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ESTIMATION OF PERMANENT AND TRANSITORY RESPONSE FUNCTIONS IN PANEL DATA: A DYNAMIC LABOR SUPPLY MODEL

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INTRODUCTION

Dynamic issues in the analysis of wages and labor supply have been recognized for some time. Friedman (1957, 1962) developed the concepts of permanent and transitory income and their role in consumption, including labor supply. Lewis (1957) outlined a concept of long-run trend, seasonal and cyclical time series variation as well as cross sectional "differentials" in hours of work. He says:

> "...the hours of labor supplied per head are made to depend chiefly upon long-run or permanent real wage rate and real property income prospects which would be little affected by short-run ('transitory') variations in real wages and real property income."

Mincer (1962) set out a reconciliation of apparently contradictory long-run time series and cross sectional labor supply (participation) results for married women. The reconciliation was based on the distinction between permanent and transitory components of (husband's) income.

Dynamic issues in the analysis of labor supply arise in a quite different set of models. I want to mention two which are particularly related to this paper. Lucas and Rapping (1969) are concerned with short run and long run aggregate labor supply functions in the context of a macroeconomic model.[1] While their results are all based on aggregate data they provide (section 2) an excellent discussion of the context in which this microdata study is to be placed. While their "operational supply hypothesis" incorporates a model of adaptive wage expectations, they outline an alternative view "in terms of a current real wage consisting of 'permanent' and 'transitory' components." At the disaggregated level of local labor markets, Lucas and Prescott (1974) provide a model which introduces local business cycles and serial correlation in wage rates at the local level. While their purpose is quite different, emphasizing job search, mobility and equilibrium unemployment, the notions of spatially distinct markets and autocorrelated predetermined labor demand discussed there are fundamentally useful in interpreting dynamic labor supply results.

Another distinct class of labor supply models has grown out of the work of Heckman (1977).[2] These studies of the labor supply of women emphasize the joint determination of participation and hours of work and incorporate permanent and transitory components of women's participation probability functions.

Another study which has come to my attention recently is closely related to parts of this paper. Hauseman and Wise (1976) present[3] a simultaneous equation model for wages and hours observed each of two years. As in the model presented here, hours are taken to be a function of predetermined wages. Their model differs from the one reported here in several important ways. First only two years of data are used so that serial correlation in transitory variables cannot be separated from the permanent component. The permanent and transitory labor supply elasticities are constrained to be equal. Their model emphasizes the important problem of estimation on data truncated with respect to an endogenous variable while the one reported here does not. One potentially severe problem with the data from the New Jersey Income Maintenance Experiment is the quality of the variables used. The hours and especially wage variables are constructed from less than ideal underlying measurements.[4] The results reported later will illustrate the importance of measurement error in both observed earnings and observed hours.

There are some important differences between previous studies and the one reported here. First, the availability of panel data makes possible the estimation of the parameters of dynamic relationships in micro data which may help reconcile previous divergent cross sectional and aggregate time series results.[5] The fully dynamic nature of many models has not yet been adequately exploited. One aspect of this is that transitory (short run) variation in economic variables may not elicit the same behavioral response as permanent (long run) variation. This possibility introduces a whole new class of models and estimation problems. The model reported here is possibly the simplest such model.

A second difference is an emphasis on the components of variation in economic variables rather than simply the regression coefficient representing the effect of predetermined variables.[6] The components of variation in economic variables become more interesting in panel data because more than the component "due to X" can be studied.

Another feature not common to many economic studies is estimation explicitly based on observed variables rather than "constructed" ones. This allows the problem of measurement error to be tackled directly. The importance of measurement error in hours, when earnings rather than the wage rate is observed, has been widely documented.[7] (See for example Mincer (1976) and Ghez and Becker (1975).)

The purpose of this paper is to develop and test a dynamic labor supply model which incorporates the essential features of these previous models. The issues of permanent and transitory effects and of cross section versus time series can be addressed much more directly given the recent availability of panel data featuring repeated observation over extended periods of time of the same individuals. The labor supply model presented below emphasizes the effect of permanent individual wage differences on permanent annual hours of work and the effect of serially correlated transitory individual wage variation on short run hours of work. Permanent and transitory deviations from the aggregate labor supply functions are also allowed. A by-product is an analysis of the relative roles of permanent and transitory components of both wages and hours in the distribution of earnings.

The next section provides a description of the essential features of the model. Section III provides a detailed outline of the empirical model and method of obtaining maximum likelihood estimates of parameters. Section IV provides a discussion of the results including the components of variation in wages, hours, and earnings. Comparisons are made by schooling group, by experience group, by union status, and by wife's work status. Finally the results are summarized in Section V.

II. A DYNAMIC LABOR SUPPLY MODEL

The purpose of this section is to outline briefly the dynamic labor supply model developed more formally in the next section and to introduce a few caveats.

The essential feature of the model is a two equation system relating the wage rate and hours worked at each point in time. Wages are presumed to be predetermined from the viewpoint of each individual laborer. The wage rate (in logs) of any particular laborer at a particular point in time is composed of several components: a year effect representing year-to-year wage variation common to all individuals; an individual specific permanent (long run) wage level; and a serially correlated transitory (short run) deviation of that individual's wage rate from its permanent level. The individual permanent component is itself composed of the effect of measured and of unmeasured individual characteristics which affect wages. The unmeasured permanent component reflects the permanent characteristics of the local labor market in which the person resides (if he doesn't move) as well as his own personal characteristics. The transitory wage component measures the effect of local business cycles and local labor market transitory variation as well as the effect of time varying individual characteristics which are not measured or incorporated into the analysis.[8]

Annual hours of work is similarly composed of several components: a year effect representing year-to-year variation in hours common to all individuals; a labor supply response to permament wage differences among persons; an individual residual or deviation from the aggregate long run labor supply function; an individual response to the personal transitory wage deviation from its permanent level; and a residual serially correlated transitory term representing involuntary transitory variation in hours (not on the aggregate transitory response function). Three concepts of the hours-wage relationship are distinguished. The first corresponds to aggregate time series on wages and hours for the population under study. In the aggregate the forces of supply and demand for labor jointly determine wages and hours. The determinants of this aggregate relationship are not modeled here.[9] The other concepts relate to labor supply decisions by individuals facing exogenously determined wages rates and wage rate deviations over time, given the aggregate level of wages. It is assumed throughout that each individual takes his wage rate as partly exogenous and partly predetermined by decisions made earlier in life. He may however respond differently to transitory than to permanent wage differences. All individuals are assumed to have the same transitory labor supply elasticity and the same degree of serial correlation in transitory variables.

The well known labor supply (labor-leisure choice) models would presumably predict the negative income effect to be larger for a permanent wage difference than for a transitory one. The (positive) substitution effect is more likely to dominate for a transitory wage deviation than for a permanent one. A crucial factor however is the degree of serial correlation in the transitory wage variation over time for the same person. The greater the serial correlation the more a transitory wage change appears to be a permanent one.

This formulation of the model begs several issues. First the model implicitly assumes costless shifts in annual hours in response to wage changes. Institutional arrangements may make such shifts more costly.[10] It should be kept in mind that other employee-firm arrangements may exist. For example, some workers may be faced with a fixed salary (annual earnings) but variable annual hours. Working when the need arises may be a condition of employment, at a fixed salary. In such a case the average annual wage rate (considered empirically) will be negatively related to annual hours of work. Many examples can be found. At the other extreme some service workers may may face fixed working hours but a random average hourly wage rate. Salesmen and self-employed barbers might be illustrations. In this case the transitory elasticity would be zero. These possibilities cloud the interpretation of measured labor supply relationships.

The model ignores taxes (and thus marginal versus average wage rates) and non-pecuniary inducements to work.[11] In fact, the model is estimated using observations on hours and earnings, rather than wages. The wage variation parameters are inferred from annual earnings and annual hours and thus refer to average annual hourly wage rates. The whole dynamic issue of expectations and anticipations is ignored. (See Lucas and Rapping (1969). The issue of life cycle joint planning of hours and wages (human capital investment) does not enter explicitly. The model ignores an important set of issues including the decision to participate and the interrelationship among the decisions of members of a family or household unit. This eliminates perhaps the most (positively) responsive segments of the potential labor force, women and retired persons. Only prime age white males (not retired, disabled or fulltime student) are considered.

Given these caveats let us proceed to the formal model.

III. THE FORMAL EMPIRICAL MODEL

The purpose of this section is to more formally outline the dynamic labor supply model and the resulting implications of dynamic earning variation. First the dynamic wage function is outlined. Second, the dynamic properties of annual hours, induced by wage variation and exogenous to wage variation, are outlined. Third, the dynamic properties of the resulting earnings function are explored. Finally, the model is fully combined into matrix form and the maximum likelihood procedure is discussed. The empirical model analyzes the covariance structure over time of the log of real annual earnings in 1970 dollars and the log of annual hours of work. Measurement error in these variables is introduced into the estimation procedure. It is assumed throughout that the random variables δ^w, δ^h, η^w, η^h and X are independently distributed. A path diagram for the model, for four years, is presented in Figure 1. Notation for variables and parameters are presented in Table 1.

a. Wages

The real average (annual) hourly wage rate (W, in logs) is assumed to be predetermined but a function of measured individual characteristics, $\underset{\sim}{X}^w$. The wage rate of individual i in year t is composed of a year component Γ_t common to all individuals, an individual specific permanent wage W_i^P, and a transitory component W_{it}^T, i.e.,

$$(1) \qquad W_{it} = \Gamma_t + W_i^P + W_{it}^T . \qquad i = 1,\ldots,N \text{ and } t = 1,\ldots,T$$

The permanent wage is a function of measured individual characteristics, including schooling and experience, plus a permanent residual δ_i^w, i.e.,

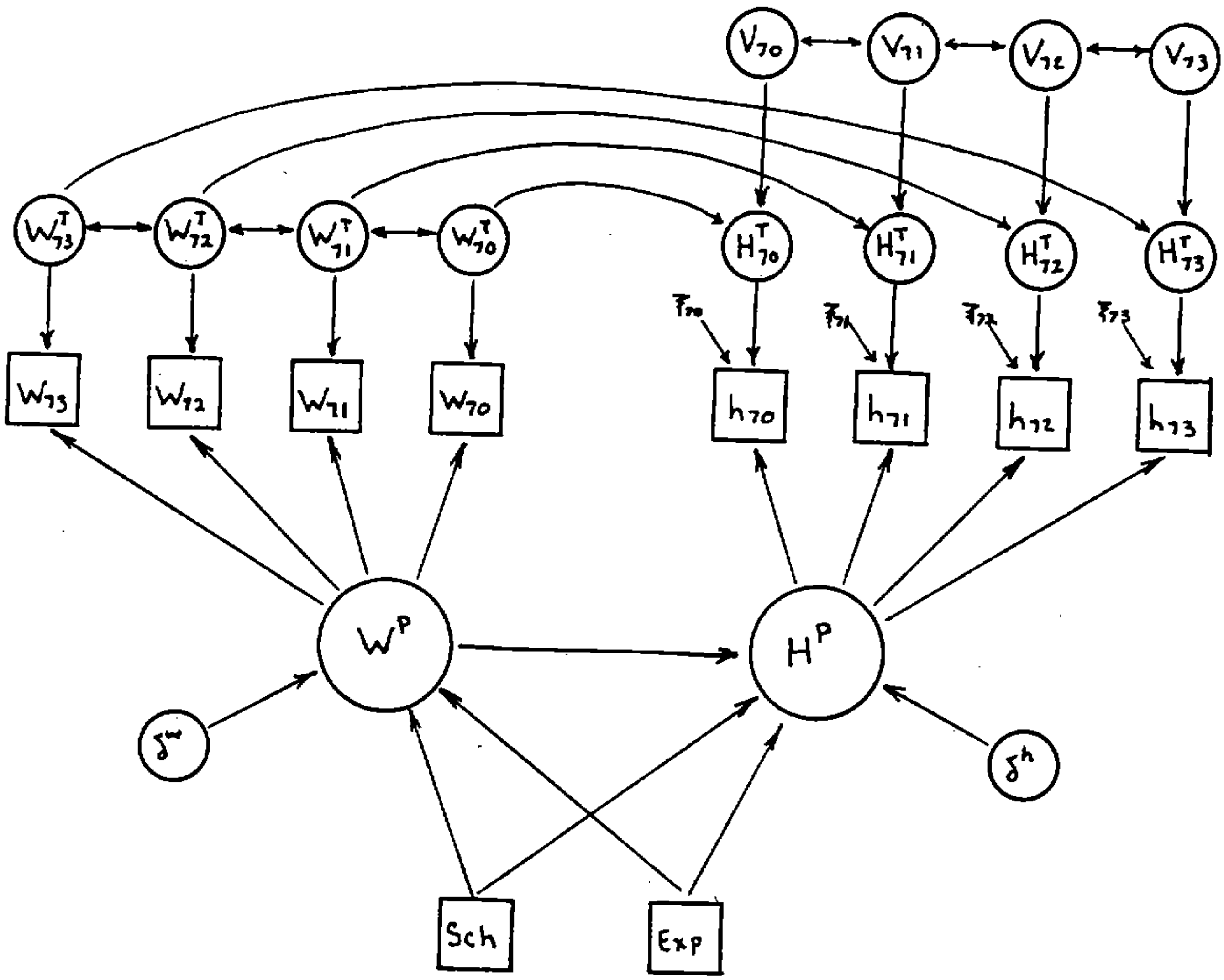

Figure 1. Path Diagram For Dynamic Labor Supply Model, As If Wages And Hours Were Observed (Empirically Earnings (Log) = $W + H^P + H^T + \epsilon$ are Observed)

Table 1. Notation for Variables and Parameters

Variable	Description
W_{it}	log of real average annual hourly wate rate in 1970 dollars of individual i in year t
W_i^P	log permanent wage rate of individual i
W_{it}^T	log transitory wage deviation of individual i in year t
γ	serial correlation coefficient for transitory wage variation
Γ_t	year effect in wage rate common to all individuals
$\underset{\sim}{X}_i$	vector of measured characteristics of individual i (not time varying)
$\underset{\sim}{\alpha}^w$	vector of effects of X_i on W_i^P
δ_i^w	permanent wage ceviation ($=W_i^P - X_i\alpha^w$), $\sim(0, \sigma_\delta^2)$
η_{it}^w	transitory shock to wages of individual i in year t $\sim$iid$(0,\sigma_\eta^2)$
$\underset{\sim}{i}$	a vector of T "1"'s
T	number of observed years
H_{it}	log of true annual hours worked (h_{it} is observed)
H_i^P	log permanent hours
H_{it}^T	log transitory hours deviation
V_{it}	log transitory deviation of hours from short run labor supply function
Δ	serial correlation coefficient for transitory hours
ϕ_t	year effect in annual hours
$\underset{\sim}{\alpha}^h$	vector of effects of X_i on h_i^P
δ_i^h	permanent hours deviation ($=h_i^P - X_i\alpha^h$), $\sim(0, \sigma_\delta^2)$
η_{it}^h	transitory shock to hours, $\sim$iid$(0,\sigma_\eta^2)$
Y_{it}	log of true real annual earnings in 1970 dollars (y_{it} is observed)
Y_i^P	log permanent earnings
Y_{it}^T	log transitory earnings deviation
Σ	covariance matrix, across years
β	long run (permanent) labor supply elasticity
θ	short run (transitory) labor supply elasticity

(2) $$W_i^P = X_i^w \alpha^w + \delta_i^w$$

where $\delta^w \sim (0, \sigma^2_{\delta w})$. The individual component δ_i^w represents the effect of unmeasured individual variables which affect wage rates including the permanent characteristics of the individual's local labor market.

The transitory wage component is assumed to be first order serially correlated, i.e.,

(3) $$W_{it}^T = \gamma W_{it-1}^T + \eta_{it}^w \qquad t = 2,3,\ldots,T$$

where $\eta_{it}^w \sim iid(0, \sigma^2_{\eta w})$ except $\eta_{i1}^w \sim (0, \sigma^2_{\eta w}/(1-\gamma^2))$.[12] The serially correlated transitory component measures the effect of local labor market conditions which affect wage rates which are presumably affected by local business cycles. The covariance structure of wages over time for a given individual is then the standard one for a first order autoregressive series, i.e.,

(4) $$\Sigma_{W^T} = \sigma^2_{w^T} Q\gamma$$

where

(5) $$\sigma^2_{W^T} = \sigma^2_{\eta w}/(1-\gamma^2)$$

and

(6) $$Q\gamma = \begin{bmatrix} 1 & \gamma & \gamma^2 & \cdots & \gamma^{T-1} \\ \gamma & 1 & \gamma & \cdots & \cdot \\ \gamma^2 & \gamma & 1 & \cdots & \cdot \\ \cdot & \cdot & \cdot & \ddots & \\ \cdot & \cdot & \cdot & & \cdot \\ \gamma^{T-1} & \cdot & \cdot & \cdot & 1 \end{bmatrix}$$

and for a random individual or aggregate of individuals is

(7) $$\underset{\sim}{\Sigma}_W = \underset{\sim}{\Sigma}_{W^T} + \sigma^2_{W^P} \underset{\sim}{\iota}\underset{\sim}{\iota}' \quad .$$

Clearly from equation (2)

(8) $$\sigma^2_{W^P} = \underset{\sim}{\alpha}^{W'} \underset{\sim}{\Sigma}_{X_W X_W} \underset{\sim}{\alpha}^W + \sigma^2_{\delta^W} \quad .$$

The share of within year wage variation which represents permanent differences among individuals is

(9) $$\rho_W = \sigma^2_{W^P}/\sigma^2_W$$

so that the correlation between any two years t and τ is $\rho_W+(1-\rho_W)\gamma^{|t-\tau|}$. This correlation is clearly a monotonically declining function of the time distance between the years and asymptotically approaches ρ_W.

This dynamic wage equation is precisely the form of the dynamic earnings function assumed in Lillard and Weiss (1977) and Lillard and Willis (1977). In those studies time varying X_{it} were included so that potentially transitory variation is explained as well. The approach taken here is to generalize the structure to the more fundamental wage and hours variables which determine earnings.

b. Hours

The individual annual hours equation similarly is composed of permanent and transitory components,

(10) $$H_{it} = \phi_t + H_i^P + H_{it}^T \quad .$$

Three concepts of hours-wage relationship are distinguished. The first corresponds to aggregate time series observations on hours and wages, i.e. ϕ_t and Γ_t. In the aggregate the forces of supply and demand for labor will jointly determine wages and hours. The other concepts relate to labor supply decisions by individuals facing exogenously determined wage rates and wage rate variations over time, given the aggregate level of wages in the economy. It is assumed throughout that each individual takes his wage rate as partly exogenous and partly predetermined by decisions made earlier in the life cycle. He may however respond differently to transitory than to permanent wage differences. We thus have an aggregate time series relationship common to all men, an across individual permanent relationship, and an individualized response to personal time series variation.

The permanent hours component is the sum of a long run labor supply function and an individual intercept term,

$$(12) \qquad H_i^P = \beta W_i^P + H_i^C$$

where

(13) $$H_i^c = \underset{\sim}{X}{}_i^h \underset{\sim}{\alpha}{}^h + \delta_i^h$$

The individual constant term, or deviation from the permanent labor supply function, is a function of measured individual characteristics $\underset{\sim}{X}_i$. The δ_i^h term captures the effect of unmeasured individual chaacteristics affecting long run labor supply and perhaps permanent exposure to involuntary spells of unemployment. Since W and H are in logs, β represents the long run labor supply elasticity.

The transitory hours component is itself composed of two parts; one part is serially correlated transitory variation induced by short run wage variation and the other is an independent source of transitory hours variation,

(14) $$H_{it}^T = \theta W_{it}^T + v_{it}^h$$

The independent transitory variation may be itself serially correlated,

(15) $$v_{it}^h = \Delta v_{it-1} + \eta_{it}^h$$

where $\eta_{it}^h \sim \text{iid}(0, \sigma^2_{\eta h})$ except $\eta_{i1}^h \sim (0, \sigma^2_{\eta h}/(1-\Delta^2))$.

The independent transitory variation reflects the operation of local labor market conditions and business cycles which affect transitory involuntary hours variation. Again since W and H are in logs, θ is the short run labor supply elasticity. The covariance structure of annual hours over time for a given individual is

(16) $\Sigma_{H^T} = \Sigma_{v} + \theta^2 \Sigma_{w^T}$

where

(17) $\Sigma_{v} = \sigma^2_{v^h} Q_{\Delta}$

and

(18) $\sigma^2_{v^h} = \sigma^2_{\eta^h}/(1-\Delta^2)$.

For a random individual or aggregate of individuals

(19) $\Sigma_{H} = \Sigma_{H^T} + \sigma^2_{H^P} \iota\iota'$.

Clearly from equation (12)

(20) $\sigma^2_{H^P} = \beta^2 \sigma^2_{W^P} + \sigma^2_{H^C} + 2\beta\, \sigma_{H^C W^P}$.

and from Equation (13)

(21) $\sigma^2_{H^C} = \alpha^{h'} \Sigma_{X^h X^h} \alpha^h + \sigma^2_{\delta h}$.

In general the permanent wage component and the exogenous permanent hours component will be correlated due to correlation among X variables, even though δ^h, δ^w and X are assumed independent, and is represented by $\sigma_{H^C W^P} = \alpha^{h'} \Sigma_{X^h X^W} \alpha^w$.

Clearly permanent wage variation contributes to permanent covariation in annual hours through long run labor supply, and serially correlated transitory wage variation contributes to serial correlation in transitory annual hours through the short run labor supply response. The serial correlation in annual hours is then a mixture of two first order autocorrelated series.

Analogously to wages, the share of within year, annual hours variation which represents permanent differences among individuals is given by

(22) $$\rho_H = \sigma^2_{H^P}/\sigma^2_H .$$

However correlations among years for annual hours are more complex than in the case of wages. The correlation between any two years t and τ is

(23) $$\rho_H + \gamma^{|t-\tau|}\theta^2\sigma^2_{W^T}/\sigma^2_H + \Delta^{|t-\tau|}\sigma^2_v/\sigma^2_H .$$

The covariance structure between hours and wages over time is due solely to the labor supply responses and correlation among $\underset{\sim}{X}$ variables

(24) $$\underset{\sim}{\Sigma}_{HW} = \theta\underset{\sim}{\Sigma}_{W^T} + \beta\sigma^2_{W^P} + \underset{\sim}{\alpha}^{h'}\underset{\sim}{\Sigma}_{X^hX^w}\underset{\sim}{\alpha}^w$$

For the purpose of estimation, measurement error in observed hours, $h_{it} = H_{it} + \xi_{it}$, is introduced. It is assumed that measurement error is distributed independently from year to year with zero mean and variance σ^2_ξ . This source of variation then contributes only additively to the diagonal elements of the observed covariance matrix for log hours.

c. Earnings

In the data annual hours and annual earnings are observed rather than the average annual wage rate. In addition, the roles of wages, hours and labor supply in the distribution of earnings over time is an interesting issue in its own right.

Since W and H are in logs, the log of annual earnings is their sum,

(25) $$Y_{it} = H_{it} + W_{it} .$$

Correspondingly the permanent earnings component is

(26) $$Y_i^P = H_i^P + W_i^P$$

and the transitory earnings component is

(27) $$Y_{it}^T = H_{it}^T + W_{it}^T \quad .$$

Straightforwardly, the covariance structure of (log) earnings over time is

(28) $$\underset{\sim}{\Sigma}_Y = \underset{\sim}{\Sigma}_v + (1+\theta)^2 \underset{\sim}{\Sigma}_{W^T} + (\sigma^2_{H^c} + (1+\beta)^2 \sigma^2_{W^P} + 2(1+\beta) \underset{\sim}{\alpha}^{h'} \Sigma_{X^h X^w} \underset{\sim}{\alpha}^w) \underset{\sim}{\iota}\underset{\sim}{\iota}'$$

and the covariance between hours and earnings over time is

(29) $$\underset{\sim}{\Sigma}_{HY} = \underset{\sim}{\Sigma}_v + \theta(1+\theta) \underset{\sim}{\Sigma}_{W^T} + (\sigma^2_{H^c} + \beta(1+\beta)\sigma^2_{W^P} + (1+2\beta) \underset{\sim}{\alpha}^{h'} \underset{\sim}{\Sigma}_{X^h X^w} \underset{\sim}{\alpha}^w) \iota\iota' \quad .$$

Again for the purpose of estimation, measurement error is introduced in observed earnings, $y_{it} = Y_{it} + \varepsilon_{it}$. It is again assumed serially independent with mean zero and variance σ^2_ε.

d. Estimation of Parameters

This model specifies a particular set of linear structural relationships among unobservable latent variables and observed variables as well as their relationship to a set of predetermined variables. First the system is re-written in matrix form and it is illustrated that the system generates the covariance structure outlined above. In this form the system clearly represents a form of LISREL model described in Joreskog (forthcoming). The parameters are then amenable to estimation by the LISREL III maximum likelihood program of Joreskog and Sorbom (1976) assuming η^h, η^w, δ^h and δ^w are normally distributed.

Since the $\underset{\sim}{v}$ and $\underset{\sim}{W}^T$ are serially correlated it is convenient to make the standard transformation to the η vector. Define

$$(30)\qquad \underset{\sim}{T}_{\gamma} \equiv \begin{bmatrix} \sqrt{1-\gamma^2} & 0 & 0 & \cdots & 0 \\ -\gamma & 1 & 0 & & \\ 0 & -\gamma & 1 & & \vdots \\ \vdots & & & & \\ 0 & \cdots & & -\gamma & 1 \end{bmatrix}$$

and similarly $\underset{\sim}{T}_{\Delta}$, such that $\underset{\sim}{T}'_{\gamma}\underset{\sim}{T}_{\gamma}/\sigma^2_{\eta^w} = \underset{\sim}{\Sigma}_{W^T}$ and $\underset{\sim}{T}'_{\Delta}\underset{\sim}{T}_{\Delta}/\sigma^2_{\eta^h} = \underset{\sim}{\Sigma}_{v}$.

The interrelationships among permanent and transitory unobservable variables can then be conveniently written[13] as

$$(31)\qquad \begin{bmatrix} I_2 & \underset{\sim}{0} & \underset{\sim}{0} \\ \underset{\sim}{0} & \underset{\sim}{T}_{\gamma} & \underset{\sim}{0} \\ \underset{\sim}{0} & \underset{\sim}{0} & \underset{\sim}{T}_{\Delta} \end{bmatrix} \begin{bmatrix} W^P \\ H^C \\ \underset{\sim}{W}^T \\ \underset{\sim}{V} \end{bmatrix} = \begin{bmatrix} \underset{\sim}{\alpha}^{w'} \\ \underset{\sim}{\alpha}^{h'} \\ \underset{\sim}{0} \\ \underset{\sim}{0} \end{bmatrix} \underset{\sim}{X} + \begin{bmatrix} \delta^w \\ \delta^h \\ \underset{\sim}{\eta}^w \\ \underset{\sim}{\eta}^h \end{bmatrix} .$$

Introducing an obvious new notation equation (31) may rewritten

$$(32)\qquad \underset{\sim}{B}\underset{\sim}{Z} = \underset{\sim}{A}\underset{\sim}{X} + \underset{\sim}{\xi}$$

where $\underset{\sim}{\xi} \sim (\underset{\sim}{0}, \underset{\sim}{\psi})$ and

$$(33)\qquad \underset{\sim}{\psi} = \begin{bmatrix} \begin{pmatrix} \sigma^2_{\delta^w} & 0 \\ 0 & \sigma^2_{\delta^h} \end{pmatrix} & \underset{\sim}{0} & \underset{\sim}{0} \\ \begin{matrix} \underset{\sim}{0} \\ \underset{\sim}{0} \end{matrix} & \sigma^2_{\eta^w} I_T & \underset{\sim}{0} \\ & \underset{\sim}{0} & \sigma^2_{\eta^h} I_T \end{bmatrix}$$

The structural relation between wages and hours are then given by

$$(34)\qquad \begin{bmatrix} \underset{\sim}{W} \\ \underset{\sim}{H} \end{bmatrix} = \begin{bmatrix} \dot{\underset{\sim}{\iota}} & \underset{\sim}{0} & I_T & \underset{\sim}{0} \\ \beta\dot{\underset{\sim}{\iota}} & \dot{\underset{\sim}{\iota}} & \theta I_T & I_T \end{bmatrix} \begin{bmatrix} W^P \\ H^C \\ \underset{\sim}{W}^T \\ \underset{\sim}{V} \end{bmatrix}$$

Also equation (34) may be rewritten

$$(35)\qquad \begin{bmatrix} \underset{\sim}{W} \\ \underset{\sim}{H} \end{bmatrix} = \underset{\sim}{\Lambda}_1 \underset{\sim}{Z}$$

The covariance structure among true wage and hours values, given in equations (7), (19) and (24), are then expressed by

$$(36)\qquad \begin{bmatrix} \underset{\sim}{\Sigma}_W & \underset{\sim}{\Sigma}_{WH} \\ \underset{\sim}{\Sigma}_{HW} & \underset{\sim}{\Sigma}_H \end{bmatrix} = \underset{\sim}{\Lambda}_1 \underset{\sim}{B}^{-1} (\underset{\sim}{A} \underset{\sim}{\Sigma}_{XX} \underset{\sim}{A}' + \underset{\sim}{\psi}) \underset{\sim}{B}^{-1'} \underset{\sim}{\Lambda}_1'$$

The observed data are for annual hours and annual earnings rather than wages and hours. The relationship between true hours and earnings is given by

$$(37)\qquad \begin{bmatrix} \underset{\sim}{H} \\ \underset{\sim}{Y} \end{bmatrix} = \begin{bmatrix} \beta\dot{\underset{\sim}{\iota}} & \dot{\iota} & \theta I_T & I_T \\ (1+\beta)\dot{\underset{\sim}{\iota}} & \dot{\iota} & (1+\theta) I_T & I_T \end{bmatrix} \begin{bmatrix} W^P \\ H^C \\ \underset{\sim}{W}^T \\ \underset{\sim}{V} \end{bmatrix}$$

or in new notation as

$$(38)\qquad \begin{bmatrix} \underset{\sim}{H} \\ \underset{\sim}{Y} \end{bmatrix} = \underset{\sim}{\Lambda}_2 \underset{\sim}{Z} \quad .$$

The observed values are then

$$(39)\qquad \begin{bmatrix} \underset{\sim}{h} \\ \underset{\sim}{y} \end{bmatrix} = \begin{bmatrix} \underset{\sim}{H} \\ \underset{\sim}{Y} \end{bmatrix} + \begin{bmatrix} \underset{\sim}{\zeta} \\ \underset{\sim}{\varepsilon} \end{bmatrix}$$

The covariance structure among true hours and earnings is then

$$(40) \qquad \begin{bmatrix} \Sigma_H & \Sigma_{HY} \\ \Sigma_{HY}' & \Sigma_Y \end{bmatrix} = \Lambda_2 B^{-1}(A\Sigma_{XX}A' + \psi)B^{-1\prime}\Lambda_2' \quad .$$

The corresponding observed covariance matrix is

$$(41) \qquad \begin{bmatrix} \Sigma_h & \Sigma_{hy} \\ \Sigma_{yh} & \Sigma_y \end{bmatrix} = \begin{bmatrix} \Sigma_{HH} & \Sigma_{HY} \\ \Sigma_{YH} & \Sigma_{YY} \end{bmatrix} + \begin{bmatrix} \sigma_\zeta^2 I_T & 0 \\ 0 & \sigma_\varepsilon^2 I_T \end{bmatrix} \quad .$$

IV. EMPIRICAL ESTIMATES

In this section I present estimates of the parameters of the dynamic labor supply model discussed in the previous section and discuss the implications of those estimates. First, several hypotheses are tested with respect to measurement error and equality of the long run and short run elasticities. Second, for the model finally selected, estimates of the predicted covariance structure are compared with the actual ones. For these parameter estimates the various aspects of true wage, hour and earnings dynamics are explored fully. The importance of the various sources of earnings inequality are compared. Finally parameter estimates are compared across several subsamples including schooling groups, experience groups, union membership status, and wife's work status.

a. The Michigan Income Dynamics Panel

The University of Michigan Panel Study of Income Dynamics represents a panel of seven contiguous years, 1967-73. The survey included 5,517 households, about 2,000 from the 1967 Survey of Economic Opportunity and an additional 3,000 from a cross section of U.S. families. Since the SEO subsample selected by the Survey Research Center for inclusion in the panel was not random with respect to income, this group is excluded from consideration. A detailed description of the data is provided in Morgan (1964). The parameters of the model are estimated for the 1,041 persons identified as a white male head of household (including single persons) between the ages 18 and 58 in 1967 who were not disabled, retired or a fulltime student during the period and who reported positive annual hours and earnings each year. All earnings values are in real 1970 dollars. The mean years of schooling is 12.12 and the mean years of experience (age minus years of schooling minus 5) in 1970 is 24.11.

b. Parameter Estimates

Individual year means of log earnings ($\phi_t + \Gamma_t$), log hours (ϕ_t) and log wages (Γ_t) are presented in Table 2 along with their respective antilogs. These parameter estimates do not vary across the various submodels because they correspond to simple means.[14] These wage and hour figures correspond roughly to aggregate time series observations.[15] They are however for a restricted subgroup of the population, prime age (18 to 58 in 1967) white males who were not disabled, retired or full time students, and who had positive annual hours and annual earnings, each year of the seven year period 1967-73. Perhaps the most positively responsive groups with respect to labor supply are omitted, especially those who would enter the labor force to work positive hours. Perhaps most importantly the values of ϕ_t and Γ_t for a panel necessarily incorporate mean experience effects as well as time effects.[16]

Estimates of all other parameters of the model are presented in Table 3. The full model is compared with three alternative restricted models. The first tests the hypothesis that the long-run and short-run labor supply elasticities are equal, $\beta = \theta$. The hypothesis is clearly not rejected. The long-run and short-run labor supply elasticities are not different. As will be illustrated this result is robust over many subsamples. This is in strong contrast to many previous studies. As will be noted later the serial correlation in transitory wage rates is .823. It appears that the serial correlation in transitory wage rates is high enough to induce workers to behave as if they were permanent changes.

Table 2. Mean Log Earnings, Log Hours and Log Wages

Year	Hours(ϕ_t)	Earn($\phi_t+\Gamma_t$)	Wage(Γ_t)		Antilogs		
					Hours	Earn	Wage
1967	7.753	9.111	1.358		2328	9054	3.89
1968	7.755	9.165	1.410		2333	9557	4.10
1969	7.744	9.195	1.451		2307	9848	4.27
1970	7.723	9.187	1.464		2260	9769	4.32
1971	7.717	9.194	1.477		2246	9838	4.38
1972	7.733	9.250	1.517		2282	10404	4.56
1973	7.730	9.282	1.552		2275	10743	4.72
Trend	-.005	.024	.029				

Table 3 . Parameter Estimates For White Males Asymptotic Standard Errors in ( ).

Parameter	Full Model	$\beta \equiv \theta$	$\sigma^2_\epsilon \equiv 0$	$\sigma^2_\xi \equiv 0$, $\sigma^2_\epsilon \equiv 0$
β	-.184	-.160	-.176	-.158
	(.026)	(.014)	(.020)	(.019)
θ	-.138	$=\beta$	-.134	-.307
	(.025)		(.025)	(.009)
Wages				
α^w: Sch	.079	.079	.078	.078
	(.004)	(.004)	(.004)	(.004)
Exp	.042	.042	.039	.039
	(.005)	(.005)	(.005)	(.005)
Exp Sq	-.001	-.001	-.001	-.001
	(.000)	(.000)	(.000)	(.000)
$\sigma^2_{\xi^w}$	.111	.111	.140	.144
	(.011)	(.011)	(.007)	(.007)
$\sigma^2_{\eta^w}$	.033	.033	.059	.073
	(.003)	(.003)	(.002)	(.002)
γ	.826	.823	.467	.372
	(.033)	(.033)	(.022)	(.018)
Hours				
α^h: Sch	.018	.016	.018	.016
	(.003)	(.003)	(.003)	(.003)
Exp	.007	.006	.006	.006
	(.003)	(.003)	(.003)	(.003)
Exp Sq	-.000	-.000	-.000	-.000
	(.000)	(.000)	(.000)	(.000)
$\sigma^2_{\xi^h}$	.037	.037	.037	.037
	(.002)	(.002)	(.002)	(.002)
$\sigma^2_{\eta^h}$	.022	.023	.025	.033
	(.001)	(.001)	(.001)	(.001)
Δ	.399	.397	.348	.283
	(.026)	(.025)	(.024)	(.017)
Measure Error				
σ^2_ξ (hours)	.016	.015	.012	
	(.001)	(.001)	(.001)	
σ^2_ϵ (earn)	.020	.020		
	(.002)	(.002)		
N	1041	1041	1041	1041
χ^2	504.0	505.1	549.2	614.7
d.f.	135	136	136	137

The other estimates concern the importance of measurement error in observed hours and earnings. These sources of variation are clearly significant individually and combined. While measurement error in earnings is significant, controlling for it has relatively little impact on parameter estimates except to reduce estimated wage components and increase estimated serial correlation. Measurement error accounts for 6.6 percent of total variation in observed log earnings. The components of earnings variation are:

$$\hat{\sigma}_y^2 = \hat{\sigma}_Y^2 + \hat{\sigma}_\varepsilon^2$$

$$.296 = .276 + .020 \quad .$$

Measurement error in observed annual hours is even more significant and controlling for it has a larger impact on parameter estimates. The most important effect on parameter estimates is to eliminate the negative bias imparted to the short-run labor supply elasticity when only hours and earnings are observed rather than the wage being observed directly. This source of bias is widely cited in the literature.[17] It also reduces the estimates of all variance parameters and both serial correlation coefficients. Measurement error accounts for 17.4 percent of total variation in observed log annual hours. The components of hours variation are:

$$\sigma_h^2 = \sigma_H^2 + \sigma_\zeta^2$$

$$.086 = .071 + .015 \quad .$$

Predicted and actual pooled covariances across pairs of years are presented in Table 4. Predicted values are obtained from the parameters of the full

Table 4. Predicted (Model) and Actual (Pooled) Covariances

$s=\lvert t-\tau\rvert$	$C(W_t,W_\tau)$ Model	$C(h_t,h_\tau)$ Model	$C(h_t,h_\tau)$ Pooled	$C(y_t,y_\tau)$ Model	$C(y_t,y_\tau)$ Pooled	$C(h_t,y_\tau)$ Model	$C(h_t,y_\tau)$ Pooled $t\le\tau$	$C(h_t,y_\tau)$ Pooled $t\ge\tau$
0	.280	.086	.086	.295	.293	.042	.042	.042
1	.277	.054	.055	.247	.246	.028	.030	.026
2	.259	.047	.049	.230	.229	.024	.025	.025
3	.245	.044	.045	.218	.216	.023	.022	.023
4	.233	.043	.043	.211	.209	.022	.021	.020
5	.223	.042	.041	.204	.200	.022	.022	.018
6	.215	.042	.040	.199	.188	.022	.021	.018
∞	.178	.040		.178		.022		

Table 5. Mean Effects of Schooling and Experience on Wages, Hours and Earnings

Variable	Wage α^w	Hours $\alpha^h+\theta\alpha^w$	Earnings $\alpha^h+(1+\theta)\alpha^w$	Non LS Hrs α^h
Sch	.079	.003	.082	.016
Exp	.042	.001	.041	.006
Exp Sq.	-.001	-.000	-.001	-.000
R^{2*} Perm.	.376	.030	.420	.098
R^2 True Total	.239	.017	.271	.059
R^2 Observed		.014	.253	

* R^2 values are computed as $\alpha'\Sigma_{xx}\alpha$ divided by the comparison variance.

model (including measurement error) with $\beta = \theta$. The estimated model parameters reproduce the actual covariance patterns remarkably well. A first order autoregressive process was assumed for both transitory wages and exogenous (not wage induced) transitory hours covariation over time. The resulting total hours and earning covariation over time is correspondingly a weighted sum of these two autoregressive series plus the permanent component. The prediction errors in each are quite small. The covariance between hours and earnings actually observed also exhibit the declining covariance property predicted by the labor supply model in conjunction with permanent and serially correlated transitory wage and exogenous hours variation. It is, in fact, this covariance structure which primarily determines the estimates of β and θ . It is quite a strong result to find that the permanent level of covariation in hours and earnings and the rate of decline in the covariation toward that permanent level imply that β and θ are equal.

c. Mean Effects of Schooling and Experience

Before turning to the components of variance consider the mean effects of schooling and experience on wages, hours and earnings. The estimated values of the effect of schooling and experience on wages $\underset{\sim}{\alpha}^w$ and the effect on exogenous hours $\underset{\sim}{\alpha}^h$ are present in Table 5 along with some other calculated coefficients. The total effect of schooling and experience on annual hours is given by $\underset{\sim}{\alpha}^h + \beta\underset{\sim}{\alpha}^w$ and the total effect on annual earnings is $\underset{\sim}{\alpha}^h + (1+\beta)\underset{\sim}{\alpha}^w$.

An additional year of schooling increases wages 7.9 percent and exogenous annual hours by 1.6 percent. The combined effect of a year of schooling on annual hours, given the labor supply elasticity -.160, is an increase of .3 percent. An additional year of schooling increases annual earnings, through exogenous hours, wages and induced hours, by 8.2 percent. The .082 is precisely the coefficient of schooling in a simple earnings function including experience and time dummies estimated by OLS on the pooled data. The experience coefficients are also the same. However, the precise sources are made evident by this estimation procedure.

Years of experience have the usual quadratic effect on wages and earnings resulting in a concave experience-wage or experience-earnings profile. The experience-exogenous hours profile has a much larger positive slope (is more concave) than the total experience hours profile including the negative reaction to the increased wage rate over the life cycle.

Schooling and experience "explain" 37.6 percent of permanent wage (W^P) variation and 23.9 percent to total wage (W) variation. They explain 9.8 percent of permanent exogenous hours variation and 5.9 percent of total exogenous wage variation. When the labor supply response is included, they explain only 3.0 percent of permanent hours (H^P) variation, 1.7 percent of total true hours (H) variation, and 1.4 percent of observed (h) variation. Schooling and experience account for 42.0 percent of permanent earnings (Y^P) variation, 27.1 percent of total true earnings (Y) variation, and 25.3 percent of observed earnings variation.

d. Wage Dynamics

Of total wage variation within any year 63.6 percent represents permanent differences among individuals. The components of within year wage variations are:

$$\sigma^2_W = \sigma^2_{W^P} + \sigma^2_{W^T}$$

$$.280 = .178 + .102$$

Of the permanent component 37.6 percent is explained by schooling and experience.

$$\sigma^2_{W^P} = \underset{\sim}{\alpha}^{W'} \underset{\sim}{\Sigma}_{XX} \underset{\sim}{\alpha}^W + \sigma^2_{\delta^W}$$

$$.178 = .067 + .111$$

The serial correlation coefficient in transitory wages γ is .823. The covariance between wages in any two years t and τ is given by

$$\sigma_{W_t W_\tau} = \sigma^2_{W^P} + \sigma^2_{W^T} \gamma^{|t-\tau|}$$

$$= .178 + .102(.823)^{|t-\tau|} \quad .$$

The covariance declines asymptotically but slowly to .178 as the years become further apart. These covariances were reported in Table 3.

e. Hours Dynamics

Total true hours variation, exogenous hours variation, and labor supply wage induced variation are discussed in turn. Permanent hours (H^P) variation accounts for 61.4 percent of total true hours (H) variation.

$$\sigma^2_H = \sigma^2_{H^P} + \sigma^2_{H^T}$$

$$.071 = .041 + .030$$

Permanent variation is due to exogenous hours, to wage induced hours and to the covariation between H^c and W^P caused by $\underset{\sim}{X}$.

$$\sigma^2_{H^P} = \sigma^2_{H^c} + \beta^2\sigma^2_{W^P} + 2\beta\sigma_{H^cW^P}$$

$$.041 = .041 + .005 - .005$$

where $\sigma_{H^cW^P} = \underset{\sim}{\alpha}^{h'}\underset{\sim}{\Sigma}_{XX}\underset{\sim}{\alpha}^{w} = .014$.

Of the transitory variation 90 percent is due to exogenous hours.

$$\sigma^2_{H^T} = \sigma^2_v + \theta^2\sigma^2_{W^T}$$

$$.030 = .027 + .003$$

The covariance between any two years t and τ is

$$\sigma_{H_tH_\tau} = \sigma^2_{H^P} + \sigma^2_v\Delta^{|t-\tau|} + \theta^2\sigma^2_{W^T}\,\gamma^{|t-\tau|}$$

$$= .041 + .027(.397)^{|t-\tau|} + .003(.823)^{|t-\tau|} .$$

Again these covariances were computed in Table 3.

Alternatively one can decompose hours variation into exogenous and wage induced variation.

$$\sigma^2_H = \beta^2\sigma^2_W + (\sigma^2_{H^c}) + 2\beta\sigma_{H^cW^P}$$

$$.071 = .007 + .068 - .004$$

(Given that $\beta \equiv \theta$.) A substantial 95.7 percent is due to exogenous hours variation.

f. Earning Dynamics and Sources of Earnings Inequality

The variance in the log of earnings is often used as a measure of inequality. (See Mincer (1974), Chiswick (1974), Atkinson (1970).) The decompositions afforded by this model yield a fairly complete analysis of these sources of earnings inequality.

First, measurement error accounts for 6.6 percent of observed earnings inequality. True earnings inequality is the desired measure. Of total true log earnings variation 64.5 percent represents permanent differences among individuals (white males).[18] The components of earnings variation are

$$\sigma^2_Y = \sigma^2_{Y^P} + \sigma^2_{Y^T}$$

$$.276 = .178 + .098$$

Of the permanent earnings variation 23.0 percent is due to permanent exogenous hours differences, 70.8 percent is due to permanent wage differences and the induced permanent hours variation and the remaining 6.2 percent is due to the correlation between exogenous permanent hours and permanent wages.

$$\sigma^2_{Y^P} = \sigma^2_{H^C} + (1+\beta)^2\sigma^2_{W^P} + 2(1+\beta)\sigma_{H^C W^P}$$

$$.178 = .041 + .126 + .011$$

Of the remaining transitory variation in true earnings 27.5 percent is due to exogenous transitory hours.

$$\sigma^2_{Y^T} = \sigma^2_v + (1+\theta)^2\sigma^2_{W^T}$$

$$.098 = .027 + .071$$

The covariance in true earnings between any two years t and τ is

$$\sigma_{Y_t,Y_\tau} = \sigma^2_{Y^P} + \sigma^2_v\Delta^{|t-\tau|} + (1+\beta)^2\sigma^2_{W^T}\gamma^{|t-\tau|}$$

$$.178 + .027(.397)^{|t-\tau|} + .071(.823)^{|t-\tau|} .$$

Alternatively total true earnings variation can be decomposed into exogenous hours and wage (plus induced hours) variation. A substantial 24.5 percent of earnings inequality is due to exogenous variation in hours, 60 percent of which is permanent.

$$\sigma^2_Y = (1+\beta)^2\sigma^2_W + (\sigma^2_{H^c} + \sigma^2_v) + 2(1+\beta)\sigma_{H^cW^P} .$$

$$.276 = .197 + .068 + .012$$

g. <u>Comparison of Schooling Groups</u>

Separate parameter estimates are obtained for the three schooling groups: (1) less than 12 years of school; (2) a high school degree, 12 years; and (3) more than a high school degree. Sample sizes would not permit smaller groupings. The year means are presented in Table 6 and the components of variance are presented in Table 7. The full set of estimates are in the Appendix.

The permanent and transitory labor supply elasticities are not significantly different in any of the schooling groups. The elasticities are remarkably close across schooling groups, and are very close to the combined elasticity

Table 6. Aggregate Means of Earnings Hours and Wages by Year by Schooling

	Sch < 12 Yrs.			Sch = 12 Yrs.			Sch > 12 Yrs.		
Year	$\bar{y}_t$	$\bar{h}_t (= \phi_t)$	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t
1967	8.871	7.742	1.129	9.076	7.767	1.309	9.357	7.749	1.609
68	8.898	7.727	1.171	9.134	7.778	1.356	9.417	7.758	1.659
69	8.904	7.700	1.204	9.175	7.767	1.408	9.453	7.760	1.693
70	8.898	7.684	1.214	9.143	7.737	1.408	9.469	7.746	1.722
71	8.903	7.664	1.239	9.153	7.734	1.419	9.474	7.749	1.725
72	8.962	7.700	1.262	9.220	7.736	1.482	9.527	7.761	1.765
73	9.001	7.685	1.316	9.249	7.738	1.512	9.547	7.762	1.785
Trend	.019	-.009	.028	.024	-.007	.031	.029	.001	.028

Table 7. Variance Components by Schooling Group

	Years of School		
Component	<12	=12	>12
$\sigma^2_{W^P}$	.182	.123	.119
$\sigma^2_{W^T}$	.071	.100	.160
$\sigma^2_{H^C}$	.030	.017	.025
σ^2_{V}	.040	.026	.018
$\sigma^2_{H^P}$	.036	.020	.027
$\sigma^2_{H^T}$	.041	.030	.021
$\sigma^2_{Y^P}$	.151	.104	.114
$\sigma^2_{Y^T}$	.092	.091	.137
N	304	358	366

of -.160. Measurement error in both observed hours and observed earnings are quite significant and similar in magnitude to the combined estimate.

Additional schooling appears to increase the wage at an increasing rate, 6.8 percent per year for less than 12 years and 10.1 percent per year for greater than 12 years; but it increases permanent hours at a declining rate, 2.3 percent per year for less than 12 years and 1.0 percent per year for greater than twelve. The implied effect on permanent annual earnings, $\alpha^h + (1+\beta)\alpha^w$, is correspondingly an increasing function of schooling, 7.8 percent per year for less than 12 years and 9.8 percent per year for greater than 12 years (using the own groups β estimate). The experience effects are all very similar to the combined estimates.

The components of wage variation vary systematically across schooling groups. The size of the permanent unmeasured wage component, $\sigma^2_{\delta^W}$, declines substantially at the higher schooling group. This result holds true to a lesser degree when the effect of schooling and experience are incorporated to obtain total permanent wage variation, $\sigma^2_{W^P}$. While the size of the variance in the random shock, $\sigma^2_{\eta^W}$, is U-shaped with increased schooling, the serial correlation coefficient increases more than enough to offset the decline so that the variation in transitory wages, $\sigma^2_{W^T}$, actually increases with schooling. There is clearly a tradeoff between the size of the permanent wage component and the amount of autocorrelation. Both increase the correlation among years. They change in opposite directions across schooling groups resulting in correlations which are quite similar. However the estimate of the proportion of wage variation which is permanent differs substantially: 71.9 percent for less than 12 years, 55.2 percent for 12 years, and 42.6 percent for greater than 12 years.

Exogenous hours is characterized by a U-shaped pattern for both $\sigma^2_{\delta^h}$ and $\sigma^2_{H^c}$ and by a declining pattern for both $\sigma^2_{\eta^h}$ and σ^2_{v}. The U-shaped pattern for the permanent component is not surprising since high school graduates should be a more homogenous group than the other two. However, it appears that increased schooling results in a decline in transitory variation in hours which is only slightly offset by an increase in auto-correlation.

Earnings variation is characterized by a U-shaped pattern of permanent variation and a larger transitory component in the higher schooling group. Of total true earnings variation the permanent component represents 62.1 percent for less than 12 years of schooling, 53.2 percent for 12 years and 45.4 percent for greater than 12 years.

h. Comparison of Experience (in 1970) Groups

Parameter estimates are obtained for experience groups of ten year intervals up to 30 years and for those men with more than 30 years of experience. The year means are presented in Table 8 and the components of variance are presented in Table 9. The full set of parameter estimates are presented in the Appendix.

The growth of the means with time reflects the average effect of experience within the intervals as well as time effects. The mean growth rate (trend) in the wage declines monotonically from 7.3 percent for the young experience group to 2.0 percent for the experience group with more than 30 years of experience. The aggregate trend in annual hours is characterized as expected by a slight rise in hours worked for young workers, a fairly flat hours profile during the middle years and a substantial decline of 1.3 percent per year on average for those with more than thirty years experience. Correspondingly the aggregate

Table 8. Mean Earnings, Hours and Wages by Experience Group

	Years of Experience											
	0–10			11–20			21–30			>30		
Year	$\bar{y}_t$	ϕ_t	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t
1967	8.836	7.738	1.098	9.134	7.770	1.364	9.234	7.761	1.473	9.080	7.734	1.346
68	8.983	7.781	1.202	9.181	7.766	1.415	9.286	7.766	1.520	9.091	7.728	1.363
69	9.084	7.801	1.283	9.234	7.766	1.468	9.304	7.747	1.557	9.084	7.702	1.382
70	9.128	7.785	1.343	9.210	7.748	1.462	9.292	7.735	1.558	9.075	7.669	1.406
71	9.162	7.780	1.382	9.216	7.748	1.468	9.291	7.727	1.564	9.082	7.640	1.442
72	9.292	7.794	1.498	9.278	7.769	1.509	9.350	7.748	1.602	9.112	7.665	1.447
73	9.332	7.784	1.548	9.330	7.769	1.561	9.362	7.729	1.633	9.134	7.677	1.457
Trend	.078	.005	.073	.027	-.004	.028	.018	-.005	.023	.007	-.013	.020

Table 9. Variance Components by Experience Group

	Years of Experience			
Component	0–10	11–20	21–30	>30
σ^2_{WP}	.099	.155	.215	.229
σ^2_{WT}	.126	.100	.053	.095
σ^2_{HC}	.022	.026	.027	.025
σ^2_{V}	.026	.031	.021	.033
σ^2_{HP}	.024	.032	.032	.031
σ^2_{HT}	.033	.034	.023	.034
σ^2_{YP}	.097	.125	.180	.184
σ^2_{YT}	.099	.098	.057	.110
N	116	284	322	306

earnings trend declines monotonically even more substantially than wages from 7.8 percent for the youngest group to .7 percent for the oldest.

While the trend Γ_t reflects the combined effect of a time trend and experience as each person in the group grows older, the effect of (linear) experience on the mean wage, W^P, within the group is characterized by a similar pattern.[19] Additional experience increases the mean wage of individuals within the same experience group by 5.8 percent per year for the younger, and by approximately 1.6 percent per year within the two middle groups. It reduces the mean wage by 1.5 percent per year for the oldest group. Exogenous hours profiles increase at 3.2 percent per year for the youngest group, and remain essentially flat over the remainder of the working life with a modest decline within the oldest experience group. Correspondingly, annual earnings profiles rise at 8.2 percent per year for the youngest group: 3.2 percent exogenous experience-hours growth, 5.8 percent direct wage growth, and a .8 percent hours reduction induced by the increased wage. Annual earnings rise at 1.4 percent per year through the middle years and eventually decline at 1.7 percent per year for the oldest experience group. These experience patterns are consistent with the patterns observed in the combined estimates.

The schooling coefficient declines monotonically by almost 40 percent from the youngest to the oldest experience group. This could be the result of a lessening of the importance of schooling over the life cycle or of those persons with more experience also being of older vintage combined with an increase in the importance of schooling for more recent vintages. Results reported in Lillard (1977) suggest that earnings-experience profiles diverge for the same cohort.

The permanent and transitory labor supply elasticities are of similar magnitudes across the groups. Again the two elasticities are not significantly different from each other.

The variance of the permanent component in wages (both measured and unmeasured) increases substantially and monotonically from low to high experience levels. The variance for the youngest group is less than half of that for the oldest two groups. The size of the transitory wage component declines considerably in spite of a large rise in the serial correlation coefficient from .549 to .852 from the youngest to oldest group. The resulting share of wage variation which represents permanent wage differences increases from 56.0 percent for the youngest to 70.7 percent for the oldest. The permanent and transitory exogenous hours components are roughly constant across experience groups. The resulting true annual earnings permanent variance component increases monotonically, and almost doubles, from the youngest to oldest experience group. The transitory true earnings component is roughly constant across experience groups (except for the 21-30 group due to both a low transitory wage component and a low transitory exogenous hours component). The share of the permanent earnings component goes from 49.4 percent for the young group to 62.6 percent for the oldest.

i. Comparison of Union Groups

Parameter estimates are obtained for three groups identified by their degree of attachment to a labor union during the seven year period. The first group never reported being a member of a labor union during the period. The second group reported being a member between 1 and 5 times and the third group reported membership all six years that the question was asked (the question was not asked in 1972). It should be kept in mind that union membership is certainly a choice variable and subdividing the sample by it may introduce some selectivity issues not discussed.[20] The year means are presented in Table 10 and the components of variance are presented in Table 11. A full set of parameter estimates are in the Appendix.

The wage differential between union (all) and non-union (none) workers is about 14 percent and constant over the period. The aggregate trend in

Table 10. Mean Earnings, Hours and Wages By Union Status

Year	Years in a Union: All			1-5			None		
	$\bar{y}_t$	ϕ_t	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t	$\bar{y}_t$	ϕ_t	Γ_t
1967	9.213	7.693	1.520	8.988	7.744	1.244	9.130	7.776	1.354
68	9.235	7.694	1.541	9.058	7.744	1.314	9.181	7.781	1.400
69	9.260	7.676	1.584	9.099	7.735	1.364	9.207	7.771	1.436
70	9.218	7.634	1.584	9.068	7.698	1.370	9.219	7.764	1.455
71	9.260	7.635	1.625	9.047	7.685	1.362	9.224	7.758	1.466
72	9.315	7.660	1.655	9.123	7.699	1.424	9.280	7.771	1.509
73	9.355	7.662	1.693	9.169	7.707	1.462	9.298	7.761	1.537
Trend	.021	-.007	.028	.022	-.009	.031	.026	-.003	.028

Table 11. Variance Components by Union Status

	Years in Union (of 6): None	1-5	All
σ^2_{WP}	.258	.111	.042
σ^2_{WT}	.124	.061	.038
σ^2_{HC}	.027	.024	.023
σ^2_{V}	.022	.040	.027
σ^2_{HP}	.032	.027	.026
σ^2_{HT}	.023	.046	.028
σ^2_{YP}	.216	.102	.045
σ^2_{YT}	.121	.069	.055
N	608	220	200

growth rates over the period 1967-73 were very similar across the groups. While those never in a union had slightly greater earnings growth it was due to greater hours reduction rather than to a differential wage growth.

The effect of schooling on wages is three times larger for those never in a union than for those always in a union. For those in a union sometimes the effect of schooling is in between. Schooling has roughly the same effect for each group on exogenous hours. The mean schooling level is 12.8 years for those never in a union and 10.7 years for those always in a union.

Wage growth with experience is substantially greater for those never in a union, especially at younger ages. However union members increase their exogenous annual hours of work at twice the rate (1.4 percent per year versus .6 percent per year) of non-union workers. Mean experience is 23.6 years for those never in a union and 27.0 years for those always in a union.

There is considerably less wage variation among union members than among those never union members. Total wage variation is .382 for non-union workers and .080 for union members (nearly 80 percent smaller). The variance in permanent wages for union members is only 16.3 percent as large as for non-union workers. Among non-union workers schooling and experience account for 46.9 percent of permanent wage variation and 31.7 percent of total wage variation. Among union members schooling and experience account for 19.0 percent of permanent wage variation and 10.0 percent of total wage variation. Transitory variation among union members in wages is only 30.6 percent as large as the corresponding variation for non-union workers. The serial correlation coefficient is the same for both.

The exogenous and total hours components are very similar across groups. Those workers in a union sometimes have slightly lower permanent hours and larger transitory hours components than the other two.

There is, as a result of the large difference in wage variation, a large difference in earnings variation among the groups. Total true earnings variance for union members is only 29.7 percent as large as among non-union workers. Permanent earnings variance is only 20.8 percent as large. Transitory earnings variation is 45.4 percent as large. Among union members permanent earnings differences account for 45.0 percent, while the share is 64.1 percent for non-union workers.

j. Comparison By Wife's Work Status

The married men in the sample are grouped by the work status of their wives. One group had wives who did not work at all (None) during the 7 year period 1967-73. Another group had wives who worked (positive annual hours and annual earnings) each (All) of the 7 years. The third group had wives who worked some (1-6 years) of the years but not all. The year means are presented in Table 12 and the components of variance are presented in Table 13. A full set of parameter estimates are in the Appendix.

The aggregate wage differential between those men whose wives work all of the time and those men whose wives don't work at all varies between 12 and 25 percent. Those whose wives don't work earn more. The earnings growth over the period is the same for both groups. The earnings growth for the men whose wives don't work comes from a greater wage rate increase accompanied by a reduction in hours relative to men whose wives work all of the time.

The effect of schooling and experience are not very different across the groups. Schooling and experience each have a slightly greater effect on wages

Table 12. Mean Earnings, Hours and Wages by Wife's Work Status (Years Worked of 7)

	None			1–6 Years			All		
Year	$\bar{y}_t$	ϕ_t	r_t	$\bar{y}_t$	ϕ_t	r_t	$\bar{y}_t$	ϕ_t	r_t
1967	8.927	7.783	1.144	9.129	7.769	1.360	8.720	7.697	1.023
68	9.036	7.765	1.271	9.219	7.769	1.450	8.811	7.716	1.095
69	9.189	7.764	1.425	9.218	7.750	1.468	8.969	7.710	1.259
70	9.317	7.756	1.561	9.205	7.736	1.469	9.076	7.675	1.311
71	9.408	7.739	1.669	9.197	7.725	1.472	9.202	7.685	1.517
72	9.526	7.741	1.785	9.267	7.750	1.517	9.297	7.717	1.580
73	9.655	7.739	1.916	9.310	7.752	1.558	9.449	7.700	1.749
Trend	.121	−.007	.128	.022	−.004	.026	.121	−.001	.122

Table 13. Variance Components by Wife's Work Status

	Years Wife Worked of 7		
Component	None	1-6 Yrs	All
$\sigma^2_{W^P}$	.280	.154	.165
$\sigma^2_{W^T}$	.096	.102	.064
$\sigma^2_{H^C}$	.026	.028	.017
σ^2_{V}	.033	.030	.017
$\sigma^2_{H^P}$	.036	.033	.021
$\sigma^2_{H^T}$	.035	.033	.017
$\sigma^2_{Y^P}$	.211	.131	.133
$\sigma^2_{Y^T}$	.099	.101	.076
N	229	434	241

for those whose wives don't work.

The greatest difference between men by wife's work status is in the components of wage variation. The permanent wage component for men whose wives work all of the years is only 60 percent of that component for men whose wives don't work at all. The transitory wage component is 66.7 percent as large. Both permanent and transitory exogenous hours components are also much smaller. The resulting permanent earnings component and transitory earnings component for men whose wives work all years are 63.0 percent and 76.7 percent respectively as large as the corresponding components for men whose wives don't work at all.

Another interesting result is obtained for those men whose wives work some but not all of the years. Those men have a smaller permanent and larger transitory wage component (and earnings component) than either extreme group. Serial correlation in the transitory component is slightly weaker as well.

Perhaps the most interesting result is that the transitory labor supply elasticity is significantly more positive, but still negative, than the permanent elasticity. The permanent labor supply elasticities are not different from the overall value. All of these results taken together indicate a need for further research on directly estimating the degree of complimentarity and substitution among the labor supply of family members (husbands and wives). Potentially the long run and short run cross elasticities are different. See Kniesner (1976) for an informative theoretical analysis of cross substitution effects and indirect empirical tests from cross section data (but with no permanent and transitory distinction).

V. SUMMARY AND CONCLUSIONS

In this paper, I present a method for estimating permanent and transitory response functions in panel data. The basic concept developed here is an analysis of the structural relationships among time varying economic variables, each of which has been decomposed into permanent and serially correlated transitory components. The permanent and transitory components can then be allowed to be related by different structural parameters. The more serial correlation in a transitory component, the more it will behave as a permanent one.

The method is applied empirically to estimate the parameters of a dynamic labor supply model. Wages are presumed to be predetermined from the viewpoint of each individual laborer. The wage rate (in logs) of any particular laborer at a particular point in time is composed of several components: a year effect representing year-to-year wage variation common to all individuals; an individual specific permanent (long run) wage level; and a serially correlated transitory (short run) deviation of that individual's wage rate from its permanent level. The individual permanent component is itself composed of the effect of measured and of unmeasured individual characteristics which affect wages. Annual hours of work is similarly composed of several components: a year effect representing year-to-year variation in hours common to all individuals; a labor supply response to permanent wage differences among persons; an indivdual residual or deviation from the aggregate long run labor supply function; an individual response to the personal transitory wage deviation from its permanent level; and a residual serially correlated transitory term representing involuntary transitory variation in hours (not on the aggregate transitory response function). All individuals are assumed to have the same transitory labor supply elasticity and the same degree of serial correlation in transitory variables.

The dynamic labor supply including errors of measurement can be straight-forwardly written as a LISREL model. Assuming normality for the relevant variables, maximum likelihood estimates of the parameters are obtained. Parameters are estimated for while males who are not disabled, retired or full time students during the panel period 1967-73. The model is estimated using annual hours of work and annual earnings in real 1970 dollars (equals hours plus wages in logs) since wages are not observed directly.

First the significance of measurement error is tested. It is quite significant for both hours and earnings. Measurement error accounts for 6.6 percent of observed variation in annual earnings and 17.4 percent of observed variation in annual hours of work. Controlling for measurement error in hours eliminates the usual negative bias in the labor supply elasticity widely cited in the literature when hours and earnings rather than hours and wages are observed. The permanent and transitory labor supply elasticities (response parameters) are found to be negative and not significantly different from each other (-.160 when constrained to be equal), while each is significantly different from zero. This equality result holds in various subgroups as well, e.g. schooling groups, experience groups and union status groups. The exception is husbands of wives who work all 7 years. In the latter case the short-run elasticity is more positive than the long-run elasticity but remains negative. It appears that serial correlation in transitory wages is high enough (.823) to induce workers to behave as if they are permanent.

The estimated regression coefficients of schooling and experience on permanent wages and on exogenous permanent hours allows a decomposition of the effect of these variables on annual hours and annual earnings. The effect of an additional year of schooling on annual hours in .3 percent per year and on annual earnings is 8.2 percent per year. The effect on the average hourly wage rate is 7.9 percent. Experience has a large effect on the wage rate of 4.2 percent per year and on annual earnings of 4.1 percent per year, but has little effect on annual hours except for those with little experience (positive) and for older workers (small negative).

Of total wage variation within any year 63.6 percent represents permanent differences among individuals. Of the permanent component 37.6 percent is explained by schooling and experience. The serial correlation coefficient in transitory wages is .823.

Permanent hours variation accounts for 61.4 percent of total true hours (net of measured error) variation. Of the permanent variation 3 percent is due to schooling and experience. Of the transitory variation 90 percent is due to exogenous hours variation (not induced by transitory wages).

Of total true (net of measurement error) log earnings earnings variation 64.5 percent represents permanent differences among individuals. Of the permanent earning component 42 percent is attributed to schooling and experience. Of the permanent earnings variation 23.0

percent is due to permanent exogenous hours differences, 70.8 percent is due to permanent wage differences and the induced permanent hours variation and the remaining 6.2 percent is due to the correlation between exogenous permanent hours and permanent wages. Of the remaining transitory variation in true earnings 27.5 percent is due to exogenous transitory hours. Alternatively total true earnings variation can be decomposed into exogenous hours and wage (plus induced hours) variation. A substantial 24.5 percent of earnings inequality is due to exogenous variation in hours, 60 percent of which is permanent.

The permanent and transitory labor supply elasticities are not significantly different by schooling group. The elasticities are remarkably close across schooling groups, and are very close to the combined elasticity. The components of wage variation vary systematically across schooling groups. The estimate of the proportion of wage variation which is permanent differs substantially: 71.9 percent for less than 12 years, 55.2 percent for 12 years, and 42.6 percent for greater than 12 years.

The wage, hours and earnings patterns with respect to experience within and across experience groups are consistent with the estimates for the combined group, but with more detail, for wage, hours and earnings. The schooling coefficient declines monotonically by almost 40 percent from the youngest to the oldest experience group. The variance of the permanent component in wages and in earnings (both measured and unmeasured) increases substantially and monotonically from low to high experience levels. The variance for the youngest group is less than half of that for the oldest two groups. The size of the transitory wage component declines considerably in spite of a large rise in the serial correlation coefficient from .549 to .852 from the youngest to oldest group. The resulting share of wage variation which represents permanent wage differences increases from 56.0 percent for the youngest to 70.7 percent for the oldest. The transitory true earnings component is roughly constant across experience groups (except for the 21-30 group due to both a low transitory wage component and a low transitory exogenous hours component). The share of the permanent earnings component goes from 49.4 percent for the young group to 62.6 percent for the oldest.

The wage differential between union (all) and non-union (none) workers is about 14 percent and constant over the period. The aggregate trend in growth rates over the period 1967-73 were very similar across the groups. While those never in a union had slightly greater earnings growth it was due to greater hours reduction rather than to a differential wage growth. The effect of schooling on wages is three times larger for those never in a union than for those always in a union. Wage growth with experience is substantially greater for those never in a union, especially at younger ages. However union members increase their exogenous annual hours of work at twice the rate (1.4 percent per year versus .6 percent per year) of non-union workers. Mean experience is 23.6 years for those never in a union and 27.0 years for those always in a union. There is considerably less wage variation among union members than among those never union members. Total wage variation is .382 for non-union workers and .080 for union members (nearly 80 percent smaller). The variance in permanent wages for union members is only 16.3 percent as large as for non-union workers. Among non-union workers schooling and experience account for 46.9 percent of permanent wage variation and 13.7 percent of total wage variation. Among union members schooling and experience account for 19.0 percent of permanent wage variation and 10.0 percent of total wage variation. Transitory variation among union members in wages is only 30.6 percent as large as the corresponding variation for non-union workers. The serial correlation coefficient is the same for both.

There is, as a result of the large difference in wage variation, a large difference in earnings variation among the groups. Total true earnings variance for union members is only 29.7 percent as large as among non-union workers. permanent earnings variance is only 20.8 percent as large. Transitory earnings variation is 45.4 percent as large. Among union members permanent earnings differences account for 45.0 percent, while the share is 64.1 percent for non-union workers.

The greatest difference between men by wife's work status is in the components of wage variation. The permanent wage component for men whose wives work all of the years is only 60 percent of that component for men whose wives don't work at all. The transitory wage component is 66.7 percent as large. Both permanent and transitory exogenous hours components are also much smaller. The resulting permanent earnings component and transitory earnings component for men whose wives work all years are 63.0 percent and 76.7 percent respectively as large as the corresponding components for men whose wives don't work at all.

Another interesting result is obtained for those men whose wives work some but not all of the years. Those men have a smaller permanent and larger transitory wage component (and earnings component) than either extreme group. Serial correlation in the transitory component is slightly weaker as well.

Perhaps the most interesting result is that the transitory labor supply elasticity is signigicantly more positive, but still negative, than the permanent elasticity. The permanent labor supply elasticities are not different from the overall value. All of these results taken together indicate a need for further research on directly estimating the degree of complimentarity and substitution among the labor supply of family members (husbands and wives).

FOOTNOTES

1. Lucas and Rapping (1969) also provide an excellent list of previous studies in their footnote (1).

2. This paper provides a nice summary of Heckman's earlier work and citations to related work. See also Heckman and Willis (1977).

3. There are two sequentially related papers. This work is to my knowledge the most closely related the study reported in this paper.

4. For example: "Wage in Period 1: Average of earnings divided by hours during the weeks prior to the second through fifth quarterly interviews. Only those weeks for which positive earnings were reported were used in the average."

5. Such a reconciliation is not my purpose in this paper. This study is meant to be suggestive of the potential for estimating even better dynamic models on panel data.

6. For an exception see Lillard and Willis (1977) where the implications of permanent and serially correlated transitory earnings components for the analysis of dynamic aspects of earnings (poverty-not poverty) mobility are explicitly derived.

7. A later footnote will explore this issue more fully in the context of the usual remedies employed in cross section data.

8. Time varying variables could be introduced into the analysis but are not in this study. The dimension of the MLE estimation problem increases by T (number of years) for each time varying variable introduced. It increases by (T + 1) if the variable is allowed to have different permanent and transitory effects.

9. I do not attempt to model the aggregate relationship between ϕ_t and Γ_t, but a recursive relationship analogous to the ones assumed in the other cases is explored empirically. That is,

$$\phi_t = d\Gamma_t = e_t \quad ,$$

based on year means.

10. The effect of fixed costs of entry, but not changing hours, are discussed by Cogan (1977) and Hanock (1976). Rees (1973) discusses why employers might be interested in fixed or inflexible working hours.

11. Some of these issues are addressed in Hurd (1976) and in Boskin (1977) as well as the survey by Keeley (1977). For a family model see Kniesner (1976).

12. The larger transitory variance may be thought of as occurring in the first year of labor force experience. This assumption makes the process stationary and replaces the usual infinite history assumed in time series analysis.

13. The appearance of the elements $\sqrt{1-\gamma^2}$ and $\sqrt{1-\Delta^2}$ and T_Δ introduces two nonlinear constraints. The problem is circumvented in the results reported here by allowing the two nonlinear elements to be estimated as free parameters. Chi-sq degrees of freedom correspondingly reflect the extra parameters. Alternative estimates obtained by iteratively constraining the elements $\sqrt{1-\hat{\gamma}}$ and $\sqrt{1-\hat{\Delta}}$, where $\hat{\gamma}$ and $\hat{\Delta}$ were the estimated values from the last iteration produced very similar estimates.

14. These parameters could be estimated along with the other parameters by maximum likelihood. However, this would require introducing a prohibitive T(T-1) extra variables into the model and would not contribute much. Alternative estimates were obtained by constraining all year effects (Γ_t and ϕ_t) to be zero. However the results are not discussed here. See Appendix for the estimates.

15. Γ_t and ϕ_t are generated by aggregate labor supply and demand forces, but it

may be instructive to estimate the aggregate labor supply elasticity implied if wages are assumed to be determined exogenously. The simple regression estimate of the parameter d in the relation $\emptyset_t = d\Gamma_t + e_t$, equation (11), for the data in Table 2 is $\hat{d} = -.154$. While this estimate is very close to the estimates of β and θ reported later, the resemblance does not hold up within subgroups.

16. See Weiss and Lillard (1977) and Klevmarkin and Quigley (1976) for a further caveat concerning the interpretations of measured time and experience effects when vintage effects are present.

17. It is informative to consider simple characterizations of the solutions to to the problem, of measurement error in hours when hours and earnings are observed, in cross section data suggested by Mincer (1976) and Ghez and Becker (1975).

One approach suggested by Mincer is to regress current log hours (at t) on lagged values of log earnings minus log hours (both at time t - s). When wages are truly fixed ($W_t = W, \forall_t$) and hours are fixed except for measurement error ($h_t = H + \xi_t$, ξ_t not serially correlated), earnings are fixed except for measurement error ($y_t = W + H + \varepsilon_t$, ε_t also not serially correlated). The model is $H = \beta W$. Under these assumptions the OLS regression coefficient, b, of $(y_{t-s} - h_{t-s})$ on h_t has expected value given by

$E(b) = \beta(1 + (\sigma_u^2 + \sigma_v^2)/\sigma_W^2)^{-1}$. The expectation is only biased toward zero due to measurement error. For the model assumed in the last section the expectation becomes (assuming $\beta \equiv \theta$)

$$E(b) = \beta \frac{(1-(1-\gamma^s)\sigma^2_{W^T}/\sigma_W^2)}{(1+(\sigma_\xi^2 + \sigma_\varepsilon^2)/\sigma_W^2)} \qquad \text{(except } s = 0) .$$

The existence of transitory wage component, serially correlated or not, introduces a source of negative bias.

An approach used by Ghez and Becker was to use the OLS regression coefficient, a, of y_t on h_t. Under the simple assumptions of the last paragraph

$$E(a) = \frac{\beta}{1+\beta} / \left(1 + \frac{\sigma^2_\varepsilon}{(1+\beta)\sigma^2_W}\right) .$$

Under the assumption of the model in the last section (assuming $\beta \equiv \theta$)

$$E(a) = \frac{\frac{\beta}{1+\beta} + (\sigma^2_{H^c} + \sigma^2_v)/((1+\beta)^2\sigma^2_W)}{1 + (\sigma^2_{H^c} + \sigma^2_v + \sigma^2_\varepsilon)/((1+\beta)^2\sigma^2_W)}$$

Another approach taken by Borjas (1976) is to use independent current estimates of the wage rate. This includes using "usual wage" to predict hours and using (earnings/hours) to predict hours last week. His results lead to a positive labor supply response but are the very short run as hours last week.

18. The corresponding estimate of ρ_y based directly on the earnings data alone in Lillard and Willis (1977) was 71.1 percent. There are a few differences in approach worth noting. The previous estimate (1) made no attempt to control for measurement error in earnings, (2) was based on an analysis of OLS residuals (from the same earnings function implied by $\underset{\sim}{\alpha}^h+(1+\beta)\underset{\sim}{\alpha}^w$ including only time dummies, schooling and experience plus race) rather than joint estimation by M.L., and (3) was not based on a separate analysis of whites, as the current results are, but instead included a dummy intercept shift variable for non white observations.

19. For an analysis of alternative interpretations of these experience and time effects when vintage (cohort) effects are important, see Weiss and Lillard (1977).

20. For an analysis of the selectivity issue with respect to union membership see Lee (forthcoming).

Appendix Table 1. Parameter Estimates By Schooling and Experience

Parameter	Years of School <12	=12	>12	Years of Experience 0–10	11–20	21–30	>30
β	−.185	−.160	−.133	−.130	−.200	−.157	−.168
	(.031)	(.036)	(.062)	(.114)	(.045)	(.029)	(.029)
θ	−.145	−.193	−.136	−.238	−.184	−.173	−.101
	(.062)	(.042)	(.031)	(.051)	(.039)	(.054)	(.055)
Wages							
α^w: Sch	.068		.101	.108	.094	.086	.062
	(.014)		(.014)	(.014)	(.007)	(.008)	(.008)
Exp	.058	.046	.052	.058	.015	.017	−.015
	(.012)	(.010)	(.009)	(.017)	(.007)	(.008)	(.006)
ExpSq	−.001	−.001	−.001				
	(.000)	(.000)	(.000)				
$\sigma^2_{\xi w}$	.152	.106	.070	.047	.084	.151	.166
	(.015)	(.018)	(.029)	(.018)	(.012)	(.016)	(.019)
$\sigma^2_{\eta w}$	.051	.027	.039	.088	.046	.026	.026
	(.011)	(.004)	(.005)	(.021)	(.006)	(.005)	(.004)
γ	.530	.855	.870	.549	.745	.712	.852
	(.112)	(.051)	(.044)	(.119)	(.053)	(.111)	(.051)
Hours							
α^h: Sch	.023		.010	.024	.021	.016	.014
	(.006)		(.009)	(.014)	(.006)	(.004)	(.004)
Exp	.008	.009	.012	.032	.002	−.001	−.005
	(.006)	(.004)	(.005)	(.011)	(.004)	(.003)	(.002)
ExpSq	−.000	−.000	−.000				
	(.000)	(.000)	(.000)				
$\sigma^2_{\xi h}$	.027	.017	.023	.017	.023	.025	.022
	(.003)	(.002)	(.003)	(.004)	(.003)	(.002)	(.003)
$\sigma^2_{\eta h}$	.036	.022	.014	.022	.030	.020	.022
	(.003)	(.001)	(.001)	(.004)	(.002)	(.002)	(.002)
Δ	.331	.374	.476	.396	.230	.246	.580
	(.044)	(.036)	(.049)	(.062)	(.042)	(.042)	(.047)
Measure Error							
σ^2_{ζ} (hours)	.019	.010	.014	.007	.014	.019	.024
	(.003)	(.001)	(.001)	(.005)	(.002)	(.004)	(.003)
σ^2_{ε} (Earn)	.015	.019	.016	.014	.008	.013	.016
	(.008)	(.002)	(.003)	(.014)	(.003)	(.002)	(.001)
N	304	358	366	116	284	322	306
χ^2	370.9	330.7	443.5	298.5	319.3	247.6	323.5
d.f.	135	120	135	137	137	137	137

Appendix

Table 2. Parameter Estimates by Union Status and Wife's Work Status and With No Time Effects (ϕ_t, ρ_t)

	Union Membership (Yrs of 6)			Wife's Work Status (Yrs Worked of 7)			No Time Effects
Parameter	None	1-5 Yrs	All	None	1-6 Yrs	All	
ρ	-.145	-.161	-.271	-.187	-.184	-.162	-.177
	(.025)	(.053)	(.098)	(.032)	(.037)	(.040)	(.053)
θ	-.106	-.315	-.145	-.169	-.166	-.036	-.144
	(.027)	(.061)	(.098)	(.064)	(.034)	(.060)	(.035)
Wages							
α^w: Sch	.104	.069	.032	.088	.084	.072	.080
	(.006)	(.008)	(.007)	(.011)	(.006)	(.008)	(.007)
Exp	.045	.027	.011	.057	.036	.048	.045
	(.007)	(.009)	(.009)	(.014)	(.007)	(.012)	(.008)
Exp Sq	-.001	-.000	-.000	-.001	-.001	-.001	-.001
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
$\sigma^2_{\xi w}$	.137	.071	.034	.182	.087	.106	.082
	(.013)	(.010)	(.011)	(.025)	(.011)	(.017)	(.030)
$\sigma^2_{\eta w}$	.046	.050	.014	.025	.049	.025	.034
	(.004)	(.015)	(.003)	(.005)	(.006)	(.005)	(.004)
γ	.793	.429	.809	.851	.723	.781	.871
	(.039)	(.124)	(.093)	(.071)	(.053)	(.082)	(.048)
Hours							
α^h: Sch	.013	.011	.014	.019	.022	.013	.017
	(.004)	(.006)	(.006)	(.005)	(.004)	(.004)	(.005)
Exp	.006	.010	.013	.003	.010	.008	.007
	(.003)	(.005)	(.006)	(.006)	(.004)	(.003)	(.004)
Exp Sq	-.000	-.000	-.000	-.000	-.000	-.000	-.000
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
$\sigma^2_{\xi h}$	.024	.022	.021	.021	.023	.015	.022
	(.002)	(.003)	(.003)	(.003)	(.002)	(.003)	(.002)
$\sigma^2_{\eta h}$	.018	.036	.026	.025	.027	.013	.023
	(.001)	(.004)	(.002)	(.002)	(.002)	(.002)	(.001)
Δ	.432	.313	.209	.481	.304	.507	.407
	(.034)	(.050)	(.056)	(.052)	(.034)	(.064)	(.039)
Measure Error							
σ^2_{τ} (Hours)	.014	.004	.022	.016	.013	.017	.015
	(.001)	(.005)	(.002)	(.002)	(.002)	(.002)	(.001)
σ^2_{ϵ} (Earn)	.021	.013	.003	.021	.017	.013	.021
	(.003)	(.010)	(.002)	(.003)	(.004)	(.003)	(.003)
N	608	220	200	229	434	241	1041
χ^2	390.3	368.6	343.6	270.0	442.5	249.3	214.1
d.f.	135	135	135	135	135	135	135

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