Estimating Life Cycle Labor Supply Tax Effects

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We present an econometrically tractable life cycle labor supply model for panel data including intertemporally progressive taxes on uncertain wage and nonwage incomes. Our two-stage fixed-effects generalized method-of-moments approach first estimates intratemporal and then intertemporal preferences. Specification testing demonstrates the value of incorporating joint progressive taxation of labor and nonlabor incomes. Results for prime-age men emphasize the roles played by hourly wage endogeneity, worker-specific effects, the measure of the rate of pay, and intertemporal budget constraint nonseparability. Simulations indicate that recent tax reforms, while not self-financing, stimulated male labor supplied by about 3 percent and reduced deadweight loss by about 16 percent.

I. Introduction

There are two main strands of empirical labor supply research. The macroeconomic literature has focused on workers' willingness to substitute into and out of leisure as real wages fluctuate, which is

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crucial to understanding the cyclicality of hours worked, employment, and unemployment (Kniesner and Goldsmith 1987). Micro labor supply research has as a main theme the work incentive effects of transfers and taxes (Pencavel 1986; Moffitt 1992). A shortcoming in the empirical labor supply literature overall is an inattention to the life cycle effects of taxes and transfers. We use panel data to estimate the intratemporal preference parameters that interest microeconomists and the intertemporal preference parameters that interest macroeconomists while examining the labor supply effects of intertemporally progressive joint taxation of wage and interest incomes.

The great leap forward in quantifying the labor supply effects of taxes came with econometric models acknowledging unobserved heterogeneity and measurement errors when the budget constraint is piecewise linear because of tax and transfer programs (Burtless and Hausman 1978; Hausman 1981*b*). Econometric models of labor supply including income taxes are still generally static and do not capture intertemporal effects of tax reforms. A substantive, but orthogonal, branch of empirical labor supply research has focused on intertemporal substitutability of labor while generally ignoring the influence of income taxes and transfers (Heckman and MaCurdy 1980, 1982; MaCurdy 1981, 1985; Mankiw, Rotemberg, and Summers 1985; Altonji 1986; Kimmel and Kniesner 1998). Incorporating the realism of interest income taxation along with wage taxation complicates the econometric model because dual taxation generates intertemporal nonseparabilities in the budget constraint (Blomquist 1985).

A result appearing regularly in empirical research on labor supply—static or dynamic, including or ignoring wage taxation—is that intratemporal wage and intertemporal substitution effects are small and are imprecisely estimated. There is still little agreement on whether the estimated compensated wage effect is positive or whether the Slutsky matrix conditions hold empirically (Killingsworth 1983; Pencavel 1986; Conway and Kniesner 1994). A positive compensated wage effect means that moving to a flatter tax induces more hours worked and reduces deadweight loss, and a negative compensated wage effect produces outcomes opposite those intended by proponents of tax reform.[1] The lack of consensus on the magnitude and sign of compensated wage effects continues to muddy discussions of the welfare implications of a flatter tax structure (Hausman 1981*b*; MaCurdy 1992; Hall and Rabushka 1995).

[1] Negative substitution effects can appear, a priori, in a life cycle model because of intertemporal nonseparabilities caused by progressive income taxes (Blomquist 1985).

Our research produces improved estimates of the work incentive effects of progressive income taxation on life cycle labor supply. The two-stage generalized method-of-moments (GMM) econometric model we develop first estimates intratemporal wage effects from labor supply conditioned on asset positions at the beginning and end of the period. Instead of the usual piecewise-linear budget set, we use a continuously differentiable smooth budget constraint to mitigate econometric complications of measurement errors from incorrectly imputing the marginal tax rate (MaCurdy, Green, and Paarsch 1990; Flood and MaCurdy 1992). We use the estimated intratemporal preferences to simulate the labor supply and deadweight loss effects of tax reforms, including the changes in the U.S federal income taxes from before the Economic Recovery Tax Act (ERTA) to after the Tax Reform Act of 1986 (TRA86). In a second stage of estimation we apply a GMM estimator to the Euler condition for the marginal utility of net wealth to recover intertemporal preferences and compute intertemporal labor supply elasticities. Our estimates from stages 1 and 2 together produce elasticity estimates that contribute to both the micro and macro empirical labor supply literatures.

We find the following results of note. The mean compensated wage elasticity from our preferred model is about +0.15, and the estimated marginal tax rate elasticity is about −0.06. There is important variation in both the compensated wage and marginal tax rate effects across wealth quartiles, with the tax effect 40 percent larger in the highest wealth quartile than in the lowest wealth quartile. Sensitivity checks indicate that the compensated wage and tax effects depend crucially on the wage measure and instrument set. Our findings reveal the underappreciated result that the instrument set and wage measure are the most crucial model specification choices the researcher makes. Most important, we find intertemporal nonseparability in the budget constraint, which signals the need to use panel data and to incorporate the joint progressive taxation of wage and nonwage incomes. Simulations building on our labor supply results indicate that (1) the average prime-age married man would work about 4 percent more and be willing to pay about 23 percent of his adjusted gross income to have his income taxes eliminated and that (2) recent U.S. tax reforms (ERTA and TRA86), while not self-financing, stimulated male labor supplied by about 3 percent and reduced deadweight loss by about 16 percent. Because of its larger estimated lifetime substitution effect, our life cycle–consistent labor supply model locates a greater amount of excess burden of income taxation than found with the static model of Hausman (1981*a*, 1981*b*).

II. Life Cycle Labor Supply with Joint Progressive Wage and Interest Income Taxes

A major innovation in estimating life cycle labor supply has been to recognize that in an environment of economic certainty extraperiod information can be summarized by a latent time-invariant worker-specific effect (λ, the marginal utility of wealth) so that the estimating equation needs only current-period economic information (Heckman and MaCurdy 1980, 1982; MaCurdy 1981). In an environment of uncertain wages and interest rates, contemporaneous net dissaving ($\mu_t = r_t A_{t-1} - \Delta A_t$) is sufficient to summarize extraperiod information, again simplifying estimation (MaCurdy 1983; Blundell and Walker 1986; Blundell, Meghir, and Neves 1993). The empirical convenience of estimating labor supply functions conditioned on λ or μ_t is maintained when only wage income is taxed or when wage and interest incomes are jointly taxed linearly. A theoretically valid econometric labor supply model becomes more complicated when, as is true in most Western economies, wage and interest incomes are jointly taxed progressively (Blomquist 1985).

To see the complications introduced by joint progressive taxation of labor and interest incomes, consider a person who has preferences over consumption, C_t, and hours of paid work, h_t ($t = 1, \ldots, T$). Let preferences over consumption and labor supply be defined by a strictly concave lifetime utility function, $U = U(C_t, h_t)$. The choice set is described by an asset accumulation constraint, $A_t = (1 + r_t)A_{t-1} + W_t h_t - C_t - T(I_t, \pi)$, where r_t and W_t are the real interest and real wage rates, and $T(I_t, \pi)$ is a progressive tax function defined over taxable income ($I_t = W_t h_t + r_t A_{t-1} - E_t$) with exemptions E_t and tax parameters π. If the researcher imposes no intertemporal separability properties on the lifetime utility function or budget constraint, then a change in the wage rate in period t will affect consumption and labor choices in period $t + 1$ through three channels. A change in W_t will (i) tighten or slacken the budget constraint, which produces a wealth effect; (ii) alter the choice of C_t or h_t, which in turn alters the indifference curves between consumption and labor choices in the next period, $t + 1$; and (iii) alter marginal prices and wages in period $t + 1$, which is due to progressive income taxation (Blomquist 1985).

Imposing intertemporal separability on the lifetime utility function eliminates the intertemporal preferences' effect of a change in wages, channel ii. Imposing intertemporal separability in the budget constraint by, say, linear taxes, $T(I_t, \pi) = \pi I_t$, eliminates the intertemporal marginal price effect, channel iii. Intertemporal separability of both lifetime preferences and the budget constraint makes a change in the current wage rate, W_t, have only a wealth effect on future labor supply, h_{t+1}. Dual separability of objective and constraint lets one write labor supply in an environment of economic certainty as a function of λ, W, and π, $h_t = h(W_t(1 - \pi), \lambda)$, or write labor supply in an economic environment of uncertainty as a function of μ, W, and π, $h_t = h(W_t(1 - \pi), \mu_t)$. When both preferences and the budget constraint are time-separable, either the marginal utility of wealth or dissaving is a sufficient statistic for unmeasured extraperiod information.

If the researcher allows a realistically progressive tax function over wage and interest incomes, then current wage changes will affect the future net wage and interest rates so that a change in W_t will have both wealth and substitution effects on future labor supplied.[2] Jointly progressive taxes make the after-tax interest rate endogenous with labor supply in both periods t and $t + 1$ (see App. A). Moreover, labor supply in period t is a function of the marginal utility of wealth, the real after-tax wage in period t, and the discounted marginal tax rate in period $t + 1$ so that if $T'(I_t)$ is the marginal tax rate for income in period t,

$$h_t = h\left\{\lambda(1 + \rho)^t\left[1 - \left(\frac{r_{t+1}}{1 + r_{t+1}}\right)T'(I_{t+1})\right], W_t[1 - T'(I_t)]\right\}.$$

Unless the researcher is willing to assume knowledge of future wages, prices, taxes, and interest rates, the λ-constant labor supply specification will not be of much practical use when there is a jointly progressive wage and interest income tax.

Under two-stage budgeting it is still possible to estimate the intratemporal utility parameters consistently by conditioning on beginning-of-period assets (A_{t-1}) and end-of-period assets (A_t), where starting assets (A_{t-1}) capture the influence of past decisions and ending assets (A_t) capture the influence of next period's prices (Blomquist 1985; Blundell and Walker 1986).[3] Even with the modified two-stage budgeting approach just described the researcher must still estimate the Euler equation for the evolution of the marginal utility of net wealth to recover intertemporal preferences. We now develop more of the details of a two-stage budgeting model that identifies lifetime preference parameters first by estimating intratemporal preferences with a labor supply equation and then by estimating in-

[2] Imposing intertemporal separability on the budget constraint but allowing intertemporal nonseparability of preferences, such as through habit formation, leads to models found in Hotz, Kydland, and Sedlacek (1988) and Bover (1991).

[3] Alternatively, $S_t = A_t - (1 + r_t)A_{t-1}$ and r_tA_{t-1} could be a set of sufficient statistics.

tertemporal preferences with an Euler equation for the marginal utility of wealth.

A. A Life Cycle–Consistent Labor Supply Function

We begin our two-step model by first parameterizing intratemporal preferences. To facilitate comparisons to the seminal econometric research on how taxes affect labor supply, we purposely select a linear labor supply function (Burtless and Hausman 1978; Hausman 1981*b*). Let h_t^* denote a worker's desired labor supply:

$$h_t^* = \alpha\omega_t + \delta A_{t-1} + \phi A_t + \mathbf{X}_t\gamma, \qquad (1)$$

where $\omega_t = W_t[1 - T'(I_t)]$ is the after-tax marginal wage rate, $\mathbf{X}_t$ is a vector of fixed and time-varying demographics affecting intratemporal preferences for work, and α, δ, ϕ, and γ are parameters to estimate. Current and lagged assets, A_{t-1} and A_t, are sufficient statistics for capturing extraperiod information in our two-stage budgeting model with jointly progressive wage and interest income tax.

Equation (1) has been labeled a life cycle–consistent labor supply function because it is invariant to monotonic transformations of the within-period utility function (Blundell and Walker 1986). If the within-period transformation is the identity transform, then the parameters in equation (1) represent both the intratemporal and intertemporal preference parameters; if the within-period transformation is some other monotonic function, then the parameters of (1) represent intratemporal preferences alone and we must turn to the Euler equation for the marginal utility of wealth to identify intertemporal preferences.

B. Marginal Utility of Net Wealth

Because we do not want to restrict intra- and intertemporal preferences to be the same, we now discuss how to identify the second-step intertemporal preferences from the Euler equation for the marginal utility of net wealth. Under rational expectations and a joint wage and interest income tax, the marginal utility of net wealth is

$$\beta[(1 + r_{n,t+1})\lambda_{A_{t+1}}] = \lambda_{A_t}\epsilon_{t+1}, \qquad (2)$$

where $\beta \equiv (1 + \rho)^{-1}$ is the subjective discount factor, $r_{n,t+1} \equiv (1 - \tau_{t+1})r_{t+1}$ is the after-tax (net) real interest rate, $\lambda_{A_t} = (\partial F_t/\partial V_t) \times (\partial V_t/\partial A_t)$ is the marginal utility of net wealth found by taking the assets derivative of indirect utility $(F_t(V_t))$, with F_t the monotonic transformation), and ϵ_{t+1} is the forecast error between $(1 + r_{n,t+1})\lambda_{A_{t+1}}$ and its expectation at time t.

We operationalize the marginal utility of net wealth with a specific indirect utility function with unknown intertemporal preference parameters. Specifically, we integrate up from the estimated labor supply equation (1) applying Roy's identity to construct within-period indirect utility, which we ultimately use to examine the welfare implications of the recent U.S. tax reforms.[4] We treat our estimate of within-period indirect utility as a known function and follow MaCurdy (1983) and Blundell et al. (1993) in taking a Box-Cox transformation of indirect utility as

$$F_t(\hat{V}_t) = \frac{[V_t(\omega_t, A_t, A_{t-1}; \hat{\Lambda})]^{1+\sigma_t} - 1}{1 + \sigma_t}, \tag{3}$$

where $V_t(\cdot)$ is a monotonically increasing function of the net real wage and assets conditioned on estimated intratemporal preference parameters $\hat{\Lambda} = [\hat{\alpha}, \hat{\delta}, \hat{\phi}, \hat{\gamma}]'$, and the $\sigma_t = \sigma_0 + \sum_k \sigma_k Z_{kt}$ are the unknown intertemporal preference parameters that determine the allocation of wealth over time. We permit intertemporal preferences to depend on observable time-varying demographics, Z_{kt}, which captures cross-sectionally varying risk aversion. Taking natural logs and first-differencing (2) along with the marginal utility of net wealth from the indirect utility function (3) produces the Euler equation we use to estimate intertemporal preferences:

$$\sigma_0 \Delta \ln \hat{V}_{t+1} + \sum_k \sigma_k \Delta(Z_{k,t+1} \ln \hat{V}_{t+1}) + \Delta \ln \hat{V}'_{t+1} + \kappa_{t+1} = \ln \epsilon_{t+1}, \tag{4}$$

where $\Delta \ln \hat{V}_{t+1} = \ln \hat{V}_{t+1} - \ln \hat{V}_t$, $\Delta \ln \hat{V}'_{t+1} = \ln(\partial \hat{V}_{t+1}/\partial A_{t+1}) - \ln(\partial \hat{V}_t/\partial A_t)$, and $\kappa_{t+1} = r_{n,t+1} - \rho$.

III. Econometric Background

Cross-section data are sufficient to identify intratemporal preference parameters, Λ. Identifying both intratemporal and intertemporal preferences requires either longitudinal or repeated cross-section data. Panel data also facilitate modeling unobserved worker hetero-

[4] From Roy's identity, we can solve the partial differential equation $h_t^* = (\partial V_t/\partial \omega_t)/(\partial V_t/\partial A_t)$ in terms of the economic variables of interest at time t, which are h_t, ω_t, and A_t. The associated within-period indirect utility function is $V_t(\cdot) = \exp(\phi\omega_t)[A_t + (\alpha/\phi)\omega_t + (\mathbf{X}_t\gamma/\phi) + (\delta/\phi)A_{t-1} - (\alpha/\phi^2)]$, which is the same as that of Hausman (1981*a*, 1981*b*) except for the additional term $(\delta/\phi)A_{t-1}$ that arises from the modified two-stage budgeting.

geneity. Our sequential two-step econometric approach—summarized immediately below and described more fully in Appendix B—is first to estimate labor supply conditioned on the starting and ending assets positions using equation (1). Next we substitute the estimated intratemporal preference parameters into the marginal utility of net wealth (4), treating first-stage parameter estimates as known. Finally, we apply a consistently estimated asymptotic covariance matrix for sequential GMM estimators to correct for the fact that the standard errors of the second-stage Euler equation (4) depend on first-stage standard errors (Newey 1984).

A. *Step 1: Estimating Intratemporal Preferences*

We allow the life cycle–consistent labor supply estimating equation to include possible latent worker heterogeneity:

$$h_t = \alpha\omega_t + \delta A_{t-1} + \phi A_t + \mathbf{X}_t\gamma + \eta_i + \xi_t, \tag{5}$$

where ξ_t is a random error in hours worked at time t, which is assumed to be independently and identically distributed as iid$(0, \sigma_\xi^2)$. We treat the after-tax wage and assets as endogenous because the marginal tax rate depends on contemporaneous hours worked through earnings. Most important, the time-invariant worker-specific labor supply heterogeneity, η_i, is generally not independent of the regressors because life cycle wealth has person-specific influences. Endogenous worker heterogeneity is commonly specified as a fixed effect. The first-differences GMM estimator we apply to labor supply in equation (5) yields consistent parameter estimates in the case of a two-stage rational expectations model such as ours (Keane and Runkle 1992).

B. *Step 2: Estimating Intertemporal Preferences*

In step 2 we estimate intertemporal preference parameters. The sample conditional moment for our second-step estimates of the Euler equation of motion in the marginal utility of net wealth (4) is

$$m(P, Z, \mathbf{M}; \hat{\Lambda}, \Theta) \equiv \mathbf{M}'\left[\sigma_0\Delta \ln \hat{V}_{t+1} + \sum_k \sigma_k\Delta(Z_{k,t+1} \ln \hat{V}_{t+1}) + \Delta \ln \hat{V}'_{t+1} + \kappa_{t+1}\right], \tag{6}$$

where $\mathbf{M}$ is an $N(T-2) \times Q$ matrix of instruments, and Θ is the $K \times 1$ vector of intertemporal preference parameters we estimate.

In step 2 we minimize

$$J_T(\Theta; \hat{\Lambda}) = m(P, Z, \mathbf{M}; \hat{\Lambda}, \Theta)'\hat{\mathbf{S}}_{mm}^{-1}m(P, Z, \mathbf{M}; \hat{\Lambda}, \Theta), \qquad (7)$$

where the weighting matrix in the criterion function (7), $\hat{\mathbf{S}}_{mm} \equiv \mathbf{M}'(\ln \hat{\epsilon}_{t+1} \ln \hat{\epsilon}'_{t+1})\mathbf{M}$, is conditionally heteroskedastic. We obtain initial consistent estimates of the random disturbance, $\ln \epsilon_{t+1}$, by setting the weighting matrix equal to the identity matrix.

C. *Parameterizing Taxes*

To incorporate a piecewise-linear budget constraint, the most influential econometric research on labor supply tax effects has applied a maximum likelihood procedure resting on strong behavioral assumptions: that a worker has complete knowledge of all tax brackets ex ante, that the pretax wage and nonwage income are exogenous to labor supply, and that the Slutsky condition is satisfied at all internal kink points of the budget constraint (Burtless and Hausman 1978; Hausman 1981*a*, 1981*b*). Pretax wage exogeneity is unlikely because researchers have most often used average hourly earnings. If hours worked are measured with error, then so are average hourly earnings, which then become endogenous. It has recently been noted that some maximum likelihood models force a nonnegative estimated wage effect and a nonpositive estimated asset income effect (MaCurdy et al. 1990; Flood and MaCurdy 1992; MaCurdy 1992). Because of the econometric complexity and stringent ex ante restrictions that the maximum likelihood estimator used in the well-known and heavily cited papers of Hausman and Burtless places on estimated labor supply parameters, our alternative instrumental variables estimator is attractive.

Our estimator requires only information on the effective marginal tax rate. Because reported taxable income is relatively free of measurement error in the typical micro data set, the marginal tax rate can be closely tracked by a differentiable polynomial in taxable income (MaCurdy et al. 1990; Rodgers, Brown, and Duncan 1993). A differentiable marginal rate can also be integrated back to infer the total taxes function needed to construct net wealth.[5]

The differentiable marginal tax rate approach to parameterizing net wages and nonwage income detailed in Appendix C easily accommodates additional income taxes including FICA, which applies to only a portion of earnings. Moreover, during our sample period,

[5] An alternative approach is to linearize the constraint at the chosen hours (Triest 1990). The linearization method depends on correctly imputing the kink points in the budget constraint, which must be constructed from a relatively noisy measure of hours of work.

most states had progressive income tax schedules: about three-fourths of the states used federal adjusted gross income or federal taxable income as their tax bases. We judge the impact of state taxes as too important to ignore while too complicated to represent exhaustively. Because we focus on how federal income taxes affect life cycle labor supply, we augment the worker's federal marginal tax and social security tax rates with the average state income tax rate, defined as the ratio of individual state income tax collections to adjusted gross income in the state.

IV. Data

Our data, for 1978–87, are taken from the Panel Study of Income Dynamics (PSID), the data used most frequently to study U.S. labor supply and the data used in much influential research on how taxes affect labor supply (Hausman 1981*b*; MaCurdy et al. 1990). We select our sample using multidimensional rules similar to those used by others studying prime ages. Our sample is continuously married, continuously working men who were aged 22–51 in 1978. The worker must be paid either an hourly wage rate or a salary; we delete piece-rate workers and the self-employed. Our selection process yields a balanced panel of 532 prime-age U.S. men over 10 years, for 5,320 person years of observations. Appendix D contains summary statistics for all variables used in estimation.

A. *Wages*

The PSID asks workers how they are paid. For workers paid by the hour the survey records the gross hourly wage rate. The interviewer asks workers paid salaries how frequently they are paid, such as weekly, biweekly, or monthly. The interviewer then norms a salaried worker's pay by a fixed number of hours depending on the pay period. For example, salary divided by 40 is the hourly wage rate constructed for a salaried worker paid weekly. The pretax hourly wage rate we use is as free as possible of the division bias found in labor supply regressions using average hourly earnings as the wage.[6]

[6] There may be some concern that the PSID's method of constructing salaried workers' hourly pay may impart a positive bias because workers with $h > 40$ per week have an artificially high wage rate and salaried workers with $h \leq 40$ per week have an artificially low hourly wage. To check for possible bias we separated our salaried workers into five groups and reconstructed the wage. Letting E be earnings, if (1) $h < 20$, we set $W = E \div 15$; (2) if $20 \leq h < 30$, we set $W = E \div 25$; (3) if $30 \leq h < 40$, we set $W = E \div 35$; (4) if $40 \leq h < 50$, we set $W = E \div 45$; and (5) if $50 \leq h$, we set $W = E \div 50$. We then reestimated the model in col. 3 of table 1 below using the more disaggregate construction of a wage for salaried workers, which should reduce or eliminate the artificially low and high average wages in the PSID's measure. The reestimated wage coefficient was statistically indistinguishable from that in table 1, differing in magnitude by 3 percent.

B. *Taxable Income*

When constructing annual taxable income, we assume that married men filed joint tax returns. Adjusted gross income is the sum of the man's labor earnings plus interest income. Taxable income is adjusted gross income less deductions and exemptions. The PSID provides the number of tax exemptions for dependents taken in each year, but how we calculate deductions requires additional explanation.

Computing the value of deductions depends on the year under consideration. To evaluate annual deductions prior to and including 1983, we follow the convention established in the PSID. With information from the Internal Revenue Service's *Statistics of Income,* we generate the typical value of itemized deductions on the basis of the man's adjusted gross income. We then calculate the difference between typical itemized deductions and the standard deduction, known as excess itemized deductions. For the years prior to and including 1983, when excess itemized deductions are positive, we subtract them from adjusted gross income; when excess itemized deductions are nonpositive, we apply the standard deduction.

Beginning in 1984 the PSID records whether the family itemized. For known itemizers we subtract excess itemized deductions from adjusted gross income and use the standard deduction for the men who did not itemize deductions. Prior to TRA86, the standard deduction was built into the tax tables so that we need only subtract the value of deductions exceeding the standard deduction from taxable income. After TRA86, the standard deduction is no longer built into the tax tables, so we subtract either the standard deduction or total itemized deductions from adjusted gross income depending on whether the family itemized.

C. *Assets*

The PSID has little information on interest rates, assets, and saving. In estimating the Euler equation for the marginal utility of net wealth (4), we use the after-tax annual average 3-month Treasury bill interest rate. We construct assets as the sum of the liquid and illiquid asset measures in the PSID. Liquid assets are nominal rent, interest, and dividend income capitalized by a nominal interest rate. We capitalize the first $200 of income from liquid assets by the annual average passbook savings account rate and capitalize rental income in excess of $200 per year by the annual average 3-month Treasury bill rate. For the illiquid component of assets we use the value of home equity defined as the difference between house value and outstanding principal remaining. Unlike previous researchers (Zeldes 1989; Runkle 1991), we include illiquid assets because more wealth resides in home equity than in other liquid wealth components.[7] In our sample, about 90 percent of the men are home owners, but just over half the men have liquid wealth. Because workers do not face their marginal tax rates for all taxable income, we add a capitalized lump-sum transfer to lagged wealth (A_{t-1}), creating virtual wealth. We adjust lagged wealth because A_{t-1} enters the current period's tax function. Virtual wealth is our life cycle model's analogue to the virtual income in a static model of labor supply with income taxes.[8]

V. Econometric Results

We now present results of our two-step econometric model detailed in Section III. First we report results from the life cycle–consistent labor supply model in equation (5), along with several specification tests, and then estimates of the intertemporal Euler equation (4). Our final task in this section is to use the estimates of prime-age males' intra- and intertemporal preferences to compute their lifetime indirect utility function and their wage and tax elasticities of labor supply with respect to transitory versus permanent net real wage changes.

A. *Step 1: Estimating Intratemporal Preferences*

All regressions reported in step 1 condition on the usual demographics in an econometric model of labor supplied: age, health status, and number of children living at home. We have three endogenous regressors whose labor supply effects we must identify:

[7] The PSID collected comprehensive wealth data in 1984 and 1989, including data on house equity, net value of other real estate, net value of vehicles, net value of a farm or other business, and net value of other assets. The measure of total wealth from the PSID has been used by others (Hubbard, Skinner, and Zeldes 1995). Ziliak (1998) demonstrates that variation in our measure of liquid wealth explains about half the variation in total wealth whereas including home equity makes variation in our measure of wealth explain 80 percent of total wealth. The ability of our wealth measure to track total wealth when measured independently is our justification for including both liquid and illiquid wealth measures. Our summary wealth statistics are comparable to measures in the Survey of Income and Program Participation (Engen, Gale, and Scholz 1994).

[8] Virtual wealth is the sum of lagged wealth plus the capitalized value of the lump-sum transfer, so that virtual wealth is $A_{t-1} + (\{\tau(I_t) - [T(I_t)/I_t]\} \times I_t)/r_t$, where r_t is the nominal annual average of the 3-month Treasury bill rate, τ is the marginal tax rate, and T is total taxes paid, which depend on income, I. In regressions using saving we include net saving plus the uncapitalized lump-sum transfer.

changes in the net wage, current assets, and lagged virtual assets. The instrument sets in step 1 are dated $t-1$ and $t-2$ to maintain orthogonality with the first-differenced error. We have attempted to be parsimonious in our choice of instruments, including obvious factors underlying the evolution of wages and wealth that also are not codetermined with the evolution of the lifetime profile of work effort. We also attempt to draw upon others' research (e.g., Holtz-Eakin, Newey, and Rosen 1988). More specifically, we include as identifying instruments the level of the net wage at time $t-2$ for the change in the net wage, the level of assets at time $t-2$ for the change in assets, and the level of virtual assets at time $t-2$ for the change in virtual assets. Overall, there are 20 instruments in the base-case instrument set: a constant; values at $t-1$ and $t-2$ of age, age^2, age $\times$ education, number of children, whether disabled, union membership, and home ownership; and values at $t-2$ of the gross real wage, the net real wage, the net 3-month Treasury bill rate, net real wealth, and net real virtual wealth.

The base-case labor supply model appears in column 1 of table 1. The net wage effect is positive, although statistically weak in significance, and both asset terms are statistically negative. The positive compensated and uncompensated wage effects subsequently satisfy Slutsky integrability. The compensated and uncompensated wage effects, which are approximations to Marshallian wage effects in light of the endogeneity of assets, imply that annual hours of work increase about 1.2 percent in response to a 10 percent net wage increase. The positive compensated wage effect indicates a welfare gain to a flatter tax rate structure. Both asset terms' entering significantly is evidence against a common convenient econometric assumption of a time-separable budget constraint, as is the case in models without nonlinear income taxes.

Because many empirical researchers find violations of Slutsky integrability and use time-separable budget constraints (Pencavel 1986), it is important to examine the robustness of our model specification. We now discuss a number of specification checks of our labor supply model, including the choice of instruments, the choice of gross wage measure, and the choice of whether to specify the budget constraint as conditioned on net saving or conditioned on current and lagged assets.

1. Instrument Set

We first check the internal consistency of the instruments, or whether the overidentifying restrictions are jointly orthogonal to the first-differenced error term. We use Hansen's J-statistic, which is the

TABLE 1

LIFE CYCLE–CONSISTENT LABOR SUPPLY EQUATION: TIME-SEPARABLE MODEL WITH A_t, A_{t-1}

	REPORTED HOURLY WAGE			AVERAGE HOURLY EARNINGS		
VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)
$\omega_t(\alpha)$	24.6556	−24.9649	27.8312	−16.5966	−9.5934	−8.7289
	(20.6555)	(6.1268)***	(14.9042)*	(10.1754)	(8.5701)	(9.3765)
$A_{t-1}(\delta)$ ($1,000's)	−.3698	−.3818	−.4941	−.3983	−.3212	−.5534
	(.1905)*	(.1796)**	(.2267)**	(.1727)**	(.2194)	(.2032)***
$A_t(\phi)$ ($1,000's)	−1.6211	−.0283	−2.0278	−.5478	−.5207	−1.2578
	(.8141)**	(.5498)	(.7852)***	(.6785)	(1.0365)	(.6453)**
Uncompensated wage elasticity†	.1153	−.1167	.1301	−.0832	−.0481	−.0408
	(.0966)	(.0286)***	(.0697)*	(.0510)	(.0429)	(.0438)
Lagged wealth elasticity	−.0100	−.0103	−.0135	−.0108	−.0087	−.0151
	(.0052)*	(.0049)**	(.0062)**	(.0047)**	(.0060)	(.0055)***
Current wealth elasticity	−.0468	−.0008	−.0586	−.0158	−.0150	−.0363
	(.0235)**	(.0159)	(.0227)***	(.0196)	(.0299)	(.0186)**
Compensated wage$\mid_{A_{t-1}}$ elasticity	.1190	−.1128	.1351	−.0788	−.0466	−.0352
	(.0966)	(.0292)***	(.0697)*	(.0510)	(.0430)	(.0439)
Compensated wage$\mid_{A_t}$ elasticity	.1318	−.1164	.1508	−.0772	−.0424	−.0279
	(.0969)	(.0292)***	(.0701)***	(.0515)	(.0444)	(.0443)
Marginal tax rate elasticity‡	−.0504	.0511	−.0567	.0364	.0211	.0179
	(.0423)	(.0123)***	(.0305)*	(.0223)	(.0188)	(.0192)
J-Statistic§	18.6825	21.1878	23.9234	20.0721	16.5671	27.9624
Degrees of freedom	14	15	20	14	15	20
p-value	.1774	.1309	.2458	.1279	.3454	.1103

NOTE.—Standard errors are in parentheses. Cols. 2 and 4 contain the gross wage as an additional instrument, and cols. 3 and 6 contain time dummies as instruments.

† Elasticities are computed at their mean values: net reported wage = 10.19; net average hourly earnings = 10.93; A_{t-1} = 59.332; A_t = 62.969; h_t = 2,179.48; marginal tax rate (MTR) = .2979.

‡ MTR elasticity = $(-\alpha W_t - \phi \mathrm{MTR}_t) \times (\mathrm{MTR}_t / h_t)$.

§ Degrees of freedom is the number of instruments less parameters estimated, and the *p*-value pertains to the null hypothesis that the overidentifying restrictions are not rejected.

* Significant at the 10 percent level.

** Significant at the 5 percent level.

*** Significant at the 1 percent level.

minimized value of the GMM criterion function evaluated at the estimated labor supply parameters and is distributed asymptotically as χ^2 with degrees of freedom equal to the number of instruments less parameters estimated (Hansen 1982). The p-value in column 1 of table 1 is .18, which suggests that the instruments are safely orthogonal to the error term. Satisfying internal consistency does not imply that the instruments are informative in the sense of being strongly associated with the endogenous regressors. Bound, Jaeger, and Baker (1995) recently revived concerns over instruments that are weakly correlated with the endogenous regressors, which makes instrumental variables parameter estimates biased in the direction of ordinary least squares. The geometric mean of the canonical correlations between the regressors and the instrument set for our most preferred specification, column 3 of table 1, is .387, which is well above the benchmark of $R^2 > .05$ offered by Bound et al. (1995) and alleviates concerns over weak instruments in our application.

A potentially good predictor of the net real wage and assets is the contemporaneous gross wage rate. The current real reported hourly wage will be endogenous if there is premium pay for overtime work or a compensating wage differential for long hours. We append the current gross wage to the base instrument set and report the results in column 2 of table 1. Both the uncompensated and compensated wage elasticities are significantly negative, which violates the Slutsky integrability conditions, suggesting that the gross wage is endogenous with labor supply. Although the overidentifying restrictions test does not reject the internal consistency of the augmented instrument set, it is not a test of instrument exogeneity. The researcher also should apply an objective function test, which is similar to a likelihood ratio test, to verify instrument exogeneity in a GMM model (Eichenbaum, Hansen, and Singleton 1988). To elaborate, let $J_T(\hat{\Lambda}^r)$ be the J-statistic from the model in column 2 with the extra overidentifying instrument and $J_T(\hat{\Lambda}^u)$ be the J-statistic from the baseline model in column 1. The difference between the criterion functions for the two models, which differ by the number of overidentifying instruments, produces a pseudo–likelihood ratio statistic that is distributed asymptotically as χ^2 with degrees of freedom equal to the number of additional restrictions imposed. The p-value for the pseudo–likelihood ratio test comparing columns 1 and 2 of table 1 is .015, which rejects exogeneity of the contemporaneous gross wage. Rejecting gross wage exogeneity not only supports the instrument set in column 1 but also supports our instrumental variables estimator over Hausman's (1981*a*, 1981*b*) maximum likelihood estimator, which relies on an exogenous gross wage.

Aggregate shocks may invalidate GMM estimates of rational expectations models such as ours because a time-specific effect that is common to each cross-sectional unit in a panel with finite T may not average out to zero in the sample orthogonality conditions (Chamberlain 1984). We test for the presence of aggregate shocks by appending time dummies to the base instrument set of column 1 and report the results in column 3 of table 1.[9] If unmodeled aggregate shocks are present, then the time dummies are not valid identifying instruments because they are correlated with the aggregate shock. The p-value on the pseudo–likelihood ratio exogeneity test comparing columns 1 and 3 is .09, which is consistent with aggregate shocks' being adequately reflected in the net wage and assets and time dummies' being valid instruments.

2. Wage Measure

The most common wage measure in both static and life cycle labor supply models is average real hourly earnings, defined as the ratio of annual earnings to annual hours of work. In the context of models without taxes, the average hourly earnings wage measure induces division bias, a form of measurement error that has been shown to drive the wage coefficient toward a negative value (Conway and Kniesner 1992). We reestimated each of the specifications in columns 1–3 with real average hourly earnings replacing the real reported wage to test the sensitivity of our results to the choice of wage measure. The results reported in columns 4–6 of table 1, where average hourly earnings are the wage measure, show the division bias and how it misleads the researcher studying labor supply and income taxation.[10] The division bias makes the labor supply schedule downward sloping, which violates the Slutsky integrability conditions. The parallel regressions in table 1 make us conclude that the real reported wage regressions in columns 1–3 are best.

3. Net Saving

The results in table 1, particularly column 3, provide evidence that we correctly condition labor supply on current and lagged assets because both asset measures enter significantly at the 5 percent level

[9] Runkle (1991) performs a similar test for liquidity constraints in consumption.

[10] The pseudo–likelihood ratio test for exogeneity of gross average hourly earnings by comparing cols. 4 and 5 highlights a problem noted by Eichenbaum et al. (1988). The restricted model may have a lower computed J-statistic. Using the unrestricted covariance matrix for cols. 4 and 5 gives a p-value of .043 for the pseudo–likelihood ratio test, so that gross average hourly earnings are not exogenous at the 5 percent level.

or better. An alternative approach that is also consistent with two-stage budgeting is to collapse the two asset terms into current net saving and adjust the marginal tax rate for the presence of capital income (MaCurdy 1983; Blomquist 1985).[11] For completeness we present the results of a life cycle–consistent model conditioned on current net saving in table 2 and perform the same exercises as in table 1 with table 2. In contrast to table 1, the estimated wage coefficient is negative in table 2, regardless of the wage measure or instruments.[12] Although the net saving coefficient has the ex ante expected negative sign, the overidentifying restrictions and the pseudo–likelihood ratio tests do not favor the models using time dummies as instruments in table 2, which may reflect the fact that net saving does not adequately capture aggregate shocks to labor supply. As a final specification test, we can use the pseudo–likelihood ratio test to compare the model in column 3 of table 1 to the model in column 3 of table 2. The pseudo–likelihood ratio test of parametric restrictions in GMM models, proposed by Newey and West (1987*a*), has a *p*-value of .000, which rejects the specification in table 2. Our results reject the implicit coefficient restrictions in the model conditioning on net saving in table 2 and support the model in table 1, where current and lagged assets can have independent effects on labor supply.

4. Summary

Based on extensive specification testing, our preferred first-step estimates are in column 3 of table 1, which is the model that includes time dummies in the instrument set and current and lagged assets. The mean uncompensated wage elasticity from our preferred model is about .13, and the mean compensated labor supply elasticity is about .15. The estimated tax elasticity is about −.06, so that hours worked by prime-age men would fall slightly more than 0.05 percent in the short run from a 10 percent increase in U.S. marginal tax rates. Our wage and tax elasticity estimates form the basis of the second-stage Euler equation presented next and the tax reform simulations in Section VI.

[11] Net saving is $S_t = A_t - (1 + r_{nt})A_{t-1}$. Because the worker does not face the same marginal tax rate for all income, we add a lump-sum transfer ($L_t \equiv \{\tau(I_t) - [T(I_t)/I_t]\} \times I_t$) to net saving to create virtual net saving.

[12] The negative wage coefficient in the models with net saving appears under a variety of possible instrument sets, including instrument sets that omit lagged endogenous variables.

TABLE 2

LIFE CYCLE–CONSISTENT LABOR SUPPLY EQUATION: TIME-SEPARABLE MODEL WITH S_t

	Reported Hourly Wage			Average Hourly Earnings		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\omega_t(\alpha)$	−24.885	−26.4032	−50.3075	−33.3578	6.4968	−84.4164
	(12.0730)**	(6.1845)	(8.1795)***	(7.3385)***	(8.3791)	(3.5079)***
$S_t(\phi)$ ($1,000's)	−.2406	−.2323	−.3394	−.2511	−.0519	−.6718
	(.0454)***	(.0454)***	(.0230)***	(.0411)***	(.0544)	(.0316)***
Uncompensated wage elasticity†	−.1163	−.1234	−.2352	−.1672	.0326	−.4232
	(.0564)**	(.0289)***	(.0382)***	(.0368)***	(.0420)	(.0176)***
Saving elasticity	−.0003	−.0003	−.0005	−.0004	−.0001	−.0010
	(.0001)***	(.0001)***	(3.3E-5)***	(.0001)***	(.0001)	(4.9E-5)***
Compensated wage$\mid_{S_t}$ elasticity	−.1139	−.1210	−.2317	−.1645	.0331	−.4158
	(.0564)***	(.0289)***	(.0382)***	(.0368)***	(.0420)	(.0176)***
Marginal tax rate elasticity‡	.0509	.0541	.1030	.0731	−.0142	.1850
	(.0247)**	(.0127)***	(.0167)***	(.0161)***	(.0183)	(.0077)***
J-statistic§	24.2758	24.4817	39.4987	23.5778	7.7816	67.5975
Degrees of freedom	15	16	21	15	16	21
p-value	.0605	.0795	.0085	.0726	.9551	.0000

NOTE.—Standard errors are in parentheses. Cols. 2 and 4 contain the gross wage as an additional instrument, and cols. 3 and 6 contain time dummies as instruments.
† Elasticities are computed at their mean values: net reported wage = 10.19; net average hourly earnings = 10.93; S_t = 3.084; h_t = 2,179.48; MTR = .2979.
‡ MTR elasticity = $(-\alpha W_t - \phi \mathrm{MTR}_t) \times (\mathrm{MTR}_t / h_t)$.
§ Degrees of freedom is the number of instruments less parameters estimated, and the *p*-value pertains to the null hypothesis that the overidentifying restrictions are not rejected.
* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.

B. *Step 2: Estimating Intertemporal Preferences*

We now build on the GMM fixed-effects labor supply estimates with reported wages and conditioning on current and lagged assets. Treating the estimated labor supply parameters as known when estimating the empirical Euler equation for the marginal utility of net wealth (4), we proceed to identify intertemporal preferences, including the subjective discount rate, ρ, and the coefficients of relative risk aversion, σ_k, which are components of the long-run (life cycle) labor supply elasticities. This means that our results contribute to the so-called endogenous preferences literature (Becker and Mulligan 1997).

Now we must instrument the changes in assets, the number of children, and health status. As in step 1 of our estimation, we use a parsimonious list of factors that fundamentally underlie the evolution of wealth, fertility, and health that are also not codetermined with the lifetime evolution of utility of wealth. For example, included as identifying instruments in step 2 are the level of assets at time $t-4$ for the change in assets, the number of children at time $t-3$ for the change in the number of children, and health status at time $t-3$ for the change in health status. Overall, in the GMM estimator in step 2, the basic instrument set contains 20 instruments: a constant; gross and net reported wages; the net 3-month Treasury bill rate; children, age, age^2, the interaction of age and education, health status, and home ownership in years $t-3$ and $t-4$; and net wealth in year $t-4$.

Euler equation estimates from step 2 appear in table 3. As in step 1, we examine the importance of adding time dummies to the instrument set in columns 2 and 4.[13] There are four specifications of the intertemporal Euler equation, a common discount rate versus a person-specific discount rate using time dummies as instruments in columns 1 and 3 and using time dummies as instruments and regressors in columns 2 and 4. In the interest of space we do not report results from models without time dummies; however, we note that the pseudo–likelihood ratio test rejects the null hypothesis of no aggregate shocks in the specifications in columns 1 and 3 with a *p*-value of .003. The after-tax interest rate and the other measured covariates do not capture the full extent of aggregate shocks to the Euler equation. The high *p*-values on the overidentifying restriction tests in both the common and person-specific discount rate specifications

[13] The geometric mean canonical correlation between the endogenous regressors and the instrument set with time dummies in step 2 is .175.

TABLE 3

INTERTEMPORAL EULER EQUATION

Variable	Common Discount Rate (1)	Common Discount Rate (2)	Person-Specific Discount Rate (3)	Person-Specific Discount Rate (4)
Subjective discount rate	.0132	.0012		
	(.0007)***	(.0024)		
	{.0026}***	{.0025}		
Constant (σ_0)	−1.0010	−1.0112	−1.0049	−1.0036
	(.0017)***	(.0030)***	(.0025)***	(.0029)***
	{.0077}***	{.0078}***		
Assets (σ_{A_t})	.0009	.0202	.0003	.0005
	(.0070)	(.0101)**	(.0001)***	(.0001)***
	{.0302}	{.0313}		
Children (σ_{K_t})	−.0026	−.0022	.0013	−.0006
	(.0003)***	(.0004)***	(.0017)	(.0019)
	{.0007}***	{.0007}***		
Health status (σ_{H_t})	.0039	−.0018	−.0148	−.0144
	(.0038)	(.0062)	(.0033)***	(.0051)***
	{.0048}	{.0049}		
λ-constant elasticity (e_λ)†	.1630	.1630	.1631	.1631
J-statistic‡	44.6233	12.6732	17.9344	5.9191
Degrees of freedom	20	15	20	16
p-value	.0012	.6275	.5917	.9889

NOTE.—Standard errors are in parentheses and corrected standard errors are in braces. The first-step indirect utility parameters come from col. 3 of table 1. Cols. 2 and 4 have time dummies as both instruments and regressors.

† $e_\lambda = e_u - \psi e^2_{A_t}(\omega_t h_t / A_t)$ is computed at its mean value, where ψ is the intertemporal substitution elasticity with respect to a change in the prices of all goods.

‡ Degrees of freedom is the number of instruments less parameters, and the *p*-value reported pertains to the null hypothesis that the overidentifying restrictions are not rejected.

* Significant at the 10 percent level.

** Significant at the 5 percent level.

*** Significant at the 1 percent level.

in columns 2 and 4 support our interpretation that adding time dummies as regressors should capture any remaining macro shocks (MaCurdy 1983; Blundell et al. 1993).

More important for our purposes than extensively modeling aggregate shocks is modeling person-specific discount rate heterogeneity. The implied *p*-value under the null hypothesis of a common discount rate is less than .000, which soundly rejects the common simplifying assumption of homogeneous time preferences. Because the heterogeneous life cycle–consistent labor supply specification dominates a homogeneous life cycle–consistent labor supply specification, it is not surprising that a specification check also locates discount rate heterogeneity. The mean value of the estimated person-specific discount rates is .015, which is in the middle of the range of estimates in the consumption literature (Hansen and Singleton 1982; Deaton 1992). With the exception of the effect of family size, the intertemporal parameters in columns 3 and 4 are precisely esti-

TABLE 4

DISTRIBUTION OF SELECTED ELASTICITIES BY WEALTH QUARTILES

	Lowest 25%	Second Quartile	Third Quartile	Highest 25%
Uncompensated wage	.1112	.1193	.1328	.1557
Compensated wage (e_u)	.1288	.1380	.1538	.1809
Marginal tax rate	−.0404	−.0465	−.0581	−.0830
λ-constant (e_λ):†				
Common	.1434	.1489	.1607	.1999
Person-specific	.1436	.1489	.1608	.2002

NOTE.— Elasticities are computed at the mean values of variables within each quartile using the parameters from models with time dummies in the instrument set.
† $e_\lambda = e_u - \psi e^2_{A_t}(\omega_t h_t / A_t)$.

mated, and we proceed to compute intra- and intertemporal labor supply elasticities.[14]

C. *Labor Supply Elasticities*

Because of its relevance to economic policy, a focal point of the empirical literature on life cycle labor supply has been the λ-constant elasticity, which is the labor supply response to an expected wage change. The λ-constant labor supply elasticity can be computed from the intertemporal substitution elasticity, which is the consumption response to an expected change in all prices (Browning 1985). The λ-constant elasticity, also known as Frisch's specific substitution elasticity, is $e_\lambda = e_u - [\psi e^2_A(wh/A)]$, where e_u is the compensated wage elasticity, ψ is the intertemporal substitution elasticity, e_A is the wealth elasticity, and wh/A is current earnings relative to wealth. The sample mean λ-constant elasticity in table 3 is about .16 in both the homogeneous and heterogeneous discount rate specifications. As required by the assumption of strictly concave preferences, the λ-constant elasticity in table 3 is larger than the compensated wage elasticity in column 3 of table 1, which is larger than the uncompensated wage elasticity in column 3 of table 1.

To understand how estimated labor supply elasticities vary importantly across families, table 4 presents five elasticities of interest by wealth quartile. The elasticities rise with wealth so that the hours response to wage changes is about 40 percent larger for the wealthi-

[14] Our econometric model assumes that the worker has rational expectations of uncertain outcomes, which implies that past forecast errors do not influence current decisions through revisions in the marginal utility of net wealth. In tests not tabulated, we do not reject the underlying rational expectations hypothesis at the .05 level.

est 25 percent of men than for the poorest 25 percent of men. Examining only elasticity averages in table 1 obscures the distributional consequences of tax policy. As wealth increases, so does workers' responsiveness to taxes, so that the marginal tax rate elasticity doubles as one moves from the lowest to the highest wealth quartiles in table 4.[15] In the next section we return to the issue of how wealth interacts with tax reforms.

VI. Implications for Tax Policy

In applying the economic literature on the welfare costs of income taxes, we use the estimated intratemporal preferences from step 1's life cycle–consistent labor supply function to form the indirect utility function and the associated expenditure function, $\tilde{E}[\omega_t, V_t(\omega_t, A_{t-1}, A_t)]$. We then use two so-called exact measures of changes in economic well-being to examine the welfare implications of recent reforms in the U.S. income tax.[16]

A. *Deadweight Loss Measures*

One measure of welfare change we calculate is a hypothetical payment to the government by the typical prime-age married male worker under the pre–tax reform wage and interest income that would leave welfare unchanged under the post–tax reform income (Kay 1980). The hypothetical payment, or equivalent variation measure, compares an initial distorted equilibrium with a final distorted equilibrium. The equivalent variation measure fixes utility at its postreform level, which under jointly progressive income taxes is a function of postreform wage and pre- and postreform assets, and lets wage differences imply a change in worker well-being across tax re-

[15] By construction the elasticity is a positive function of ω/h, which is 40 percent larger in the highest wealth quartile than in the lowest wealth quartile. The partial derivative of labor supplied with respect to the marginal tax rate is not the same across workers, and the marginal tax rate elasticity differs by 100 percent between the lowest and highest wealth quartiles too. Our result that labor supply is more elastic for wealthier workers is consistent with the results of Hausman (1981*a*, 1981*b*) and Triest (1990), who find that the labor supply elasticity rises as one moves up the wage distribution. Juhn, Murphy, and Topel (1991), who combine workers and nonworkers in their labor supply measure, find that labor supply is least elastic for the high-wage workers. The difference between our results and those of Juhn et al. is likely due to the contribution of the participation margin. It seems reasonable to us that, conditional on working, the wealthiest workers are most responsive to wage changes.

[16] Fully dynamic simulations using both intra- and intertemporal preferences require specifying the complete expectations formation process, which is beyond the boundaries of what we do. The life cycle–consistent simulations we present are directly comparable to those of Hausman (1981*a*, 1981*b*).

gimes. Another calculation we make is the change in consumers' surplus, called welfare variation, where the wage vector is held at the pre–tax reform level and utility differs when taxes change (King 1983; Triest 1987). The welfare variation measure of moving from one distorted equilibrium to another is the change in consumer utility less the actual revenue extracted. Both welfare measures we present give similar ordinal rankings under revenue-neutral tax changes (Triest 1987).

B. *Tax Simulation Details*

In examining changes in economic well-being, we simulated the labor supply responses to four federal income tax reforms. We applied numerical methods to solve for the endogenous variables because the system we estimated in Section V is a nonlinear function of the income tax schedule, where the marginal tax rate is endogenously determined with hours worked.[17] The model is a life cycle–consistent labor supply model. As demonstrated in table 4, most of the labor supply adjustments occur within a period.

The nonlinear simultaneous equations system we solved describes labor supplied, wealth accumulation, the marginal tax rate, and tax payments as

$$\begin{aligned} h_{it} = {} & 27.8312 W_{it}(1 - \tau_{it}) - 0.4941 A_{it-1} \\ & - 2.0278 A_{it} + \mathbf{X}_{it}\hat{\gamma} + \hat{\eta}_i + \xi_{it}, \end{aligned} \tag{8}$$

$$A_{it} = [1 + r_t(1 - \tau_{it})]A_{it-1} + W_{it}(1 - \tau_{it})h_{it} - C_{it} - T(I_{it}), \tag{9}$$

$$\tau_{it} = (\Phi_{1it} - \Phi_{2it})b(I_{it}) + \Phi_{2it}\tau_{uit}, \tag{10}$$

and

$$T(I_{it}) = \int \tau(I_{it})\, dI_{it}, \tag{11}$$

where C_{it} is consumption, $\hat{\eta}_i$ is the estimated person-specific fixed effect, and τ_{it} is the marginal tax rate that depends on hours worked and assets.

We solve the system in (8)–(11) by backward induction using the

[17] To be consistent with past research, our structural simulation model takes the spouses' labor supply decisions as sequential wherein the husband first chooses his labor supply subject to a marginal tax rate calculated at the wife's earnings set to zero. In the sequential decision making underlying our labor supply simulations, the wife's income contributes to the husband's marginal tax rate calculations used in planning only through the level of household wealth accumulated. Adding the wife's labor earnings to virtual saving in the models in table 2 leaves our preferred labor supply model unchanged.

Gauss-Newton algorithm and 100 Monte Carlo draws for each of the 532 men from the distribution $\xi \sim N(0, \sigma_\epsilon = 458)$, where 458 is the estimated standard deviation of the error in the preferred model (col. 3 of table 1).[18] Finally, we use simulated values in deadweight loss calculations of four tax regime changes.

C. Four Tax Regime Changes

We calculate the relative welfare effects of four U.S. federal tax regimes: (1) the 1987 (post-TRA86) U.S. income tax structure versus a regime in which income taxes are absent, (2) the 1987 U.S. income tax structure versus a 10 percent across-the-board rate cut, (3) the 1987 income tax rates versus the 1981 (pre-ERTA) income tax regime, and (4) the 1987 income tax rates and tax base versus the pre-ERTA income tax regime. Because our tax experiments refer to tax cuts, the deadweight loss calculations we present in table 5 are the maximum amounts the typical prime-age married male worker would pay to lower his taxes. In all four cases the equivalent-variation and welfare change measures are close, differing by no more than 1 percent, and give consistent ordinal rankings of welfare changes.

1. Eliminating Income Taxes

Eliminating income taxes would lead prime-age married men to work about 4 percent more on average, an estimate that is 60 percent larger than from a static labor supply model (Triest 1990). Workers in the highest wealth quartile would supply about 7 percent more labor. The typical U.S. prime-age married male worker would pay up to 23 percent of his adjusted gross income to eliminate the current progressive income tax. As an additional reference point we note that Hausman's (1981*a*) widely cited estimates of the labor supply effects of removing income taxes are much higher than ours (double) and his estimates of the willingness to pay are much lower than ours (one-eleventh). Hausman's estimates are driven by a large income effect, and our calculations have a larger lifetime substitution effect. By adding progressive interest income taxation to a life cycle model including worker heterogeneity and a time-nonseparable income stream, we have located a greater extent of the excess burden of income taxes than Hausman found with a static model estimated from a single cross section of the PSID.

[18] Tripling the number of Monte Carlo draws changed the simulated values by no more than 1 percent.

TABLE 5

HOURS AND WELFARE RESPONSES TO ALTERNATIVE TAX REFORMS BY WEALTH QUARTILE

	Change in Hours (%)	Change in Taxes Paid (%)	Equivalent Variation (% AGI)	Welfare Variation (% AGI)
	1. No-Tax Case			
Average	4.1	−100	−22.5	−22.8
Lowest 25%	2.5	−100	−17.2	−17.3
Second quartile	2.8	−100	−17.5	−17.6
Third quartile	3.9	−100	−20.5	−20.7
Highest 25%	6.9	−100	−30.1	−30.8
	2. 10 Percent Tax Cut			
Average	.6	−6.3	−2.1	−2.1
Lowest 25%	.0	−9.2	−1.7	−1.7
Second quartile	.7	−8.7	−1.6	−1.7
Third quartile	.6	−7.4	−1.9	−1.9
Highest 25%	1.1	−4.5	−2.7	−2.8
	3. Pre-ERTA to Post-TRA86 Tax Rate			
Average	2.0	−37.6	−11.0	−11.2
Lowest 25%	1.7	−40.6	−8.6	−8.8
Second quartile	1.0	−39.7	−9.1	−9.2
Third quartile	2.0	−39.3	−10.4	−10.5
Highest 25%	3.5	−35.5	−14.1	−14.5
	4. Pre-ERTA to Post-TRA86			
Average	3.1	−46.2	−15.6	−15.9
Lowest 25%	2.4	−49.5	−13.8	−14.0
Second quartile	2.3	−45.9	−13.8	−14.0
Third quartile	2.9	−44.4	−15.3	−15.5
Highest 25%	5.0	−46.0	−18.1	−18.6

2. An Across-the-Board Rate Cut

A 10 percent across-the-board rate cut from the current tax structure would cause about a 0.6 percent increase in the labor supplied annually by prime-age married men (about 13 hours) accompanied by a reduction in government tax revenues of about 6 percent. A typical prime-age married male worker would pay 1–2 percent of adjusted gross income to have a 10 percent tax rate cut and the wealthiest 25 percent would pay 2–3 percent of adjusted gross income for a 10 percent income tax rate cut.

3. TRA86 Rate Cuts Alone

Comparing the labor supply and deadweight loss when changing from the pre-ERTA (1981) income tax regime to the post-TRA86

(1987) income tax rates shows that the average prime-age married man raised annual hours supplied by 2 percent and would have paid 11 percent of his adjusted gross income for the change to TRA86 tax rates alone. We estimate that the wealthiest workers increased their labor supplied by about 4 percent and had about a 14 percent improvement in their economic well-being due to the tax rates under TRA86 compared to the pre-ERTA tax regime.

4. TRA86 Rate and Base Cuts

Our final simulation in table 5 compares the labor supply and deadweight loss response when moving from the pre-ERTA (1981) income tax regime to the post-TRA86 income tax rates and tax base. The TRA86 took over six million people off the tax rolls so that incorporating both tax rate and base changes should make the simulated hours response higher than incorporating only the tax rate changes under TRA86. Our simulation of the dual effects of the rate and base changes under TRA86 in table 5 shows a 2–5 percent increase in labor supplied across wealth quartiles.[19] Comparing cases 3 and 4 implies the tax base effect of TRA86. Changes in the tax base under TRA86 increased both average labor supplied and the welfare improvement under TRA86 by about an additional 50 percent, with the largest effects occurring, of course, in the lowest two wealth quartiles.

VII. Conclusion

Our research develops a structural model of life cycle labor supply of workers facing a progressive tax on both wage and interest incomes, which generates an intertemporally nonseparable budget constraint and labor supply function conditioned on start-of-period and end-of-period assets. With data for prime-age men for 1978–87 from the Panel Study of Income Dynamics and a smoothed nonlinear intertemporal net budget constraint, our two-step generalized method-of-moments estimator first identified intraperiod and then interperiod preferences.

The GMM estimator we presented yields labor supply elasticities of interest to both micro- and macroeconomists. Our estimates support labor supply models with intertemporally nonseparable budget constraints. We used our labor supply estimates in stochastic simulations of the welfare gains from recent tax reforms that produced a flatter income tax in the United States. In simulations of prime-age men's labor supply and economic welfare, we found that the tax reforms

[19] Actual hours worked increased 3–4 percent during 1981–87.

of the 1980s stimulated labor supplied by about 3 percent, reduced deadweight loss by about 16 percent, and were not self-financing. Our results emphasize that the study of the work incentive effects of income taxes should use longitudinal data, which permit including the empirical realism of latent worker heterogeneity and a time-nonseparable labor supply due to a jointly progressive tax on wage and interest incomes.

Appendix A

Two-Stage Budgeting and Life Cycle–Consistent Labor Supply

We begin by demonstrating the complications with the λ-constant approach in the context of a multiperiod model with jointly progressive income taxes (Blomquist 1985). The consumer has strictly concave preferences over consumption, C_t, and hours of work, h_t, as represented by the utility function $U(C_t, h_t)$. The consumer's problem is to choose consumption and hours in each period to maximize the intertemporally separable present discounted value of lifetime preferences:

$$\max \sum_t (1 + \rho)^{-t} U(C_t, h_t) \quad (t = 0, 1, \ldots, T) \tag{A1}$$

subject to the lifetime asset accumulation constraint

$$A_t = (1 + r_t)A_{t-1} + W_t h_t - C_t - T(I_t; \pi), \tag{A2}$$

where A_t is end-of-period t wealth, r_t is the period t real interest rate, W_t is the gross hourly wage rate, $T(\cdot)$ is the nonlinear tax function, and $I_t = W_t h_t + r_t A_{t-1} - E_t$ with exemptions E_t and tax parameters π.

If an interior optimum exists, then the first-order conditions imply

$$\frac{\partial U}{\partial C_t} = \lambda(1 + \rho)^t \left[1 - \left(\frac{r_{t+1}}{1 + r_{t+1}}\right) T'(I_{t+1}; \pi)\right] \tag{A3}$$

and

$$\frac{-\partial U}{\partial h_t} = -\lambda(1 + \rho)^t W_t [1 - T'(I_t)] \left[1 - \left(\frac{r_{t+1}}{1 + r_{t+1}}\right) T'(I_{t+1})\right] \tag{A4}$$

and satisfaction of the asset accumulation constraint. The term $[r_{t+1}/(1 + r_{t+1})]T'(I_{t+1})$ arises because $r_{t+1}A_t$ is taxed next period, with A_t a function of current hours of work and consumption.

Exploiting the concavity of $U(\cdot)$ and the implicit function theorem, we find λ-constant functions

$$C_t = C\left\{\lambda(1+\rho)^t\left[1-\left(\frac{r_{t+1}}{1+r_{t+1}}\right)T'(I_{t+1};\pi)\right], W_t[1-T'(I_t)]\right\} \tag{A5}$$

and

$$h_t = h\left\{\lambda(1+\rho)^t\left[1-\left(\frac{r_{t+1}}{1+r_{t+1}}\right)T'(I_{t+1})\right], W_t[1-T'(I_t)]\right\}. \tag{A6}$$

Consumption and labor supply in (A5) and (A6) illustrate that in general with nonlinear incomes the λ-constant functions depend on current and future prices and tax rates along with the marginal utility of wealth. The advantage of the λ-constant approach as detailed in MaCurdy (1981) is that λ is a sufficient statistic for out-of-sample information, which is clearly violated in the case of nonlinear income taxation described above.

Intratemporal preferences can still be recovered with two-stage budgeting (Blomquist 1985). In the first stage the consumer allocates wealth to equate the discounted expected marginal utility of wealth over time, as described in equation (2) of the text. Denote the optimizing values as C_t^*, h_t^*, and A_t^*. For the second stage the consumer maximizes the instantaneous utility function at time t, $U(C_t, h_t)$, subject to

$$A_t^* = (1+r_t)A_{t-1}^* + W_t h_t - C_t - T(I_t;\pi). \tag{A7}$$

The first-order conditions in the second stage are

$$\frac{\partial U}{\partial C_t} = \lambda \tag{A8}$$

and

$$\frac{-\partial U}{\partial h_t} = -\lambda W_t[1-T'(I_t)]. \tag{A9}$$

With C^* and h^* as the solution to the second stage of the two-stage budgeting model, we obtain by the implicit function theorem the conditional demand functions

$$C_t = C\{W_t[1-T'(I_t)], A_{t-1}^*, A_t^*;\pi\} \tag{A10}$$

and

$$h_t = h\{W_t[1-T'(I_t)], A_{t-1}^*, A_t^*;\pi\}. \tag{A11}$$

Unlike the λ-constant functions in (A8) and (A9) above, current hours of work, h_t, do not enter next period's tax function after A_t and A_{t-1} are held constant under two-stage budgeting. The advantage of our approach is that no assumptions about future prices and tax rates are necessary to identify intratemporal preference parameters. Of course, one must assume a form for the period-specific utility function or choose an explicit functional form for the hours equation, (A11), as we do in the text, in equation (1).

Appendix B

Econometric Details

What follows describes the two-step GMM estimator we use and our parameterization of the differentiable tax function. We begin by defining the function $g(\mathbf{P}, \mathbf{D}; \mathbf{\Lambda})$ as

$$g(\mathbf{P}, \mathbf{D}; \mathbf{\Lambda}) = \mathbf{D}'(\mathbf{\Delta h} - \mathbf{P\Lambda}) \equiv \mathbf{D}'\boldsymbol{\xi}, \tag{B1}$$

where $\mathbf{P} \equiv [\Delta w_t, \Delta A_{t-1}, \Delta A_t, \Delta X_t]$ is the $N(T-2) \times L$ matrix of first-differenced regressors in the estimated labor supply function in (5), $\mathbf{D}$ is an $N(T-2) \times K$ matrix of instruments dated $t-1$ and $t-2$, $\mathbf{\Delta h}$ is the $N(T-2) \times 1$ vector of first-differenced hours worked, and $\mathbf{\Lambda}$ is the $L \times 1$ vector of intratemporal preference parameters to estimate, $[\alpha, \delta, \phi, \gamma]'$. The criterion function we minimize in step 1 is

$$J_t(\mathbf{\Lambda}) = g(\mathbf{P}, \mathbf{D}; \mathbf{\Lambda})'\mathbf{S}_{gg}^{-1} g(\mathbf{P}, \mathbf{D}; \mathbf{\Lambda}), \tag{B2}$$

where $\mathbf{S}_{gg}$ is an optimal weighting matrix, $(\mathbf{D}'E(\mathbf{\Delta}\boldsymbol{\xi}\mathbf{\Delta}\boldsymbol{\xi}')\mathbf{D})$. Initial consistent estimates for the vector $\mathbf{\Delta}\boldsymbol{\xi}$ come from a consistent but suboptimal weighting matrix, the identity matrix. Solving the criterion function for the feasible GMM estimator gives

$$\hat{\mathbf{\Lambda}} = [\mathbf{P}'\mathbf{D}\hat{\mathbf{S}}_{gg}^{-1}\mathbf{D}'\mathbf{P}]^{-1}\mathbf{P}'\mathbf{D}\hat{\mathbf{S}}_{gg}^{-1}\mathbf{D}'\mathbf{\Delta h}, \tag{B3}$$

which has the estimated asymptotic covariance matrix

$$\mathrm{var}(\hat{\mathbf{\Lambda}}) = [\mathbf{P}'\mathbf{D}\hat{\mathbf{S}}_{gg}^{-1}\mathbf{D}'\mathbf{P}]^{-1}. \tag{B4}$$

Estimating life cycle–consistent labor supply in first differences due to latent heterogeneity and rational expectations creates an MA(1) process in the transformed random disturbance, $\xi_t - \xi_{t-1}$, which influences the functional form of the weighting matrix, $\mathbf{S}_{gg}$ (Maeshiro and Vali 1988). The weighting matrix in our GMM model, $\hat{\mathbf{S}}_{gg}$, is the sum of a conditional heteroskedasticity matrix ($\hat{\mathbf{\Omega}}_0$) and an autocorrelation matrix ($\hat{\mathbf{\Omega}}_1$) such that

$$\hat{\mathbf{S}}_{gg} = \hat{\mathbf{\Omega}}_0 + (\hat{\mathbf{\Omega}}_1 + \hat{\mathbf{\Omega}}_1'), \tag{B5}$$

where

$$\hat{\mathbf{\Omega}}_0 = \frac{1}{N(T-2)} \sum_i \sum_t (D_{it}'\Delta\hat{\xi}_{it}\Delta\hat{\xi}_{it}'D_{it}), \tag{B6}$$

$$\hat{\mathbf{\Omega}}_1 = \frac{1}{N(T-2)} \sum_i \sum_t (D_{it}'\Delta\hat{\xi}_{it}\Delta\hat{\xi}_{it-1}'D_{it-1}), \tag{B7}$$

$i = 1, \ldots, N$ and $t = 1, \ldots, T-2$. Predetermined information dated $t-1$ and earlier along with endogenous information dated $t-2$ and earlier can be instruments given the MA(1) errors in the first-differenced life cycle–consistent labor supply (Griliches and Hausman 1986).

When the weighting matrix is not positive semidefinite in step 1, we use a method of modified Bartlett weights (Newey and West 1987*b*). We sidestep the additional complexity that possible measurement errors can introduce nonlinear random errors into the estimated indirect utility function, requiring a nonlinear errors-in-variables estimator in step 2. Developing an instrumental variables estimator for nonlinear errors in the variables of our second step's indirect utility function is beyond our research. For examples of nonlinear errors-in-variables models, see Hsiao (1989) and Amemiya (1990).

Standard errors for the estimator of intertemporal preferences Θ in step 2 may be inconsistent because they depend on first-stage standard errors. We use a consistently estimated asymptotic covariance matrix of $\hat{\Theta}$ that is

$$\hat{\Omega}_\Theta = (m'_\Theta \hat{S}^{-1}_{mm} m_\Theta)^{-1} + \{m'_\Theta m_\Lambda^{-1}[\mathrm{var}(\hat{\Lambda})]^{-1} m_\Lambda^{-1\prime} m_\Theta\}^{-1} - [m'_\Theta(m_\Lambda g_\Lambda^{-1}\hat{S}_{gm} + \hat{S}_{mg} g_\Lambda^{-1\prime} m'_\Lambda)^{-1} m_\Theta]^{-1}, \tag{B8}$$

where m_Θ, m_Λ, and g_Λ are partial derivatives, and $\hat{S}_{mg}$ is the sample covariance between $g(\cdot)$ and $m(\cdot)$, which corrects for potential bias in the second-stage standard errors of estimated intertemporal preferences (Newey 1984).

Appendix C

Differentiable Marginal Tax Rate

We adopt the total marginal tax rate specification

$$\tau_t = (\Phi_{1t} - \Phi_{2t})\tau_{st} + (\Phi_{2t} - \Phi_{3t})b(I_t) + \Phi_{3t}\tilde{\tau}_t + \Phi_{sst}\tau_{sst}, \tag{C1}$$

where τ_{st} is the average state tax rate, $b(I_t)$ is an estimated polynomial in taxable income (I_t), $\tilde{\tau} = \tau_{st} + \tau_{ut}$, with τ_{ut} the top federal marginal tax rate in year t, and τ_{sst} is the payroll tax rate (MaCurdy et al. 1990). In the marginal tax rate in (C1), $\Phi_{jt}[(I_t - \mu_{jt})/\sigma_{jt}]$ ($j = 1, 2, 3$) is the cumulative distribution function for the standard normal, where Φ_{jt} is a pseudo-spline function equal to one when $I_t \geq \mu_{jt}$ and equal to zero when $I_t < \mu_{jt}$. The speed at which a worker switches from one marginal tax bracket to another is determined by σ_{kt}, with greater smoothness produced by larger values of σ_{kt}. We set the standard deviation, σ_{jt}, to 0.2 for each segment j, which provides an adequate degree of curvature to the tax function (MaCurdy et al. 1990). The parallel pseudo-spline function for social security taxes is $\Phi_{sst}[(\mu_{sst} - Y_t)/\sigma_{sst}]$, where μ_{sst} is the cutoff for the social security tax base, and Y_t is labor earnings. A worker's marginal tax rate is then the state income tax rate, τ_{st}, plus the federal marginal tax rate and the social security tax rate.

The polynomial $b(I_t)$ in the tax function (C1) approximates all the marginal tax brackets within a given range. In 1978, for example, there are 15 marginal tax brackets between taxable incomes of $3,200 and $67,200. Taking $50 increments in incomes from $3,200 to $67,200 and calculating the associated statutory marginal tax rates in 1978 yields 1,280 pairs of incomes and marginal tax rates. The cubic ordinary least squares regression we ran through the 1,280 marginal tax rate–income pairs to summarize the 1978 federal tax table for married couples filing jointly had an $R^2 = .98$ and is

$$b(I_t) = \tau_{st} + 0.0402 + (1.4410^{-5})I_t - (1.2110^{-10})I_t^2 + (2.4910^{-16})I_t^3. \quad \text{(C2)}$$

The first year of our sample, 1978, provides an example of how the marginal tax function (C1) operates for a married couple filing jointly. The first term in the tax function (C1) reflects the zero bracket amount in the tax schedule. For taxable income above zero but less than \$3,200, $\Phi_{1t} \cong 1$, $\Phi_{2t} \cong 0$, $\Phi_{3t} \cong 0$, $\Phi_{sst} = 1$, and the marginal tax rate is the state tax rate plus the payroll tax rate of 6.05 percent. When taxable income reaches \$3,200, $\Phi_{2t} = 1$, making the first term in (C1) zero but adding the second term so that the worker faces the marginal tax rate implied by the polynomial $b(I_t)$ in (C2). When taxable income reaches \$67,200, then $\Phi_{3t} = 1$, the second term in (C1) vanishes, and the effective marginal tax rate is the 1978 maximum federal rate of 55 percent, the state income tax rate, plus the payroll tax rate for gross labor earnings below \$17,000.

Appendix D

TABLE D1

SUMMARY STATISTICS FOR CONTINUOUSLY WORKING MEN AGED 22–51 IN 1978 FOR THE YEARS 1978–87

Variable	Mean	Standard Deviation
Annual hours of work	2,182.6	496.1
Reported gross wage	14.9	7.3
Reported net wage	10.2	4.1
Average gross hourly earnings	15.6	8.8
Average net hourly earnings	10.8	5.8
Marginal tax rate (%)	29.2	6.9
Liquid assets†	15,084.3	50,790.1
Home equity	49,196.3	54,109.1
Total wealth	64,280.6	81,276.8
Virtual wealth	78,879.8	90,181.2
Net saving	3,867.8	62,743.3
Virtual saving	5,188.9	62,893.3
Gross 3-month Treasury bill (%)	3.0	1.8
Net 3-month Treasury bill (%)	.3	1.7
Age	39.0	8.4
Kids	1.6	1.2
Grades completed	13.2	2.6
White (%)	91.9	27.1
Home owner (%)	88.8	31.5

NOTE.—Number of observations is 5,320. All wealth, prices, and income variables are in real terms using the base 1987 personal consumption expenditure deflator.

† Liquid assets equal nominal interest, dividend, and rental income earnings with the first \$200 deflated by the average passbook savings account rate and the remainder deflated by the average annual 3-month Treasury bill rate.

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