPLIT | = 0 if children living with both mother and father in 1960<br>= 1 Otherwise  |
| EDMAL | = Years of father's education  |
| EDFEM | = Years of mother's education  |
| CHIL  | = Number of living children (in 1960) in the family in which the respondent grew up                                      |
| RURAL | = 1 if pupils in grades 9-12 came from an area primarily small town (under 5,000 people) or rural farm<br>= 0 Otherwise. |

TABLE 1 (cont.)

|                |  |
|----------------|--|
| MOCWAG         | = (mean occupational wage) Log of mean earnings (as of 1960) of full-time workers in father's occupation |
| HC             | = Number of jobs held between 1965 and 1970  |
| N              | = The total sample size = 1373   |
| N <sub>1</sub> | = Number of observations in the first group (those who went to college = 909)                            |
| N <sub>2</sub> | = Number of observations in the second group (those that did not go to college = 464)                    |

TABLE 2  
PROBIT EQUATION TO EXPLAIN THE DECISION OF WHETHER OR NOT TO GO TO COLLEGE

| Variable      | Coeff. Est. | S.E.  |
|---------------|-------------|-------|
| Constant      | -5.259      | 2.108 |
| Rural (Dummy) | -.164       | .093  |
| Split         | -.078       | .145  |
| MATH          | .015        | .001  |
| MOCWAG        | .922        | .589  |
| EDMAL         | .044        | .017  |
| EDFEM         | .029        | .019  |
| CHIL          | -.057       | .021  |

TABLE 4  
EARNINGS FUNCTIONS WITH D-METHOD

| Variables        | Equation 1            | Equation 2            | Equation 3            |
|------------------|-----------------------|-----------------------|-----------------------|
| Constant         | 5.72467<br>(0.12918)  | 5.69896<br>(0.08953)  | 5.70961<br>(0.09773)  |
| Marital Status   | 0.14620<br>(0.06281)  | 0.15656<br>(0.01298)  | 0.15511<br>(0.01808)  |
| Rural            | -0.07161<br>(0.07239) | -0.05352<br>(0.02185) | -0.05030<br>(0.02416) |
| MATH             | -0.00359<br>(0.00231) | -0.00377<br>(0.00206) | -0.00336<br>(0.00193) |
| HC               | 0.03196<br>(0.01304)  | 0.03184<br>(0.01275)  | 0.03234<br>(0.01315)  |
| $\phi$           | 0.74827<br>(0.48986)  | 0.82369<br>(0.35637)  | 0.66080<br>(0.20604)  |
| $\phi$           | -0.12980<br>(0.34249) | -0.15768<br>(0.27731) |                       |
| $\phi^*$ Marital | 0.01454<br>(0.08599)  |                       |                       |
| $\phi^*$ Rural   | 0.03258<br>(0.10696)  |                       |                       |
| $\phi^*$ MATH    | 0.00560<br>(0.00306)  | 0.00589<br>(0.00262)  | 0.00507<br>(0.00226)  |
| $\phi^*$ HC      | -0.06444<br>(0.02026) | -0.06335<br>(0.01920) | -0.06671<br>(0.01894) |
| S                | 0.05141<br>(0.04710)  | 0.05774<br>(0.03536)  | 0.04202<br>(0.02590)  |

(Table 3 is available from the authors upon request.)

OMA PROFESSIONAL PAPERS - 1978 TO PRESENT

- PP 211  
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Mangel, Marc, "Fluctuations in Systems with Multiple Steady States. Application to Lancaster Equations," 12 pp., Feb 78 (Presented at the First Annual Workshop on the Information Linkage Between Applied Mathematics and Industry, Naval PG School, Feb 23-25, 1978), AD A071 472
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Weinland, Robert G., "A Somewhat Different View of the Optimal Naval Posture," 37 pp., Jun 1978 (Presented at the 1976 Convention of the American Political Science Association (APSA/IUS Panel on "Changing Strategic Requirements and Military Posture"), Chicago, Ill., September 2, 1976), AD A056 228
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Collie, Russell C., "Comments on: Principles of Information Retrieval by Manfred Kochen," 10 pp., Mar 78 (Published as a Letter to the Editor, Journal of Documentation, Vol. 31, No. 4, pages 298-301), December 1975), AD A054 426
- PP 216  
Collie, Russell C., "Lotka's Frequency Distribution of Scientific Productivity," 18 pp., Feb 1978 (Published in the Journal of the American Society for Information Science, Vol. 28, No. 6, pp. 366-370, November 1977), AD A054 425
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Collie, Russell C., "Bibliometric Studies of Scientific Productivity," 17 pp., Mar 78 (Presented at the Annual meeting of the American Society for Information Science held in San Francisco, California, October 1976), AD A054 442
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Huntzinger, R. LaVar, "Market Analysis with Rational Expectations: Theory and Estimation," 60 pp., Apr 78, AD A054 422
- PP 220  
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"Portions of this work were completed at the Institute of Applied Mathematics and Statistics, University of British Columbia, Vancouver, Canada.
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Glasser, Kenneth S., "The d-Choice Secretary Problem," 32 pp., Jun 1979, AD A075 225
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Mizrahi, M.M., "Correspondence Rules and Path Integrals," Jul 1981. Published in "Nuovo Cimento B", Vol. 61 (1981)
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Trost, R.P.; Luria, Philip and Berger, Edward, "A Note on Estimating Continuous Time Decision Models," 15 pp., Sep 1981
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- PP 334  
Kenny, Lawrence W., Lee, Lung-Fei, Maddala, G.S., and Trost R.P., "Returns to College Education: An Investigation of Self-Selection Bias Based on the Project Talent Data," 15 pp., Jan 1982. Published in International Economic Review, Vol. 20, No. 3, October 1979.
- PP 335  
Lee, Lung-Fei, G.S. Maddala, and R.P. Trost, "Asymptotic Covariance Matrices of Two-Stage Probit and Two-Stage Tobit Methods for Simultaneous Equations Models with Selectivity," 13 pp., Jan 1982. Published in Econometrica, Vol. 48, No. 2 (March, 1980).
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Trost, Robert P. and Vogel, Robert G., "Prediction with Pooled Cross-Section and Time-Series Data: Two Case Studies," 6 pp., Feb 1982
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