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ABSTRACT

We propose an index of "true disability" by treating disability status as an unobservable phenomenon which is both causally related to a number of exogenous characteristics of an individual and correlated with a number of observed indicators of health, impairment and qualifications for employment.

First, we define true disability and distinguish it from related concepts. We then discuss the importance of an objective and reliable measure of disability for research on the determinants of behavior. Next, we present the specification of our structural model for estimating true disability as a latent variable. Finally, we report the results of our estimation in a simple model of labor force participation, and compare the effect of using the constructed index and a self-reported disability measure on understanding the determinants of behavior and choice.

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Disability Status as an Unobservable: Estimates from a Structural Model

The true health or disability status of an individual is an important determinant of a wide variety of his/her decisions. Prominent among these are decisions regarding fertility and marriage, whether or not to work, how much to work and the kind of work to do, whether or not to apply for income transfer benefits, whether or not to seek retraining and rehabilitation services, and the extent of health care service utilization. Research designed to model and empirically estimate the determinants of these decisions requires reliable and objective indicators of the presence of a health problem or disabling condition, and, if present, of the severity of the problem. Nearly without exception, studies of the determinants of individual behavior have employed one of the following health or disability status indicators, each of which has substantial disadvantages for both behavioral research and statistical descriptions of the disability status of the population:

1. Individual self-reports. These are subjective and potentially endogenous with the choices under consideration. The self-reports are likely to reflect preferences in addition to true activity-limiting conditions.

2. Medical reports. These are partial in their evaluation, loosely related to individual labor market potential, and of limited availability.

3. Post-observation mortality. This measure reflects only those physical and mental characteristics associated with individual longevity, many of which may be unrelated to functional ability.

In this paper, we propose and estimate a new index which is designed to measure the "true disability" status of an individual. This index treats true disability status as an unobservable phenomenon, but one which is both causally related to a variety of exogenous characteristics of an individual and correlated with a variety of observed measures of statuses and behaviors believed to be associated with true limits on functioning. In Section I, we define what we mean by true disability, and distinguish it from the related concepts of impairment, handicap, and health status. Section II discusses the importance of an objective and reliable indicator of disability status for economic research, using the studies of the work-effort response of individuals to available income transfers to illustrate the problem. Section III presents the specification of our structural model for estimating true disability as a latent variable, and Section IV presents the resulting estimates of the relevant parameters. Finally, we compare our estimated index with a limited self-reported measure in a simple model of labor force participation.

I. DISABILITY, IMPAIRMENTS, AND HEALTH STATUS

A definition of disablement or impairment is necessary to identify the population group we will label "disabled." Unfortunately, there is no definition that is unambiguously the correct one, as the concept of disability ultimately rests on a social judgment. Only when a person falls significantly below some threshold of deviation from the level of physical or mental capacity required to engage in productive activities within a social environment does society designate that person as sufficiently atypical to be classified as disabled. However, no unambiguous threshold has been identified and no uncontroversial indicator exists by which to designate certain individuals as disabled or to indicate the severity of their condition. All efforts to identify the disabled population and to measure the extent of their limitation have relied on some surrogate or proxy indicator, often a response to a survey questionnaire.

We seek a measure of disability appropriate for analyzing the nature and determinants of economic behavior. Such a measure should accurately reflect the functional capabilities possessed by individuals relevant to the aspect of behavior being studied. Hence, in analyzing individual market work behavior, we define disability as a shortfall in the physical, mental, or emotional capability of an individual to adequately perform activities required for jobs which, on other grounds, he or she would be qualified to hold. Consistent with this functional-capability definition of disability, we define handicap to be a limitation of a physical, mental, or emotional sort which reduces, to varying degrees, one's ability to perform the functions required for jobs as well as other activities. And we define impairment as a loss in physiological, anatomical or mental capacity which may lead to a handicap. These definitions reflect three considerations which affect an individual's success in the labor market: whether or not an individual is limited in specific work-related functions; the severity of these limitations; and the requirements in terms of functional performance that are imposed by occupations which an individual could normally hold, given his or her age, education, training, and skills (see Nagi, 1969).

With these definitions, an individual's true disability status is distinguishable from his or her health status, even though the two concepts overlap. Health status concerns deviations from what is commonly referred to as "good health," and typically involves impairments in one or more of the body's systems. Such impairments are often short-term (e.g., influenza); they may also be long term or terminal. When they are long term, they may or may not impair a person's ability to perform the functions required by his or her occupation. Thus, a severely disabled person (e.g., a quadriplegic) may well be in good health. Conversely, a person sick with influenza may have no job-prejudicing impairments. On the other hand, a person bedridden with terminal cancer has poor health status and is severely disabled.[1]

II. DISABILITY STATUS AND ECONOMIC BEHAVIOR

An individual's disability (and health) status is relevant to a wide variety of his or her economic choices--e.g., marital status, fertility, labor supply, occupation, and geographic location. Studies of the determinants of individual choice in all of these dimensions typically focus on the role of economic and demographic factors in explaining observed behavior. Success in obtaining unbiased estimates of the role played by the economic variables requires accurate measures of control variables which are also related to the observed status, including the presence and severity of handicaps.

Consider, for example, studies analyzing the decision to retire, most of which have relied upon some form of self-reported disability (or health) status. Use of such self-report measures has been criticized on grounds that the disability or health-status responses offered by individuals both reflect and serve to justify decisions that have already been made (see Parsons, 1982; Leonard, 1986). If, for stigma or other reasons, respondents rationalize a decision not to work (e.g., retiring before age 65) by citing work-related handicaps (or poor health) as reasons, the coefficient associated with the self-reported disability status variable will be larger than that on a variable measuring true disability status (Bound, 1987). As a corollary, the measured effect of expected labor market income on the decision to work will be a biased estimate of its true effect.[2]

Parsons (1982) attempted to evaluate the problems associated with use of a self-reported disability index in a single equation retirement/ replacement rate/disability transfer model. Comparing results from using both a self-reported disability indicator and actual mortality experience five years after the observed work status choice decision, be found that the subsequent mortality measure was less closely related to the work effort decision than was the contemporaneous self-reported measure, and that the replacement rate was more significant when the mortality measure was used. From this exercise, he concluded that use of self-reports of disability in models of behavior tends to distort the measured effect of economic variables.

The use of the subsequent mortality indicator to proxy true disability status at the time of a work-retirement decision has been criticized by Haveman and Wolfe (1984) as being arbitrary, a notoriously weak proxy for work-impairing limitations (the factor which is likely to be dominant in affecting work choices), and as excluding a wide variety of handicaps that are unrelated to longevity. The results of Colvez and Blanchet (1981), indicating the inverse movement over time of mortality rates and the incidence of handicaps and impairments of a wide variety of types cast further doubt on the appropriateness of this indicator in studies of individual behavior. The puzzle is made even more complicated by the findings of recent studies indicating that individual self-reports of health are stable over time, highly correlated with medical doctor reports, and show no evidence of exaggeration of problems related to being out of the work force (see Maddox and Douglass, 1973; Waldron, Herold, and Dunn, 1982; Ferraro, 1980 and Mossey and Shapiro, 1982).

Existing research findings, then, leave unresolved the choice of a disability indicator for studies of individual economic behavior. Both simple self-reports of the disabled/nondisabled status of the individual and indicators of current disability based on physicians reports or subsequent mortality have serious limitations for use in behavioral studies. More comprehensive self-reported indicators, especially those that reflect the severity of impairing conditions, may be subject to fewer of these weaknesses.

III. AN INDICATOR OF TRUE DISABILITY: THE MODEL

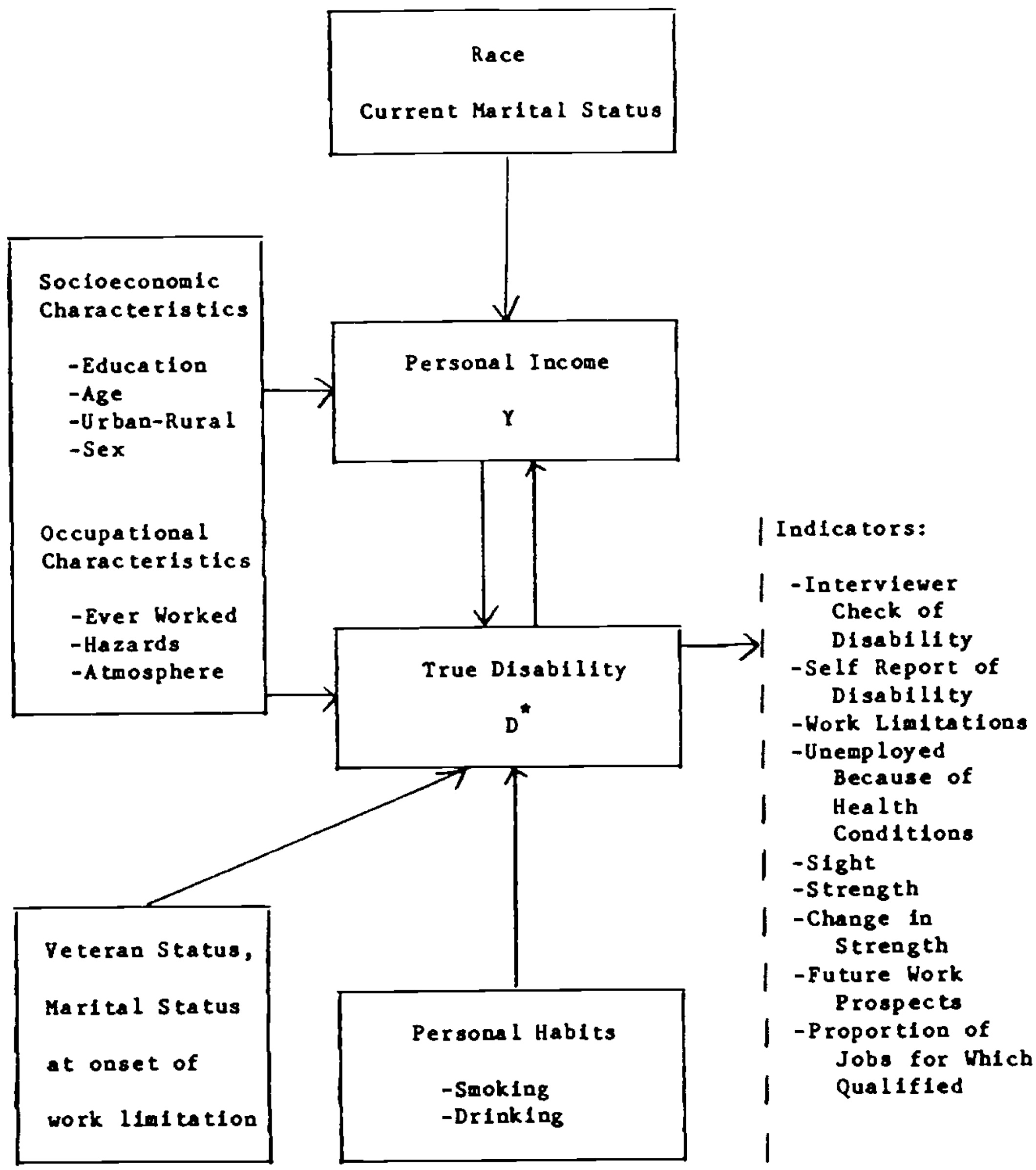
Given the absence of a reliable empirical counterpart to an economic concept of disability--and the controversy regarding use of simple self-reported disability or subsequent mortality indicators in the analysis of the determination of individual choice--an attempt to develop an independent, more comprehensive measure of true disability is in order. In this section, we present our proposed measure. This indicator is designed to be a multi-purpose indicator of true disability, and emphasizes the functional and work-related character of impairing conditions. Hence, the indicator is applicable for a number of purposes, including the identification of the size and characteristics of the disabled population, and as a control variable in analyses of the determinants of economic behavior.

Consistent with the economic definition of disability presented in Section I, a reliable measure of true disability should reflect three phenomena: (1) functional limitations, (2) severity of handicap, and (3) occupational capacity related to functional limitations. The index of "true disability" proposed here treats disability status as an unobservable condition, which is both causally related to a number of exogenous individual characteristics and correlated with a number of observed indicators of individual health and disability, and with the availability of employment for which one is qualified. This measure of "true disability" is modelled jointly along with the individual's income from a system of structural equations. Figure 1 presents a sketch of the model.

The relationship between the disability index and income net of transfers (personal income) is clear. Better health and less severe handicaps are positively related to productivity and hence one's earnings. On the other hand, the demand for health increases with the wage rate. In the model, true disability and income are also determined by a set of exogenous variables. These include the socioeconomic characteristics of the individual (education, age, race, urban-rural, sex, marital and veteran status), personal habits, and the requirements and characteristics of an individual's normal occupation. They are shown in the boxes on the left-hand side and bottom of the figure. The exclusion of race and current marital status variables from the true disability structural equation, and of the variables capturing personal habits and

Figure 1

Model of Disability as Latent Variable



veteran and marital status at the onset of any impairment from the income equation identify the model.

The model also includes a set of observable disability indicators--variables which reflect the presence or absence of impairing conditions or functional limitations and provide indirect measures of the underlying disability. These are shown on the right-hand side of the figure, and include the extent of disability reported by both the interviewer and the respondent, self-reported work limitations, whether the individual is unemployed because of a health problem, the presence of a sight problem, an indicator of strength and of the change in strength, and the percentage of weighted occupations for which a person is qualified (based on a comparison of individual capabilities with requirements of each occupation from the Dictionary of Occupational Titles). Among these, the self-report of disability and self-report of future work prospects are ordered 4-category discrete variables; the interviewer disability check, and the presence of a sight problem are ordered 3-category discrete variables; self-report work limitations, being unemployed because of a health problem, and the strength indicator are binary variables; the variables reflecting strength change and the percent of jobs for which the individual is qualified are continuous indicators. Each of these 9 indicators are taken to be associated with the measurement of the unobserved "true disability" index.

Let Y be the logarithm of individual personal income, D^* be the unobservable disability index, and $\underline{X}_1$, $\underline{X}_2$ be vectors of exogenous characteristics of the individual. In essence, we estimate a three stage model. In the first stage, a set of measurement equations for D^* are estimated including Y (personal income). In the second stage, we estimate a set of reduced form equations for D* and Y from the measurement equations (stage one). Also in this stage, we obtain the estimates of the coefficient parameters of the measurement equations. In the third stage, we estimate a structural model in which D* and Y are jointly determined. We begin these estimates with the reduced form estimates from stage two. Throughout, we use ordered polychotomous probit equations and linear regressions as appropriate to the indicator variable.

The structure of this model, using the notation and parameters corresponding to the notation of all post-parameterized variables and parameters in the Appendix[3], can be stated as

$$(1) \qquad Y + \beta_{12} D^* = \underline{\gamma}_1' \underline{X}_1 + U_1$$

$$\beta_{21} Y + D^* = \underline{\gamma}_2' \underline{X}_2 + U_2$$

where $U' = (U_1, U_2)$ is bivariate normal and is i.i.d. across individuals. The measurement equations for D^* are

$$(2) \qquad Z_j = \alpha_j + \lambda_j D^* + \epsilon_j, \qquad j = 1, 2, \ldots, 9$$

where Z_j is a measure of the unobserved variable D^*; the ϵ_j's are independent of U and have an i.i.d. normal distribution across individuals. In order to identify the measurement equations, α_1 and λ_1 have been normalized to be 0 and 1 (or -1), respectively.[4] Solving equations (1) and inserting the reduced form of D^* into (2), we obtain a set of reduced form equations.

$$(3) \qquad Y = \underline{\Pi}_1' \underline{X} + \eta_1$$

$$D^* = \underline{\Pi}_2' \underline{X} + \eta_2$$

$$Z_1 = \underline{\Pi}_2' \underline{X} + \eta_2 + \epsilon_1$$

$$Z_j = \alpha_j + \lambda_j \underline{\Pi}_2' \underline{X} + \lambda_j \eta_2 + \epsilon_j, \qquad j = 2, \ldots, 9$$

Since $U' = (U_1, U_2)$ is a bivariate normal and $\eta = (\eta_1, \eta_2)$, the linear combination of U_1 and U_2 is also a bivariate normal. By the property of bivariate normal distributions, the conditional expectation of η_2 on η_1 is equal to $\sigma_{12} \sigma_1^{-2} \eta_1$; that is equal to $\sigma_{12} \sigma_1^{-2} (Y - \underline{\Pi}_1' \underline{X})$ in our model. Based on this, equations (3) can be restated as:[5]

$$(4) \qquad Y = \underline{\Pi}_1' \underline{X} + \eta_1$$

$$(5) \qquad Z_1 = \underline{\Pi}_2' \underline{X} + \sigma_{12} \sigma_1^{-2} (Y - \underline{\Pi}_1' \underline{X}) + \xi_1$$

$$(6) \qquad Z_j = \alpha_j + \lambda_j \underline{\Pi}_2' \underline{X} + \lambda_j \sigma_{12} \sigma_1^{-2} (Y - \underline{\Pi}_1' \underline{X}) + \xi_j, \qquad j = 2, \ldots, 9$$

In our model, two observed indicators are continuous variables and seven are ordered polychotomous variables which relate to Z_j with K categories. Let I_j be an ordered polychotomous indicator with values 1, ..., K. The value of I_j is associated with Z_j as follows

$$I_j = 1 \qquad \text{if } Z_j < 0$$

$$I_j = 2 \qquad \text{if } 0 \leq Z_j < \mu_{j1}$$

$$\vdots$$

$$I_j = K \qquad \text{if } \mu_{jK-2} \leq Z_j < \infty$$

Due to the computational complexity of the model, maximum likelihood estimation for this model is generally not feasible. Lee (1982) proposed a three-stage procedure on a multiple discrete indicators model, which is a consistent and tractable estimation procedure. The estimation in our model follows this three-stage procedure.

Stage 1. To estimate the reduced form parameters of equations (4), (5), and (6) separately.

Equations (5) and (6) can be rearranged into

$$(5') \quad Z_1 = \delta_{11} Y + \underline{\delta}_{12}' \underline{X} + \xi_1$$

$$(6') \quad Z_j = \delta_{j1} Y + \underline{\delta}_{j2}' \underline{X} + \xi_j, \qquad j = 2, \ldots, 9$$

where

$$\delta_{11} = \sigma_{12} \sigma_1^{-2}$$

$$\underline{\delta}_{12}' = \underline{\Pi}_2' - \sigma_{12} \sigma_1^{-2} \underline{\Pi}_1'$$

$$\delta_{j1} = \lambda_j \sigma_{12} \sigma_1^{-2} \qquad j = 2, \ldots, 9$$

$$\underline{\delta}_{j2}' = \alpha_j + \lambda_j(\underline{\Pi}_2' - \sigma_{12} \sigma_1^{-2} \underline{\Pi}_1')$$

Equation (4) and the equations for the two continuous indicators (the change in strength and the percent of jobs for which the individual is qualified) can be estimated by linear regression. Without loss of generality, we assume that the 8th and 9th measures are the two continuous indicators. The estimators of their coefficient parameters are

$$(7) \quad \hat{\underline{\Pi}}_1 = (\underline{X}' \underline{X})^{-1} \underline{X}' Y$$

$$\hat{\underline{\delta}}_j = \begin{pmatrix} \hat{\delta}_{j1} \\ \hat{\underline{\delta}}_{j2} \end{pmatrix} = \left((Y, \underline{X})' (Y, \underline{X})\right)^{-1} (Y, \underline{X})' Z_j \qquad j = 8, 9$$

and variances can be estimated by $\hat{\sigma}^2_{\eta_1} = \frac{1}{N}(Y - \underline{\hat{\Pi}}_1' \underline{X})' (Y - \underline{\hat{\Pi}}_1' \underline{X})$ and $\hat{\sigma}^2_{\xi_j} = \frac{1}{N_j}\left(Z_j - \underline{\hat{\delta}}_j' (Y, \underline{X})\right)' \left(Z_j - \underline{\hat{\delta}}_j' (Y, \underline{X})\right)$, for $j = 8, 9$ respectively. The remainder of the reduced form equations in (5') and (6') are polychotomous probit equations, and can be estimated separately by maximum likelihood procedures with a log-likelihood function

$$(8) \qquad \ln L_j(\underline{\theta}_j) = \Sigma_{i=1}^{N_j} \Sigma_{k=1}^{K} d_{ik} \ln\left(\Phi\left(\mu_{jk-1} - \underline{\delta}_j' (Y, \underline{X})\right) - \Phi\left(\mu_{jk-2} - \underline{\delta}_j' (Y, \underline{X})\right)\right)$$

for $j = 1, 2, \ldots 7$

where

$$\underline{\theta}_j' = (\underline{\delta}_j', \mu_{j1}, \ldots, \mu_{jK-2}),\ \mu_{-1} = -\infty,\ \mu_{j0} = 0, \text{ and } \mu_{jK-1} = \infty.$$

and

$$d_{ik} = \begin{cases} 1 \text{ if } I_i = k \\ 0 \text{ otherwise} \end{cases} \qquad k = 2, \ldots, K$$

and $d_{i1} = 1 - d_{i2}, \ldots, d_{iK}$. i denotes the observation in each polychotomous probit equation. $\Phi(v)$ is the standard normal distribution function evaluated at v.

The estimates of $\underline{\theta}_j$ in each polychotomous probit equation can be derived by maximizing (8) for $j = 1, \ldots, 7$. Let $\underline{\hat{\omega}}' = (\underline{\hat{\Pi}}_1', \underline{\hat{\delta}}_1', \underline{\hat{\delta}}_2', \ldots, \underline{\hat{\delta}}_9')$ be the estimates of $\underline{\omega}' = (\underline{\Pi}_1', \underline{\delta}_1', \underline{\delta}_2', \ldots, \underline{\delta}_9')$. Evidently, $\sqrt{N}(\underline{\hat{\omega}} - \underline{\omega}) \xrightarrow{D} N(\underline{0}, \Omega_\omega)$ by the strong law of large numbers.

Let W be the diagonal matrix which contains only the diagonal element of Ω_ω, and $\hat{W}$ be the consistent estimate of W. Then

$$(9) \qquad \hat{W} = \begin{bmatrix} \hat{W}_{\underline{\Pi}_1} & & & & & & 0 \\ & \hat{W}_{\underline{\delta}_1} & & & & & \\ & & \hat{W}_{\underline{\delta}_2} & & & & \\ & & & \cdot & & & \\ & & & & \cdot & & \\ & 0 & & & & \cdot & \\ & & & & & & \hat{W}_{\underline{\delta}_9} \end{bmatrix}$$

where

$$\hat{W}_{\underline{\Pi}_1} = \hat{\sigma}^2_{\eta_1} \left(\frac{1}{N} (\underline{X}' \ \underline{X})\right)^{-1}, \quad \hat{W}_{\underline{\delta}_j} = \hat{\sigma}^2_{\xi_j} \left(\frac{1}{N_j} (Y, \underline{X})' \ (Y, \underline{X})\right)^{-1}, \quad j = 8, 9$$

$$\hat{W}_{\underline{\delta}_j} = J_j \left(\frac{1}{N_j} \Sigma^{N_j}_{i=1} \frac{\partial \ell_{ij}}{\partial \theta_j} \frac{\partial \ell_{ij}}{\partial \theta_j}\right)^{-1} J_j, \quad j = 1, \ldots, 7,$$

and

$$\ell_{ij} = \Sigma^{K}_{k=1} d_{ik} \ln\left(\Phi\left(\hat{\mu}_{jk-1} - \hat{\underline{\delta}}_j' \ (Y, \underline{X})\right) - \Phi\left(\hat{\mu}_{jk-2} - \hat{\underline{\delta}}_j' \ (Y, \underline{X})\right)\right)$$

Stage 2. To estimate the reduced form parameters $\underline{\Pi}_1'$, $\underline{\Pi}_2'$ and the coefficient parameters in the measurement equations.

Let

$$\underline{\tau}' = (\underline{\Pi}_1', \underline{\Pi}_2', \alpha_2, \lambda_2, \alpha_3, \lambda_3, \ldots, \alpha_9, \lambda_9, \sigma_{12} \sigma_1^{-2}),$$

then ω as defined above is a function of $\underline{\tau}$:

$$\underline{\omega} = h(\underline{\tau})$$

The relations are

$$\underline{\Pi}_1 = \underline{\Pi}_1$$

$$\delta_{11} = \sigma_{12}\,\sigma_1^{-2}$$

$$\underline{\delta}_{12} = \underline{\Pi}_2 - \sigma_{12}\,\sigma_1^{-2}\,\underline{\Pi}_1 \qquad j = 2, \ldots, 9$$

$$\delta_{j1} = \lambda_j\,\sigma_{12}\,\sigma_1^{-2}$$

$$\underline{\delta}_{j2} = \alpha_j + \lambda_j\,(\underline{\Pi}_2 - \sigma_{12}\,\sigma_1^{-2}\,\underline{\Pi}_1)$$

To estimate $\underline{\tau}$, we minimize the following quadratic form by choosing $\underline{\tau}$ to

$$\min_{\underline{\tau}} (\hat{\underline{\omega}} - h(\underline{\tau}))'\,\hat{W}^{-1}\,(\hat{\underline{\omega}} - h(\underline{\tau}))$$

$\hat{\underline{\tau}}$ is strongly consistent and has an asymptotic normal distribution

$$\sqrt{N}\,(\hat{\underline{\tau}} - \underline{\tau}) \xrightarrow{D} N(0, \Omega_\tau)$$

where

$$\Omega_\tau = (\nabla h'(\underline{\tau})W^{-1}\,\nabla h(\underline{\tau}))^{-1}\,(\nabla h'(\underline{\tau})W^{-1}\,\Omega_\omega W^{-1}\,\nabla h(\underline{\tau}))(\nabla h'(\underline{\tau})W^{-1}\,\nabla h(\underline{\tau}))^{-1}$$

and $\nabla\,h(\underline{\tau}) = \partial h(\underline{\tau})/\partial \underline{\tau}'$

<u>Stage 3</u>. To estimate the structural coefficient parameters B, Γ from $\hat{\Pi}_1$ and $\hat{\Pi}_2$.

Define vec' Π = $(\underline{\Pi}_1', \underline{\Pi}_2')$. Let L be the matrix such that vec Π = $L\underline{\tau}$ and vec $\hat{\Pi} = L\hat{\underline{\tau}}$. Let $\hat{\Omega}_\tau$ be the consistent estimate of Ω_τ. Then, the estimate of the variance - covariance matrix of vec Π is equal to $L\,\hat{\Omega}_\tau\,L'$. From structural equations (1) and reduced form equations of Y and D^* in (3), Π is equal to $B^{-1}\,\Gamma$. To estimate B and Γ, we minimize

$$(10) \quad Q = \mathrm{vec}'(\hat{\Pi} - B^{-1}\Gamma)\,(L\,\hat{\Omega}_\tau\,L')^{-1}\,\mathrm{vec}(\hat{\Pi} - B^{-1}\Gamma)$$

w.r.t. B and Γ, subject to the fixed parameters and exclusion constraints imposed on B and Γ. The estimates of B and Γ are consistent and have an asymptotic normal distribution. Let $\underline{\theta}' = (\beta_{12}, \beta_{21}, \underline{\gamma}_1', \underline{\gamma}_2')$. Define a function g such that $\mathrm{vec}\,\Pi \equiv \mathrm{vec}\,B^{-1}\Gamma = g(\underline{\theta})$. Then, the asymptotic normal distribution of $\hat{\underline{\theta}}'$, i.e., $\hat{B}$ and $\hat{\Gamma}$ would be

$$\sqrt{N}\,(\hat{\underline{\theta}} - \underline{\theta}) \xrightarrow{D} N\left(0, \left(\nabla g'(\underline{\theta})(L\,\Omega_\tau\,L')^{-1}\,\nabla g(\underline{\theta})\right)^{-1}\right)$$

where

$$\nabla g(\underline{\theta}) = \partial g(\underline{\theta})/\partial\underline{\theta}'$$

The data used are the 5222 men and 4299 women aged 18-64 in the 1978 Social Security Administration Survey of Disabled and Nondisabled Adults. To these data we added a constructed variable measuring the percentage of occupations for which a person is qualified, based on information in the Dictionary of Occupational Titles compared to their own education and physical capabilities. We weighted the education and physical requirements of 3-digit occupations by the prevalence of each occupation by sex, and then matched these to individuals according to their education and physical characteristics.

In Table 1, the notation and definition of the variables is provided. Tables 2-6 present the estimation results from our model, fit separately over male and female observations.[6]

IV. AN INDICATOR OF TRUE DISABILITY: EMPIRICAL RESULTS

Tables 2 and 3 present the reduced form estimates of the first stage of the model, represented in equations (4) - (6), for males and females

Table 1

Description of the Variables

Variables		$\bar{X}$	σ	N[a]	
Exogenous Variables					
Race: White	race of respondent, 1=white, 0=else	0.85	0.36	9521	
Black	race of respondent, 1=black, 0=else	0.14	0.34	9521	
Education	number of years of education	10.62	3.52	9521	
Age	age of respondent in years	45.72	13.74	9521	
Sex	sex of respondent, 1=female, 0=male	0.45	0.50	9521	
Urban-Rural	urban-rural residence of respondent, 1=rural, 0=urban	0.24	0.43	9521	
Current Marital Status	marital status of respondent, 1=currently married, 0=else	0.67	0.47	9521	
Marital Status at Onset of Disability	marital status of respondent when initially disabled (or current if not disabled), 1=married, 0=else	0.69	0.46	9521	
Income	log of total personal income of respondent in 1977	3.61	4.29	9521	
Vet. Mos.	number of months respondent was in military service	12.34	34.35	9521	
Vet. War	respondent a war veteran, 1=in military during wartime, 0=else	0.26	0.44	9521	
Booze	respondent drinks excessively: yes=1; sometimes=.5; no=0	0.16	0.37	9521	
Cigs.[b]	cigarette consumption per day times smoking life, in packs	14.75	21.13	9521	
Occupational characteristics[c]					
Hazards	exposure to hazardous conditions on job before onset of work limitations	15.56	19.50	9521	
Atmosphere	exposure to adverse atmospheric conditions on job before onset of work limitations	1.90	1.31	9521	
Work-Nonwork	1=respondent has never worked, 0=otherwise	0.25	0.43	9521	
Indicator Variables					
Interviewer Check of Disability	severe=1, secondary=2, occupationally=2, none=3	1.91	0.96	9521	1=4910 2= 575 3=4036
Self Report of Health		2.31	1.09	9439	
Poor	1=respondent reports poor health				1=2879
Fair	2=respondent reports fair health				2=2436
Good	3=respondent reports good health				3=2400
Excellent	4=respondent reports excellent health				4=1724
Limited Work	dummy variable, 1=respondent is limited in work because of an impairment, 0=else	0.62	0.49	9495	1=5849 0=3646
Strength	current strength of respondent: dummy, 1=trouble lifting 10 lbs. and some trouble sitting for long, 0=else	0.65	0.48	9301	1=6085 0=3216

Table 1, continued

Variables		$\bar{X}$	σ	N[a]	
Strength Change	change in strength from before onset of work limitation to present	0.23	0.39	9521	
Unemployed-Health	dummy variable, 1=respondent is unemployed because of a health condition	0.49	0.50	9521	
Future Work	(for respondents unemployed because of health condition) 4=respondent reports definitely or is currently working, 3=respondent reports maybe working in future, 2=respondent reports not sure will work in future, 1=will not work in future	1.94	1.11	4715	1=2564 2= 387 3=1258 4= 506
Sight	blind or trouble seeing with glasses=1, no trouble seeing with glasses=2, does not wear glasses=3	2.10	0.67	9521	1=1688 2=5146 3=2687
Job Qual.[d]	percentage of jobs for which respondent qualifies	0.46	0.36	9521	

[a]Number of observations over which variable defined.

[b]For current smokers, packs of cigarettes smoked per day times (Age - 18); for former smokers, packs of cigarettes smoked per day times (Age when quit smoking - 18) times $(.8)^t$, when t equals years since respondent quit smoking.

[c]These variables were constructed by matching the respondent's 3-digit occupation before onset of a work limitation (or current occupation if no work limitation) to the physical demands of the occupations, obtained from the Dictionary of Occupational Titles (DOT). Values represent percentage of persons in occupation with specified requirement.

Hazards: 1=if work requires exposure to conditions in which there is danger to life, health, or bodily injury

Atmosphere: 1=if work requires exposure to fumes, odors, toxic conditions, dust, or poor ventilation

[d]The percentage of the jobs in the economy for which a person is qualified, based on a comparison of the physical (climb, stoop, reach, strength, sight) and education requirements of 3 digit occupations (obtained from the Dictionary of Occupational Titles) with the physical and educational capabilities of the individual, with occupations weighted by their proportion of total employment, done separately for each sex.

Table 2

Stage 1: Reduced Form Estimates of Equations (4) - (6); Personal Income and the True Disability Indicators

[Equations (8), (9) and (10) Ordinary Least Squares Estimation; Other Equations Ordered Probit Maximum Likelihood Estimation]
Males, Unit = 10^{-3} (t-value)

	Interviewer Check of Disability (1)	Self-Report of Disability (2)	Limited Work (3)	Unemployed Health (4)	Future Work (5)
Education	-37.76 (-1.53)	-16.88 (-0.99)	43.17 (1.60)	75.09*** (2.76)	-18.31 (-0.76)
Education Square	3.45*** (2.80)	4.09*** (4.78)	-3.56*** (-2.73)	-5.64*** (-3.97)	2.00 (1.51)
Age	-85.38*** (-6.01)	-91.62*** (-9.33)	111.72*** (7.51)	64.82*** (3.93)	-33.88* (-1.92)
Age Square	0.66*** (4.17)	0.83*** (7.57)	-1.01*** (-6.00)	-0.46** (-2.50)	-0.06 (-0.29)
Urban-Rural	172.45*** (3.22)	14.12 (0.37)	-159.37*** (-2.84)	-282.66*** (-4.54)	-43.80 (-0.75)
Hazards	1.79 (1.27)	-0.71 (-0.73)	-1.58 (-1.08)	-1.81 (-1.09)	-0.41 (-0.28)
Atmosphere	-60.15* (-1.74)	-75.48*** (-3.06)	140.65*** (3.82)	24.08 (0.59)	-54.30 (-1.48)
Work-Nonwork	-343.24*** (-2.67)	-348.16*** (-3.82)	447.83*** (3.28)	516.88*** (3.45)	-289.44** (-2.20)
White	-249.92 (-1.23)	44.27 (0.31)	259.99 (1.27)	77.05 (0.33)	-137.17 (-0.65)
Black	-281.35 (-1.33)	-50.45 (-0.34)	183.50 (0.85)	2.62 (0.01)	23.73 (0.11)
Current Marital Status	57.99 (0.69)	-33.46 (-0.55)	-9.80 (-0.10)	-102.44 (-1.09)	-123.18* (-1.72)
Marital Status at Onset	-52.12 (-0.61)	-62.84 (-1.00)	-103.46 (-1.05)	241.56** (2.50)	-51.45 (-0.68)

Table 2, continued

	Interviewer Check of Disability (1)	Self-Report of Disability (2)	Limited Work (3)	Unemployed Health (4)	Future Work (5)
Vet. Mos.	-0.59	-0.74*	0.09	0.84	0.45
	(-0.99)	(-1.69)	(0.14)	(1.26)	(0.87)
Vet. War	-30.57	14.00	11.05	58.65	-58.85
	(-0.53)	(0.35)	(0.18)	(0.89)	(-1.08)
Booze	86.03	6.90	-85.15	-87.95	131.08**
	(1.55)	(0.18)	(-1.47)	(-1.34)	(2.18)
Cigs	-3.05***	-2.37***	4.01***	4.01***	1.52
	(-2.79)	(-3.19)	(3.30)	(3.27)	(1.61)
Income	256.20***	144.02***	-223.61***	-280.46***	89.48***
	(46.01)	(33.84)	(-36.09)	(-43.99)	(9.04)
Constant	1545.65***	2344.86***	-1744.46***	-1119.05**	2081.16
	(3.88)	(8.44)	(-4.21)	(-2.41)	(4.36)
Log Likelihood	-2335.28	-5506.01	-1694.11	-1410.54	-2895.93

Table 2, continued

	Sight (6)	Strength (7)	Strength Change (8)	Job Qualified (9)	Income (10)
Education	-21.69 (-1.29)	-15.53 (-0.74)	10.32 (1.82)	56.24*** (18.53)	-49.36 (-0.89)
Education Square	-0.003 (-0.003)	-0.54 (-0.49)	-0.56** (-1.96)	0.16 (1.04)	16.31*** (5.88)
Age	-26.12** (-2.53)	750.64*** (5.26)	11.82*** (3.53)	-18.24*** (-10.16)	1.03 (0.03)
Age Square	-0.17 (-1.47)	-0.67*** (-4.32)	-0.12*** (-3.29)	0.16*** (7.98)	-1.28*** (-3.50)
Urban-Rural	36.03 (0.92)	-158.29*** (-3.14)	-2.16 (-0.17)	1.61 (0.23)	967.96*** (7.64)
Hazards	-0.44 (0.45)	-1.82 (-1.42)	1.12*** (3.34)	-0.05 (-0.29)	11.38*** (3.49)
Atmosphere	63.67** (2.53)	21.03 (0.66)	47.04*** (5.58)	-7.88* (-1.74)	-137.75* (-1.67)
Work-Nonwork	174.36* (1.88)	165.35 (1.41)	195.13*** (6.26)	-11.56 (-0.69)	-994.63*** (-3.27)
White	89.31 (0.62)	147.19 (0.77)	63.98 (1.33)	17.80 (0.69)	-189.70 (-0.40)
Black	352.56** (2.35)	12.33 (0.06)	66.28 (1.32)	41.15 (1.53)	-265.99 (-0.54)
Current Marital Status	-0.69 (-0.01)	87.38 (1.21)	11.04 (0.53)	-6.07 (-0.55)	1411.81*** (7.03)
Marital Status at Onset	-26.17 (-0.41)	23.27 (0.31)	-0.77 (-0.04)	-1.34 (-0.12)	-198.86 (-0.95)
Vet. Mos.	-0.06 (-0.13)	-0.12 (-0.24)	-0.06 (-0.40)	0.004 (0.05)	-2.18 (-1.51)
Vet. War	-103.24* (-2.55)	58.58 (1.17)	6.05 (0.44)	0.35 (0.05)	-45.99 (-0.34)
Booze	57.82 (1.42)	-70.47 (-1.33)	-13.83 (-1.03)	11.26 (1.56)	855.78*** (6.52)

Table 2, continued

	Sight (6)	Strength (7)	Strength Change (8)	Job Qualified (9)	Income (10)
Cigs	-0.58	1.77**	0.18	-0.05	-5.68**
	(-0.80)	(2.01)	(0.71)	(-0.35)	(-2.32)
Income	29.11***	-123.72***	-32.57***	21.36***	
	(6.89)	(-22.58)	(-22.99)	(28.11)	
Constant	2635.65***	-2067.66***	-121.40	219.65***	4840.20***
	(9.15)	(-5.27)	(-1.29)	(4.35)	(5.27)
Log Likelihood	-4558.11	-2560.13	R^2 = 0.15	R^2 = 0.67	R^2 = 0.28

*Statistically significant at the 10% level.
**Statistically significant at the 5% level.
***Statistically significant at the 1% level.

Table 3

Stage 1: Reduced Form Estimates of Equations (4) - (6); Personal Income and the True Disability Indicators

[Equations (8), (9) and (10) Ordinary Least Squares Estimation; Other Equations Ordered Probit Maximum Likelihood Estimation]
Females, Unit = 10^{-3} (t-value)

	Interviewer Check of Disability (1)	Self-Report of Disability (2)	Limited Work (3)	Unemployed Health (4)	Future Work (5)
Education	35.77 (1.19)	19.20 (0.86)	-33.57 (-1.08)	-438.40 (-1.39)	-24.11 (-0.73)
Education Square	1.41 (0.96)	3.50*** (3.23)	-1.30 (-0.88)	-0.60 (-0.38)	3.27* (1.85)
Age	-73.40*** (-5.53)	-66.61*** (-7.00)	69.49*** (5.35)	76.04*** (5.13)	-6.77 (-0.31)
Age Square	0.41*** (2.70)	0.46*** (4.19)	-0.41*** (-2.72)	-0.48*** (-2.83)	-0.36 (-1.53)
Urban-Rural	194.13*** (3.76)	48.65 (1.22)	-132.38** (-2.53)	-381.31*** (-6.66)	-86.14 (-1.18)
Hazards	-0.09 (-0.05)	-1.53 (-1.08)	1.66 (0.88)	-1.17 (-0.54)	0.71 (0.29)
Atmosphere	-52.98 (-1.33)	-41.32 (-1.39)	57.44 (1.43)	56.73 (1.28)	50.54 (1.00)
Work-Nonwork	249.29** (2.33)	110.85 (1.37)	-219.03** (-2.04)	-343.58*** (-2.89)	54.07 (0.39)
White	-92.58 (-0.50)	24.13 (0.17)	63.58 (0.34)	-85.37 (-0.42)	-438.23* (-1.82)
Black	-376.47** (-1.96)	-260.66* (-1.75)	328.03* (1.69)	303.62 (1.43)	-90.68 (-0.37)
Current Marital Status	528.54*** (5.81)	328.03*** (4.70)	-457.60*** (-4.66)	-573.90*** (-5.98)	-98.70 (-1.19)
Marital Status at Onset	-36.64 (-0.40)	-21.06 (-0.30)	-28.08 (-0.28)	63.00 (0.64)	-98.73 (-1.18)

Table 3, continued

	Interviewer Check of Disability (1)	Self-Report of Disability (2)	Limited Work (3)	Unemployed Health (4)	Future Work (5)
Vet. Mos.	-7.28	-4.62	3.27	7.76	-1.79
	(-1.09)	(-1.38)	(0.59)	(1.10)	(-0.40)
Vet. War	-68.75	164.55	166.89	16.72	-595.91*
	(-0.22)	(0.79)	(0.58)	(0.05)	(-1.77)
Booze	90.91	28.82	-95.78	-249.55***	5.73
	(1.10)	(0.48)	(-1.17)	(-2.60)	(0.46)
Cigs	-2.62***	-1.05	2.31*	4.06***	3.21**
	(-2.00)	(-1.02)	(1.67)	(2.89)	(2.17)
Income	175.52***	102.69***	-145.89***	-203.70***	91.77***
	(27.97)	(21.09)	(-23.64)	(-27.46)	(6.55)
Constant	1259.30***	1772.67***	-843.44**	-1076.95**	1522.13***
	(3.32)	(6.37)	(-2.24)	(-2.56)	(2.64)
Log Likelihood	-2509.66	-4875.79	-2006.92	-1744.88	-1916.94

Table 3, continued

	Sight (6)	Strength (7)	Strength Change (8)	Job Qualified (9)	Income (10)
Education	34.11 (1.51)	42.51 (1.54)	-1.61 (-0.28)	79.70*** (18.70)	-35.31 (-0.52)
Education Square	-1.52 (-1.39)	-4.36*** (-3.14)	-0.26 (-0.93)	-0.78*** (-3.78)	10.56*** (3.18)
Age	-15.52 (-1.56)	70.69*** (5.32)	8.35*** (3.28)	-13.70*** (-7.35)	-41.89 (-1.40)
Age Square	-0.27** (-2.32)	-0.49*** (-3.25)	-0.05* (-1.80)	0.08*** (3.88)	-0.49 (-1.39)
Urban-Rural	20.02 (0.48)	-173.41*** (-3.35)	-23.13** (-2.16)	8.20 (1.04)	401.22*** (3.18)
Hazards	-1.11 (-0.76)	4.43** (2.38)	1.14*** (3.01)	-1.15*** (-4.16)	16.08*** (3.61)
Atmosphere	29.95 (0.96)	76.51** (1.96)	4.24 (0.53)	-17.03*** (-2.90)	-260.23*** (-2.76)
Work-Nonwork	187.03** (2.21)	-0.51 (-0.01)	77.38*** (3.56)	-7.13 (0.45)	-1914.32*** (-7.52)
White	-228.42 (-1.52)	-255.33 (-1.40)	80.65** (2.11)	-2.81 (-0.10)	279.17 (0.62)
Black	-270.02* (-1.73)	-79.15 (-0.42)	122.63*** (3.09)	-23.21 (-0.80)	69.27 (0.15)
Current Marital Status	227.53*** (3.17)	-349.34*** (-4.18)	-15.77 (-0.85)	52.04*** (3.84)	857.93*** (3.94)
Marital Status at Onset	-160.47** (-2.21)	44.64 (0.52)	-34.76* (-1.85)	-15.05 (-1.10)	-1128.55*** (-5.12)
Vet. Mos.	-8.39* (-1.92)	-2.07 (-0.48)	0.61 (0.73)	-1.66*** (-2.72)	-16.29* (-1.66)
Vet. War	228.31 (0.99)	75.60 (0.29)	25.90 (0.48)	73.09* (1.83)	-21.37 (-0.03)
Booze	20.84 (0.33)	-185.26** (-2.20)	11.65 (0.71)	27.03** (2.26)	955.76*** (4.98)

Table 3, continued

	Sight (6)	Strength (7)	Strength Change (8)	Job Qualified (9)	Income (10)
Cigs	-0.87 (-0.80)	3.84*** (3.05)	-0.45 (-1.60)	-0.10 (-0.47)	1.75 (0.52)
Income	25.49*** (5.06)	-102.10*** (-16.17)	-16.83*** (-13.01)	17.04*** (17.96)	
Constant	2168.54*** (7.47)	-1802.44*** (-4.84)	-66.85 (-0.91)	119.06** (2.20)	5745.60*** (6.65)
Log Likelihood	-3699.25	-2190.53	R^2 = 0.14	R^2 = 0.63	R^2 = 0.23

*Statistically significant at the 10% level.
**Statistically significant at the 5% level.
***Statistically significant at the 1% level.

respectively. Continuous variable equations are estimated by ordinary least squares; K-chotomous variables by ordered Probit maximum likelihood procedures.

Among males, for the disability measures [reported in columns (1) - (9)], education and age are generally significant and enter with signs that the literature would predict. Those living in rural areas tend to have less indication of the presence of impairing conditions, and this variable is statistically significant in about one-half of the cases. Having been exposed to adverse atmospheric conditions prior to the onset of disability is positively related to impairments and is significant in several cases; few of the hazardous job characteristics are significant. With but few exceptions, neither the race nor the marital status variables are significant. Having been a veteran is generally related to poorer health status, but is statistically significant in but a few cases. While the alcohol consumption variable is generally positively related to the absence of disability status, it is rarely significant. The opposite is true of the cigarette consumption variable; it is positively related to disability status and has a statistically significant coefficient in several of the estimates. Finally, the two economic variables--income and having a work history--are inversely related to the presence or severity of disability, and are generally significant.

The last column of the table reports the personal income regression. Education and age enter with the expected signs, and the squared terms of each are very significant. Rural residence is associated with higher income, and is also significant. Being exposed to hazardous employment prior to being disabled is associated with significantly higher income; being married prior to the onset of disability also has higher associated income. Somewhat surprisingly, the race variables are not significant. As has often been found, alcohol consumption is positively and significantly associated with income; tobacco consumption is a negative and significant determinant.

Table 3 presents estimates from the same model, but for females. The patterns are similar to those for males, with the primary exception of the work-nonwork variable. For females, a history of never working tends to be positively associated with better health and fewer impairments, perhaps indicating the economic pressure on women with impairments who simultaneously tend to be unmarried. Again, alcohol consumption tends to be positively related to health; cigarette consumption is associated with more serious disablements and is significant in about one-half of the cases. The results in the income equation are similar to those for men.

Stage 2 entails estimation of the reduced form parameters, $\underline{\Pi}_1'$, $\underline{\Pi}_2'$ [see equation (3)] and the coefficients of the measurement equations for D^* [see equation (2)].

The reduced form coefficients are reported in Table 4 for both men and women. The income coefficients are the same as those reported in Tables 2 and 3; the reduced form coefficients on D^* are in the second column of the two panels of the table. For both males and females, education and age are strongly related to the unobserved D^*, and have the expected signs. Being a rural resident is negatively and significantly associated with true disability in these reduced form estimates. Again, hazardous work does not appear to contribute strongly to D^*, while exposure to adverse atmosphere on the job is positively related to disability status for females. While being married at the outset of an impairment

Table 4

Second Stage Estimation: The Estimates of Reduced-Form Cofficients (Π_1, Π_2) of Structural Equations, Male and Female, Unit = 10^{-3} (t-value)

	Male		Female	
	Reduced Y	Reduced D	Reduced Y	Reduced D
Education	-49.36 (-0.89)	-36.534*** (-24.67)	-35.31 (-0.52)	-152.093*** (-81.95)
Education Square	16.31*** (5.88)	-3.245*** (-28.22)	10.56*** (3.18)	0.80*** (17.28)
Age	1.03 (0.03)	30.825*** (26.21)	-41.89 (-1.40)	60.559*** (94.48)
Age Square	-1.28*** (-3.50)	-0.074*** (-12.33)	-0.49 (-1.39)	-0.225*** (-45.00)
Urban-Rural	967.96*** (7.64)	-179.111*** (-20.02)	401.22*** (3.18)	-167.880*** (-18.67)
Hazards	11.38*** (3.49)	-2.028*** (-4.90)	16.08*** (3.61)	0.004 (0.004)
Atmosphere	-137.75* (-1.67)	-3.704* (-1.91)	-260.23*** (-2.76)	73.425*** (9.46)
Work-Nonwork	-994.63*** (-3.27)	66.074*** (5.53)	-1914.32*** (-7.52)	50.893*** (3.68)
White	-189.70 (-0.40)	-7.87 (-0.51)	279.17 (0.62)	-17.692 (-0.90)
Black	-265.99 (-0.54)	-69.625*** (-5.55)	69.27 (0.15)	157.724*** (6.07)
Current Marital Status	1411.81*** (7.03)	-82.77*** (-5.71)	857.93*** (3.94)	-394.472*** (-38.74)
Marital Status at Onset	-198.86 (-0.95)	-13.408 (-0.98)	-1128.55*** (-5.12)	184.133*** (12.56)
Vet. Mos.	-2.18 (-1.51)	0.606*** (7.05)	-16.29* (-1.66)	-1.201 (-0.73)
Vet. War	-45.99 (-0.34)	6.326 (0.71)	-21.37 (-0.03)	185.05* (1.86)

Table 4, continued

	Male		Female	
	Reduced Y	Reduced D	Reduced Y	Reduced D
Booze	855.78*** (6.52)	-106.879*** (-2.50)	955.76*** (4.98)	-315.926*** (-14.55)
Cigs	-5.68** (-2.32)	1.754*** (7.07)	1.75 (0.52)	1.415*** (2.79)
Constant	4840.20*** (5.27)	-646.445*** (-18.74)	5745.60*** (6.65)	-442.105*** (-19.94)
$\sigma_{12}\ \sigma_1^{-2}$		-96.761*** (-28.64)		-100.336*** (-101.04)

*Statistically significant at the 10% level.
**Statistically significant at the 5% level.
***Statistically significant at the 1% level.

tends to be positively associated with current levels of true disability for females, lower levels of D^* are associated with being currently married for both genders. Black men (women) have significantly lower (higher) levels of D^*, relative to whites and the omitted racial categories. Male veterans tend to be more disabled. And, consistent with the estimates in Tables 2 and 3, alcohol (cigarette) consumption is associated with lower (higher) levels of true disability.

The parameters in the measurement equations for D^* (see equation 2) are shown in Table 5, with $\lambda = 1$, $\alpha = 0$ imposed on the Future Work (Limited Work) equations for males (females). All of the signs are as expected and the coefficients on each of the eight indicators are very significant--with t-values ranging from 1.4 to 117. The last indicator, percentage of jobs for which the respondent is qualified has a very significant association suggesting the importance of vocational considerations.

The final or third stage involves estimation of the structural parameters, B and Γ [equation (10)] from $\hat{\Pi}_1$, $\hat{\Pi}_2$. See Table 6. Consider first the income equation estimates. For both males and females, D^* is inversely and significantly associated with personal income--the t-statistics are very large. Again for both groups, age and education are significant determinants of income, with reasonable nonlinear patterns of the relationships. For males and females, education beyond 6 years is positively associated with income. The age variable for males indicates a standard hump-shaped profile, peaking at 53 years. For females, the profile is positive throughout, suggesting that earnings increase after

Table 5

Second Stage Estimation:
The Estimates of Measurement Equations:
$\underline{Z} = \underline{\alpha} + \underline{\lambda}D^*$, Male and Female (t-value)

	Male (imposed λ = 1, α = 0 on Future Work)			Female (imposed λ = -1, α = 0 on Limited Work)	
	$\hat{\lambda}$ (slope)	$\hat{\alpha}$ (constant)		$\hat{\lambda}$ (slope)	$\hat{\alpha}$ (constant)
Interviewer Check of Disability	-1.97*** (-28.55)	-0.36*** (-6.32)	Interviewer Check of Disability	-1.18*** (-84.28)	1.17*** (1.40)
Self Report of Disability	-1.24*** (-28.83)	0.57*** (12.95)	Self Report of Disability	-0.88*** (-101.15)	0.28*** (20.50)
Limited Work	1.70*** (28.81)	1.05*** (52.5)	Future Work	-0.59*** (-59.00)	0.26*** (7.03)
Unemployed-Health	2.00*** (27.78)	0.66*** (27.5)	Unemployed-Health	1.33*** (86.36)	-0.54*** (-64.63)
Strength	1.02*** (26.84)	-0.28*** (-21.54)	Strength	0.78*** (97.50)	-0.53*** (-106.00)
Sight	-0.69*** (-27.6)	1.29*** (37.94)	Sight	-0.59*** (-95.16)	0.94*** (26.86)
Strength Change	0.21*** (26.25)	0.49*** (24.00)	Strength Change	0.12*** (52.17)	0.04** (2.00)
Job Qual.	-0.39*** (-27.86)	0.56*** (19.31)	Job Qual.	-0.28*** (-116.67)	0.38*** (13.10)

*Statistically significant at the 10% level.
**Statistically significant at the 5% level.
***Statistically significant at the 1% level.

Table 6

Third Stage Estimation: The Estimates of Structural-Form Coefficients in Structural Equations, Males and Females, Unit = 10^{-2} (t-value)

	Male		Female	
	Structural Y	Structural D*	Structural Y	Structural D*
Y		-7.16*** (-71.6)		-19.62*** (-32.70)
D*	-536.98*** (-57.99)		-398.61*** (-47.34)	
Education	-12.09* (-1.88)	-1.69** (-2.25)	-19.24*** (-7.60)	-29.69*** (-3.20)
Education Square	0.70 (0.41)	-0.32 (-1.16)	1.54*** (38.50)	0.33*** (13.90)
Age	10.05*** (54.32)	1.86*** (53.14)	40.93* (1.70)	10.46* (1.76)
Age Square	-0.10*** (-46.47)	-0.01*** (-51.50)	-0.14*** (-14.49)	-0.03*** (-20.31)
Urban-Rural	-1.96 (-0.13)	-11.49*** (-53.52)	-35.13 (-0.16)	-11.13* (-1.87)
Hazards	10.87*** (6.43)	1.89*** (6.52)	1.56*** (3.64)	0.31*** (31.00)
Atmosphere	-22.50 (-1.21)	-2.61 (-0.75)	12.06 (0.17)	4.76 (0.27)
Work-Nonwork	-70.23*** (-19.14)	-1.70 (-0.58)	-170.17*** (-2.39)	-31.39* (-1.74)
White	-11.75 (-1.52)		6.96*** (6.37)	
Black	-16.18 (-1.51)		2.49 (0.37)	
Current Marital Status	84.49*** (53.06)		16.47*** (24.58)	
Marital Status at Onset		2.20*** (8.15)		5.64*** (10.40)

Table 6, continued

	Male		Female	
	Structural Y	Structural D*	Structural Y	Structural D*
Vet. Mos.		0.03*** (4.85)		0.08*** (6.30)
Vet. War		0.54*** (3.17)		0.62 (0.08)
Booze		-9.78*** (-36.22)		-5.34*** (-11.86)
Cigs		0.06*** (12.19)		-0.01 (-0.43)
Constant	136.55*** (24.04)	-29.97*** (-49.95)	406.95*** (23.77)	70.44*** (36.71)

*Statistically significant at the 10% level.
**Statistically significant at the 5% level.
***Statistically significant at the 1% level.

childbearing. This relationship is likely to be related to the large and significant coefficient on the never worked variable for females.

As is expected, for both sexes, being currently married is associated with higher income. Urban-rural location is negatively related to income, but is never significant. The atmosphere variable reduces personal income for males, but is not significant. For both black and white males in this sample, personal income is lower than for the omitted racial categories; for white females personal income is higher than for black females and for those in the omitted racial category.

The second column in each panel presents the structural estimates of the determinants of true disability. For both males and females, income is negatively related to D^*, and is significant in both cases. For males and females, education appears to be negatively associated with D^*, as expected. Age is positively and very strongly associated with the true disability variable for both men and women. For men and women, rural residence is significantly and negatively associated with D^*. Hazardous work contributes to disability status for males and females. Never having worked is negatively associated with true disability for females, and the coefficient is statistically significant. The negative coefficient on the atmosphere variable for males is unexpected, but if compensating wage differentials exist, this effect may be picked up in the income variable. As expected, veterans status is significantly related to D^* for males, and somewhat less so for females. Marital status at onset is positively associated with D^* for both females and males. Finally, as observed previously, alcohol consumption appears to be inversely related to disability status, while cigarette consumption is a significant contributor to disability status for males. For females, alcohol consumption appears to positively affect disability status; no affect of cigarette consumption is observed.

We use these estimates to obtain a predicted disability status for each observation using the formula $\hat{D}^* = -\hat{\beta}_{21} Y + \hat{\underline{r}}_2', \underline{X}_2$ where $-\hat{\beta}_{21}$, and $\hat{\underline{r}}_2'$ are obtained from the previous three stages estimation procedure as listed in Table 6. Our mean predicted values for D* are -.2085 (0.62) for men and 1.182 (1.916) for women.

Table 7 compares our estimated D^* measure, a continuous variable, with two N-chotomous disability indicators--an interviewer check of disability and self-reported disability--for a selection of demographic subgroups. All of the values reported there are stated as a ratio to the mean of the sex-specific indicator; higher values indicate more severe disability. While the patterns across the three measures are similar, the D^* indicator displays a greater range and variance which is consistent with its continuous nature.

V. HEALTH STATUS AND LABOR SUPPLY: A COMPARISON

The effort to estimate an index of true disability (or health) status is motivated by the need for an independent and comprehensive measure of individual health or disability, if estimates of the determinants of behavior and choice are to be unbiased. In this section, we compare D^* with a self-reported disability variable in a labor supply model, and compare the resulting partial derivatives of the variables in this model in their role as determinants of labor supply. The model of labor supply that we estimate is:

Table 7

A Comparison of Values (Relative to Sex-Specific Mean) of D^*, Interviewer Check, and Self-Reported Disability

	Males			Females		
	D^*	Interviewer Check	Self-Report	D^*	Interviewer Check	Self-Report
Married	1.123	1.02	1.03	.91	.95	.96
Not married	.67	.98	.95	1.14	1.08	1.06
White	.93	1.00	.99	.94	.97	.97
Not white	1.05	1.08	1.09	1.08	1.13	1.15
Age						
30	-.04	.61	.63	.18	.67	.70
50	.84	.89	.92	1.20	.93	.94
64	1.45	1.22	1.20	1.26	1.24	1.20
Mean	.5235	1.8081	2.22	1.108	2.047	2.4503

$$(11) \quad Y_i^* = \alpha H_i + X_i' \beta + u_i$$

where X_i' is a vector of K exogenous variables and u_i is normally distributed with mean = 0 and variance = σ^2. H_i represents individual health status. In our estimate we substitute D^* (see above) and a self-reported disability indicator for H_i. Y_i^* is observed to be 1 when Y_i is greater than 0; otherwise Y_i is observed to be 0. That is

$$(12) \quad Y_i = \begin{cases} 1 \text{ if } Y_i^* > 0 \\ 0 \text{ otherwise.} \end{cases}$$

We estimate equation 11 by standard probit estimation methods. The partial derivatives from these regressions are reported in Table 8. Included in this simple model are race (white), education, age, other family income and disability status. The model is estimated separately by gender.

Consider first the male results. Both of the disability measures have the expected sign--work and disability status are negatively related. Both measures are statistically significant at the 1 percent level of significance. Recalling that the means are .52 and 2.22 for D^* and self-reported health, respectively, the measured influence of D^* is substantially greater than for self-reported health. A 5 percent increase in D^* is expected to decrease male labor force participation by .5 percent; the same percentage increase in self-reported health is expected to increase participation by .18 percent.

Table 8

Probit Estimates of Labor Force Participation (Y^*), by Gender,
Using D^* and Self-Reported Health
(t-value in parenthesis)

	Male			Female		
	β	$\bar{X}$	Partial Derivative at the Means $\frac{\partial\Phi(X'\beta)}{\partial X_k}$	β	$\bar{X}$	Partial Derivative at the Means $\frac{\partial\Phi(X'\beta)}{\partial X_k}$
$\underline{D^*}$						
White	0.50** (2.40)	0.89	0.074	0.07 (0.32)	0.89	0.010
Education	-0.020 (-0.91)	12.32	-0.003[a]	-0.506*** (-14.64)	12.15	-0.073[a]
Age	0.01* (1.80)	37.87	0.0015[b]	0.188*** (16.92)	37.33	0.027[b]
Other family income	-0.184*** (-4.22)	7.22	-0.027	-0.066* (-1.81)	8.63	-0.009
D^*	-1.333*** (-7.50)	-0.70	-0.197	-2.487*** (-20.28)	-0.099	-0.357
Constant	1.229*** (19.16)	1	0.181	0.821* (1.70)	1	0.118
Self-Report of Disability						
White	0.26 (1.39)	0.89	0.015	-0.034 (-0.28)	0.89	-0.010
Education	0.005 (0.25)	12.32	0.0003	0.05*** (3.49)	12.15	0.015
Age	-0.005 (-1.09)	37.87	-0.0003	-0.01*** (-4.73)	37.33	-0.003
Self-report of health	0.27*** (3.20)	3.33	0.016	0.19*** (3.51)	3.27	0.058
Other family income	-0.13*** (-3.72)	7.22	-0.008	-0.13*** (-6.44)	8.63	-0.039
Constant	1.90*** (3.81)	1	0.110	1.04*** (3.45)	1	0.315

Notes:

[a]Education is also a variable in the final D^* equation, Table 6. The total effect (partial derivative) of education for males is 1.78; for females, 7.82.

[b]Age is also a variable in the final D^* equation, Table 6. The total effect (partial derivative) of age for males is -.186; for females, -2.74.

While white males are estimated to be more likely participants in both equations, the measured influence of race is approximately 5 times greater in the equation including the D^* measure of disability.

In the case of D^* the influence of education on labor force participation should include both the direct effect and the indirect effect via its influence on disability (see Table 6). In both equations more education is associated with greater participation. The total (direct and indirect) effect of education in the probit with D^* (as measured by the partial derivative at the mean) is 1.78, a value substantially greater than the very small .0003 partial derivative from the equation with the self-reported health measure.

As with education, measurement of the effect of age on work requires consideration of both direct and indirect effects (see Table 6). The partial derivative of age on male participation in the D^* equation is -.186, as compared to -.0003 in the equation with self-reported health. Again a sizable difference exists, with a very small influence measured in the equation with self-reported health and a large and significant influence in the equation with D^*.

The last variable in the male equations is other family income. The coefficient has the same sign in both estimates, but once again the partial derivatives at the mean are quite different in magnitude (-.027 and -.008); again the larger influence is in the probit with D^*.

The pattern among women is similar. The partial derivative (at the mean) of the disability measure is substantially greater for D^* than self-reported health. A 5 percent increase in the disability measure is associated with a 1.98 percent decrease in women's labor force participation for D^*, but only a .7 percent increase using self-reported health. Race (white) is not significant in either equation, but the partial derivative for the total effect of age is -2.74 in the D^* equation, compared to -.003 in the estimate using self-reported health. For education, the partial derivative for the total effect is 7.82 in the estimate with D^*, and .015 with self-reported health. For other family income this pattern is reversed--the partial derivative is -.009 in the D^* equation, and a larger -.039 in the equation with self-reported health.

These results indicate the importance of the choice of the measure of health status in understanding the determinants of economic behavior--in this case, work effort. Not only is the health status measure chosen crucial to accurately estimating the effect of health on work effort, but also to effectively capturing the influence of a variety of other variables on choice.

VI. CONCLUSION

An indicator of true disability status has been constructed using a 3-stage multiple discrete indicators model. Disability, impairments, functional limitations, work limitations, and jobs for which qualified have all been incorporated into the index. Hence, D^* would appear to capture the essential characteristics of disability: the inability of an individual to adequately perform activities required for jobs (or otherwise perform productively in a social environment) owing to a shortfall in physical, mental, or emotional capacities. In particular, D^* would appear to reflect the three most important dimensions of disability: the extent of functional limitations, the severity of these limitations, and the requirements of functional performance in jobs for which the individual is qualified on other grounds. D^* can be constructed for any data set with the exogenous variables included in its construction; it does not require that the indicators (extensive data on disability, impairments and limitations) be available.

The usefulness of the measure is tested in a simple model of labor force participation. The results suggest that the choice of the health status indicator included in behavioral equations (such as labor force participation) has an important influence on the measurement of both the contribution of health status to behavior and the effects of other determinants on the behavior under investigation. The known limitations of alternatives to the comprehensive, though unobserved, indicator, D^*, suggest its use in empirical work.

Notes

[1]Extensive discussions of the concepts of disability, impairment, and health status are found in Riley and Nagi (1970); Nagi (1979); Berg (1973); Eisen, et al. (1979); Haveman, Halberstadt, and Burkhauser (1984). The importance of the concept used to measure health or disability status in assessing the extent of health or disability problems in the population, and changes in it, was revealed in Colvez and Blanchet (1981). Their analysis of trends in the annual Health Information Survey (HIS) reveals that health conditions limiting work and other activities increased substantially in the United States from 1965 to 1975 among all age and demographic groups, at the same time that longevity was increasing.

[2]Anderson and Burkhauser (1985) emphasize another problem. It may be that true disability status is itself a choice variable which depends on the same exogenous variables as, say, retirement (or depends on variables that are correlated with those determining work effort). If this is the case, the effect of disability status, however measured, on work effort will be overstated, and the true effect of economic variables camouflaged.

[3]The $\underline{\Pi}_2'$, η_2, σ_{12}, ε_j, α_j, λ_j, ξ_j, for $j = 1, 2, \ldots 9$ in the text are equivalent to their starred (*) counterpart in the Appendix (i.e., $\underline{\Pi}_2'$ in text = $\underline{\Pi}_2^{*'}$ in Appendix).

[4]It does not matter which indicator is used for the first measurement equation.

[5]To include Y in the measurement equations, we can have the disturbance terms of the measurement equations independent of the reduced form equation of Y. See Appendix.

[6]The basic differences in labor market behavior between sexes were judged to yield different structural relationships between variables and a D* emphasizing work capabilities.

Appendix

Consider the following structural equation:

$$(1)\qquad \begin{aligned} Y_1 + \beta_{12}\, Y_2 &= \underline{r}_1'\, \underline{X}_1 + U_1 \\ \beta_{21}\, Y_1 + \qquad Y_2 &= \underline{r}_2'\, \underline{X}_2 + U_2 \end{aligned}$$

which can be abbreviated as:

$$\underset{2x2}{B}\ \underset{2x1}{Y} = \underset{2xk}{\Gamma}\ \underset{kx1}{\lambda} + \underset{2x1}{U}$$

where $U' = (U_1, U_2)$ is bivariate normal and is i.i.d. across individuals and B is nonsingular (that is $\beta_{12}\,\beta_{21} \neq 1$). Assume that Y_1 is an observable continuous variable and Y_2 is an unobservable continuous variable with several indirect measures Z_j. The measurement equations for Y_2 are expressed as

$$(2)\qquad Z_j = \alpha_j + \lambda_j\, Y_2 + \varepsilon_j \qquad j = 1, 2, \dots 9$$

where ε_j's are independent of U and have an i.i.d. normal distribution across individuals.

Solving equations (1), the reduced-form equations of (1) become

$$(3)\qquad Y = \begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix} = B^{-1}\, \Gamma\, X + B^{-1} U$$

$$= \frac{1}{1-\beta_{12}\beta_{21}} \begin{pmatrix} \underline{r}' & -\beta_{12}\, \underline{r}_2' \\ -\beta_{21}\, \underline{r}_1' & \underline{r}_2' \end{pmatrix} \begin{pmatrix} \underline{X}_1 \\ \underline{X}_2 \end{pmatrix} + \begin{pmatrix} \dfrac{U_1 - \beta_{12}U_2}{1 - \beta_{12}\beta_{21}} \\ \\ \dfrac{-\beta_{21}U_1 + U_2}{1 - \beta_{12}\beta_{21}} \end{pmatrix}$$

$$= \begin{pmatrix} \underline{\Pi}_1' \\ \underline{\Pi}_2' \end{pmatrix} X + \begin{pmatrix} \eta_1 \\ \eta_2 \end{pmatrix}$$

Therefore, we have

$$\underline{\Pi}_1' = \left(\frac{1}{1 - \beta_{12}\beta_{21}} \underline{\Gamma}_1' , \frac{-\beta_{12}}{1 - \beta_{12}\beta_{21}} \underline{\Gamma}_2' \right)$$

$$\underline{\Pi}_2' = \left(\frac{-\beta_{21}}{1 - \beta_{12}\beta_{21}} \underline{\Gamma}_1' , \frac{1}{1 - \beta_{12}\beta_{21}} \underline{\Gamma}_2' \right)$$

and

$$\eta' = (\eta_1, \eta_2) = \left(\frac{U_1 - \beta_{12}U_2}{1 - \beta_{12}\beta_{21}} , \frac{-\beta_{21}U_1 + U_2}{1 - \beta_{12}\beta_{21}} \right)$$

is a bivariate normal distribution

$$N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix} , \begin{pmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{pmatrix} \right)$$

since η' are the linear combination of U_1 and U_2. We assume that equations (1) satisfy the rank conditions. Then, once the reduced form parameters ($\underline{\Pi}_1'$, $\underline{\Pi}_2'$) are identified, the structural parameters (β_{12}, β_{21}, $\underline{\Gamma}_1'$, $\underline{\Gamma}_2'$) will be identifiable.

Inserting the reduced-form equation of Y_2 into (2), the measurement equations become

(4) $$Z_j = \alpha_j + \lambda_j \underline{\Pi}_2' \underline{X} + \lambda_j \eta_2 + \varepsilon_j , \quad j = 1, 2, \ldots 9$$

By the property of bivariate normal distributions, the conditional distribution of η_2 given η_1 will be a normal distribution $N(\sigma_{12}\sigma_1^{-2}\eta_1$, $\sigma_2^2 - \sigma_{12} \sigma_1^{-2})$.

Thus η_2 can be expressed as

$$\eta_2 = \sigma_{12}\ \sigma_1^{-2}\ \eta_1 + e$$
$$= \sigma_{12}\sigma_1^{-2}\ (Y - \underline{\Pi}_1'\ \underline{X}) + e$$

and equations (4) become

$$(5) \qquad Z_j = \alpha_j + \lambda_j \underline{\Pi}_2'\ \underline{X} + \lambda_j \sigma_{12}\sigma_1^{-2}\ (Y_1 - \underline{\Pi}_1'\ \underline{X}) + \lambda_j e + \varepsilon_j$$

$$= \lambda_j \sigma_{12}\sigma_1^{-2} Y_1 + \alpha_j + \lambda_j\ (\underline{\Pi}_2' - \sigma_{12}\sigma_1^{-2}\underline{\Pi}_1')\ \underline{X} + \xi_j$$

$$j = 1,\ 2,\ \ldots\ 9$$

where e and ξ_j are independent of η_1. Without loss of generality, we assume that the first seven measures of Y_2 relate ordered polychotomous indicators with values 1, 2, ... k_j and the last two measures relate continuous indicators. Since the parameters of probit regression can only be identified up to a scale, we normalize the model in following way. Let $E(\xi_j^2) = \sigma_{oj}^2$ and $A = \begin{pmatrix} 1 & 0 \\ 0 & \frac{\lambda_1}{\sigma_{o1}} \end{pmatrix}$.

Equation (1) can be rewritten as

$$(6) \qquad B\ A^{-1}\ A\ Y = \Gamma\ X + U$$

Premultiplying by $A\ B^{-1}$, equations (6) become

$$A\ Y = A\ B^{-1}\ \Gamma\ X + A\ B^{-1}\ U$$

that is

$$\begin{pmatrix} 1 & 0 \\ 0 & \frac{\lambda_1}{\sigma_{o1}} \end{pmatrix}\begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & \frac{\lambda_1}{\sigma_{o1}} \end{pmatrix}\begin{pmatrix} \underline{\Pi}_1' \\ \underline{\Pi}_2' \end{pmatrix} X + \begin{pmatrix} 1 & 0 \\ 0 & \frac{\lambda_1}{\sigma_{o1}} \end{pmatrix}\begin{pmatrix} \eta_1 \\ \eta_2 \end{pmatrix}$$

or

$$\begin{pmatrix} Y_1 \\ \frac{\lambda_1}{\sigma_{o1}} Y_2 \end{pmatrix} = \begin{pmatrix} \underline{\Pi}_1' \\ \frac{\lambda_1}{\sigma_{o1}} \underline{\Pi}_2' \end{pmatrix} X + \begin{pmatrix} \eta_1 \\ \frac{\lambda_1}{\sigma_{o1}} \eta_2 \end{pmatrix}$$

Let $D^* = \frac{\lambda_1}{\sigma_{o1}} Y_2$, $\underline{\Pi}_2^{*\prime} = \frac{\lambda_1}{\sigma_{o1}} \underline{\Pi}_2'$, $\eta_2^* = \frac{\lambda_1}{\sigma_{o1}} \eta_2$, and

$\sigma_{12}^* = E\,(\eta_1\eta_2^*) = \frac{\lambda_1}{\sigma_{o1}} \sigma_{12}$. Then we have

$$(7) \qquad \begin{pmatrix} Y_1 \\ D^* \end{pmatrix} = \begin{pmatrix} \Pi_1' \\ \Pi_2^{*\prime} \end{pmatrix} X + \begin{pmatrix} \eta_1 \\ \eta_2^* \end{pmatrix}$$

On the other hand, the first seven measurement equations of (5) are normalized as

$$\frac{Z_j}{\sigma_{oj}} = \left(\frac{\lambda_j}{\sigma_{oj}} \frac{\sigma_{o1}}{\lambda_1} \right)\left(\frac{\lambda_1}{\sigma_{o1}} \sigma_{12}\sigma_1^{-2} \right) Y_1 + \frac{\alpha_j}{\sigma_{oj}} + \left(\frac{\lambda_j}{\sigma_{oj}} \frac{\sigma_{o1}}{\lambda_1} \right)$$

$$\left(\frac{\lambda_1}{\sigma_{o1}} \underline{\Pi}_2' - \frac{\lambda_1}{\sigma_{o1}} \sigma_{12}\sigma_1^{-2} \underline{\Pi}_1' \right) X + \frac{\xi_j}{\sigma_{oj}}$$

that is

$$(8)\ Z_j^* = \lambda_j^* \sigma_{12}^* \sigma_1^{-2} Y_1 + \alpha_j^* + \lambda_j^* \left(\underline{\Pi}_2^{*\prime} - \sigma_{12}^* \sigma_1^{-2} \underline{\Pi}_1'\right) X + \xi_j^*$$

for $j = 1, 2, \ldots 7$

and the last two measurement equations of (5) are normalized as

$$Z_k = (\lambda_k \frac{\sigma_{o1}}{\lambda_1}) (\frac{\lambda_1}{\sigma_{o1}} \sigma_{12} \sigma_1^{-2}) Y_1 + \alpha_k + (\lambda_k \frac{\sigma_{o1}}{\lambda_1}) (\frac{\lambda_1}{\sigma_{o1}} \underline{\Pi}_2' -$$

$$\frac{\lambda_1}{\sigma_{o1}} \sigma_{12} \sigma_1^{-2} \underline{\Pi}_1') X + \xi_k$$

that is

(9) $$Z_k^* = \lambda_k^* \sigma_{12}^* \sigma_1^{-2} Y_1 + \alpha_k^* + \lambda_k^* (\underline{\Pi}_2^{*\prime} - \sigma_{12}^* \sigma_1^{-2} \underline{\Pi}_1') X + \xi_k$$

for $k = 8, 9$

where $Z_j^* = \frac{Z_j}{\sigma_{oj}}$, $\lambda_j^* = \frac{\lambda_j}{\sigma_{o1}} \frac{\sigma_{o1}}{\lambda_1}$, $\alpha_j^* = \frac{\alpha_j}{\sigma_{oj}}$, $\xi_j^* = \frac{\xi_j}{\sigma_{oj}}$ for

$j = 1, 2, \ldots 7$ and $\lambda_k^* = \lambda_k \frac{\sigma_{o1}}{\lambda_1}$, $Z_k^* = Z_k$

$\alpha_k^* = \alpha_k$ for $k = 8, 9$. Obviously, λ_1^* and Var (ξ_j^*) for $j = 1, 2, \ldots 7$ are normalized to be equal to 1. Furthermore, since X contains a constant term, we normalized $\alpha_1^* = 0$.

After normalization, the measurement equations (8) and (9) can be rewritten as

$$Z_j^* = \delta_{j1} Y_1 + \underline{\delta}_{j2}' X + \xi_j^* \qquad j = 1, 2, \ldots 9$$

where $\delta_{11} = \sigma_{12}^* \sigma_1^{-2}$

$$\underline{\delta}_{12}' = \underline{\Pi}_2^{*\prime} - \sigma_{12}^* \sigma_1^{-2} \underline{\Pi}_1$$

$$\delta_{j1} = \lambda_j^* \sigma_{12}^* \sigma_1^{-2} \qquad j = 2, \ldots 9$$

$$\underline{\delta}'_{j2} = \alpha_j^* + \lambda_j^* (\underline{\Pi}_2^{*\prime} - \sigma_{12}^* \sigma_1^{-2} \underline{\Pi}'_1)$$

and the first seven measurement equations relate to the ordered polychotomous indicators I_j as follows:

$$
\begin{aligned}
I_j &= 1 && \text{if } Z_j^* < 0 \\
I_j &= 2 && \text{if } 0 \leq Z_j^* < \mu_{1j} \\
&\vdots \\
I_j &= K_j && \text{if } \mu_{Kj-2,j} \leq Z_j^*
\end{aligned}
$$

$$j = 1, 2, \ldots 7$$

Therefore:

<u>In stage 1</u>, we estimate $\underline{W}' = (\underline{\Pi}'_1 , \underline{\delta}'_1 , \underline{\delta}'_2 , \ldots \underline{\delta}'_9)$

$$\mu_{j1}, \ldots \mu_{j,k-2}, \; j = 1, 2 \ldots 7$$

and σ_1^2 , $\delta_{\xi_8}^{\;2}$, $\delta_{\xi_9}^{\;2}$ by polychotomous probit regressions and linear regressions.

<u>In stage 2</u>, we estimate $\underline{\Pi}_2^{*\prime}$, $\sigma_{12}^* \sigma_1^{-2}$ and the coefficient parameter of measurement equations

$$\alpha_j^* , \lambda_j^* \qquad j = 2, \ldots 9$$

<u>In stage 3</u>, we estimate the structural form coefficient parameters β_{12} , β_{21} , $\underline{\Gamma}'_1$, $\underline{\Gamma}'_2$.

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