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**THE EFFECT OF INCOME TAXATION ON  
CONSUMPTION AND LABOR SUPPLY**

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## **Abstract**

We estimate the incentive effects of income taxation in a life-cycle model of consumption and labor supply that relaxes the standard assumption of strong separability within periods. Our model permits identification of both within-period preference parameters and life-cycle preference parameters such as the inter-temporal substitution elasticity. Results indicate that consumption and hours worked are direct complements in utility, and both increase with an increase in the after-tax share and with a compensated increase in the net wage. The compensated net wage elasticity is about 0.3, nearly double the standard estimates for men in the United States that ignore within-period non-separability between consumption and hours and rely on linear preferences. Given our estimated inter-temporal elasticity of substitution of about  $-0.96$ , the Frisch specific substitution elasticities of consumption and labor supply with respect to the after-tax wage are about 0.1 and 0.5, indicating significant inter-temporal smoothing of utility. Depending on consumption measure, static estimates of the marginal welfare cost of revenue-neutral taxation are 6–20 percent, which is about half the estimated welfare cost when additivity between consumption and leisure is incorrectly imposed.

**Keywords:** Life Cycle, Labor Supply, Consumption, Taxation, Marginal Welfare Cost

Estimating the effect of income taxes on labor supply has been a focal point of research by labor and public economists for over three decades (Blundell and MaCurdy 1999; Pencavel 1986). The keen economic interest stems from the well established result that the deadweight loss from reduced incentives to work is increasing in the progressivity of the tax code (Auerbach 1985; Auerbach and Slemrod 1997; Blundell, Duncan, and Meghir 1998; Carroll, Holtz-Eakin, Rider, and Rosen 1999; Hausman 1981; Ziliak and Kniesner 1999). However, there has been much disagreement over the years on the magnitude (and sometimes even the sign) of compensated wage effects — a positive compensated wage effect means that moving to a revenue-neutral flatter income tax induces more hours worked and reduces deadweight loss. Moreover, much of the research on labor supply and taxation has been conducted with static models on cross-sectional data (recent exceptions include Blundell et al. 1998, and Ziliak and Kniesner 1999), and all previous empirical work on taxes and labor supply maintains the assumption of additive separability between consumption and leisure. A more complete understanding of the economic implications of tax reform requires an evaluation of income taxation in a more flexible framework that admits interactions among consumption and leisure choices over time. We exploit the natural experiments of the tax reforms of the 1980s and 1990s in the United States to examine empirically the joint effect of income taxes on life-cycle consumption and labor supply.

The interest in identifying the impact of income taxes on labor supply was renewed in the 1990s when MaCurdy, Green, and Paarsch (1990) challenged the seminal econometric framework of Hausman (1981), who had modeled and estimated via maximum likelihood the intricacies of the piecewise linear budget set facing the worker by a simultaneous choice of segment (kink) location and hours of work. Hausman's estimates suggested that the deadweight

loss of income taxation was sizable, which provided the intellectual foundation for the 1980s tax reforms. MaCurdy, et al. (1990) argued that internal consistency of Hausman's model required an upward sloping labor supply schedule, and upon relaxing some key assumptions by smoothing the budget set the previously accepted result of a vertical or backward-bending male labor supply schedule reappeared. Ziliak and Kniesner (1999) extended the single-period linear model to the life-cycle case and found estimates closer to Hausman's, with a compensated wage elasticity ranging from 0.13 to 0.18 across wealth quartiles. The implied life-cycle deadweight loss from the 1980s U.S. income tax structure was about 20 percent of current income.

Unlike labor supply, there is comparatively little research on how income taxes affect consumption expenditures, either independently or in conjunction with labor supply choices. Most of this work has focused on the consumption-smoothing aspects of distortionary income taxation (Auerbach and Feenberg 2000; Kniesner and Ziliak 2002; Low and Maldoom 2004; Strawczynski 1998; Varian 1980). Empirical work addressing the effects of income taxes on labor supply in a framework that simultaneously models the consumption decision has been nonexistent. Other empirical research has relaxed and rejected within-period separability between consumption and leisure in the contexts of a conditional demand model (Blundell, Browning, and Meghir 1994; Browning and Meghir 1991), habit-formation (Hotz, Kydland, and Sedlacek 1988), and endogenous human capital (Shaw 1989), but the research has not been concerned with income tax effects.<sup>1</sup> Obtaining estimates of labor-supply tax effects in the context of a flexible framework with consumption is critical to more informed tax policy, especially in light of major reforms to the U.S. tax system over the past two decades and recent procedural changes adopted by the Congressional Budget Office to score tax revenue effects dynamically.

Research examining the connections among taxes, consumption, and labor supply is of further interest in light of the burgeoning macroeconomics literature on precautionary saving. In aggregate data current consumption tracks current income closely, contrary to the standard life-cycle permanent income model of consumption (Carroll and Summers 1991). To explain the apparent excess sensitivity puzzle some researchers have turned to alternative models with impatient consumers and buffer-stock saving (Carroll, 1997; Deaton, 1991). The recent macroeconomics literature has ignored the possibility that in the face of unanticipated wage changes households may alter their labor supply choices over time to accumulate precautionary balances instead of forgoing current consumption if consumption and leisure are direct substitutes (Low 1999). The potential importance of labor supply was first noted by Heckman (1974) in a deterministic setting, highlighting the fact that consumption tracking income may arise out of anticipated wage changes as well as uncertain wage changes.

We extend the labor supply and taxation literature by estimating a life-cycle model of consumption and labor supply under uncertainty with nonlinear wage income taxation and relaxing the standard assumption of strong separability in consumption and labor supply choices within periods. Unlike the conditional demand literature we estimate within-period preferences over both consumption and labor supply via the marginal rate of substitution function and a direct translog felicity function. We then estimate inter-temporal preference parameters using the Euler equation governing the first-order condition for the evolution of discounted marginal utility of wealth under uncertainty. Demographics enter the model through so-called demographic translating, which means that demographic variables directly affect the parameters governing utility (Pollak and Wales 1992). The combination of within-period preferences and inter-temporal preferences permits us to identify both after tax share and net wage elasticities, as well

as inter-temporal substitution elasticities. Although uncertainty is permitted in our framework we do not attempt to quantify the responses of consumption and labor supply to uncertain wage and tax changes and instead focus on anticipated changes (Altonji and Ham 1990; Pistaferri 2003). Because of the endogeneity of regressors in both the first and second stages of the two-stage budgeting model, we use a generalized method-of-moments estimator (Hansen 1982).

We employ data on male heads of household from the 1980–1999 waves of the Panel Study of Income Dynamics, which spans the major recent federal tax reforms in the United States from the Economic Recovery Tax Act of 1981 to the Taxpayer Relief Act of 1997. Our results indicate that consumption and hours worked are direct complements in utility and both increase with an increase in the after-tax share and with a compensated increase in the net wage. The compensated net wage elasticity is about 0.3, which is nearly double the typical estimate for U.S. men based on a linear specification of preferences. Given our estimated inter-temporal elasticity of substitution of about  $-1.0$ , the Frisch specific substitution elasticity of consumption with respect to the after-tax wage is about 0.1, and the corresponding Frisch elasticity of labor supply is about 0.5. We conclude by relating our estimated within-period preference parameters to the static marginal welfare cost of taxation. We find that revenue-neutral tax reforms imply a marginal welfare cost that is upwards of 20 percent, which is roughly half the estimated welfare cost if one incorrectly imposes strong separability between consumption and leisure ex ante.

## **II. A Model of Life-Cycle Consumption and Labor Supply**

The model of life-cycle consumption and labor supply we adopt is standard in that the consumer is assumed to choose consumption and hours of work optimally to maximize the present discounted value of uncertain utility subject to an asset accumulation constraint

(MaCurdy 1983). Uncertainty arises due to the unknown paths of future wages, prices, taxes, and interest rates. Inter-temporal preferences are assumed to be time separable, as are budgets, which rules out preference dependence over time due to habits (Hotz, Kydland, and Sedlacek 1988) and rules out non-separabilities in the budget constraint due to possible endogenous human capital and joint nonlinear taxation of wage and capital incomes (Blomquist 1985; Shaw 1989; Ziliak and Kniesner 1999). We do permit non-separabilities in within-period preferences over consumption and labor supply, which are chosen freely.<sup>2</sup> Added endogeneity of labor supply permits direct, unconditional assessment of the effects of wages and taxes on both margins, which is not possible in the conditional consumption demand framework.

## A. Basic Theoretical Setup

The value function governing the representative household's decision problem is

$$(1) \quad V^t(A_t) = \max_{C_t, h_t} \{G[U(C_t, \bar{L} - h_t)] + \beta E_t V^{t+1}[(1 + r_t)(A_t + w_t h_t - p_t C_t - T_t(I_t))]\}.$$

$A_t$  is the beginning of period  $t$  assets,  $U(\cdot)$  is the within-period felicity function, and  $G[\cdot]$  is a monotonic transformation of within period preferences that governs inter-temporal preferences.  $C_t$  is composite non-durable consumption,  $\bar{L}$  is total time available,  $h_t$  is annual hours of work,  $\beta = 1/(1 + \rho)$  is the time discount rate,  $E_t$  is the expectations operator conditional on the information set at time  $t$ ,  $r_t$  is a risk-free interest rate,  $w_t$  is the gross hourly wage rate,  $p_t$  is the price index on non-durable consumption, and  $T_t(\cdot)$  is the household's income tax liability as a function of taxable income,  $I_t = w_t h_t - D_t - Ex_t$ , which is gross labor income less deductions ( $D_t$ ) and exemptions ( $Ex_t$ ). We assume that both the utility function and the tax function are twice

continuously differentiable. Finally, we normalize by the price of consumption so that wages and interest rates are in real terms. The value function  $V^{t+1}$  is unknown as of time  $t$  because future realizations of the function's arguments are uncertain.

The first-order conditions for consumption and hours from maximizing the value function are

$$(2) \quad E_t[G'U_{C,t} - \beta(1+r_t)\lambda_A^{t+1}] = 0,$$

$$(3) \quad E_t[-G'U_{h,t} + \beta(1+r_t)w_t(1-\tau_t)\lambda_A^{t+1}] = 0,$$

and

$$(4) \quad \lambda'_A = \beta E_t[(1+r_t)\lambda_A^{t+1}],$$

where  $G'$  is the first derivative of the inter-temporal transformation function,  $U_{C,t}$  is the first derivative of within-period utility with respect to consumption,  $U_{h,t}$  is the first derivative of utility with respect to hours of work,  $\tau_t = \partial T_t(\cdot) / \partial h_t$  is the marginal tax rate, and  $\lambda_A^{t+1} = \partial V^{t+1} / \partial A_{t+1}$  is the marginal utility of wealth.

Substituting for  $\lambda_A^{t+1}$  in equation (3) using equation (2) and known time  $t$  values yields the familiar first-order condition for an interior solution, which equates the marginal rate of substitution of hours for consumption to the after-tax wage rate,  $\omega_t = w_t(1-\tau_t)$ ,

$$(5) \quad -U_{h,t} / U_{C,t} = \omega_t.$$

It is clear from equation (5) that the monotonic transformation  $G[\cdot]$  plays no role in determining within-period consumption and hours allocations, so that cross-sectional data are sufficient to identify intra-temporal preferences (MaCurdy 1983, Altonji 1986). To identify inter-temporal preferences it is necessary to have panel data (or time-series or pseudo-panel data) and the Euler equation (4) governing the allocation of wealth over time.

Most of the literature on life-cycle labor supply (MaCurdy 1981, Pistaferri 2003) and life-cycle consumption, including tests of full risk sharing, precautionary saving, and of the permanent-income hypothesis (for example, Cochrane 1991; Deaton 1991; Hall and Mishkin 1982; Ogaki and Qiang 2001), restrict intra- and inter-temporal preference parameters to be the same. An ex ante restriction that intra- and inter-temporal preference parameters be the same is costly in terms of reduced flexibility of behavioral responses to wage, price, and interest rate changes (Browning 1985).

To elaborate on the importance of maximum preference function flexibility, a familiar parameter in life-cycle models of consumption is the inter-temporal substitution elasticity (ISE), which is the proportional change in consumption expenditure needed to keep the marginal utility of wealth constant given an anticipated one-percent change in prices. Under the standard model with time-additive preferences, the inter-temporal substitution elasticity is minus the inverse of the coefficient of relative risk aversion,  $U_c / (CU_{cc})$ . Given the monotonic transformation in equation (1) the ISE is  $U_c / \{C(U_{cc} + (G'' / G')U_c^2)\}$ , which will vary based on the choice of the function for  $G$  (Browning 1985). Moreover, consider the Frisch (marginal utility of wealth constant) specific-substitution elasticity between any two goods  $j$  and  $k$

$$(6) \quad e_{jk}^F = e_{jk}^U + e_j e_k s_k \Phi,$$

where  $e_{jk}^F$  is the Frisch elasticity,  $e_{jk}^U$  is the compensated cross-price elasticity,  $e_j$  and  $e_k$  are expenditure (income) elasticities,  $s_k$  is the share of good  $k$  in the household budget, and  $\Phi$  is the ISE. If  $G$  is the identity transform, and within-period preferences are additive, then  $e_{jk}^F = e_j \Phi \approx e_{jk}^Y$ , where  $e_{jk}^Y$  is the income-constant Marshallian cross-price elasticity of demand.

The dual assumptions that within-period preferences are additive and transform exactly into

inter-temporal preferences are not innocuous as they imply that the path of consumption is independent of the path of wages, regardless of whether wage changes are anticipated (Heckman 1974) or unanticipated (Low 1999).

## B. A Tractable Empirical Representation

Our empirical strategy is to adopt the two-stage estimation method of MaCurdy (1983) where in the first stage we estimate the intra-temporal equilibrium condition in equation (5) by specifying a functional form for within-period preferences that permits non-separabilities between consumption and labor supply choices. Given the estimated within-period preference parameters we construct the period-specific utility functions to estimate the inter-temporal preference parameters from the Euler equation (4).

We specify within-period preferences with a direct translog felicity function

$$(7) \quad U(C, \bar{L} - h) = \alpha_1 \ln(\bar{L} - h) + \alpha_2 \ln C - \alpha_3 \ln(\bar{L} - h) \ln C - \alpha_4 \ln(\bar{L} - h)^2 - \alpha_5 \ln C^2,$$

which is a local second-order approximation to any arbitrary utility function (Christensen, Jorgensen, and Lau 1975). Important for our purposes is that the direct translog does not impose additivity between consumption and leisure — a positive coefficient on  $\alpha_3$  implies that consumption and leisure are direct substitutes, or that consumption and work hours are direct complements. Identification requires a normalization. We chose  $\alpha_5 = 1$ . Demographics are introduced into the model via the method of demographic translating whereby the utility parameters are explicit functions of demographic characteristics ( $x_{jt}$ ), such that

$$\alpha_j = \alpha_{j0} + \sum_{k=1}^K \alpha_{jk} x_k, \quad j = 1, \dots, 4 \quad (\text{Pollak and Wales 1992}).$$

Based on a demographically translated direct translog specification of intra-temporal preferences we then estimate the MRS condition in equation (5) as

$$(8) \quad \{[-\alpha_1 + \alpha_3 \ln C + 2\alpha_4 \ln(\bar{L} - h)]/(\bar{L} - h)\} - \omega\{\alpha_2 - \alpha_3 \ln(\bar{L} - h) - 2 \ln C\}/C + \varepsilon = 0$$

where  $\varepsilon$  reflects unobserved idiosyncratic tastes.

For the monotonic transformation  $G$  we specify preferences as

$$(9) \quad G(U(C_t, \bar{L} - h_t)) = \frac{(U(C_t, \bar{L} - h_t))^{1+\sigma} - 1}{1 + \sigma},$$

where  $\sigma = \sigma_0 + \sum_{j=1}^J \sigma_j d_{jt}$  are the inter-temporal preference parameters permitting variation in risk

aversion and the ISE according to time-varying demographic characteristics,  $d_{jt}$ .<sup>3</sup> Combining the first-order condition for consumption (2) with equation (4) that governs the evolution of the marginal utility of wealth, taking expectations and natural logs, and then first differencing, the parameterization in (9) yields the estimating equation

$$(10) \quad \sigma_0 \Delta \ln \hat{U}_{t+1} + \sum_j \sigma_j \Delta (d_{j,t+1} \ln \hat{U}_{t+1}) + \Delta \ln \hat{U}_{C,t+1} + \kappa_{t+1} = v_{t+1},$$

where  $\Delta$  is the first difference operator,  $\hat{U}_{t+1}$  and  $\hat{U}_{C,t+1}$  are the estimated values of utility and marginal utility found by replacing  $\alpha_j$  with  $\hat{\alpha}_j$  in equations (7) and (8),  $\kappa_{t+1} = r_{t+1} + (\theta_t - \rho)$ ,

$\theta_t = -E_t(\ln \zeta_{t+1})$ , and  $\ln \zeta_{t+1}$  is the time  $t$  forecast error uncorrelated with the model's variables.

In deriving equation (10) we exploit the approximations  $\ln(1 + r_{t+1}) \approx r_{t+1}$  and  $\ln(1 + \rho) \approx \rho$ . If

$\zeta_{t+1}$  is lognormally distributed then  $\theta_t = (1/2)\psi_t^2$ , where  $\psi_t^2$  is the variance of  $\ln \zeta_{t+1}$ , and

$(\theta_t - \rho)$  captures the tradeoff between impatience and caution, which is a key parameter in

determining the extent of precautionary saving in augmented life-cycle models with precautionary motives (Blundell, Browning, and Meghir 1994). The demographics affecting the MRS equation,  $x_k$ , need not be time varying but demographics affecting inter-temporal risk,  $d_j$ ,

must change over time, as indicated in equation (10), to have their effects identified separately from the constant term  $\sigma_0$ .

### **III. Data and Estimation Issues**

To identify the tax effects on work incentives and consumption we use household-level data on male heads of household from the 1980–1999 waves of the Panel Study of Income Dynamics (1979–1998 calendar years). The survey has followed a core set of households since 1968 plus newly formed households as members of the original core have split off into new families. Following the 1997 survey year the PSID began interviewing households every other year so there are no data for the 1997 calendar year. The PSID is advantageous because it contains detailed information on income and household composition, and after 1979 more detailed tax-related data. Our data are additionally desirable because they span multiple tax reforms in the United States: the Economic Recovery Tax Act of 1981, the Tax Reform Act of 1986, the Omnibus Reconciliation Tax Acts of 1990 and 1993, and the Taxpayer Relief Act of 1997. Together the tax reforms of 1981 and 1986 reduced marginal tax rates across-the-board, reduced the number of tax brackets from 16 to four, and expanded the taxable income base. Although the tax reforms of the 1990s reversed the trend of the 1980s’ reforms by adding two new higher marginal tax rates on upper-income Americans, the tax reforms of the 1990s also significantly expanded the Earned Income Tax Credit among low-income working families.

#### **A. Estimation Sample Details**

The sample we use in estimation is an unbalanced panel treating missing observations as random events. By eliminating only a missing person year of data the time series for each

household can be of different length within 1980–1999. To be included in the sample the household head must be (1) a male, (2) in the sample at least five years, (3) at least 25 years old in 1980 and no older than 60 in the last year in the sample, and (4) not a student, retired, permanently disabled, or institutionalized. Focusing on prime-age male heads of household allows us to ignore issues associated with labor force nonparticipation. To reduce further the influence of possible outliers we follow the existing literature and delete person-years with more than a 300 percent increase or more than a 75 percent decrease in consumption and family income from the previous year. We also require annual nominal food expenditures (inclusive of food stamps) to be no less than \$520 (about \$10 per week) and annual nominal family income to be no less than \$1,000 (about \$20 per week). Using our four sample filters we obtain 3,402 household heads in the 19-year sample. Because we require households to be present for five years, and because we invoke more detailed filters such as missing-data codes and extreme consumption and income changes, we retain 21,186 household-years for econometric estimation. All wage, price, income, and consumption expenditure data are deflated by the personal consumption expenditure deflator with 1998 base year.

The focal variables in the models in equations (8) and (10) are consumption expenditures, labor supply, real wage rates, taxable income, marginal tax rates, total tax payments, interest rates, and demographics. We measure consumption as total non-durable consumption expenditures. The PSID only collects food expenditures on an annual basis, and did not collect food expenditures information in the 1988 and 1989 surveys. Blundell, Pistaferri, and Preston (2001) recently proposed a method of imputing non-durable expenditures in the PSID. Using data from the Consumer Expenditure Survey (CEX) they estimated the demand for food at home

as a function of measured demographics (available in both the PSID and CEX), food prices, and non-durable expenditures. The model is

$$(11) \quad \ln(c_{it}^f) = X_{it}\varphi + \pi \ln(C_{it}) + e_{it},$$

where  $c_{it}^f$  is food expenditures in the home and  $C_{it}$  is non-durable expenditures. Given estimates  $\hat{\varphi}$  and  $\hat{\pi}$  from the CEX, along with data on food and demographics in the PSID, it is possible to predict non-durable consumption as  $\ln(\hat{C}_{it}) = (\ln(c_{it}^f) - X_{it}\hat{\varphi}) / \hat{\pi}$ .<sup>4</sup> Provided that food expenditures are monotonic in non-durable expenditures, that the point estimates from the CEX are estimated consistently, and that the trends in the variance of non-durable consumption are the same across the CEX and PSID, using (11) produces a consistent estimate of non-durable expenditures in the PSID.<sup>5</sup> Browning, Crossley, and Weber (2003) recently argued that imputation methods may be a fruitful approach to deal with limited consumption data. As a sensitivity check on the model we also present estimates based on food expenditures and an alternative imputed measure of non-durables consumption proposed by Skinner (1987).

Labor supply here is defined as annual hours of work from all jobs. For workers paid by the hour the survey records the gross hourly wage rate. Given that the data after 1993 are still in the early release form the hourly wage is missing for many observations in certain years. We then follow a procedure akin to the PSID's calculation of hourly wages for salaried workers. For workers with annual hours less than 1000 we divide annual earnings by 750; for workers with hours between 1000 and 1800 we divide earnings by 1500; for workers with hours between 1800 and 2200 we divide earnings by 2000; and for workers with more than 2200 hours we divide earnings by 2400. Dividing earnings by standardized work years reduces so-called division bias that plagues wages computed as the ratio of annual earnings to actual annual hours (Borjas 1981, Ziliak and Kniesner 1999).

When constructing annual taxable income we assume that married men filed joint tax returns and unmarried men filed as head of household. Adjusted gross income is the sum of labor earnings, cash transfers, and property income.<sup>6</sup> Taxable income is adjusted gross income less deductions and exemptions. The Panel Study of Income Dynamics 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 based on 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 it from adjusted gross income; when excess itemized deductions are non-positive 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 the Tax Reform Act of 1986 (TRA86) the standard deduction was built into the tax tables; we only need 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.

The PSID significantly improved their method of tax imputation beginning in 1980 but then stopped calculating household income tax liability after the 1991 interview year. We

approximate the income tax liability via several steps. First, using a method derived by MaCurdy, Green, and Paarsch (1990) and implemented by Ziliak and Kniesner (1999), we approximate federal income tax payments with a smooth cubic polynomial in taxable income. The idea is to act as if the household faces a smooth tax function, rather than a piecewise-linear function, and use the smooth tax function to approximate the marginal tax rate. Because the marginal tax rate is also a smooth and continuously differentiable function of taxable income we can integrate the function back to obtain total tax payments. From total federal tax payments we net out the imputed Earned Income Tax Credit for each year (assuming a 100 percent take-up rate) and add in FICA (payroll) taxes and the relevant state income tax payments, which for tractability we take as a proportional tax on income with the tax rate determined by the average income tax rate in the state (State Government Tax Collections, 1980–1999 Tax Years).<sup>7</sup> Our tax imputation method coincides well with the PSID in the years in which our two methods overlap.

Lastly, for the demographics moderating the parameters  $\alpha_j$  in the MRS equation (8) we use a parsimonious specification with the number of children in the household, the race of the male head, and the age of the youngest child. To maintain tractability we only admit the demographics in  $\alpha_1$  and  $\alpha_2$ , assuming the remaining two parameters are homogeneous across the sample. The parallel demographics that affect risk aversion and the ISE are the age of the household head and the health status of the head. Appendix Table 1 contains selected summary statistics for the variables used in our econometric model.

## **B. Econometric Issues**

Estimation of the MRS equation (5) and the Euler equation (4) are complicated both because the models are nonlinear in the parameters and because the regressors are endogenous (hours, consumption, and wages in the MRS equation and utility in the Euler equation).<sup>8</sup>

Although the empirical counterparts in equations (8) and (10) are linear functions of parameters, we still must address endogeneity. It is possible to rearrange equations (8) and (10) into a linear instrumental variables framework by using the normalization  $\alpha_5 = 1$  in equation (8) to make  $-2\omega \ln(C)/C$  the left-hand-side variable, and using the change in marginal utilities ( $\Delta \ln \hat{U}_{C,t+1}$ ) as the left-hand-side variable in Euler equation (10). The particular instrumental variable estimator we adopt is the generalized method of moments (GMM) estimator (Hansen 1982). Given a  $(1 \times Q)$  vector of instrumental variables for the MRS equation,  $z_{it}$ , the population orthogonality conditions we estimate for the first stage are  $E[z'_{it} \varepsilon_{it}] = 0$ . The analogous conditions for equation (10) are  $E[m'_{it} v_{it+1}] = 0$ , where  $m_{it}$  is a  $(1 \times M)$  vector of instrumental variables. The two-stage GMM estimator we employ admits conditional heteroskedasticity where in the first stage we estimate equations (8) and (10) via 2SLS and use the estimated residuals to form the second-stage optimal weight matrix for the GMM estimator.

In selecting instrumental variables for the MRS equation we assume that  $\varepsilon$  is not autocorrelated but may be conditionally heteroskedastic. We use as instruments a constant and the  $(t - 1)$  values of the head's age, the family size, the number of kids, the age of the youngest child, and dummy indicators for marital status, education, race, self-employment status, health status, home ownership, union status, industry, occupation, and region of country. For the Euler equation (10) we use the  $(t - 2)$  values of the variables in the MRS instrument set along with time dummies and twice lagged real after-tax wages, non-durable expenditures (or food expenditures), and hours of work.

Because the Euler equation (10) is a function of estimated parameters from the first stage, it is necessary to correct the second-stage standard errors for the additional sampling variation. Although asymptotic approximations to the variance-covariance matrix of sequential method-of-

moments estimators are available (Newey and McFadden 1994), we instead utilize the bootstrap to construct the second-stage standard errors. The typical regression-based bootstrap is a multi-step procedure whereby the researcher re-samples with replacement the estimated residuals, constructs a new dependent variable as the sum of the fitted value from the regression plus the bootstrapped residual, re-estimates the model, and repeats the exercise  $B$  times ( $b = 1, \dots, B$ ). There are then  $B$  observations from which to compute measures of bias, variability, or confidence intervals. The basic bootstrap approach is consistent under the assumptions of conditional homoskedasticity, no serial dependence, and non-stochastic regressors.

When the regressors are stochastic or there is conditional heteroskedasticity as is typical in IV estimation, Freedman (1984) suggests an alternative procedure. Instead of re-sampling the residuals, one re-samples simultaneously the estimated residuals along with the regressors and instruments. More specifically, one re-samples with replacement from  $(\hat{v}, \hat{P}, m)$ , where  $\hat{v}$  is the Euler equation residual,  $\hat{P}$  is the matrix of regressors in the Euler equation, and  $m$  is the matrix of instruments. Call the constructed information bootstrap data  $(\hat{v}^*, \hat{P}^*, m^*)$ . One then constructs the new dependent variable,  $\Delta \ln \hat{U}_{C,t+1}^*$ , from the bootstrap data (the bootstrapped residuals and accompanying regressors), which is then in turn re-estimated with the accompanying instruments,  $m^*$ . Defining the vector of bootstrapped parameters estimates as  $\hat{\delta}_b$ , then the

bootstrap standard error is  $\left[ \left( \sum_{b=1}^B (\hat{\delta}_b - \frac{1}{B} \sum_{b=1}^B \hat{\delta}_b)^2 \right) / (B-1) \right]^{1/2}$ . We set  $B$  equal to 1000

replications. The multi-stage approach, in which each observation has equal probability weight  $1/N$  of being drawn from the discrete empirical distribution function, is an asymptotically valid method of bootstrapping an IV estimator and offers efficiency gains over first-order asymptotics (Hall and Horowitz 1995; Ziliak 1997).

## IV. Results

In Table 1 we record the estimates of both the intra-temporal preferences from the MRS equation (8) and the inter-temporal preferences from the Euler equation (10). We set the value of total time,  $\bar{L}$ , equal to the number of hours in a year (8,760).

[Table 1 here]

The estimates in Table 1 show that the marginal rate of substitution between hours of work and consumption is increasing in the number of children and in the age of the youngest child and is larger for white men. *Ceteris paribus*, labor supply is then higher for men with more children, higher for men with older children relative to men with younger (or no) children, and is higher for white men relative to non-white men. The parameter governing the within-period relationship between consumption and work hours,  $\alpha_3$ , is positive and statistically different from zero, which implies that consumption and leisure hours are direct substitutes in utility. We explore the implications of the inverse dependence between consumption and leisure choices below.

Although the  $p$ -value from the Sargan test of the validity of the over-identifying restrictions in the first-stage 2SLS does not reject our model specification, the test statistic from the second-stage GMM model reported in Table 1 indicates possible model misspecification due to invalid instruments. As one check on our instrument set we replaced the initial set of instruments with their corresponding values at  $(t - 2)$ , but obtained equally weak test results. It is important to note that the GMM Sargan test based on a relatively large number of moment conditions is poorly sized and tends to over-reject (Hall and Horowitz, 1995; Ziliak 1997). Given that the 2SLS version of the Sargan test does not reject the over-identifying conditions and that the GMM variant is poorly sized, we have reasonable confidence in our instrument choice.

In the second column of Table 1 we record the estimates of the Euler equation for non-durable consumption.<sup>9</sup> The estimate of  $(\theta_t - \rho)$  equals 0.07, suggesting that prudence outweighs impatience and that precautionary saving motives are present. The nondurable consumption Euler equation model suggests (weakly) that risk aversion is declining with age, but that risk preferences are not affected economically or statistically by health-induced work limitations.

### A. Intra- and Inter-temporal Elasticities

It is informative to characterize the estimates in Table 1 into terms useful for labor-market and tax policy; namely, compensated and uncompensated wage and tax elasticities for within-period preferences, and the ISE and Frisch specific substitution elasticities for inter-temporal preferences. When closed-form solutions for within-period demand and supply functions are not available, MaCurdy (1983) observed that it is still possible to derive the implied compensated and uncompensated wage effects by exploiting a result in Philips (1974) known as the fundamental matrix equation. We follow the fundamental matrix equation method closely, and summarize it here for completeness.

Ignoring for the time being the monotonic transformation,  $G[\cdot]$ , define the Hessian matrix for the utility function as  $H$  and the marginal utility of income as  $\mu = U_{c,t} / p_t$ . Furthermore, define the price vector of interest as  $q' \equiv [p_t, \omega_{it}]$ , where  $p_t$  is the price of consumption normalized to 1 and  $\omega_{it}$  is the real after-tax wage rate. The implied income effects, compensated effects, and uncompensated effects are

$$\begin{pmatrix} \partial C / \partial Y \\ -\partial h / \partial Y \end{pmatrix} = \frac{1}{n} H^{-1} q,$$

$$(12) \quad \begin{pmatrix} \partial C / \partial q' |_U \\ -\partial h / \partial q' |_U \end{pmatrix} = \mu H^{-1} - \frac{\mu}{n} H^{-1} q q' H^{-1},$$

$$\begin{pmatrix} \partial C / \partial \omega |_Y \\ -\partial h / \partial \omega |_Y \end{pmatrix} = \begin{pmatrix} \partial C / \partial \omega |_U \\ -\partial h / \partial \omega |_U \end{pmatrix} + \begin{pmatrix} \partial C / \partial Y \\ -\partial h / \partial Y \end{pmatrix} h,$$

where  $n \equiv q' H^{-1} q$ . The values in equation (12) are evaluated at the estimated parameters from the MRS equation (8),  $\hat{\alpha}_j$ .

Aside from the net wage effects on consumption and labor supply, an important calculation for tax purposes is the responsiveness of consumption and labor supply to changes in the after-tax share,  $(1 - \tau)$ , which is readily computed using the formulas in (12). There is no so-called taxpayer illusion in our model that would cause a difference in the effect of the net wage versus after-tax share on labor supply. Such a difference between  $\partial \hat{h} / \partial w$  and  $\partial \hat{h} / \partial (1 - \tau)$  could arise, however, not from illusion but from changes in the after-tax share that trigger tax avoidance responses not triggered by gross wage changes (Slemrod 2001).<sup>10</sup> For ease of interpretation we convert the marginal effects in (12) into point elasticities.

The intra-temporal elasticities derived from (12) tell only part of the story because lifetime considerations are a critical component in evaluating tax reforms. The estimates of the monotonic transformation from the Euler equation for consumption in Table 1 provide the information necessary to construct the ISE, which uses  $\hat{U}_c / \{C(\hat{U}_{cc} + (\hat{G}'' / \hat{G}') \hat{U}_c^2)\}$ . Combining the compensated elasticities from (12) with the ISE, along with the associated consumption and hours of work non-labor income elasticities, it is possible to construct the Frisch specific substitution elasticities of equation (6). The elasticities are complicated nonlinear functions of parameters. Procedures such as the delta method, although straightforward with numerical gradient methods, may not yield very efficient standard errors. We adopt instead the bootstrap

procedure described in Section 3 to calculate standard errors for both the first and second stage model elasticities.

[Table 2 here]

In Table 2 we report the within-period and inter-temporal elasticities implied by our point estimates from Table 1, evaluated at the sample means of hours, net wages, non-durable consumption, and after-tax shares. The non-labor income elasticities of consumption and labor supply are 0.035 and  $-0.517$ , indicating that both consumption and leisure are normal goods. Note that the property income elasticity of consumption is not the same as the total income elasticity reported in consumption studies such as Browning and Meghir (1991).<sup>11</sup> The corresponding utility-constant compensated wage elasticities of consumption and labor supply are 0.086 and 0.328.

Our estimated compensated wage elasticity of labor supply exceeds that typically reported in the literature and implies a sizable deadweight loss of taxation. For example, in a model based on linear preferences and additive separability between consumption and hours, Kniesner and Ziliak (1999) find a compensated wage elasticity about one-half that reported here. Below we explore whether the difference is driven more by functional form differences than by the possibility of non-separability between consumption and labor supply. Because of the sizable non-labor income effect relative to the compensated wage effect, we find that the uncompensated wage elasticity of labor supply is negative. Male labor supply bends backward. Although the income elasticity of labor supply is large, it is in the range of previous estimates reported in the literature, as is the finding of backward-bending male labor supply (Blundell and MaCurdy 1999; Pencavel 1986). Important for estimates of the economic efficiency of the tax system is that we do find an upward-sloping compensated labor-supply supply function.

The estimate of the ISE at the means is about  $-1.0$  for nondurable expenditures, which is consistent with strictly concave inter-temporal preferences. The estimated ISE here is similar to the ISE estimated by Blundell, Browning, and Meghir (1994) in their application to UK data. Given the ISE and compensated wage elasticities, the Frisch-specific substitution elasticity of labor supply is 0.54. The parallel Frisch net wage elasticity of consumption is 0.072. Our Table 1 estimates imply that consumption and leisure are substitutes within periods, and intertemporally the elasticities in Table 2 confirm that with an anticipated increase in the real after-tax wage hours of market work increase, leisure falls, and consumption rises.

In Table 2 there is also evidence that increasing the after-tax share raises both hours of work and consumption. A 10 percent increase in the after-tax share results in a 0.33 percent compensated increase in consumption and a 1.3 percent compensated increase in total hours within a period; there is a 0.2 percent increase in consumption and a 3.3 percent increase in labor supply across periods based on the Frisch elasticity estimates. Unlike the uncompensated net wage elasticity of labor supply the uncompensated after-tax share elasticity is positive. The after-tax share result is important for tax policy because it means that a lower marginal tax rate raises hours of work, as well as welfare, as indicated by the positive compensated elasticity. The difference between the backward-bending labor supply schedule in response to net wage changes and the upward sloping schedule in response to increases in the after-tax share appears to be driven by the fact that workers respond to gross wage changes with a strong income effect relative to the substitution effect. Collectively the elasticity estimates in Table 2 imply that welfare gains from increased labor supply and consumption are possible from revenue-neutral tax reforms that raise the after-tax share.

## B. Robustness

We consider a number of specification checks on our base-case results. First, we reduce the time endowment for work and leisure from 24 hours per day to 16 hours per day. The assumption is that 8 hours per day are overhead or human capital maintenance in the form of non-work, non-leisure sleep time. We re-estimated the model in equations (8) and (10) and report the relevant elasticities in the first two columns of Table 3. The estimated elasticities evaluated at the mean values of the functions are both qualitatively and quantitatively smaller, differing from the base case by no more than 5–7 percent.<sup>12</sup>

Second, we replace imputed non-durable expenditures with food expenditures as the measure of consumption. Food is the prevalent measure of expenditures used in consumption-based analyses in the PSID, though more by default than choice as food may be a poor proxy for non-durable consumption (Altonji 1986, Attanasio and Weber 1995; Skinner 1987; Ziliak 1998). The property income effect for food consumption based on equation (12) is about 0.5; because the point elasticity involves multiplying the marginal effect by the ratio of property income to food consumption, the elasticity is also about 0.5 because average food spending is of comparable magnitude to average property income. Using food consumption leads to a significantly larger uncompensated wage elasticity of consumption. As in the case of non-durables the Frisch specific substitution elasticity is positive, reflecting that food consumption and leisure are substitutes. Indeed, the coefficient on the food consumption-leisure interaction term is 15.14 with a standard error of 0.90, as compared to the base case estimate of 4.26 (0.43). Although our results coincide with Altonji's (1986) estimates qualitatively, he is not able to reject the null of separability due to large standard errors. The implications for labor supply elasticities in the case of food consumption are to cut the estimated property income elasticity in

half and to cut the compensated wage elasticity by about 70 percent.<sup>13</sup> Although the qualitative results remain unchanged when we switched from non-durable consumption to food consumption the magnitudes clearly depend on the consumption measure.

[Table 3 here]

We explore sensitivity of the estimated elasticities to the consumption measure further in Table 3 by replacing non-durable consumption with another variant of non-durable consumption. Skinner (1987) predicts non-durable consumption in the PSID using data on food consumed at home and away from home, house value, expenditures on rent and utilities, and number of automobiles. The PSID stopped collecting data on utilities and automobiles in the part of our sample. We therefore use a simple variant defined in column 1 of Table 1 of Skinner (1987) that is  $\hat{C}_{it} = 1.930 * Food \text{ (home)} + 2.928 * Food \text{ (away)} + 0.1374 * HouseValue + 1.828 * Rent$ , which imposes linear homogeneity by suppressing the constant term and frees the researcher from updating the coefficients for inflation. The estimated elasticities based on Skinner's consumption variant in Table 3 are dampened somewhat relative to the benchmark measure. Although it is not surprising, considering that the Skinner measure is narrower than the base case, the Skinner consumption based estimates are much closer to the base case compared to food consumption.

The final robustness check we perform is to impose the common assumption of additivity between consumption and leisure to examine how important allowing for non-separabilities in within-period preferences is for key parameters used in policy analysis. Specifically, we return to our base-case model of translog preferences and non-durable consumption but modify the functional form of utility by setting  $\alpha_3 = 0$ . We record the resulting elasticities in the second two columns of Table 3. Focusing on the labor supply results, we estimate significantly larger non-

labor income, compensated wage, and Frisch wage elasticities of labor supply, and a correspondingly smaller (in absolute value) uncompensated wage elasticity of labor supply.

The pattern of results in Tables 1 and 3 reveals something akin to the classic omitted variables bias problem. We demonstrated in Table 1 that consumption and hours of work are not separable and are direct complements. Given that consumption and property income are positively correlated, as are consumption and labor supply, omitting consumption imparts a downward (negative) bias on the non-labor income elasticity of labor supply and an upward bias on the compensated wage elasticity of labor supply. Allowing for non-separability between consumption and labor supply is important economically. Models that ignore consumption-hours interactions likely provide upper bounds on labor supply elasticities.

To explore the non-separability issue further we examined whether a similar pattern emerges in the standard linear labor supply model with and without consumption. Specifically, we regress annual hours of work on the log of the real net wage, virtual non-labor income, and the same demographics as in equation (8), with and without consumption.<sup>14</sup> The linear labor supply model with consumption is similar to the conditional demand framework described in Browning and Meghir (1991) where consumption is not formally modeled as above but simply serves as a conditioning variable for labor supply decisions. Although the magnitudes of the elasticities are significantly lower in the linear case the estimated compensated wage elasticity of labor supply without consumption is 0.024 and with consumption is 0.02. While the 20 percent difference in the linear estimates with and without consumption is smaller than the difference between the translog and quadratic log specifications reported in Tables 2 and 3, the result is the same in that imposing additivity between consumption and leisure has important consequences for estimates of labor-market behavior.<sup>15</sup>

### **C. Implications for the Marginal Welfare Cost of Taxation**

We close the results section by examining one avenue through which our results can be informative to discussions of tax reform. We now map our within-period estimates into the marginal welfare cost of taxation (MWC). The MWC measures the extent to which welfare changes in response to a change in tax revenue produced when a tax rate changes. The calculations are static and only provide a portion of the potential behavioral response to a tax change. The other obvious behavioral margin of interest is inter-temporal changes, which may include both anticipated components and the unanticipated components occurring in the case of uncertain tax policy. A more detailed simulation is beyond the scope of the current project but should be a high priority for future research. However, in the two-stage budgeting formulation that we use the within-period preferences, and thus the corresponding MWC calculations, are life-cycle consistent.

The bulk of the econometric estimates of the welfare cost of taxation stemming from models of labor supply and taxes have emphasized tax reforms that are revenue neutral (Hausman 1981, Triest 1994, Ziliak and Kniesner 1999). Econometric research has largely presented so-called differential tax calculations where there is no balanced-budget spending or revenue effects so that the MWC reflects pure distortions of labor supply (Ballard 1990; Browning 1987). In contrast, much of the theoretical research on the marginal cost of public funds has focused on balanced-budget tax policy in which a marginal dollar of public spending is financed by raising an additional dollar of tax revenue (Snow and Warren 1996). We follow the econometric literature and focus on a transparent calculation of the marginal welfare cost of taxation in the event of revenue-neutral reforms (Browning 1987, equation (10)). Browning

defines the marginal welfare cost of taxation as  $MWC = \left[ \frac{\tau + 0.5d\tau}{1 - \tau} \right] \eta_w^c \frac{d\tau}{d\bar{t}}$ , with  $\tau$  as the marginal tax rate,  $d\tau$  the change in the marginal tax rate,  $\eta_w^c$  the compensated wage elasticity of labor supply,  $\bar{t}$  the average tax rate, and  $\frac{d\tau}{d\bar{t}}$  the change in the progressivity of the tax code in response to the tax reform. The *MWC* formula highlights that only substitution effects and no income effects matter for revenue-neutral welfare calculations.

For each calculation we set  $\tau = 0.323$ , which is the sample average marginal tax rate,  $d\tau = 0.01$ , which is a one percentage point change in the marginal tax rate, and  $\frac{d\tau}{d\bar{t}}$  equal to 1.32, for progressive tax reforms (the ratio of the sample average marginal tax rate to the sample average tax rate) or equal to 1.0 for proportional tax reforms. We consider three specifications for the marginal welfare cost of taxation. In specification (1) we set  $\eta_w^c = 0.328$  based on the direct translog MRS elasticities with non-durable consumption in Table 2; in specification (2) we set  $\eta_w^c = 0.092$  for the direct translog MRS elasticities with food consumption in Table 3; in specification (3) we set  $\eta_w^c = 0.652$  for the quadratic direct MRS elasticities with non-durable consumption in Table 3. There are six calculations in Table 4, then, three for each of progressive and proportional changes in the tax code.

[Table 4 here]

In the base case model with non-separable preferences in the direct translog model in Table 4 the marginal welfare cost of an additional dollar of taxation ranges from 16 to 21 percent depending on whether the reform is a proportional or a progressive change in the tax structure. The deadweight welfare losses are sizable and suggest possibilities for welfare-improving revenue neutral tax reforms in the United States. Turning to specification (2) it becomes clear

that how we measure consumption has a large impact on our estimates of welfare loss. With food as our measure the MWC of taxation is a modest 4.5 to 6 percent. Specification (3), however, pushes the estimated MWC in the opposite direction. Imposing additivity between consumption and leisure yielded a larger estimate of the compensated wage elasticity of labor supply in Table 3, which translates into a doubling of the marginal welfare cost of taxation relative to the base case model that relaxes separability. Models with additive preferences between consumption and labor supply likely yield upper-bound estimates of the deadweight loss of taxation.

## **V. Conclusion**

We estimated a model of life-cycle consumption and labor supply where the empirical equilibrium conditions governing the optimal interior consumption and work choices identify intra-temporal preferences, and the empirical Euler equation for consumption identifies inter-temporal preferences.

Our estimates based on direct translog preferences for within-period utility reject the separability of consumption choices from labor supply choices. The implied elasticities indicate that labor supply responds positively to (compensated) after-tax wage increases both within periods and across periods. Although the overall labor supply schedule within periods is backward bending, labor supply is increasing in the after-tax share, whether in response to compensated, uncompensated, or inter-temporal increases in the net of tax share. The estimated complementarity of consumption and labor supply, coupled with the positive Frisch elasticity of consumption with respect to the net wage rate, is informative for the macroeconomic literature on consumption and saving because it suggests an avenue for why consumption tracks income over time.

We also further clarified the scope for improved labor-market efficiency with beneficial revenue-neutral tax reforms. Our base-case estimates with non-durable consumption suggest that the marginal welfare cost of taxation is 16–21 percent depending on whether the reform results in a proportional or progressive change in the tax structure. Most importantly, our research has highlighted that imposing additivity between consumption and leisure misrepresents important elasticities used in evaluating labor-market and tax policies, which can be up to twice as large when the researcher incorrectly imposes additivity. Further empirical research on models that identify the insurance aspects of progressive income taxation from the efficiency cost aspects in the context of uncertainty in labor markets and in public policies would be the logical next step in pinning down the implications of tax policy more completely.

## Endnotes

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1. Pistaferri (2003) is a recent exception. Using Italian data he failed to reject the null hypothesis of additive separability between consumption and leisure within the context of a life-cycle labor supply model without income taxes. The author urges caution in interpreting his result because "... we are using an unsophisticated approximation to individuals' preferences for consumption and leisure....In light of the large standard errors I do not wish to put too much emphasis on this result." (p. 745) In his test Pistaferri (2003) did not explicitly rely on consumption data as we do in this project, and thus our model should be a more robust framework for examining the interactions of consumption and leisure. In a model without income taxes, Altonji (1986) finds that food expenditures and leisure are substitutes, consistent with our findings, but his estimates are inefficiently estimated such that he cannot reject the null of separability.
  2. Alternative approaches are Browning and Meghir (1991) and Blundell, Browning, and Meghir (1994), who model consumption decisions within the context of a conditional (on labor supply) demand framework. Altonji (1986) assumes within-period separability in consumption and leisure, but then tests separability by approximating non-separability by appending the  $\lambda$ -constant equations with cross-substitution terms.
  3. Ogaki and Zhang (2001) show that introducing a subsistence consumption level into CRRA preferences permits increasing, decreasing, and constant relative risk aversion and that the flexibility of risk tolerance affects tests of complete consumption insurance. We experimented with permitting a threshold utility level in the G[.] transformation, but the threshold parameter was not statistically significant and often created problems with convergence. MaCurdy (1983) reported similar difficulties.
  4. We use a scaled-down version of the prediction equation appearing in Table 4 of Blundell, Pistaferri, and Preston (2001). We predict non-durable expenditures as  $\ln(\hat{C}_{it}^f) = (\ln c_{it}^f) - (3.6674 - 0.5746 \ln(cpi_i^f)) / 0.4573$ . We are grateful to Luigi Pistaferri for providing us with the necessary information.

5. A related method of predicted non-durable consumption in the PSID appears in Skinner (1987). He, too, used data from the CEX, but many of the variables needed to construct the broadest version of Skinner's measure are no longer collected by the PSID. We use a simple variant of Skinner's approach in the robustness section below. Ziliak (1998) proposed a method of imputing total consumption in the PSID by netting out saving from income where it is necessary first to predict saving using wealth information in the PSID. Inferring consumption from saving measured by changes in wealth requires an additional year of data for each household to construct saving and is likely to be a noisier measure of consumption.
6. To approximate the actual marginal tax rate facing the household we include property income in AGI, inclusive of wife's earnings in cases where married men have working wives. For tractability we abstract from the fact that this may generate non-separabilities both within-periods in spousal labor supply choices, and across periods in intertemporal labor supply as in Ziliak and Kniesner (1999). Confronting both forms of non-separability are areas in need of future research.
7. Details of the tax calculations are available from the authors upon request.
8. Endogeneity is not unique to the MRS-Euler equation estimation approach; a model that estimates consumption or labor supply directly need still address the issue of wage endogeneity (Altonji 1986).
9. There is an unintended by-product of the flexibility of the direct translog utility function. The marginal utilities of consumption and leisure are not restricted to be positive for all observations, which creates obvious problems when we take the log of the marginal utility of consumption for the second-stage Euler equation. In cases with non-positive marginal utilities we assumed that the person-years contribute nothing to inter-temporal substitution and set the difference in log marginal utilities of these observations to zero.
10. We thank Art Snow for bringing the Slemrod (2001) reference to our attention. The net wage and after-tax share responses also may differ because the elasticities are evaluated at the means of the nonlinear functions and under progressive taxation the mean of the net wage is not necessarily the mean of the wage times the mean after-tax share.
11. The formula of the point elasticity is revealing here. The elasticity is  $\frac{\partial C}{\partial Y} \frac{\bar{Y}}{\bar{C}}$ , and because the mean of non-labor income is small in relation to the mean of nondurable consumption, the elasticity is small.
12. With the time endowment set to 16 hours per day, some observations had negative leisure hours. For these observations we top-coded annual hours of work at 5740, which leaves 100 hours of annual leisure time. We also set the time endowment at 19 hours per day, which did not require any top-coding of labor supply. The results were virtually the same as the base case.

13. The magnitudes for labor supply elasticities that we find when food is the consumption measure are similar to others who use food consumption, such as Altonji (1986).
14. Virtual non-labor income is the adjustment to non-labor income ( $y_t$ ) necessary to compensate the worker to act as if they faced the same marginal tax rate for all taxable income; virtual income is  $y_t + \tau_t w_t h_t - T(\bullet)$ . The instruments for the linear model are the same as the instruments in the MRS equation (8), but with the addition of  $(t-1)$  lagged wages, virtual income, and consumption. The additional instruments were necessary for the model to satisfy Slutsky integrability; without the additional instruments the linear model yielded negative compensated wage elasticities.
15. Another potential source of model sensitivity in equation (8) is the omission of unobserved person-specific heterogeneity that affects the marginal rate of substitution between consumption and leisure. To investigate the potential for so-called fixed effects in the MRS model we estimated a first-differenced variant of equation (8). The results, not tabulated, indicate that the qualitative results in Table 2 remain with additional latent heterogeneity included, although there are some differences. In the case of the nondurable consumption model the compensated wage elasticity of labor supply increases by a factor of 5 so that the resulting uncompensated labor supply schedule is upward sloping.

*Table 1. GMM Estimates of Intra-temporal and Inter-temporal Preference Parameters*

Direct Translog MRS Preference Parameters (Equation (8))		Euler Equation Preference Parameters (Equation (10))	
Variable		Variable	
$\alpha_1$ (constant)	77.496 (28.676)	Constant	0.844 (0.230) {0.214}
$\alpha_1$ (number of kids)	3.035 (0.784)	$\theta_t - \rho$	0.070 (0.022) {0.024}
$\alpha_1$ (race = 1 if white)	8.877 (1.922)	Age	-0.039 (0.035) {0.0004}
$\alpha_1$ (age of youngest child)	1.470 (0.254)	Health (work limited = 1)	0.006 (0.030) {0.035}
$\alpha_2$ (constant)	51.407 (3.954)		
$\alpha_2$ (number of kids)	0.822 (0.299)		
$\alpha_2$ (race = 1 if white)	2.285 (0.425)		
$\alpha_2$ (age of youngest child)	0.499 (0.088)		
$\alpha_3$	4.263 (0.434)		
$\alpha_4$	3.085 (1.573)		
Sargan [dof]	110 [28]		138 [55]

NOTE: Asymptotic standard errors corrected for conditional heteroskedasticity are in parentheses. Bootstrap standard errors from 1000 replications are reported in { }. The number of observations is 21,186 person years.

*Table 2. Selected Intra-temporal and Inter-temporal Elasticities*

Changes in Real After-Tax Wages ( $\omega_t$ )	Consumption	Labor Supply
Income Elasticity	0.035 (0.015)	-0.517 (0.078)
Compensated Elasticity	0.086 (0.014)	0.328 (0.064)
Uncompensated Elasticity	0.232 (0.080)	-0.468 (0.098)
Inter-temporal Substitution Elasticity	-0.964 (0.009)	—
Frisch Specific Substitution Elasticity	0.072 (0.010)	0.535 (0.124)
Changes in After-Tax Shares ( $1 - \tau_t$ )		
Compensated Elasticity	0.033 (0.003)	0.125 (0.012)
Uncompensated Elasticity	0.036 (0.015)	0.083 (0.065)
Frisch Specific Substitution Elasticity	0.019 (0.011)	0.333 (0.070)

NOTE: The elasticities, which are based on the parameter estimates in Tables 1 and 2, are evaluated at the mean values of the functions. The standard errors are based on 1000 bootstrap replications of the MRS and Euler equations.

Table 3. Robustness of Elasticities to Alternative Model Assumptions

	Time Endowment = 16 hours per day		Food Expenditures as Proxy for Nondurable Consumption	
	Consumption	Labor Supply	Consumption	Labor Supply
<hr/>				
Changes in Real After-Tax Wages ( $\omega_t$ )				
Income Elasticity	0.046 (0.042)	-0.481 (0.087)	0.492 (0.061)	-0.251 (0.017)
Compensated Elasticity	0.081 (0.017)	0.309 (0.067)	0.213 (0.021)	0.094 (0.011)
Uncompensated Elasticity	0.274 (0.189)	-0.424 (0.154)	2.582 (0.254)	-0.442 (0.033)
Inter-temporal Substitution Elasticity	-0.899 (0.010)	—	-1.038 (0.013)	—
Frisch Specific Substitution Elasticity	0.065 (0.021)	0.478 (0.127)	0.107 (0.031)	0.148 (0.016)
<hr/>				
Changes in After-Tax Shares ( $1 - \tau_t$ )				
Compensated Elasticity	0.031 (0.006)	0.117 (0.020)	0.101 (0.014)	0.045 (0.006)
Uncompensated Elasticity	0.034 (0.016)	0.055 (0.067)	0.158 (0.018)	0.016 (0.011)
Frisch Specific Substitution Elasticity	0.015 (0.080)	0.285 (0.043)	0.005 (0.028)	0.099 (0.010)

*Table 3 Continued.*

	Skinner's (1987) Measure as Proxy for Nondurable Consumption		Direct Quadratic Utility Function for First-Stage MRS Equation ( $\alpha_3 = 0$ )	
	Consumption	Labor Supply	Consumption	Labor Supply
<hr/>				
Changes in Real After-Tax Wages ( $\omega_t$ )				
Income Elasticity	0.102 (0.008)	-0.191 (0.014)	0.036 (0.044)	-0.781 (0.200)
Compensated Elasticity	0.134 (0.006)	0.220 (0.017)	0.128 (0.080)	0.652 (0.443)
Uncompensated Elasticity	0.671 (0.023)	-0.313 (0.025)	0.270 (0.260)	-0.157 (0.492)
Inter-temporal Substitution Elasticity	-0.859 (0.191)	—	-0.725 (0.004)	—
Frisch Specific Substitution Elasticity	0.120 (0.006)	0.246 (0.019)	0.112 (0.058)	1.004 (0.655)
<hr/>				
Changes in After-Tax Shares ( $1 - \tau_t$ )				
Compensated Elasticity	0.075 (0.005)	0.123 (0.017)	0.036 (0.007)	0.180 (0.026)
Uncompensated Elasticity	0.092 (0.006)	0.093 (0.017)	0.038 (0.080)	0.137 (0.443)
Frisch Specific Substitution Elasticity	0.061 (0.006)	0.150 (0.009)	0.019 (0.036)	0.533 (0.253)

NOTE: The elasticities are evaluated at the mean values of the functions. The standard errors are based on 1000 bootstrap replications of the MRS and Euler equations.

*Table 4.* Alternative Estimates of the Marginal Welfare Cost of Taxation for Revenue-Neutral Tax Reforms  
(Percent)

	(1)	(2)	(3)
Progressive Tax: $\frac{d\tau}{d\bar{t}} = 1.32$	20.9 (4.1)	5.9 (0.73)	41.7 (28.3)
Proportional Tax: $\frac{d\tau}{d\bar{t}} = 1$	15.9 (3.1)	4.5 (0.56)	31.6 (21.4)

NOTE: All estimates are based on equation (10) in Browning (1987) where the marginal welfare cost of taxation is  $MWC = \left[ \frac{\tau + 0.5d\tau}{1 - \tau} \right] \eta_w^c \frac{d\tau}{d\bar{t}}$ , with  $\tau$  as the marginal tax rate,  $d\tau$  the change in the marginal tax rate,  $\eta_w^c$  the compensated wage elasticity of labor supply,  $\bar{t}$  the average tax rate, and  $\frac{d\tau}{d\bar{t}}$  the change in the progressivity of the tax code in response to the tax reform. For each calculation we set  $\tau = 0.323$ ,  $d\tau = 0.01$ , and  $\frac{d\tau}{d\bar{t}}$  equal to 1.32 for progressive tax reforms (the ratio of the sample average marginal tax rate to the sample average tax rate) or equal to 1.0 for proportional tax reforms. In specification (1) we set  $\eta_w^c = 0.328$  based on the direct translog MRS elasticities with nondurable consumption in Table 2, in specification (2) we set  $\eta_w^c = 0.092$  for the direct translog MRS elasticities with food consumption in Table 3, and in specification (3) we set  $\eta_w^c = 0.652$  for the quadratic direct MRS elasticities with nondurable consumption in Table 3. The standard errors are based on 1000 bootstrap replications of the MRS and Euler equations.

*Appendix Table 1. Selected Summary Statistics*

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	Mean	Standard Deviation
Non-durable Expenditures	48.775	168.231
Annual Hours of Work	2.241	0.575
After-Tax Wage	12.478	7.940
Total Marginal Tax Rate	0.323	0.088
After-Tax Interest Rate	0.005	0.015
Age	38.024	6.548
Family Size	3.573	1.388
Number of Children	1.464	1.216
Age of Youngest Child	4.930	5.136
Marital Status (=1 if married)	0.878	0.327
Health (= 1 if work limited)	0.071	0.257
Race (= 1 if white)	0.749	0.433
Less Than High School	0.186	0.389
High School Graduate	0.312	0.463
More Than High School	0.503	0.500
Self Employed	0.133	0.339
Home Owner	0.746	0.435
Union Member	0.244	0.430
Live in North East	0.173	0.378
Live in North Central	0.242	0.428
Live in South	0.405	0.491
Live in West	0.179	0.384

All income and price data are in real (1998) dollars using the personal consumption expenditure deflator.

Number of Person Years = 21,186

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