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ABSTRACT

This paper presents a new simulation methodology for determining the pure efficiency gains from tax reform along the general equilibrium rational expectations growth path of life cycle economies.

The principal findings concern the effects of switching from a proportional income tax with rates similar to those in the U.S. to either a proportional tax on consumption or a proportional tax on labor income. A switch to consumption taxation generates a sustainable welfare gain of almost 2 percent of lifetime resources. In contrast, a transition to wage taxation generates a loss of greater than 2 percent of lifetime resources.

A second general result is that even a mild degree of progressivity in the income tax system imposes a very large efficiency cost.

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The efficiency gains from dynamic tax reform are the object of increasing interest among academic economists and economic policy makers. Recent research by Feldstein (1978), Summers (1981), and Chamley (1981) has greatly increased understanding of this issue by examining respectively the efficiency costs of proportional tax structures in partial equilibrium, in steady state general equilibrium, and, for the case of infinite-horizon households, along the economy's general equilibrium transition path. This paper presents a new simulation methodology for determining the pure efficiency gains from tax reform along the general equilibrium rational expectations growth path of life cycle economies. The simulation model measures the efficiency gains from changes in the degree of progressivity of tax structures as well as changes in the tax base. It also distinguishes pure pareto efficiency gains from the welfare changes arising from simple economic redistribution among generations.

The principal findings of this study concern the effects of switching from a proportional income tax with average rates similar to those in the U.S. to either a proportional tax on consumption or a proportional tax on labor income. Given our assumptions about production technology and individual preferences, a switch to consumption taxation generates an efficiency gain sufficient to improve the welfare of all future generations by almost 2 percent of lifetime resources. This result is not greatly influenced by reasonable changes in parameters of the utility and production functions. In contrast, a transition from an income tax to a wage tax generates an efficiency loss greater than 2 percent of lifetime resources for the same set of parameter values; however, this number varies substantially for moderate changes in preference parameters.

For a constant level of revenues, the consumption tax combines a one-time, nondistortionary lump sum tax with a wage tax. Since a wage tax itself is distortionary, it is natural to expect the consumption tax to be more efficient. It is this element of lump-sum taxation, and not the exemption from taxation of capital income per se that is crucial to the achievement of efficient tax reform.[1]

A second general result is that even a mild degree of progressivity in the income tax system (as measured by the steepness of the marginal rate schedule) imposes a very large efficiency cost. For example, in comparison with an equal revenue proportional income tax, a progressive income tax with average tax rates varying over the life cycle between .23 and .32 and marginal rates ranging from .23 to .43 imposes an efficiency cost greater than 6 percent of full lifetime resources.

Section I of this paper reviews selections from the voluminous literature on optimal taxation that are most relevant to the present analysis. Section II describes the basic simulation model. The model, which incorporates variable labor supply and endogenous retirement behavior, is a more elaborate version of the Auerbach-Kotlikoff (1981) simulation model. Section III describes the maxi-min method of welfare analysis that permits one to distinguish economic efficiency from redistribution. The model and maxi-min technique are used in Section III to determine the efficiency gains from switching from a proportional income tax to proportional consumption and wage taxes. Section IV examines the sensitivity of section III's results to changes in the static and intertemporal elasticities of substitution in consumption and leisure demand as well as the elasticity of substitution in production. A similar analysis of the progressive tax is conducted in Section V, this section considers both changes in the degree of progressivity of the income tax as well as changes in the progressive tax base either to consumption or wages. The final section discusses some of the implications of this paper for current tax policy.

I. Selected Literature Review

Measurement of the efficiency aspects of tax structures dates at least from the development of a consumers' surplus measure of excess burden by Hotelling (1938) and the refinement of this approach by Harberger (1964). Today, there is a large body of literature dealing with issues of welfare measurement; this literature is concerned with the appropriate measure of excess burden (Diamond and McFadden 1974, Kay 1980, Auerbach and Rosen 1980, and Hausman 1981a) as well as methods of approximating its magnitude (Green and Sheshinski 1979).

An outgrowth of this interest in measuring the efficiency of alternative tax structures was the renewed examination of Ramsey's (1927) optimal tax problem (Baumol and Bradford 1970) and its extension to the question of the optimal structure of proportional commodity taxes given a restricted set of policy instruments (see, for example, Diamond and Mirrlees 1971, Stiglitz and Dasgupta 1971, and Atkinson and Stern 1974).

Both the measurement of excess burden and the calculation of optimal tax schedules have been extended to the intertemporal issues surrounding the taxation of capital income. Feldstein (1978) presents efficiency calculations based on a two-period model in which an individual supplies labor in the first period and consumes in both periods. Feldstein concludes that a proportional tax on labor income is significantly more efficient than a proportional income tax. While instructive, Feldstein's analysis ignores general equilibrium changes in prices due to changes in factor supplies and uses Harberger's (1964) local approximation formula to measure the efficiency effects of large tax rate changes (Green and Sheshinski 1979). The single period of labor supply also raises problems. Summers (1981) demonstrates that uncompensated labor supply elasticities with respect to the net return to capital are markedly different for multi-period models than for one period labor supply models. The same point pertains to those compensated labor supply elasticities relevant for excess burden calculations. A final issue is the sensitivity of Feldstein's conclusion to the particular choice of preference parameters (King 1980).

In studying the taxation of savings, an alternative to the static, two-period model is the dynamic, two-period model introduced by Diamond (1965). Papers by Auerbach (1979) and Atkinson and Sandmo (1980) characterize tax structures that maximize the utility of individuals in the steady state of such an economy. While derived from the general equilibrium model, these results are still based on the simple two-period model of individual behavior with a single labor supply decision. Moreover, for purposes of analytical tractability, these papers ignore the effect of the tax structure on the welfare of earlier generations alive during the economy's transition to its steady state. Determination of the tax schedule that maximizes steady state utility is a quite different exercise from the standard optimal tax problem of minimizing excess burden; it is possible to improve the utility of steady state generations by switching from one efficient tax system to another by imposing a greater fraction of the economy's long-run tax burden on earlier, pre-steady state generations.

With a numerical simulation model, line that developed by Miller and Upton (1974), Summers (1981) compares steady state utility for a model with fixed labor supply, but a more realistic, multi-period description of life-cycle consumption behavior; his study also attempts to measure the efficiency consequences of an explicit transition from one tax system to another. His analysis demonstrates that proportional wage and consumption taxes with equal annual revenue have markedly different long run impacts despite the fact that the structure of these two tax systems in the long run are identical in the sense that neither imposes a distortion on intertemporal choice. The common assumption of steady state models that the government's budget be balanced at each instant implies a quite different inter-cohort distribution of the tax burden of financing government expenditures under the wage tax versus the consumption tax. While long-run tax structures are identical under the two tax systems, the inter-cohort distribution of the economy's tax burden is not[2].

Summers' transition analysis, however, like that found in the earlier work of Miller and Upton, is based on the assumption of myopic rather than rational expectations; it also assumes completely inelastic supplies of labor. The exclusion of variable labor supply in an analysis that purports to compare the efficiency of capital income taxation with consumption or wage taxation is an obvious shortcoming: the assumption of myopic expectations is also undesirable. The transition paths of myopic life cycle economies are likely to differ significantly from perfect foresight rational expectations paths.

These advances in the measurement of dynamic tax efficiency would, of course, be inconsequential if economic theory alone could provide a clear guide to efficient, dynamic tax structures. Unfortunately, theory provides little guidance for the choice of tax base even in static settings. Even in the simple static case where the welfare of a single generation alive for two periods with no initial endowment is considered, a particular argument advanced by Feldstein (1978) and others in favor of a zero tax on capital income no longer applies if leisure is a choice variable in the second period. As shown by Sandmo (1974), if utility is separable into the untaxed numaire good and a homogenous function of all other commodities, uniform taxation of these commodities is optimal[3]. If the untaxed good is labor, and the remaining commodities are first and second period consumption, then Sandmo's conditions are met. The optimal tax structure is a pure consumption tax or, equivalently, a labor income tax. However, if a fourth taxable commodity, second period labor, is added, separability of the utility function into goods and leisure and homogeneity with respect to consumption is no longer sufficient to insure the optimality of the pure consumption tax[4]. In fact, in this case, a proportional income tax may be less distortionary than a proportional consumption tax. Given the failure of economic theory to guide the choice of an efficient tax base, let alone the choice of efficient dynamic tax rates, the efficiency properties of alternative tax structures remain a suitable object for study through numerical simulation.

II. The Basic Model and Its Solution

The basic model extends the Auerbach and Kotlikoff (1981) life cycle simulation model by incorporating endogenous labor supply and retirement and by permitting the production technology to differ from a simple Cobb-Douglas specification. The model describes the evolution over time of an economy consisting of government, household, and production sectors. The household sector comprises of fifty-five overlapping generations of individuals. The fifty-five period life span is intended to correspond roughly to the life span of an adult, that is, the years between ages twenty and seventy-five. In each generation, there is a single, representative individual, and individuals in different generations differ only with respect to their opportunity sets.[5] The population as a whole grows at a fixed rate n (assumed to equal .01 throughout the paper).

The Household Sector

Each household is a self-contained unit, engaging in life-cycle consumption and labor supply behavior with no bequests. The lifetime utility of each household takes the nested, constant elasticity form:[6]

$$(1) \qquad u(\underset{\sim}{c}, \underset{\sim}{\ell}) = \left(\frac{1}{1-\frac{1}{\gamma}}\right) \sum_{t=1}^{55} (1+\delta)^{-(t-1)} \left(c_t^{(1-\frac{1}{\rho})} + \alpha \ell_t^{(1-\frac{1}{\rho})}\right)^{\left(\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}\right)}$$

$$\alpha, \ \gamma, \ \rho > 0$$

where ℓ_t and c_t are the household's leisure (out of a unit labor endowment) and consumption at the end of year t, and δ, α, and γ are taste parameters. A large value of δ. the household's pure rate of time preference, indicates that the individual will consume a greater fraction of lifetime resources in the early years of life. The term α is the intensity parameter of leisure. Given prices, a larger value of α would lead to a greater fraction of full resources being spent on leisure. The terms ρ and γ are the household's elasticities of substitution between consumption and leisure in a given period and between consumption (or leisure) in different periods, respectively. Though this is an extremely general utility function, it does impose certain constraints on preferences, such as equal intertemporal substitutability of consumption and leisure.

The individual maximizes lifetime utility (1) subject to a budget constraint, the exact specification of which depends on the particular tax system in force. For a progressive income tax, the lifetime budget constraint is:

$$(2) \quad \sum_{t=1}^{55} \{ \prod_{s=2}^{t}(1+r_s(1-\bar{\tau}_{ys}))\}^{-1}(1-\bar{\tau}_{yt})w_t e_t(1-\ell_t) \geq \sum_{t=1}^{55} \{ \prod_{s=2}^{t} (1+r_s(1-\bar{\tau}_{ys}))\}^{-1}c_t$$

where r_s is the gross interest rate in period s, w_t is the gross wage rate (in output units) in period t, and τ_{yt} is the <u>average</u> tax rate on income faced by the household in year t. The e_t terms are included to reflect the accumulation of human capital, these terms describe how many units of "standard" labor the household supplies per unit of leisure foregone in any given year. Thus, $w_t e_t$ may by interpreted as the individual's gross wage rate. The human capital profile $\underset{\sim}{e}$ (the shape of which is discussed below) is the same for all households, and labor supplied by different generations, after adjustment for efficiency, is homogenous.

In addition to this overall budget constraint, we impose the requirement that labor supply can never be negative, i.e., if the notional demand for leisure, ℓ, exceeds one, the individual must "retire" for that period, supplying zero labor. This is represented by the inequality constraints:

(3) $\ell_t \leq 1$ for all t

Construction of a Lagrangian from expressions (1), (2), and (3), and differentiation with respect to c_t and ℓ_t, produces the respective first-order conditions:[7]

$$(4a)\qquad (1+\delta)^{-(t-1)}\Omega_t c_t^{-\frac{1}{\rho}} = \lambda\{\prod_{s=2}^{t}(1+r_s(1-\bar{\tau}_{ys}))\}^{-1}\theta_t$$

$$(4b)\qquad (1+\delta)^{-(t-1)}\Omega_t \alpha\ell_t^{-\frac{1}{\rho}} = \lambda\{\prod_{s=2}^{t}(1+r_s(1-\bar{\tau}_{ys}))\}^{-1}w_t^*\theta_t$$

where λ is the Lagrange multiplier of the lifetime budget constraint,

$$(5)\qquad \Omega_t = \left(c_t^{(1-\frac{1}{\rho})} + \alpha\ell_t^{(1-\frac{1}{\rho})}\right)^{\left(\frac{\frac{1}{\rho}-\frac{1}{\gamma}}{1-\frac{1}{\rho}}\right)}$$

(6) $$\theta_t = \prod_{s=t+1}^{55} \left\{ \frac{1+r_s(1-\tau_{ys})}{1+r_s(1-\bar{\tau}_{ys})} \right\}$$

(7) $$w_t^* = w_t e_t (1-\tau_{yt}) + \mu_t$$

τ_{yt} is the marginal income tax rate in the year t, and μ_t is the multiplier of the period t labor supply constraint.

With progressive taxes, θ_t is less than one, and represents a reduction in the implicit price of year t consumption or leisure. This additional term reflects the fact that an increase in current consumption or leisure will reduce savings and, hence, income from assets in all future years, thus reducing all future average tax rates. The "effective wage" w_t^* equals the net marginal wage per unit of leisure foregone when $\mu_t=0$. When μ_t differs from zero, no labor is supplied and the individual is "retired." In this case, w_t^* is the "shadow" or "reservation" wage at which the household would freely choose to supply zero labor.

Combination of conditions (4a) and (4b) yields:

(8) $$\ell_t = \left(\frac{w_t^*}{\alpha}\right)^{-\rho} c_t$$

Substitution of (8) into (5) provides an expression for Ω_t in terms of c_t, given this formula, (4a) yields the "transition equation":

(9) $$c_t = \left(\frac{1+r_t(1-\tau_{yt})}{1+\delta} \right)^{\gamma} \left(\frac{\nu_t}{\nu_{t-1}}\right) c_{t-1}$$

where:

$$(10) \qquad \nu_t = [1 + \alpha^{\rho} w_t^{*1-\rho}]^{\left(\frac{\rho-\gamma}{1-\rho}\right)}$$

The interpretation of (9) is complicated by the presence of the term ν_t/ν_{t-1} that involves the effective wages in the two periods. Since the derivative of ν_t with respect to the effective wage w_t^* has the same sign as $(\rho-\gamma)$, the effect of the slope of the wage profile on the slope of the consumption profile depends on whether the elasticity of substitution between consumption and leisure in the same period is greater than or less than the intertemporal elasticity of substitution. For the special case where $\rho=\gamma$, $\nu_t/\nu_{t-1}\equiv 1$, and (9) reduces to a simpler, more familiar formula in which the growth rate of consumption depends positively on the net rate of return and negatively on the pure rate of time preference, with the intertemporal elasticity of substitution determining the sensitivity of the consumption profile to these other parameters.

The corresponding transition equation for leisure follows from (8) and (9):

$$(11) \qquad \ell_t = \left(\frac{1+r_t(1-\tau_{yt})}{1+\delta}\right)^{\gamma} \left(\frac{\nu_t}{\nu_{t-1}}\right) \left(\frac{w_t^*}{w^*_{t-1}}\right)^{-\rho} \ell_{t-1}$$

It is straightforward to show that ℓ_t/ℓ_{t-1} is negatively (positively) related to the net marginal wage in period t (period t-1), regardless of the values of ρ and γ.

It is important to remember that equations (9) and (11) determine the shape of the consumption and leisure profiles, not their absolute levels. In general, no analytic solution for the actual values of $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$ is possible, and values for $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$ must be determined numerically.[8]

Two other tax systems examined here are progessive annual consumption taxes and progressive annual labor income taxes. (The proportional versions are special cases.) For these two tax systems, suitable redefinitions of the budget constraint (2) yield conditions analagous to (8) and (9).[9] If we redefine the effective wage to be:

$$(7') \qquad w_t^* = (w_t e_t(1-\tau_{wt}) + \mu_t) \,/\, (1+\tau_{ct})$$

where τ_{wt} is the marginal labor income tax and τ_{ct} the marginal consumption tax, then condition (8) is a general expression for all tax systems, and condition (9) becomes.

$$(9') \qquad c_t = \left(\left(\frac{1+r_t}{1+\delta}\right) \left(\frac{1+\tau_{ct-1}}{1+\tau_{ct}}\right) \right)^{\gamma} \left(\frac{\nu_t}{\nu_{t-1}}\right) c_{t-1}$$

where ν_t remains defined by (10). Again, while no analytical solution for $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$ is normally possible, a number of interesting points concerning these two tax systems are readily apparent. First, the "equivalence" between wage and consumption taxes disappears when taxes are progressive or marginal tax rates change over time. In particular, a rising consumption profile normally leads to a rising marginal tax rate schedule under a progressive expenditure tax. As a comparison of (9) and (9') indicates, this is equivalent to taxing the rate of return to savings. In general, the degree of progressivity of any of the three tax systems is just as important as the tax base in determining economic efficiency.

The Production Sector

The economy's single production sector is characterized by the CES production function:[10]

(12) $$Y_t = A\left(\varepsilon K_t^{(1-\frac{1}{\sigma})} + (1-\varepsilon)L_t^{(1-\frac{1}{\sigma})}\right)^{\left(\frac{1}{1-\frac{1}{\sigma}}\right)}$$

where Y_t, K_t and L_t are output, capital and labor at time t, A is a scaling constant, ε is the capital intensity parameter (assumed throughout the paper equal to 0.25) and σ is the elasticity of substitution between capital and labor. L_t is simply equal to the sum of effective units of labor supply of all households. K_t is generated by a recursive equation that dictates that the change in capital stock equals private plus public savings. Competitive behavior on the part of producers plus constant returns to scale in production insure that the gross factor returns r_t and w_t are equated to the marginal products of capital and labor and that factor payments exhaust output. This is summarized by:

(13a) $$w_t/r_t = \left(\frac{1-\varepsilon}{\varepsilon}\right)(K_t/L_t)^{(1/\sigma)}$$

(13b) $$r_tK_t + w_tL_t = Y_t$$

This specification of production makes no allowance for technical change. While productivity growth was incorporated by Auerbach and Kotlikoff (1981) in an earlier version of the model with fixed labor supply, it is impossible, in general, to retain this element once labor supply is endogenous; the steady rise of wage rates over time is not compatible with a steady state unless $\rho=1$, i.e., unless the utility function of contemporaneous consumption and leisure is Cobb-Douglas.[11] Such a restriction seems undesirable in the present context.

The Government Sector

In this model the government's sole concern is the financing of a stream of public expenditures, G_t, that grow at the same rate as population.[12] For simplicity, the impact of these expenditures on individual utility is ignored in the analysis. Aside from various taxes, the government can issue one-period debt to help finance current expenditures; such debt is a perfect substitute for capital in household portfolios. If D_t is defined as the value of government's debt (taking a negative value if there is a national surplus), government tax revenue at the end of period t is:

$$(14) \qquad R_t = \bar{\tau}_{yt}[w_t L_t + r_t(K_t + D_t)] + \bar{\tau}_{ct} C_t + \bar{\tau}_{wt} L_t$$

where $\bar{\tau}_{yt}$, τ_{ct} and $\bar{\tau}_{wt}$ are aggregate average tax rates on income, consumption, and wages, respectively, calculated as weighted averages of individual average tax rates and C_t is aggregate consumption. Given the government's ability to issue and retire debt, its budget constraint relates the present value of its value of its expenditures plus the value of its initial debt to the present value of its tax receipts.

$$(15) \qquad \sum_{t=0}^{\infty} [\prod_{s=0}^{t} (1+r_s)]^{-1} R_t = \sum_{t=0}^{\infty} [\prod_{s=0}^{t} (1+r_s)]^{-1} G_t + D_0$$

Solution of the Model

Determination of the economy's dynamic equilibrium behavior begins with a characterization of the initial steady state. The next step is to solve for the economy's transition to the new steady state that results from the adoption of a new policy or sequence of policies. It is important to remember that the transition described is the one the economy would actually take if all agents had perfect foresight.

After specification of the tax structure and level of national debt in the initial steady state, solution for this steady state proceeds using a Gauss-Seidel iteration technique. The algorithm requires initial guesses of the aggregate supplies of capital, K, and labor, L; also needed are initial guesses for the labor supply multipliers, $\underset{\sim}{\mu}$, and the marginal and average tax rates faced by individuals of each age. Starting from these initial values, the iteration produces new estimates used to update the guesses. This procedure is repeated until a fixed point is reached. Given the nature of the algorithm, such a fixed point corresponds to a steady-state equilibrium.

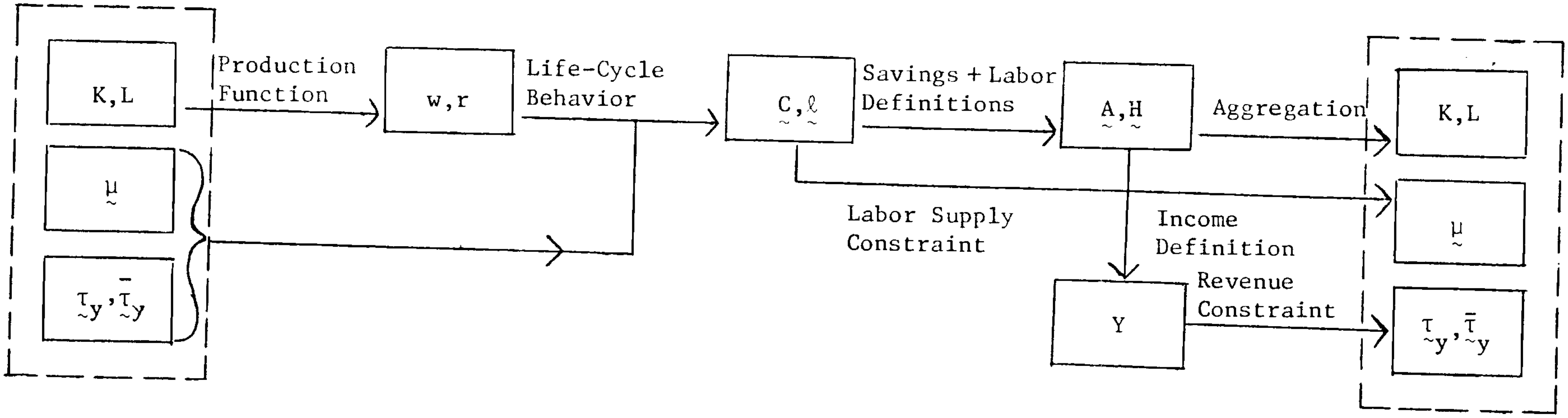
Though the iteration routine is slightly different for each type of tax system, the following description of the procedure used for a progressive income tax is illustrative of the general methodology that applies to other tax systems as well. A schematic representation is provided in Figure 1. Substitution of the initial guesses for K and L into the marginal productivity conditions (13) yields values for the gross returns w and r. Combination of these with initial guesses of the tax rates and labor supply multipliers allows a solution for the life-cycle consumption and leisure plans of the representative individual, $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$, using equations (2), (8) and (9). From the definitions of savings and labor, this yields the age-asset supply profile, labelled $\underset{\sim}{A}$ and the age-labor supply profile, $\underset{\sim}{H}$, which may be aggregated to provide new values of the overall supplies of capital (subtracting from aggregate assets any national debt assumed to exist) and labor, respectively. The asset and labor supply profiles, along with the initial guesses of w and r, also provide a solution for the age-income profile which, in turn, dictates the general level at which taxes must be set (typically one parameter is varied in the tax function) to satisfy the government budget constraint and, hence, determines new values of marginal and average tax rates faced over the life cycle, $\underset{\sim}{\tau_y}$ and $\underset{\sim}{\bar{\tau}_y}$, respectively. New values for the multipliers, $\underset{\sim}{\mu}$, are derived from the estimated labor supply profile. If the computed value of ℓ_t is less than 1, μ_t is set to zero. If the computed value of ℓ_t exceeds one, thereby violating the constraint, μ_t is set at the value that, <u>ceteris paribus</u>, would have led to a value of ℓ_t exactly equal to one.

Once these new values for K, L, $\underset{\sim}{\tau_y}$, $\underset{\sim}{\bar{\tau}_y}$ and $\underset{\sim}{\mu}$ are calculated, they are used to update the previous guesses, and a new iteration step begins. When the initial and final values are the same, a steady state has been reached.

Figure 1

Iteration Procedure:

Progressive Income Tax



Solution for the economy's equilibrium transition path proceeds in a similar manner. However, because the economy undergoes a transition with conditions changing over time, it is necessary to solve explicitly for behavior in each year. Moreover, because households are assumed to take account of future prices in determining their behavior, it is necessary to solve simultaneously for equilibrium in all transition years. This is done in the following way. the simulation model provides the economy with 150 years to reach a new steady state. After 150 years, the model constrains all prices, tax rates, and labor suply multipliers to be constant.[13] Again, the path of national debt is specified, and initial guesses are provided for the values of K, L, $\underset{\sim}{\mu}$, $\overline{\underset{\sim}{\tau}}_y$, and $\underset{\sim}{\tau}_y$ for each of the 150 transition years.[14] Based on these initial guesses, new guesses are generated until a fixed point is reached. The procedure is similar to that depicted in Figure 1 for the initial steady state. Aside from the greater complexity of solving simultaneously for equilibrium in 150 years, the major difference in solving for the transition path as opposed to the initial steady state is that individuals alive at the time the policy is adopted must be treated differently. While individuals born after the transition begins know the prices that will confront them, those born before the beginning of the transition behave up to the time of the change in government policy as if the old steady state would continue forever. At the time of the announcement of a new policy to be instituted either immediately or in the near future, existing cohorts are "born again;" they behave like members of the new generations except their horizon is less than fifty-five years, and they possess initial assets as a result of prior accumulation.[15]

Parameterization of the Model

To solve the model, it is necessary to choose values for the preference parameters, δ, α, ρ and γ, the production elasticity σ, the production scaling constant, A, and the human capital vector, $\tilde{e}$.

The human capital vector determines relative wages by age. The profile used in this paper is calculated from a cross-section regression of weekly labor earnings of full-time workers on personal variables including experience and experience squared, reported by Welch (1979).[16] The resulting wage profile peaks at age 30, with wages at that age 45 percent higher than at age one. The age 55 wage is 22 percent smaller than the age one wage.

For our basic parameterization, we set $\sigma=1$, thereby assuming a Cobb-Douglas production function. There has been a considerable amount of research into the elasticity of substitution between capital and labor in U.S. manufacturing (see, for example, Nerlove 1967, Berndt and Christensen 1973) with the general finding that $\sigma\leq 1$, however, only a few studies have been able to reject the hypothesis that $\sigma=1$.

The intertemporal elasticity of substitution between goods (or leisure) in different periods, γ, has also been the subject of a number of studies, most focusing on consumption. Weber (1970) estimated γ to lie between .13 and .41. In a later study (Weber 1975), he found a range of γ from .56 to .75. More recently, Grossman and Shiller (1980) estimated γ to lie between .07 and .35, and Hall (1981) found values generally below .1. In a study of both leisure and consumption, Ghez and Becker (1975) estimated γ to be at most .28. Based on these studies, we choose a value of γ=.25 for our basic simulations.[17]

There is little direct empirical evidence on the value of ρ, except for the results of Ghez and Becker (1975), who find an aggregate value of ρ=.83. Much evidence is available on the labor supply elasticities of both men and women with respect to the contemporaneous wage, with "standard" values for the uncompensated elasticity equal to near zero for men and at least one for married women (see, for example, Heckman 1974, Rosen 1976, MaCurdy 1980 and Hausman 1981b). However, the translation of these elasticities into estimates of ρ depends on the degree to which the underlying wage changes are permanent or temporary, and whether they are anticipated or unanticipated. A detailed discussion of this issue is provided in the appendix. While a range of values seems plausible for ρ, .8 seems to be a reasonable compromise. Moreover, this value of ρ provides realistic age-earnings and age-consumption profiles in our simulation of the initial steady state. For lower values of ρ, consumption growth is too high in later years and retirement does not occur. For higher values, consumption actually declines during retirement. These effects occur because leisure is relatively cheaper in later years (e declines); the greater the elasticity of substution, ρ, the greater the shift from consumption into leisure (see (8)).

The leisure intensity parameter, α, and the scaling constant, A, really depend on the choice of labor and output units. For convenience, we always choose output units so that the wage in the initial steady state is unity for age one individuals. This determines A. Adopting the convention of a labor endowment equal to 5000 hours per year, we choose α so that prime age labor supply is about 2000 hours per year, or 40 hours per week. This suggests a value of α=1.5, which is used in all simulations. Finally, there is scant empirical evidence on the appropriate value of δ. Since an increase in δ would reduce the steepness of consumption and leisure profiles (see (9) and (11)), it would lead to less saving and hence a lower capital-output ratio as well as a smaller likelihood of retirement in later years. We find that setting δ=.015 gives realistic values both for the capital-output ratio and the age of retirement. Lowering δ eliminates retirement, while raising it makes the capital-output ratio unreasonably low.

The exact values of the key substitution elasticities remain uncertain. Hence, we also present simulation results for different values of σ, γ and ρ. The aim of this paper is not, however, to calculate exact estimates of the efficiency gains or losses resulting from particular policies, but rather to reach certain qualitative conclusions about the differences among alternative policies.

Basic Simulation Results

The initial fiscal structure used as the starting point for most simulations is a proportional income tax of 30 percent, with no national debt. The parameterization outlined above generates an initial, long-run equilibrium with a capital-output ratio of 3.04 and a gross interest rate of 8.22 percent.

Retirement occurs at age 53, with labor supply peaking at a value of 0.468 (2340 hours per year) at age 9. The solid and dashed lines in Figure 2 depict, respectively, the age-consumption and age-earnings profiles in this initial steady state. The age-consumption profile rises slowly over time, nearly levelling off before retirement. Earnings rise until age 20 and then begin to fall off. This drop in earnings becomes more rapid after age 30 as a result of the combination of lower labor supply and a decline in wages. The sudden jump in consumption during retirement results as a spillover from the retirement constraint placed on the individual's purchase of leisure.

Starting from this long-run equilibrium, we calculate the path of the economy to a new long-run equilibrium after the immediate adoption of either a proportional consumption tax or a proportional wage tax, with annual budget balance imposed in each year. Figure 3 presents the effects on cohort welfare of these two potential changes in tax regime. The various cohorts alive during the economy's transition are identified on the vertical axis by their year of birth, taking zero to be the year of the initiation of the tax change. Welfare gains and losses are measured on the vertical axis as the fraction of full lifetime labor endowment required under the original income tax regime to generate the same level of utility actually achieved with the change in tax regime. For example, a value of 1.02 means that a cohort's utility is increased as a result of the tax change by the same amount as would have been induced by a 2 percent increase in human capital endowment under the income tax. We refer to these measures, as "wealth equivalents." The dashed line in Figure 3 represents the wealth equivalents under a transition to a consumption tax; the dotted line represents those resulting from a transition to a wage tax.

Figure 2

AGE-CONSUMPTION, AGE-EARNINGS PROFILES

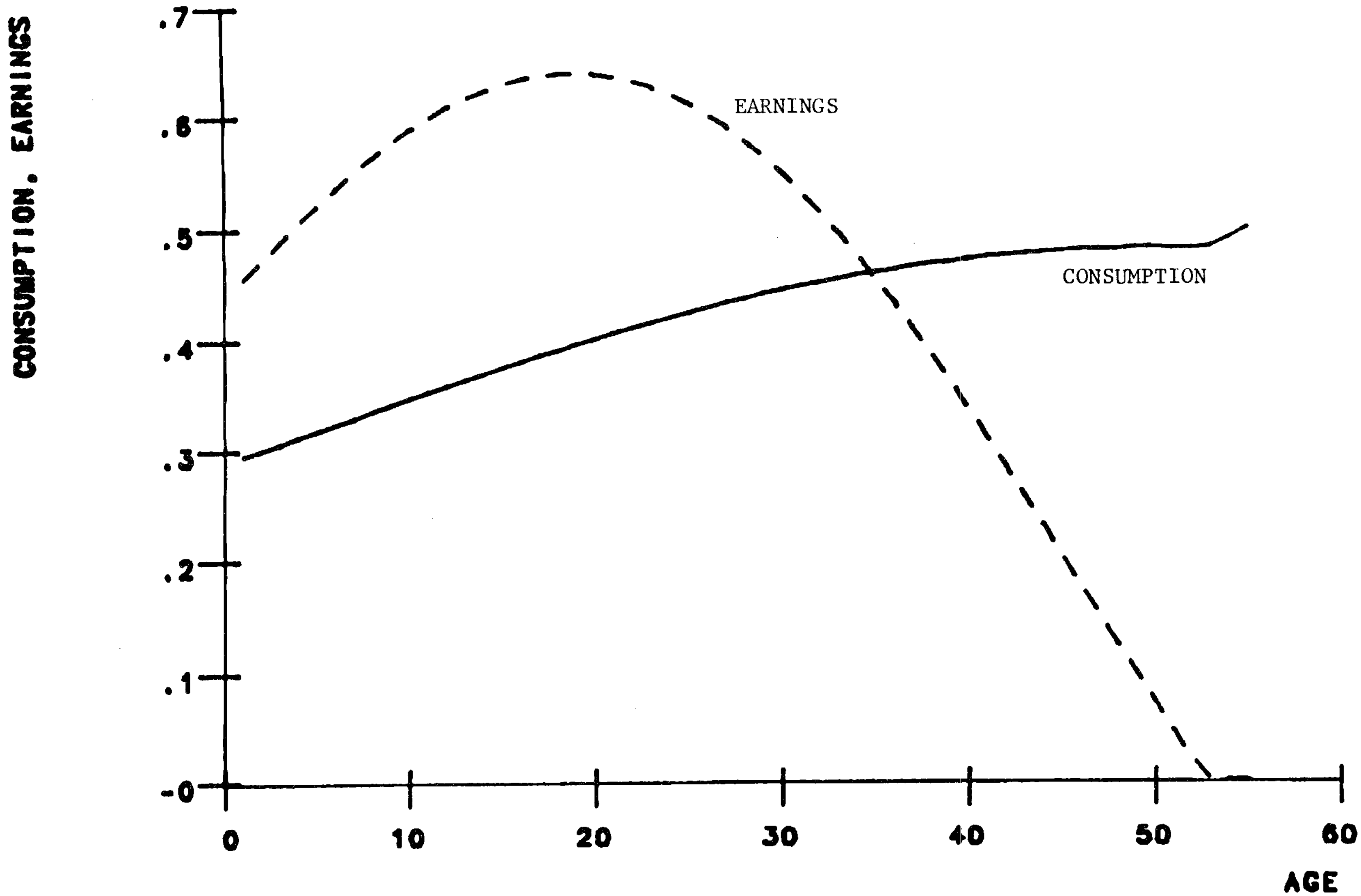
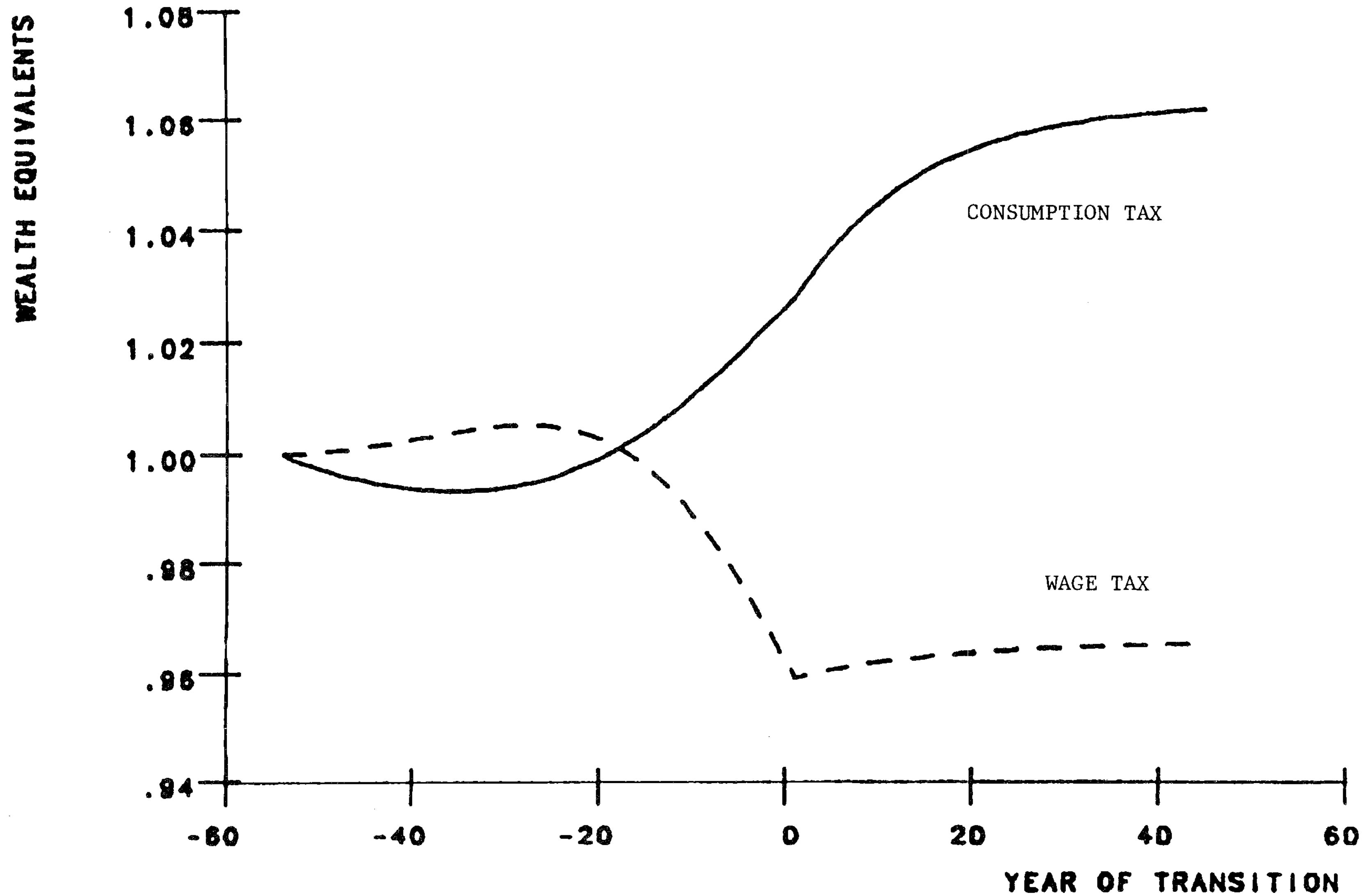


Figure 3

WEALTH EQUIVALENTS



As the diagram clearly demonstrates, the consequences for the distribution of cohort welfare are markedly different under these two alternative "tax reforms." Along the consumption tax transition path, young and future cohorts achieve substantial utility gains, partly at the expense of older cohorts. The long-run steady state gain is over 6 percent under the consumption tax. Under the wage tax, older cohorts gain, while generations either young or unborn at the time of the policy switch are hurt. There is eventually a steady state welfare loss of almost 4 percent. Interestingly, the identity of gainers and losers under the two regimes is almost exactly opposite. Those above the age of about 18 at the time of the policy change gain from a wage tax and lose from a consumption tax, while all subsequent cohorts gain from a consumption tax and lose from a wage tax.

The shapes of these curves are readily understood. Under the consumption tax, elderly cohorts are faced with a much heavier tax burden than they would have experienced under the income tax. For these older cohorts, labor earnings are small, and consumption is financed by depleting accumulated savings. Thus, consumption far exceeds earnings, and the base of the consumption tax is far greater than that of the income tax. Young and future cohorts gain from a switch to a consumption tax because older cohorts have been forced to bear a larger portion of the present value of government expenditures.

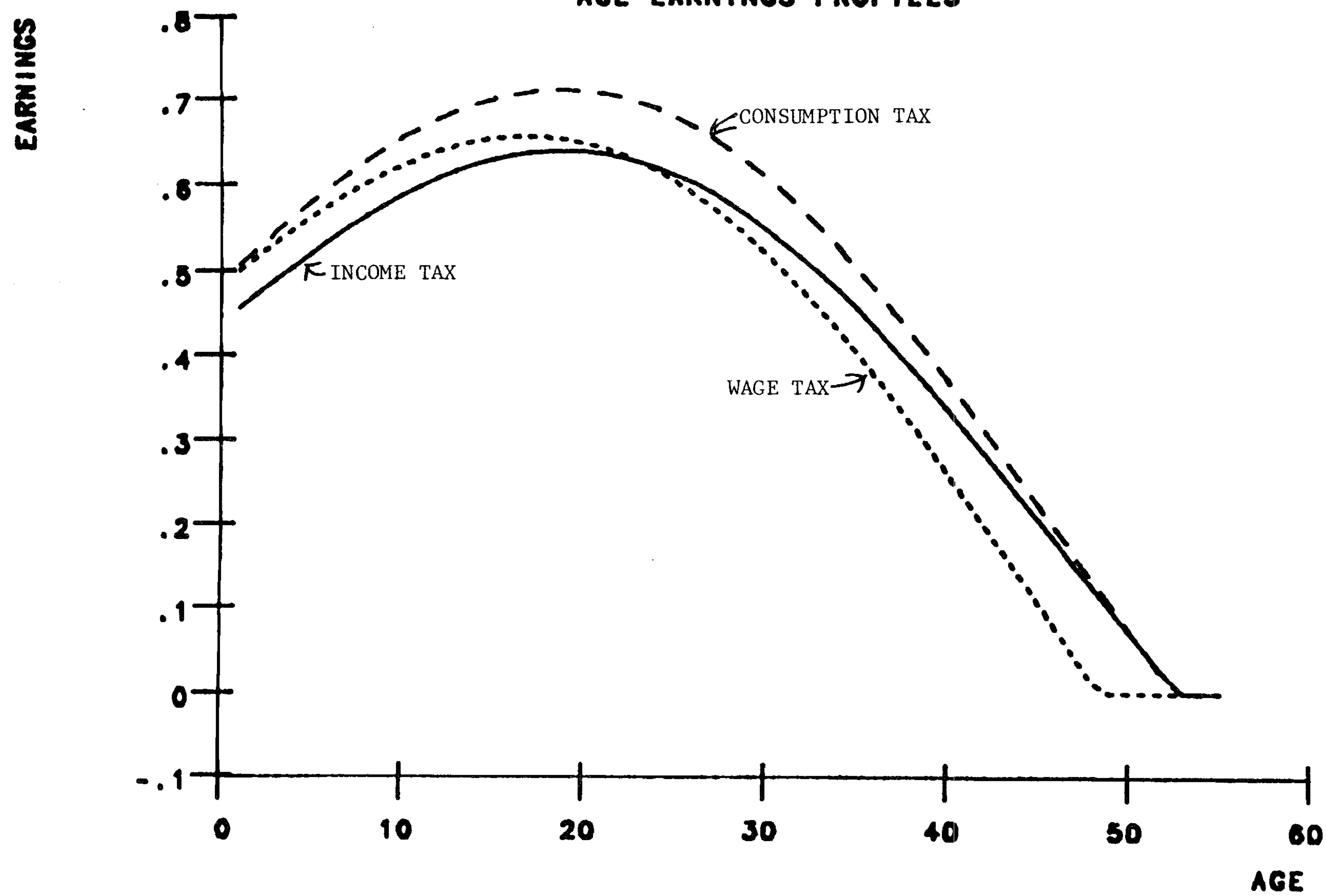
The switch to a proportional wage tax raises the welfare of the elderly for much the same reason that a consumption tax lowers it. Here, taxes on capital income that would have been due under the income tax are eliminated. However, these gains must be supported by a greater tax collection from young and future generations.

Despite the very different effects these two tax regimes have on steady state welfare, both lead to a greater capital-output ratio by exempting capital income from taxation and hence encouraging savings. Under a consumption tax, which has a steady state value of 0.395, the capital output ratio rises so much, from 3.04 to 4.38, that the net-of-tax interest rate actually falls, from 5.75 percent (0.7x8.22) to 5.71 percent. Under a wage tax, which equals 0.411 in the new steady state, the capital-output ratio rises less, to 3.45. Because of this smaller rise in capital accumulation, the gross interest rate falls less, to a value of 7.25 percent.

The results of these differences in interest rates, as well as the differential impact on welfare, may be seen by comparing the steady-state age-earnings and age-consumption profiles under the consumption and wage taxes with those in Figure 2 that occur under an income tax. Figure 4 presents the long-run age-earnings profiles for the consumption tax (dashed line), wage tax (dotted line) and income tax (solid line, reproduced from Figure 2). Because of the higher equilibrium capital intensity, the wage rate is higher under a consumption tax than under a wage tax (1.129 versus 1.043); this is reflected in the fact that the age-earnings profile for the consumption tax lies entirely above that of the wage tax. Because of the higher net interest rates under the wage tax, labor supply is concentrated more in the early years, and retirement occurs in year 49.

Figure 4

AGE-EARNINGS PROFILES

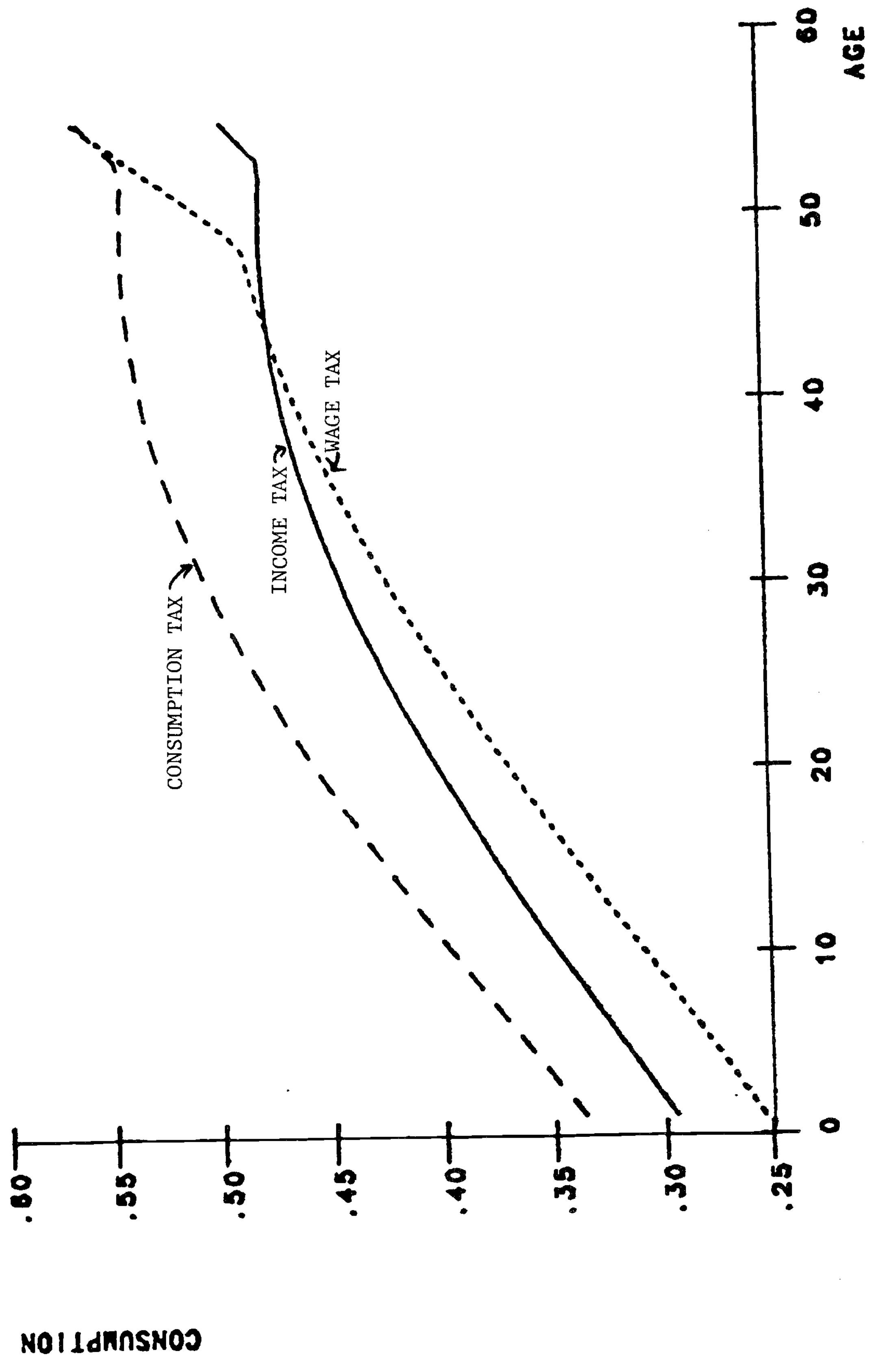


The age-consumption profiles shown in Figure 5 reflect a similar story. Consumption rises most steeply under a wage tax. The profile under a consumption tax is much higher than those of the other two tax systems because of the higher wage rates achieved by individuals under this regime.

These results beg the question of whether policies that increase capital accumulation also increase economic efficiency. Since some generations gain and some lose under each of the tax changes considered thus far, some method is necessary to isolate the substantial intergenerational transfers associated with "tax reforms" like these from any inherent gains in efficiency associated with these policies. One approach, explored by Auerbach and Kotlikoff (1981), is to seek combinations of wage and consumption taxes and deficit policy that raise the utility of all cohorts to at least the level enjoyed under the income tax. However, such "Pareto welfare paths" cannot offer an exact measure of the efficiency gain (or loss) resulting from a tax change. The next section presents a methodology for doing so.

Figure 5

AGE-CONSUMPTION PROFILES



III. Distinguishing Efficiency from Redistribution: The Lump Sum Redistribution Authority (LSRA)

The LSRA is a hypothetical construct used to measure the pure efficiency gains from tax reform. The LSRA is modelled as a separate, self-financing goverment agency that uses lump sum taxes and transfers to keep cohorts born before a specified date at their status quo level of utility, and to raise the utility of all cohorts born after this date by a uniform amount. Maximization of the minimum level of utility of those born after a certain date, a policy analyzed in a two-period setting by Phelps and Riley (1978), seems to be a logical way of characterizing the infinite set of welfare paths the LSRA could generate.[18]

The simulation model was adapted to solve for the economy's general equilibrium transition path consistent with the behavior of the standard government fiscal authority as well as the lump sum tax-transfer activity of the LSRA. Thus, for example, household consumption decisions under a consumption tax transition take account of the LSRA lump-sum taxes and transfers. It is also important to note that the equilibrium path of consumption tax rates will differ from that generated in the absence of the LSRA, since changes in the behavior of households will necessitate modifications in the tax schedule imposed by the main government authority.

The LSRA faces a budget constraint requiring that the total value of its lump-sum taxes and transfers sum to zero in present value. At any point in time, the LSRA holds net assts that may be positive or negative, but that equal the present value of its net future payments. These net assets are added to those held by the private sector to determine the economy's total stock of capital.

Lump sum taxes and transfers are collected and paid in year one (the first year of the transition) for all existing cohorts and in the first year of economic life for all subsequent cohorts. Equation (16) expresses the LSRA budget constraint, where v_i is the lump sum tax (negative, if a transfer) paid by members of generations born in year i, and n is the economy's population growth rate. The two pieces of the expression in (16) correspond, respectively, to the net taxes collected from existing and future cohorts.

$$\text{(16)} \qquad \sum_{i=-53}^{0} (1+n)^i v_i + \sum_{i=1}^{\infty} (1+n)^i \left[\prod_{j=1}^{i} (1+r_j)^{-1} \right] v_i = 0$$

The method of simulation is essentially the same as that previously described. However, the budget constraints of existing and future cohorts now include the terms v_i, and updated guesses of these must be made in each iteration step along with those of factor prices, tax rates and shadow wages. In the first iteration of the simulation, all v_i's are given preliminary values of zero. In the course of each iteration, the model produces new estimates of the path of this vector $\mathbf{v}$. A weighted average of the initial guess and this computed path generates a guess for the next iteration.

The calculation of $\underset{\sim}{v}$ in each step, described in detail in the appendix, proceeds as follows. Under the assumption that all prices and tax rates are fixed, the transfers necessary to insure cohorts born before i* the original steady state level of utility are calculated; in the same fashion, we calculate the transfers required by all future cohorts as functions $v_i(u^*)$ of the unknown new level of utility that prevails after i*, u*. We then take the present value of all taxes and transfers, which is also a function of u*, set this equal to zero, and solve for u* and hence the transfers for $i \geq i^*$.

Figures 6 and 7, respectively, present the efficiency effects, as measured from the LSRA simulations, of moving from a proportional income tax to a proportional consumption or wage tax. The original cohort welfare paths without the LSRA are reproduced from Figure 3 (as solid lines in Figures 6 and 7) for comparison. The dashed lines in each figure correspond to the welfare paths achieved for the LSRA critical date i* equal to 1 and 20.

Starting in year one, the efficiency gains from switching to a proportional consumption tax are sufficient to raise the wealth of all future generations by 1.73 percent without harming the welfare of earlier generations. Delaying the gains until i* = 20 allows a per cohort gain of about 5 percent. While substantial, these gains are smaller than those achieved in the steady state without the LSRA, because the heavy tax burden levied on the elderly starting in year zero has been undone.

The LSRA transition to a wage tax involves a <u>loss</u> in efficiency.

Figure 6

WEALTH EQUIVALENTS UNDER A CONSUMPTION TAX

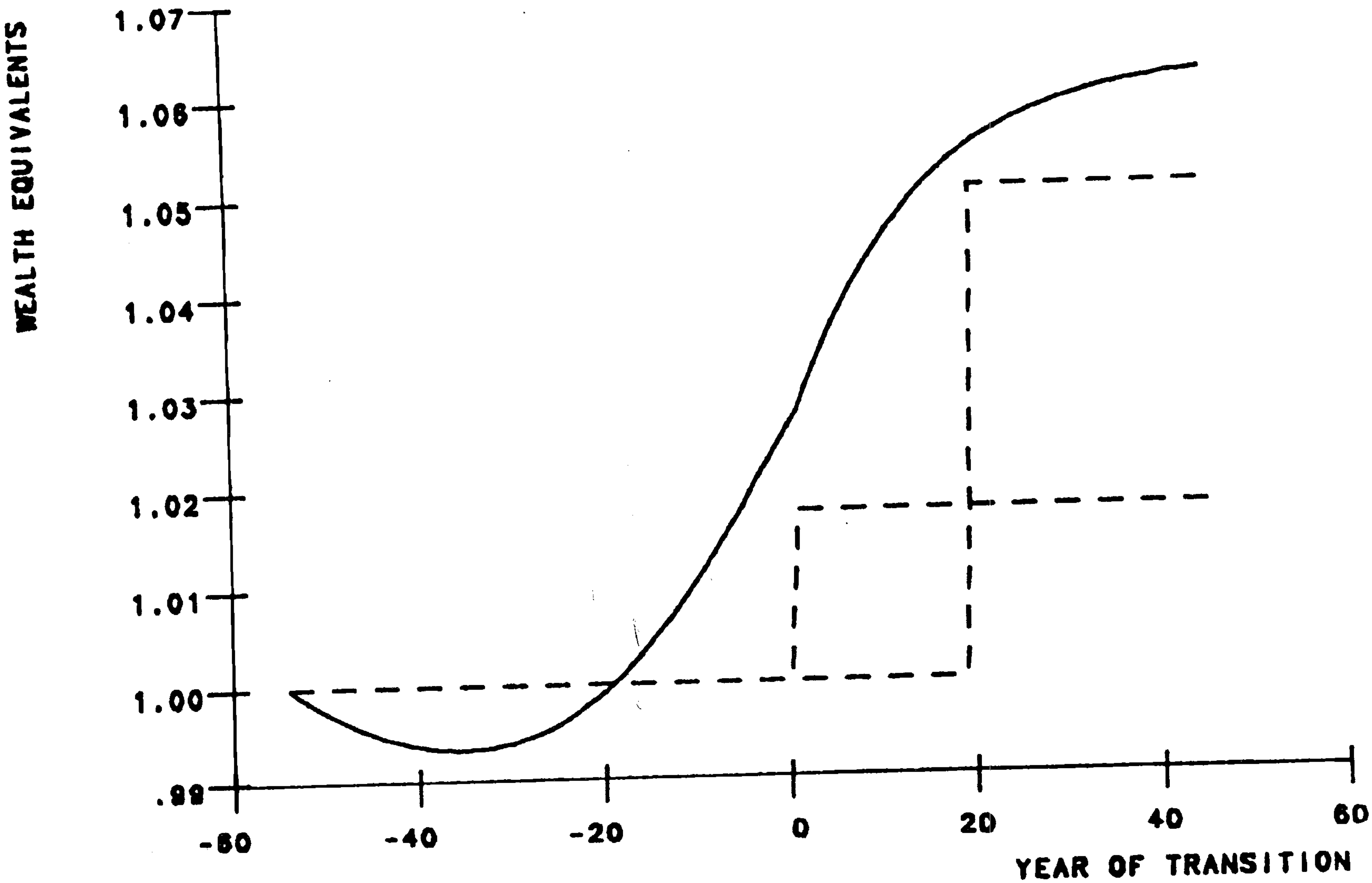
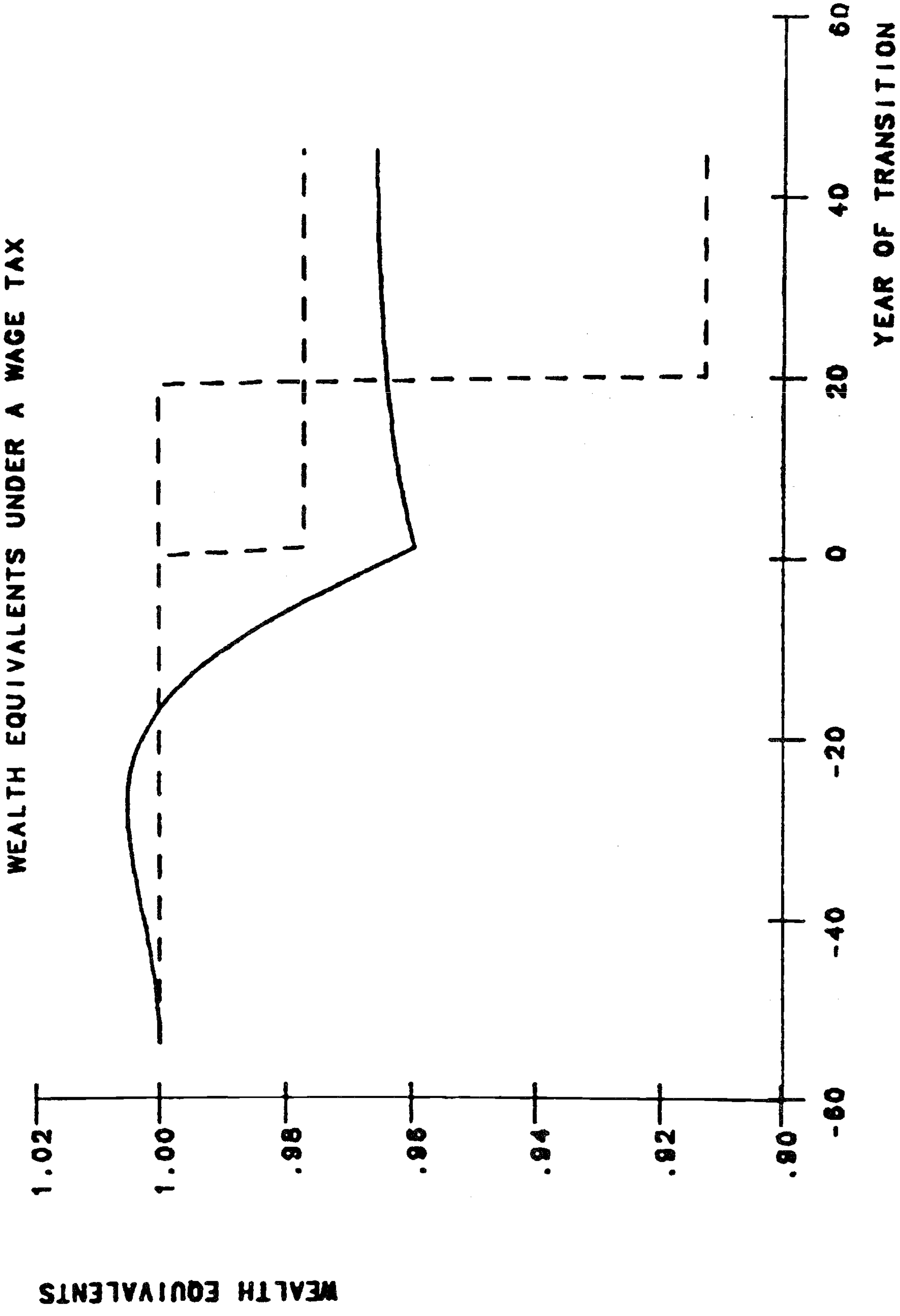


Figure 7


WEALTH EQUIVALENTS UNDER A WAGE TAX
WEALTH EQUIVALENTS
1.02
1.00
.98
.96
.94
.92
.90
-60
-40
-20
0
20
40
60
YEAR OF TRANSITION

The sustainable level of utility for i*=1 is 2.33 percent below what it would have been under the income tax. Delay of the loss until i*=20 leads to a drop of almost 9 percent in full lifetime resources for all future generations.

This difference between the sustainable levels of utility at i*=1 under the alternative tax regimes is remarkably large in light of the apparent similarity of the regimes themselves. Taking account of the fact that the present value of full lifetime resources is approximately four times as large as lifetime earnings for our simulations of the initial income tax, the 1.73 percent gain under the consumption tax and 2.33 percent loss under the wage tax represents a swing of about 16.25 percent of lifetime earnings. Except for the difference between the population growth rate and the individual rate of discount, this is also a measure of the annual loss as a fraction of total labor income. For the U.S. economy in 1980, total wage and salary compensation was 1,344 billion dollars[19], 16.25 percent of which is 218 billion dollars, or about one-third the size of the federal government's budget.

The key to this difference lies in the pattern of tax burden each new system imposes on different generations. Aside from the differences in distributional impact, which the LSRA neutralizes, the tax systems also differ in their excess burden because they tax different generations at different marginal rates. A consumption tax places high marginal tax rates on the elderly who, because they have few years over which to alter their consumption-leisure decisions, exhibit relatively inelastic behavior with respect to tax-induced changes in net prices. This allows a lower burden, and, consequently, lower distortionary marginal tax rates, to be placed on those with a more elastic response, the young. The wage tax does just the opposite, giving low marginal tax rates to the elderly, paid for through higher distortionary taxes on the young. It is thus crucial to the efficiency gain resulting from a consumption tax that the initial generations face high marginal tax rates.

IV. Sensitivity Analysis of Efficiency Gains

As stressed in section II, the parameters chosen for the baseline simulations are subject to a great deal of uncertainty. It is important to examine the sensitivity of our results to changes in such parameters. Table 1 presents the sustainable maximin wealth effects (for $i^*=1$) of movements from a proportional income tax to proportional consumption and wage taxes for alternative values of ρ, the intratemporal elasticity of substitution between goods and leisure, γ, the intertemporal elasticity of substitution, and σ, the elasticity of technical substitution between capital and labor.

For the wage tax, the results are quite sensitive to parameter changes, but in directions that intuition would dictate. Lowering γ, and, hence, the distortions associated with taxes on capital income, worsens the effects of going to a wage tax. Reducing γ from .25 to .1 increases the welfare loss from 2.33 percent to 6.74 percent at ρ=.8. Decreasing ρ, and, hence, the distortions associated with taxes on labor income, improves the outcome. With γ held at .25, a

Table 1

Sensitivity Analysis

Maximin Gain (i*=1)

Proportional Consumption Tax

γ	ρ = .3	ρ = .8	σ
.1	1.81	2.06	1
.25	1.48	1.73	1
.25		1.18	.8

Proportional Wage Tax

γ	ρ = .3	ρ = .8	σ
.1	-1.17	-6.74	1
.25	.03	-2.33	1
.25		-1.04	.8

reduction of ρ to .3 is sufficient to neutralize the negative impact of the wage tax. Changing σ to .8 reduces the effect of the change in regime, since gross factor prices change more as a result of initial changes in factor supplies, thus making the general equilibrium changes in net prices, as well as associated behavioral responses, smaller.[20]

In contrast, the efficiency effects of moving to a consumption tax appear much less sensitive to the preference paramters ρ and γ, though the effect of a change in σ still appears important. To explain this result, it is helpful to recall why the consumption tax is more efficient than the wage tax in the first place. The consumption tax may be thought of as the combination of a wage tax plus a levy on the initial elderly population. Though these elderly individuals are relatively inelastic in their behavior, they can shift away from the consumption tax to a certain extent, by shifting resources to periods when the consumption tax may be lower (it is highest in the first year of the transition, and then declines steadily until the new steady state is reached). The extent to which they will do this depends on γ, the intertemporal elasticity of substitution. The higher is γ, the more they will shift and the less like a lump sum tax will be the initial levy on the elderly. Thus, the rise in γ makes the wage tax relatively more efficient, compared to the income tax, but it also reduces the efficiency advantage of the consumption tax over the wage tax.

V. The Progressive Tax: Efficiency Gains from Switching to Alternative Tax Structures

Additional distortions are introduced with the progressivity of tax rates. It is important to see how the results of the previous section are influenced by allowing marginal and average tax rates to differ.

For each of the tax structures, marginal tax rates are determined by the following formula

$$(17) \qquad t = \Psi_0 + \Psi_1 B$$

where B is the tax base, either annual income, annual consumption or annual labor earnings. It follows that the average tax rates corresponding to (17) are

$$(18) \qquad \bar{t} = \Psi_0 + 1/2\,\Psi_1 B$$

As explained in section II, each cohort in each transition year faces a different path of marginal and average tax rates, because of differences in behavior and differences in the tax schedule parameters Ψ_0 and Ψ_1. These rates are solved for in each iteration step along with factor prices and shadow wages (see Figure 1).

To investigate reform of the progressive income tax, we specify an initial steady state with $\Psi_0 = .22$ and $\Psi_1 = .28$ for the income tax. This yields a profile of average tax rates that ranges from .282 at age 1 to .323 at age 26 to a minimum of .227 at age 55, and is concentrated around .30, the level of proportional income tax considered above. The marginal rates range from .234 to .426. The first experiment involves switching from this regime to a proportional income tax (roughly equal to .28 in the long run) to evaluate the excess burden due to the progressivity of the income tax. The sustainable welfare gain is larger than any of those reported in Table 1, equalling 6.15 percent of the lifetime resources. The size of this distortion may seem somewhat surprising, given the relatively small gap between marginal and average tax rates in the initial steady states. However, it must be remembered that, for any single tax, the magnitude of the distortion rises roughly in proportion to the square of the marginal tax rate. Moreover, a further efficiency loss is introduced here by the variation in marginal tax rates over time. Shifting to either a proportional consumption tax or a proportional wage tax also leads to a large welfare gain (7.08 percent and 4.24 percent, respectively) although, as before, the wage tax is inferior to the proportional income tax, while the consumption tax is superior, however, it may be more appropriate to compare the progressive income tax with alternative taxes possessing a similar degree of progressivity. To do this, we choose values of Ψ_1 for the alternative tax bases that give top marginal rates having roughly the same proportion to overall average rates as is the case for the income tax. For example, the progressive income tax resulting from Ψ_0=.22 and Ψ_1=.28 yields a top marginal rate of 0.43 compared to an overall average rate of about .3. In our previous simulations for proportional taxes, we had a consumption tax of .39 in the new steady state versus a wage tax of .41. Thus, we seek top marginal rates of about .55 and .58, respectively.

These outcomes are roughly achieved by Ψ_1=.6 for the consumption tax and Ψ_1=.4 for the wage tax.[21] The values of Ψ_0 depend on the size of the annual tax bases; in the steady state, they equal .24 and .32, respectively.

Transition from a progressive income tax to a consumption tax with Ψ_1=0.6 still results in a substantial efficiency gain of 4.97 percent. However, the switch to a wage tax produces a loss of 3.14 percent, this loss is even larger than the loss of 2.33 percent occuring with a switch under proportional taxation.

To summarize these results, a truly progressive income tax is substantially more distortionary than a proportional income tax. If progressive taxation must be used (for distributional objectives, presumably), the general efficiency results from the study of proportional taxation carry over. A transition to a consumption tax is considerably more efficient than a transition to a wage tax; the first generates a large efficiency gain while the second induces an equally large efficiency loss.

VI. Conclusions

The simulations presented above suggest that a shift to a wage tax from an income tax can significantly reduce economic efficiency. While a consumption tax does offer efficiency gains, these arise chiefly from the placement (probably implausible, politically) of large marginal tax burdens on the relatively inelastic elderly when capital income taxes are reduced. Foregoing such taxes on the elderly effectively removes the distinction between a consumption tax and a wage tax. While wage taxation will also stimulate capital formation, it may reduce economic efficiency. Thus, it is important that policy makers not confuse programs that stimulate capital formation with those that increase welfare.

The paper also points out that the progressivity of a tax may be at least as important as the tax base itself in determining the efficiency of the tax system.

Appendix

Some of the results reported in the text are derived below.

Progressive Income Taxes

Maximization of the Lagrangian

$$\frac{1}{1-\frac{1}{\gamma}} \sum_{t=1}^{55} (1+\delta)^{-1} \left(c_t^{(1-\frac{1}{\rho})} + \alpha\ell_t^{(1-\frac{1}{\rho})}\right)^{\left(\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}\right)}$$

$$+ \lambda \sum_{t=1}^{55} \left[\prod_{s=2}^{t} (1+r_s(1-\bar{\tau}_{ys}))\right]^{-1} \{[(1-\bar{\tau}_{yt})w_t e_t + \mu_t](1-\ell_t) - c_t\}$$

with respect to c_t yields:

$$(A1) \qquad (1+\delta)^{-(t-1)} \Omega_t c_t^{-\frac{1}{\rho}} = \lambda\{[\prod_{s=2}^{t} (1+r_s(1-\bar{\tau}_{ys}))]^{-1} - J_t\}$$

where Ω_t is as defined in (5) and J_t is the indirect effect of c_t on the budget constraint through changes in the average tax rates $\bar{\tau}_{yt+1}, \ldots, \bar{\tau}_{y55}$; letting M_s, $s>t$, be the partial derivative of the budget constraint with respect to $\bar{\tau}_{yt}$, we have

$$(A2) \qquad J_t = \sum_{s=t+1}^{55} M_s \frac{\partial \bar{\tau}_{ys}}{\partial c_t}$$

where

$$\text{(A3)} \qquad M_s = \left[\prod_{z=1}^{s-1}(1+r_z(1-\bar{\tau}_{yz}))\right]^{-1}\left[\frac{r_s}{(1+r_s(1-\bar{\tau}_{ys}))^2}\right]$$

$$X \sum_{q=s}^{55}\left[\prod_{z=s+1}^{q}(1+r_z(1-\bar{\tau}_{yz}))\right]^{-1}\left[(1-\bar{\tau}_{yz})w_z e_z(1-\ell_z)-c_z\right]$$

$$-\left[\prod_{z=1}^{s}(1+r_z(1-\bar{\tau}_{yz}))\right]^{-1} w_s e_s(1-\ell_s)$$

Note that assets at the beginning of year s must equal the present value of planned consumption less planned earnings over the years s through 55, i.e.

$$\text{(A4)} \qquad A_s = \sum_{x=s}^{55}\left[\prod_{z=s}^{x}(1+r_z(1-\bar{\tau}_{yz}))\right]^{-1}\left[(1-\bar{\tau}_{yz})w_z e_z(1-\ell_z)-c_z\right]$$

we can simplify (A3):

$$\text{(A5)} \qquad M_s = -\left[\prod_{z=1}^{s}(1+r_z(1-\bar{\tau}_{yz}))\right]^{-1}\left[w_s e_s(1-\ell_s)+r_s A_s\right] = -\left[\prod_{z=1}^{s}(1+r_z(1-\bar{\tau}_{yt})\right]^{-1} Y_s$$

IF $T_Y(\cdot)$ is the progressive income tax function, then $\bar{\tau}_{ys} = T_Y(y_s)/y_s$ and $\tau_{ys} = T_Y'(y_s)$. Thus,

$$\text{(A6)} \qquad \frac{d\bar{\tau}_{ys}}{dc_t} = \left(\frac{T_y'(y_s)}{y_s} - \frac{T_Y(y_s)}{{y_s}^2} \right) \frac{dy_s}{dc_t} = (\tau_{ys} - \bar{\tau}_{ys}) \cdot \frac{1}{y_s} \frac{dy_s}{dc_t}$$

Thus, from (A5) and (A6),

$$\text{(A7)} \qquad M_s \frac{d\bar{\tau}_{ys}}{dc_t} = -\left[\prod_{z=1}^{s} (1+r_z(1-\bar{\tau}_{yz})) \right]^{-1} (\tau_{ys}-\bar{\tau}_{ys}) \frac{dy_s}{dc_t}$$

Since $\underset{\sim}{\ell}$ is held fixed,

$$\text{(A8)} \qquad \frac{dy_s}{dc_t} = r_s \frac{dA_s}{dc_t}$$

By definition,

$$\text{(A9)} \qquad A_s = A_{s-1}((1+r_s(1-\bar{\tau}_{ys-1})) + w_{s-1}e_{s-1}(1-\ell_{s-1})(1-\bar{\tau}_{ys-1}) - c_{s-1}$$

Thus,

$$\text{(A10)} \qquad \frac{dA_s}{dc_t} = \begin{cases} (1+r_{s-1}(1-\bar{\tau}_{ys-1}))\dfrac{dA_{s-1}}{dc_t} - y_{s-1}\dfrac{d\tau_{ys-1}}{dc_t} & s>t \\ -1 & s=t \end{cases}$$

Using (A6) and (A8) to solve for $d\bar{\tau}_{s-1}/dc_t$ in terms of dA_{s-1}/dc_t, we may rewrite (A10) as

$$\text{(A11)} \qquad \frac{dA_s}{dc_t} = \begin{cases} (1+r_{s-1}(1-\tau_{ys-1}))\dfrac{dA_{s-1}}{dc_t} & s>t \\ -1 & s=t \end{cases}$$

which, solved recursively, yields:

$$\text{(A12)} \qquad \frac{dA_s}{dc_t} = -\prod_{z=t+1}^{s-1} (1+r_z(1-\tau_{yz}))$$

and, using (A7) and (A8),

$$\text{(A13)} \qquad M_s \frac{d\bar{\tau}_{ys}}{dc_t} = \left[\prod_{z=1}^{s} (1+r_z(1-\bar{\tau}_{yz}))\right]^{-1} (\tau_{ys}-\bar{\tau}_{ys}) r_s \left[\prod_{z=t+1}^{s-1} (1+r_z(1-\tau_{yz}))\right]$$

$$= \left[\prod_{z=1}^{t} (1+r_z(1-\bar{\tau}_{yz}))\right]^{-1} \left[\prod_{z=t+1}^{s-1} \frac{(1+r_z(1-\tau_{yz}))}{(1+r_z(1-\bar{\tau}_{yz}))}\right] \left[\frac{(1+r_s(1-\bar{\tau}_{ys}) - (1+r_s(1-\tau_{ys})}{(1+r_s(1-\tau_{ys})}\right]$$

$$= \left[\prod_{z=t+1}^{t} (1+r_z(1-\bar{\tau}_{yz}))\right]^{-1} [Q_{s-1} - Q_s]$$

where

$$\text{(A14)} \qquad Q_s = \prod_{z=t+1}^{s} \frac{(1+r_z(1-\tau_{yz})}{(1+r_z(1-\bar{\tau}_{yz})}$$

Thus, from (A2)

(A15) $$J_t = [\prod_{z=1}^{t}(1+r_z(1-\bar{\tau}_{yz}))]^{-1}\,[(Q_t-Q_{t+1})+(Q_{t+1}-Q_{t+2})+\ldots+((Q_{54}-Q_{55})]$$

$$= [\prod_{z=1}^{t}(1+r_z(1-\bar{\tau}_{yz}))]^{-1}\,[Q_t-Q_{55}]$$

$$= [\prod_{z=1}^{t}(1+r_z(1-\bar{\tau}_{yz}))]^{-1}\,[1-\prod_{z=t+1}^{55}\left(\frac{(1+r_z(1-\tau_{yz})}{(1+r_z(1-\bar{\tau}_{yz})}\right)]$$

Substitution of (A15) into (A1) yields condition (4a). Condition (4b) is derived by an analagous method.

<u>Progressive Consumption and Wage Taxation</u>

Maximization of the Lagrangian

(A16) $$\left(\frac{1}{(1-\frac{1}{\gamma})}\right)\sum_{t=1}^{55}(1+\delta)^{-(t-1)}\left(c_t^{(1-\frac{1}{\rho})}+\alpha\ell_t^{(1-\frac{1}{\rho})}\right)^{\left(\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}\right)}$$

$$+\lambda\sum_{t=1}^{55}[\prod_{s=2}^{t}(1+r_s)]^{-1}\{[(1-\bar{\tau}_{wt})w_te_t+\mu_t](1-\ell_t)-(1+\bar{\tau}_{c_t})c_t\}$$

with respect to c_t yields:

$$\text{(A16)}\qquad (1+\delta)^{-(t-1)}\ \Omega_t c_t^{-\frac{1}{\rho}} = \lambda[\ \pi\ (1+r_s)]^{-1}[(1-\bar{\tau}_{c_t}) + c_t\frac{d\bar{\tau}_{c_t}}{dc_t}]$$

$$= \lambda[\prod_{s=2}^{t}(1+r_s)]^{-1}(1+\tau_{c_t})$$

using the definitions of $\bar{\tau}_{c_t}$ and τ_{c_t}. The first-order condition for ℓ_t is:

$$\text{(A17)}\qquad (1+\delta)^{-(t-1)}\ \Omega_t \alpha \ell_t^{-\frac{1}{\rho}} = \lambda[\ \pi\ (1+r_s)]^{-1}[(1-\bar{\tau}_{w_t})w_t e_t + \mu_t + w_t e_t(1-\ell_t)\frac{d\bar{\tau}_{w_t}}{d\ell_t}]$$

$$= \lambda[\prod_{s=2}^{t}(1+r_s)]^{-1}\ [(1-\tau_{w_t})w_t e_t + \mu_t]$$

using the definitions of $\bar{\tau}_{w_t}$ and τ_{w_t}. Dividing (A17) by (A16) and using the definition of w_t* in (7') yields (8). Substitution of (8) into (A16) yields

$$\text{(A18)}\qquad (1+\delta)^{-(t-1)}\ c_t^{-\frac{1}{\gamma}}\ v_t^{-\frac{1}{\gamma}} = \lambda[\prod_{s=2}^{t}(1+r_s)]^{-1}(1+\tau_{c_t})$$

which, combined for successive values of t, yields equation (9').

<u>LSRA Transfers</u>

Because the utility function described in (1) is homothetic, increases in individual wealth, given fixed prices, bring about proportional increases in the vectors $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$. Thus, to solve for the additional resources needed by an individual born after time zero to attain a utility level $\hat{u}$, we solve for ϕ such that

$$\text{(A19)} \qquad \left(\frac{1}{1-\frac{1}{\gamma}}\right) \sum_{t=1}^{55} (1+\delta)^{-(t-1)} \{[(1+\phi)c_t]^{(1-\frac{1}{\rho})} + \alpha[(1+\phi)\ell_t]^{(1-\frac{1}{\rho})}\}^{\left(\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}\right)} = \hat{u}$$

or

$$\text{(A20)} \qquad \phi = \left(\frac{\hat{u}}{\bar{u}}\right)^{\frac{1}{1-\frac{1}{\gamma}}} - 1$$

where $\bar{u}$ is the current level of utility being attained with a transfer level $\bar{v}_i$. The difference between $\bar{v}_i$ and the product of ϕ and the present value of earnings yields a guess of the additional resources, Δv_i, that must be transferred to the individual to attain the utility level $\hat{u}$. Adding Δv_i to $\bar{v}_i$ gives us a function $v_i(\hat{u})$ of total transfers needed for utility level $\hat{u}$.

For individuals alive when the transition begins, the same procedure is followed using the utility subfunctions that apply over the remaining years of life.

For individuals of cohorts $i < i^*$, $\hat{u}$ is set at the level that would have been enjoyed under the original tax regime, u_0. The present value, T, of all such transfers, $v_i(u_0)$, $i<i^*$, is then calculated. The value of u^* is chosen by assuming that the present value of <u>all</u> LSRA transfers is zero:

$$\text{(A21)} \qquad T + \sum_{i=i^*}^{\infty} [\prod_{j=0}^{i} (1+r_j)]^{-1} (1+n)^i \, v_i(u^*) = 0$$

This also yields solutions for $v_i(u^*)$, the new guesses for v_i, which are weighted with the old vector $\underset{\sim}{\bar{v}}$ to provide values for the next iteration.

Estimating ρ from Labor Supply Elasticities

It is difficult to recover values of ρ from empirical labor supply estimates without making assumptions about whether observed wage changes are permanent or temporary, and how far in advance, if at all, they are anticipated by the individual workers. Typically, all we have is an estimate of the uncompensated elasticity of labor supply with respect to the contemporaneous wage. Though some authors do calculate "compensated" elasticities, it is not always clear that the compensation experiment is in accordance with the nature of the wage change. In short, the size of the income effect is crucial to calculating ρ, but it may be hard to identify.

Consider an experiment where an individual worker has his wage increased equiproportionally from date t_1 until date t_2. Suppose, further, that the worker becomes aware of the prospective change at date $t_0 \leq t_1$. If $t_0 = 1$, perfect foresight prevails. If $t_0 = t_1$, the change is entirely unanticipated.

Using equations (2), (8), (9) and (10) in the text and (A4) in the appendix, we may solve for the individual's labor supply in terms of assets held at time t_0, which are fixed by assumption, and all relevant prices after date t_0. For the simple case without taxes and with interest rates constant over time, this procedure yields the demand for leisure at time t_1:

$$\text{(A22)} \qquad \ell_{t_1} = \left(\frac{1+r}{1+\delta} \right)^{\gamma(t_1-t_0)} \nu_{t_1} \left(\frac{w_{t_1}^*}{\alpha} \right)^{-\rho} \left(\frac{A_{t_0}+E_{t_0}}{X_{t_0}} \right)$$

where

$$(A23) \qquad E_{t_0} = \sum_{t=t_0}^{55} (1+r)^{-(t-t_0)} w_t^*$$

is the present value of earnings begining in period t_0 and

$$(A24) \qquad X_{t_0} = \sum_{t=t_0}^{55} (1+r)^{-(1-\gamma)(t-t_0)} (1+\delta)^{-\gamma(t-t_0)} \zeta_t$$

where

$$(A25) \qquad \zeta_t = (1+\alpha^{\rho} w_t^{*(1-\rho)})^{(\frac{1-\gamma}{1-\rho})} = \nu_t^{(\frac{1-\gamma}{\rho-\gamma})}$$

For simplicity, we assume that, initially, w_t^* is the same for all t, and consider a unit increase in all wages between t_1 and t_2. From (A22), this yields:

$$(A26) \qquad \frac{d\ell_{t_1}}{dw^*} = \frac{\ell_{t_1}}{w^*} [-\rho+(\frac{\tilde{E}_{t_0}}{A_{t_0}+E_{t_0}})] + [\frac{\alpha^{\rho} w^{*(1-\rho)}}{1+\alpha^{\rho} w^{*(1-\rho)}}] [(\rho-\gamma)-(1-\gamma)(\frac{\tilde{X}_{t_0}}{X_{t_0}})]$$

where $\tilde{E}_{t_0}$ is that part of E_{t_0} occurring between dates t_1 and t_2, and $\tilde{X}_{t_0}$ is defined analagously with respect to X_{t_0}.

Using (8) and the fact that labor supply in period t equals $(1-\ell_t)$, we may solve (A26) for the uncompensated labor supply elasticity, η, in period t_1 and then express ρ in terms of this elasticity

(A27) $$\rho = \frac{1}{z}\left[\left(\frac{1\;\ell_{t_1}}{\ell_{t_1}}\right)\eta + \left(\frac{\tilde{E}_{t_0}}{A_{t_0}+E_{t_0}}\right) - (1-z)\left(\gamma+(1-\gamma)\left(\frac{\tilde{X}_{t_0}}{X_{t_0}}\right)\right)\right]$$

where

(A28) $$z = c/(w^{*}\ell + c)$$

is the expenditure share of consumption, constant over time because of the assumption of initially constant w^{*}. If we ignore savings in period t_1, then $c = w^{*}(1-\ell)$ and $z = (1-\ell)$ this allows us to rewrite (A27) as

(A29) $$\rho = \left(\frac{\eta}{\ell_{t_1}}\right) - \gamma\left(\frac{\ell_{t_1}}{1-\ell_{t_1}}\right) + \left(\frac{1}{1-\ell_{t_1}}\right)\left[\left(\frac{\tilde{E}_{t_0}}{A_{t_0}+E_{t_0}}\right) - \ell_{t_1}(1-\gamma)\left(\frac{\tilde{X}_{t_0}}{X_{t_0}}\right)\right]$$

The last term in (A29) has two components that depend on how big, in present value terms, the interval is between t_1 and t_2 relative to that between t_0 and 55. They each become smaller as either t_2 is decreased (the wage increase becomes more temporary) or t_0 is decreased (the wage increase is anticipated further in advance). In each case the income effect on period t_1 labor supply is reduced, since either total wealth increases by less or anticipation of the wage increase allows increased purchases in the period s before t_1. The two extreme cases are when the tax increase is permanent and unanticipated ($t_0=t_1$, $t_2=55$) and when it is very short or anticipated ($t_2 \doteq t_1$, $t_0 \ll t_1$). These two cases yield respective expressions for ρ, based on (A29).

$$\text{(A30)} \qquad \rho = \left(\frac{\eta}{\ell_{t_1}}\right) + 1 - \left(\frac{A_{t_0}}{A_{t_0}+E_{t_0}}\right)/(1-\ell_{t_1})$$

$$\text{(A31)} \qquad \rho = \left(\frac{\eta}{\ell_{t_1}}\right) - \gamma\left(\frac{\ell_{t_1}}{1\ \ell_{t_1}}\right)$$

As discussed in the paper, estimates of η for men tend to be small, near zero, estimates for women are usually at least one. Taking zero and one as conservative estimates of η, and weighting them according to labor force participation, we obtain a rough guess of .3 for η. For $\gamma=.25$, and letting assets equal .2 of future earnings and $\ell=.65$ (both values consistent with averages for middle-aged individuals in our simulations), we obtain a range of ρ of between .00 and .99. For a slightly higher, plausible value of $\eta=.45$, the range is from .23 to 1.22. However, to choose the "best" estimates, we must decide what values of t_0 and t_2 are "typical" for the empirical literature. For example, if we let $t_0=19$, $t_1=20$, $t_2=35$, $r=.055$ and $\delta=.015$, we obtain a value of $\rho=.65$ for $\eta=.3$ and $\rho=.88$ for $\eta=.45$.

Footnotes

1 Chamley (1981a, 1981b) and Black (1981) emphasize this point in discussing tax efficiency for infinite horizon economies.

2 See Summers (1981) or Auerbach and Kotlikoff (1981) for further discussion.

3 See Auerbach (1979b) for further discussion.

4 Letting ℓ_1, ℓ_2, c_1 and c_2 be leisure and consumption in the first and second periods, respectively, a utility function of the form $u(\ell_1, \ell_2, \phi(c_1, c_2))$, where ϕ is homogenous, would normally call for a uniform tax on c_1 and c_2 plus a tax on second period labor supply, assuming first period labor to be untaxed. Even if utility was of the form $u(\psi(\ell_1,\ell_2),\phi(c_1,c_2))$ with both ψ and ϕ homogenous, a pure consumption tax would not be called for, it is homogeneity in labor rather than leisure that would suffice for such a result.

5 Auerbach and Kotlikoff (1981) examine issues arising from intragenerational differences in ability, and intergenerational differences due to technological change. As discussed below, both of these extensions would be difficult to maintain in the current model and are not directly relevant to the questions being addressed.

6 For $\gamma=1$, the use of l'Hôpital's Rule yields:

$$u(\underset{\sim}{c},\underset{\sim}{\ell}) = \left(\frac{1}{1-\frac{1}{\rho}}\right) \sum_{t=1}^{55} (1+\delta)^{-(t-1)} \log\left(c_t^{(1-\frac{1}{\rho})} + \alpha\ell_t^{(1-\frac{1}{\rho})}\right)$$

For $\rho = 1$,

$$u(\underset{\sim}{c},\underset{\sim}{\ell}) = \left(\frac{1}{1-\frac{1}{\gamma}}\right) \sum_{t=1}^{55} (1+\delta)^{-(t-1)} \left(c_t^{\left(\frac{1}{1+\alpha}\right)} + \ell_t^{\left(\frac{\alpha}{1+\alpha}\right)}\right)^{1-\frac{1}{\gamma}}$$

7 The derivation of this and of further results in this section is provided in the appendix.

8 It is not possible to obtain an analytical solution for the absolute level of consumption and leisure for the following reason. successive application of (9) yields an expression for c_t in terms of c_1, from (8) and the budget constraint (2), c_1 can be solved in terms of net average and marginal factor returns and labor endowments, given c_1, (8) and (9), one can solve for all other values of c_t and ℓ_t. However, this procedure would yield an analytical solution for the consumption and leisure profiles $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$ only if net factor returns actually were exogenous. There are two reasons why this is not the case. First, under a progressive tax system, tax rates are function of the vectors $\underset{\sim}{c}$ and $\underset{\sim}{\ell}$. Second, even with proportional taxes, the multipliers μ_t may depend on the labor supply decision. Thus, the procedure just outlined would amount to no more than a solution for $\underset{\sim}{c}$ and ℓ in terms of some complicated nonlinear functions of $\underset{\sim}{c}$ and ℓ.

9 See the appendix for a demonstration.

10 As is well-known, this specification reduces to Cobb-Douglas when σ=1.

11 In a steady state both ℓ_t and c_t/w_t^* must be constant over successive generations for any age t. However, from (8),

$$\ell_t = \alpha^{-\rho} (w_t^*)^{1-\rho} \left(\frac{c_t}{w_t^*}\right)$$

so that these conditions cannot simultaneously be met, if there is general wage growth, unless $\rho=1$.

12 Note that G_t corresponds to a different concept from that reported in the National Income Accounts, which includes government purchases of capital goods.

13 In actual simulations, convergence always occurs well before year 150, so these constraints are not binding. The solution technique merely requires that some date be specified for the beginning of the final steady state.

14 It is also possible to allow debt to be endogenous, and tax rates exogenous. For example, instead of specifying the path of debt, one could specify the path of tax rates for a certain number of years and solve for the debt path consistent with this. An example of such a simulation is presented in Auerbach and Kotlikoff (1981).

15 This methodology does not restrict us to consider only those policies where existing generations are "fooled," since we may specify that a policy change

begins, say, in year 50. The transition path begins at the time a policy is <u>announced</u>, not when it actually begins.

16 The equation used, based on one reported by Welch (1979) for the earnings of high school graduates, is $e_t = 4.47 + 0.033t - 0.00067t^2$, where t is the number of years of experience. We take t to equal the age of the individual, since, by our measure, adult life begins at t=1.

17 For a detailed survey of the empirical evidence relevant for the choice of γ, as well as other preferences parameters, see Skinner (1981).

18 Because the LSRA is only a theoretical construct, there is still a potential problem, dating from the welfare analysis of Hicks (1939) and Kaldor (1939), in using it to make a comparison between tax systems. The "maximin" level of utility achieved by cohorts born after one date might be higher under tax regime A than tax regime B, while if a different date were chosen, all subsequent cohorts might do better under regime B. Unless one particular redistribution scheme is actually carried out, theoretical "as if" comparisons may yield ambiguous results.

19 U.S. Economic Report of the President, 1981, Table B-20.

20 This sensitivity to σ has been examined carefully by Chamley (1981b).

21 The actual top marginal rates that occur in the final steady state are 0.572 at age 55 for the consumption tax and 0.553 at age 16 for the wage tax.

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