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Consumption Smoothing and the Measured Regressivity of Consumption Taxes

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A maintained assumption of nearly all macroeconomic analysis is that households prefer their consumption to remain smooth across time and states of nature. Their ability to smooth consumption is affected by a variety of constraints, including fiscal policy, and, in particular, the choice of tax base. In practice, labor income and interest income on savings have constituted the bulk of taxed activities. However, the preceding forms of taxation create potentially important distortions. Prescott (2004) shows that labor income taxes may be important in depressing labor supply and average incomes to inefficient levels, while Atkeson, Chari, and Kehoe (1999) show that it can never be optimal to tax capital income in the steady state. In particular, capital income taxes hinder the household's ability to smooth consumption intertemporally by lowering the return on savings.

An alternative tax that avoids the hurdles to smoothing created by capital income taxes is a tax on consumption. In general, however, consumption taxes have been opposed on the basis that they are "regressive" in the sense that, at any point in time, the revenues may be disproportionately collected from households whose incomes are lower than average. Households in the U.S. economy also face substantial persistent and uninsurable idiosyncratic risks to their income (see, e.g., Storesletten, Telmer, and Yaron [2004]). As a result, many with currently low income will be those who have suffered an adverse shock in the past. From this perspective, a tax system that collects a

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substantial portion of its revenues from those who find themselves with low income may seem undesirable.

Evaluating the burden of tax payments by income requires choosing a definition of income by which to order households. Two candidates are (i) income received in a given year and (ii) income realized over the lifetime. For each of these definitions, one can compute the regressivity of a given tax regime. The first measure of incidence, which we term *annual incidence,* will compare the cumulative contributions to tax collections of households collected at a point in time, and then ranked by current (annual) income. The second, which we refer to as *lifetime incidence*, will compare the cumulative contributions to tax collections of households ranked by their realized lifetime income.

Some have noted that the measured incidence of consumption taxes depends on the notion of income being used. Notably, Metcalf (1997) shows that while the annual incidence of consumption taxes appears regressive, the lifetime incidence is roughly proportional. In particular, when income is deterministic and has a "hump" at middle age, relatively young households can expect income to grow, while relatively old households can expect income to fall. Under the presumption that households prefer smooth consumption, the young will generally borrow, if allowed, while the old will run down assets to finance consumption in retirement. This behavior implies that households will consume large amounts relative to their income when young while the reverse will hold when old. As a result, any cross-sectional assessment of "who pays" a consumption tax will conclude that it is paid disproportionately by the currently relatively poor. However, this apparent regressivity is merely an artifact of households successfully achieving smooth consumption.

The preceding intuition was derived in a purely deterministic setting. However, the logic extends to the more general case where income has both deterministic and stochastic components. In stochastic settings, people in any cross-sectional data will differ even if they share many characteristics such as age, gender, and education. However, the nature of the shocks that lead a priori similar households to differ matter for the assessment of the effects of tax policy. In particular, given the variance of innovations to income faced by a household, its ability to smooth consumption in the absence of complete insurance markets depends crucially on the *persistence* of shocks. Loosely speaking, the more that annual income "looks like" long-run average income, the more informative annual incidence of consumption taxes will be. When shocks are transitory, a current shock to productivity will have less influence on the lifetime resources that a household can expect over its remaining lifetime. As a result, consumption levels will not need to be adjusted by much in order for the lifetime budget constraint to be satisfied. In turn, unless the household is near a constraint on borrowing, its consumption will not respond to such shocks. By contrast, in an economy with highly persistent labor income risk, a household who has just received a bad shock may expect more of the same in the near and intermediate-term future; thus, expected lifetime resources have to be revised downward, possibly significantly (see, e.g., Deaton [1992]). Therefore, satisfaction of the household's lifetime budget constraint will require a commensurate reduction in current and future consumption. Conversely, if a household receives a good realization of a persistent shock, consumption is likely to jump up as lifetime expected resources are revised upwards.

From a policymaker's perspective, the issue is this: the less closely that consumption tracks income, the more effective we can say that consumption smoothing is. However, annual incidence measures will suggest regressivity. As a result, consumption taxes may appear undesirable in precisely those instances in which households are successful in managing the impact of income fluctuations on their standard of living. The preceding is a relevant consideration: A relatively large body of work has shown that households engage in significant consumption smoothing over their lifetimes (see, e.g., Attanasio et al. [1999] and Gourinchas and Parker [2002]). In contrast to annual incidence, lifetime incidence will not be distorted by the effectiveness of household consumption smoothing.

Unfortunately for policymakers, recent work has debated the persistence of income shocks (which are taken to represent productivity shocks), with estimates that lie substantially away from each other. At one end of the spectrum are the estimates of Storesletten, Telmer, and Yaron (2004) who argue that aggregate cross-sectional evidence suggests a unit-root component for shocks. At the other end of the spectrum are the more recent estimates of Guvenen (2007), who has argued that shock persistence is in fact far lower, and in an AR(1) setting, better approximated by a persistence parameter of 0.8. Given this large range, we present the implications of a switch to consumption taxes under a variety of values for shock persistence and show that measured regressivity does depend on the persistence of shocks.

In this article, we address two questions. First, how will a move to pure consumption taxation matter for aggregate outcomes, and how do the results depend on the persistence of shocks to productivity? Specifically, under varying shock persistence, how do the levels and variability of consumption, wealth, and labor supply respond to this tax reform? Second, how regressive are consumption taxes? Do annual and lifetime incidence measures of consumption taxes differ, and how do the results depend on the persistence of productivity shocks? Specifically, we utilize the Suits Index (Suits 1977), a standard measure of the incidence of taxes, to determine how regressivity depends on (i) the frequency at which income is measured and (ii) the stochastic structure of idiosyncratic household productivity. We will then describe the relationship of the Suits Index to direct cross-sectional measures of inequality, in particular, the Gini Index and the coefficient of variation.

Given our objectives, it is essential that we face the household with a stochastic productivity process that accurately captures both the true nature of household risk *and* the tools with which households smooth consumption. Therefore, our model features a stochastic process for productivity that contains a transitory component, a persistent component, and a well-defined "hump-shaped" life-cycle profile for average productivity. We equip households with the two tools thought to be empirically most relevant for consumption smoothing: self-insurance through asset accumulation, and flexible labor supply. Our work is most closely related to Fullerton and Rogers (1991) and Metcalf (1997), who study the dependence of measured regressivity on the frequency of income measurement, though in stylized models that abstract from uncertainty. Given the potential for uncertainty to alter consumption smoothing, our article contributes to the literature by allowing for stochastic shocks of varying persistence and flexible labor supply. It is also related to Ventura (1999), Nishiyama and Smetters (2005), Athreya and Waddle (2007), and Fuster, Imrohoroglu, and Imrohoroglu (2008). Our work differs from prior work as it derives the implications for tax incidence as a function of the stochastic properties of income.

Our main findings are as follows. In terms of aggregates, we find that a move to a consumption tax will increase savings taken into retirement but will not alter either labor supply or consumption variability substantially. The *level* of inequality does vary with the persistence of productivity shocks, especially when using lifetime measures of the relevant variables. With respect to regressivity, our results show that the findings of Metcalf (1997) carry over to a substantially richer setting: We show that regressivity is a measure that is quantitatively sensitive to the frequency of income being used. Our results obtain in spite of the fact that borrowing constraints bind for most households early in life. While annual incidence shows substantial regressivity, the lifetime incidence of a consumption tax is proportional, *irrespective* of the persistence of income shocks. Perhaps the central lesson of our article is that standard measures of the incidence of consumption taxes can be rather misleading as a guide to its implications for household consumption smoothing.

In what follows, Section 1 lays out some intuition for the role played by consumption taxes. Section 2 presents the model and equilibrium, Sections 3 and 4 present the parameterization and results, and Section 5 concludes.

1. WHY MIGHT A SWITCH TO CONSUMPTION TAXES MATTER?

First, we provide some intuition for why a switch to consumption taxation may indeed alter the optimization problem faced by agents. Notice that in some very simple settings, tax systems that tax both labor income and capital income are actually equivalent to systems in which there is a pure consumption tax.

As a result, the move to a consumption tax from a regime of labor and capital income taxes is not inherently a meaningful change, as it may not change the household's underlying optimization problem. Following Nishiyama and Smetters (2005), it is instructive to consider a simple two-period model in which households enter with zero wealth ($a_1 = 0$), work only in the first period of life whereby they earn a deterministic wage, w_1, pay a flat tax on labor income, τ_l, and save an amount, a_2. In the second period, households are taxed on their capital income at a flat rate, τ_k, and live off gross-of-interest (and net-of-capital income tax) savings $a_2(1+r(1-\tau_k))$ in the second period. The per-period budget constraints are as follows. In the first period, we have

$$c_1 + a_2 = w_1(1 - \tau_l),$$

and in the second period we have

$$c_2 = (1 + r(1 - \tau_k))a_2.$$

In the absence of borrowing constraints, the relevant constraint on households is the single lifetime budget constraint:

$$\frac{c_1}{(1-\tau_l)} + \frac{c_2}{(1-\tau_l)(1+r(1-\tau_k))} = w_1.$$

Next, consider the same environment, but where labor and capital income taxes have been replaced by consumption taxes alone. In this case, the lifetime budget constraint is

$$c_1(1+\tau_{c_1}) + \frac{c_2(1+\tau_{c_2})}{(1+r)} = w_1. \tag{1}$$

Inspecting (1) reveals that a regime in which consumption taxes in period 1 are set at $\tau_{c_1} \equiv \frac{1}{1-\tau_l} - 1$ and $\tau_{c_2} \equiv \frac{1+r}{[1+r(1-\tau_k)](1-\tau_l)} - 1$ generates identical incentives and constraints for the household. In this case, a system of flat capital and labor income taxes is equivalent to a system of consumption taxes that vary with age. The age-dependency of the equivalent consumption tax regime is a direct result of nonzero capital income taxation: $\tau_{c_1} = \tau_{c_2}$ if $\tau_k = 0$. Thus, whenever $\tau_k \neq 0$, it is as if future consumption is being taxed at a rate different from current consumption. In particular, a positive capital income tax implies that $\tau_{c_1} < \tau_{c_2}$: Future consumption is more expensive than current consumption.[1]

[1] It is for this reason that Erosa and Gervais (2001) emphasize that wherever a consumption tax system would be optimally age-dependent, but is unavailable for exogenous reasons, positive *flat* capital income taxes can be used along with labor income taxes to acheive the same outcome.

More generally, in a longer (but still deterministic and finite-lived) model, flat capital and labor income taxes are equivalent to a regime in which there are (i) an age-dependent sequence of consumption taxes, $\{\tau_{c_j}\}_{j=1}^{J}$, and (ii) a lump-sum transfer, Υ_0, to all households to offset the difference in present values of labor income created by the presence of capital income taxes. That is, the equivalent consumption tax at any age j=1, 2,..., J, is given by

$$\tau_{c_j} = \frac{(1+r)^j}{(1+r(1-\tau_k))^j(1-\tau_l)} - 1,$$

where we see again that if $\tau_k = 0$, $\tau_{c_j} = \frac{1}{1-\tau_l}\ \forall\ j = 1, \ldots, J$. Letting $\widetilde{w}_j$ denote income/productivity while the lump-sum *transfer* to households under a consumption tax is given by

$$\Upsilon_0 = \sum_{j=0} \frac{\widetilde{w}_j}{(1+r(1-\tau_k))^j} - \sum_{j=0} \frac{\widetilde{w}_j}{(1+r)^j}.$$

Notice again that when $\tau_k = 0$, there is no age-dependence in the sequence of consumption taxes, nor is there any transfer (i.e., $\Upsilon_0 = 0$).

Given these cases, we now turn to the aspects of our preferred model that break the equivalence between consumption tax regimes and those regimes that tax labor and capital income. First of all, like both recent tax reform proposals and analyses, we will consider a move to a regime of a flat consumption tax, implemented here as a flat sales tax on all household purchases.[2] These are among the most practical forms of consumption taxes under consideration in policy discussions. Notably, the inherent difficulties in implementing age-dependent taxes perhaps account for the fact that they are not a feature of any major economy. The absence of age-dependence then immediately rules out any equivalence with income taxes. Second, the interest rate on savings in the model is strictly positive. As a result, regardless of the size of capital income, as long as it is positive, an age-dependent consumption tax will be required to obtain equivalence. Third, we do not augment household income with lump-sum transfers or taxes. Fourth, we do not allow households to hold negative asset positions. As a result, young households may find themselves unable to consume as much as they would like. To the extent that consumption tracks household income, consumption taxes will not look as regressive—even though the observed fall in regressivity is an artifact of a binding constraint! Given all these departures, it is likely that a switch to a flat consumption tax regime generates meaningful changes in the economic environment within which households operate.

[2] Alternative regimes to implement consumption taxes include making all savings fully tax-deductible, or imposing a value-added tax.

2. MODEL

The economy is closely related to that in Ventura (1999), in that it features a well-defined life-cycle path for labor productivity, stochastic shocks, taxes, and elastic labor supply. There is a large number of agents who consume and work for J periods and then retire. We will focus on stationary settings where there is a time-invariant measure of agents of each age j, and, moreover, that the age-distribution is uniform.

During working life, households' productivity has a deterministically evolving component, but is also subject to stochastic shocks. In each period, households must choose labor effort, consumption, and savings. After working life, households then enter "retirement," which lasts for K periods. Households in retirement are assumed to face no further labor market risk and, therefore, solve a simple deterministic consumption-savings problem. They face only the constraint that the optimal consumption path have a present value equal to the present value of resources brought into retirement, inclusive of transfers.

Preferences

Households value consumption and leisure. All households have identical time-separable constant relative risk aversion (CRRA) utility functions over an composite good defined by a Cobb-Douglas aggregate of consumption and leisure, c_j and l_j, respectively, at each age-j during working life, and a "retirement felicity function," ϕ, that is defined on wealth, x_R, taken into retirement.

Households discount future consumption of the composite good exponentially using a time-invariant discount factor, β, and weight total consumption expenditures, c_j, in each period by an adjustment for the age-specific average household size, ES_j (a mnemonic for "equivalence scale"). Effective consumption is then defined to be $\frac{c_j}{ES_j}$. The problem for the household is to choose a vector sequence, $\{c_j, l_j\}_{j=1}^{J}$, and retirement wealth, x_R, to maximize lifetime utility. The absence of labor income in retirement implies that the value to a household of entering retirement with a given level of wealth, x_R, is the solution to the following problem. Let the maximal leisure available to households be denoted by $\bar{l}$, and let $\Pi(x_R)$ be the feasible set of consumption sequences given that a household enters retirement with resources x_R:

$$\phi(x_R) = \max_{\{c_k\}\in\Pi(x_R)} \sum_{k=1}^{K} \beta^k \frac{\left[c_k^{\theta}\bar{l}\right]^{1-\alpha}}{(1-\alpha)}. \tag{2}$$

The overall objective of the household can now be expressed as the sum of the optimization problem applicable to working life and a "continuation" value given by resources brought into retirement. Let $\Pi(\Psi_0)$ denote the space of all feasible combinations $(\{c_j, l_j\}, x_R)$ given initial state Ψ_0. The household optimization problem is

$$\max_{(\{c_j,l_j\},x_R)\in\Pi(\Psi_0)} E_0 \sum_{j=1}^{J} \beta^j \frac{\left[\left(\frac{c_j}{ES_j}\right)^{\theta} l_j^{1-\theta}\right]^{1-\alpha}}{1-\alpha} + \phi(x_R). \tag{3}$$

Endowments

Households are endowed with one unit of time, which they can divide between labor and leisure. Household income is determined as the product of labor effort and labor productivity. Productivity in any given period is the outcome of a process that has both deterministic and stochastic components. We follow Storesletten, Telmer, and Yaron (2004) to represent the logarithm of productivity (wages per effective unit of labor), $\ln w_j$, of households as the sum of three components: an age-specific mean of log productivity, μ_j, persistent shocks, z_j, and transitory shocks, η_j. Therefore, we have

$$\ln w_j = \mu_j + z_j + u_j \tag{4}$$

with

$$z_j = \rho z_{j-1} + \eta_j, \ \ \rho \leq 1, \ \ j \geq 2 \tag{5}$$

$$u_j \sim i.i.d\ N(0, \sigma_u^2), \eta_j \sim i.i.d.\ N(0, \sigma_\eta^2), \ \ u_j, \eta_j \text{ independent.} \tag{6}$$

Households draw their first realization of the persistent shock from a distribution with a conditional mean of zero, i.e., z_0. The innovation to the persistent shock, η_1, is also mean-zero, but has variance, $\sigma_{\eta_1}^2$, that is drawn to help match the inequality of log labor income among those entering the labor force. The variance of persistent shocks drawn at all other ages differs from $\sigma_{\eta_1}^2$ and is denoted σ_η^2.

Market Arrangement

As is standard in models of exogenous uninsurable risks, households of age-j can save and dissave by choosing a position in only a single noncontingent bond, denoted x_{j+1}. The economy is a small open-economy setting, whereby savings earn an exogenous gross rate of return (net of taxes). The household can also vary its labor supply, both to respond to changes in labor productivity and to smooth consumption of the composite good. For example, if financial resources are low in the current period, a household with a given labor productivity may choose to supply more labor than they would if they had more financial wealth. This is because they would otherwise be forced into a current period allocation that had low consumption and high leisure, while their intertemporal smoothing motives dictate preventing a fall in consumption. According to the experiment under study, labor income, capital income from savings, and consumption may each be taxed at (time-invariant) flat rates denoted by τ_l, τ_k, and τ_c, respectively.[3] Notice that in this model, given the abstraction from multiple layers of production of the final consumption good, the consumption tax will also be identical to a value-added tax. Because we treat the economy as one that is open to world trade and, furthermore, one in which the households under study do not affect the total demand or supply of assets worldwide, the interest rate on risk-free savings is assumed to be unaffected across tax policies. Given elastic labor supply and the three taxes, the generalized household budget constraint in each period is

$$c_j(1+\tau_c) + x_{j+1} = \widetilde{w}_j(1-l_j)(1-\tau_l) + x_j(1+r(1-\tau_k)). \tag{7}$$

Optimal Household Decisions

Retirement

Age-J households value retirement savings via $\phi(x_R)$. The consumption flow arising from a given level of savings is specified as follows. Households aged $J+1$ are guaranteed to have a minimal standard of living given by a threshold, $\underline{\tau}^R$, representing Social Security and Medicare. Transfers during retirement are therefore *not* means-tested and are given instead by a single lump-sum transfer, $x_{\underline{\tau}}$, to all retiring households. Our approach follows Huggett (1996). A household's wealth level at retirement is then the sum of the household's personal savings, x_{J+1}, and the baseline retirement benefit, $x_{\underline{\tau}^R}$,

$$x_R = x_{J+1}\widetilde{R} + x_{\underline{\tau}^R}. \tag{8}$$

The amount $x_{\underline{\tau}^R}$ is the wealth level that, when annuitized at the gross after-tax interest rate $\widetilde{R} \equiv (1+r(1-\tau_k))$, yields a flow of income each period equal to the societal minimum retirement consumption floor, $\underline{\tau}^R$. That is, minimal retirement wealth, $x_{\underline{\tau}}$, solves

[3] An interesting extension for future work would be to allow for more general, possibly progressive, tax schemes.

$$\sum_{k=1}^{K} \frac{\underline{\tau}^R}{(\widetilde{R})^k} = x_{\underline{\tau}^R}. \quad (9)$$

To solve for indirect utility at retirement, define the budget constraint for a retiree in period-k of retirement as follows:

$$(1+\tau_c)c_k + x_{k+1} = x_k(1 + r(1-\tau_k)) + \underline{\tau}^R. \quad (10)$$

Given the objective function during retirement (equation 2), the optimal intertemporal allocation of consumption must satisfy the following Euler equation:

$$\frac{c_{t+1}}{c_t} = \left(\frac{1}{\beta\widetilde{R}}\right)^{\frac{1}{\theta(1-\alpha)-1}}. \quad (11)$$

Defining $\gamma = (\frac{1}{\beta\widetilde{R}})^{\frac{1}{\theta(1-\alpha)-1}}$, we then see that (11) implies that consumption at any date-k of retirement can be defined as:

$$c_k = \gamma^k c_0. \quad (12)$$

Given the preceding requirement on optimal consumption growth, we use the budget constraint to pin down the level of the sequence of retirement consumptions. First, we iterate on the per-period budget constraint (equation 10) to obtain a single present value budget:

$$\sum_{k=0}^{K} \frac{c_k(1+\tau_c)}{\widetilde{R}^k} = x_R,$$

where x_R is defined in (8).

As a result, we obtain

$$c_0 = \frac{x_R}{\sum_{k=0}^{K} \gamma^k \frac{(1+\tau_c)}{\widetilde{R}^k}}.$$

The remaining sequence is given by (12), which we denote as $\{c^*_{R_k}\}_{k=0}^{K}$, which then yields the indirect utility of retirement:

$$\phi^*(x_R) = \sum_{k=0}^{K} \beta^k \frac{\left[c^*_{R_k}\bar{l}\right]^{1-\alpha}}{(1-\alpha)}. \quad (13)$$

Working life

The solution of the household's problem during working life is simplified by our use of Cobb-Douglas preferences. It is instructive to display the manner in which the various taxes alter the optimal allocation of consumption over time and the optimal mix of consumption and leisure. First, within any given period, it is useful to think of a household as first working full time and then "buying back" consumption and leisure. Therefore, if a household works full time (normalized to unity), has entered a period with savings x_j, and plans to save x_{j+1}, its resources available to purchasing consumption and leisure are pinned down. That is, consumption and leisure purchases must satisfy

$$c_j(1+\tau_c) + \widetilde{w}_j l_j(1-\tau_l) = \widetilde{w}_j(1-\tau_l) + x_j(1+r(1-\tau_k)) - x_{j+1}. \quad (14)$$

Letting $\Lambda_j \equiv \widetilde{w}_j(1-\tau_l) + x_j(1+r(1-\tau_k)) - x_{j+1}$ denote the total "resources" available for consumption and leisure, we have from the intratemporal first-order conditions of the household's problem that the optimal mix of expenditures on leisure and consumption satisfies

$$\frac{l_j}{c_j} = \frac{(1-\theta)}{\theta}\frac{(1+\tau_c)}{(1-\tau_l)\widetilde{w}_j}. \quad (15)$$

Notice that for any given realization of current productivity, $\widetilde{w}_j$, and elasticity of substitution, θ, the optimal mix of leisure and consumption depends only on the ratio $\frac{(1+\tau_c)}{(1-\tau_l)}$. That is, the levels of either tax alone do not determine how households divide their resources between leisure or consumption. The preceding expression, when substituted into the household budget constraint, gives the optimal levels of consumption and leisure, respectively, as a function of resources Λ_j:

$$c_j = \frac{\Lambda_j\theta}{1+\tau_c}, \text{ and} \quad (16)$$

$$l_j = \frac{\Lambda_j(1-\theta)}{(1-\tau_l)\widetilde{w}_j}. \quad (17)$$

Given these rules for optimal consumption and leisure for any given resources, the only remaining decision for the household is to choose what resources to keep in the current period; this is simply done by choosing the savings level x_{j+1} optimally. Let $U(.)$ denote the within-period utility function. During working life, the intertemporal first-order condition is given by

$$U'_{c_j}(c_j, l_j) = \beta(1+r(1-\tau_k))U'_{c_{j+1}}(c_{j+1}, l_{j+1}). \quad (18)$$

Notice here that consumption and labor income taxes do not appear, while the capital income tax does. This is the crux of the distortion to private savings decisions induced by capital income taxes. Moreover, as shown above, an equivalent system of consumption exists that implies systematically increasing tax rates on consumption in the increasingly distant future. This implies that capital income taxes lower the return to saving and thereby encourage current consumption; when consumption and leisure are complements, there is resultant reduction in work effort.

Recursive Formulation

The household's problem can be represented recursively as follows. At the beginning of each period, the household's options are completely determined by its age-j, its wealth, x_j, its current realized value of the persistent shock, z_j, and the current realization of the transitory shock, η_j. These items are sufficient to determine the budget constraint faced by households in the current period, and also to obtain the best forecast of next period's realization of the persistent shock.[4]

Optimal household behavior requires that in each period, given their state vector, the household chooses consumption, c_j, and savings, x_{j+1}, to satisfy the following recursion:

$$V(j, x_j, z_j, \eta_j) = \max_{c_j, x_{j+1}} U(c_j) + \beta E_{(z_{j+1},\eta_{j+1}|z_j)} V(j+1, x_{j+1}, z_{j+1}, \eta_{j+1}), \tag{19}$$

subject to the budget constraint described in equation (7), and where $\beta E_{(z_{j+1},\eta_{j+1}|z_j)}$ denotes the expectation of the value of carrying savings, x_{j+1}, into the following period when the shocks tomorrow (z_{j+1}, η_{j+1}) are drawn from the conditional joint distribution that reflects the current realization of the persistent shock, z_j. We focus on a stationary equilibrium: Households optimize given prices, and the distribution of the households over values of the state is stationary (time-invariant).

3. PARAMETERIZATION

The model period is one calendar year. Households work for $J = 44$ periods, where $j = 1$ represents real-life age 21, and $j = 44$ is retirement at age 65. Retirement lasts for $K = 25$ periods, so all agents die at real-life age 90. Risk aversion and discounting are set at $\alpha = 3$ and $\beta = 0.96$, respectively. The (gross) risk-free interest rate on savings is $R^f = 1.01$. Households are born

[4] Given that the tax rates are assumed to remain constant throughout time, they do not need to be included in the "state vector."

Table 1 Parameter Values

Variable	Value
β (Discount Factor)	0.96
J (Working Life)	44
K (Retirement Length)	25
R^f (Risk-Free Rate)	1.01
x_1 (Beginning of Life Assets)	0
$\bar{l}$ (Maximum Leisure)	1
θ (Elasticity of Labor Supply)	0.5

with zero financial wealth: $x_1 = 0$. Maximum leisure time, $\bar{l}$, is normalized to unity and the elasticity of labor supply, θ, is set to 0.5 to reflect that, on average, half of a household's discretionary hours (16 hours per day) are spent working. Our benchmark model features taxes on consumption, labor income, and capital income, and we follow Fuster, Imrohoroglu, and Imrohoroglu (2008) to assign the following values for these taxes: $\tau_c = 0.055$, $\tau_k = 0.35$, and $\tau_l = 0.173$. Under a switch to a pure consumption tax, we ensure revenue-neutrality relative to our benchmark economy.

A brief summary of the stochastic process for productivity is the following. We set $\rho = 0.99$, $\sigma_u^2 = 0.063$, $\sigma_{\eta_1}^2 = 0.22$, and $\sigma_\eta^2 = 0.0275$, as these values generate reasonable income variability (given optimal labor supply) among the youngest working-age households in the data, as well as the nearly linear life-cycle growth of cross-sectional variance in log income documented in Storesletten, Telmer, and Yaron (2004) and the total increase in cross-sectional (log) income variance over the life cycle. The parameters governing the income process also generate reasonable wealth-to-income ratios over the life cycle (see, e.g., Athreya [2008]).

The mean of log productivity is given by the profile $\{\mu_j\}_{j=1}^{J}$ and is based on the estimates of Hansen (1993). We approximate the continuous state-space stochastic process for income via a discrete state-space Markov chain using the method of Tauchen (1986). Specifically, we use a 32-point discretization of the persistent shock and a three-point discretization for the transitory shock. We employ standard discrete-state space dynamic programming and Monte Carlo simulation to solve for decisions and generate aggregate outcomes, respectively.[5] The values of all policy-invariant parameters are reported in Table 1.

[5] All code is available from the authors on request.

4. CONSUMPTION TAX REFORM

We first report the model's implications for the aggregate consequences of a move to pure consumption taxation for several specifications of income persistence and risk aversion. Specifically, we set $\tau_l = \tau_k = 0$ and set τ_c such that the change is revenue-neutral. We provide measurements of consumption, labor supply, and wealth distributions across tax regimes in each case. We then turn to the issue of the measurement of the progressivity of consumption taxes.

Consumption, Asset Accumulation, and Leisure

The means and coefficients of variation for the variables mentioned above appear in Table 2, while Table 3 contains the Gini Coefficients for annual income, lifetime income, annual consumption, lifetime consumption, and wealth. The model does fairly well under relatively high productivity shock persistence in reproducing estimates of observed labor income and wealth inequality. Rodríguez et al. (2002), using the 1998 Survey of Consumer Finances, report a wealth Gini of 0.8 and an annual income Gini of 0.55, very close to the model's predictions under our benchmark model, which features high persistence. The model also preserves the observed ordering of inequality seen in the data (e.g., Rodríguez et al. 2002), where wealth is more unequal than income, which in turn is more unequal than consumption. Therefore, the limited insurance that households provide through saving and dissaving is partially effective but nonetheless results in large wealth inequality.

Our first result is that the largest effects of a move to a consumption tax occur in savings. This is due to the removal of the intertemporal distortion created by the taxation of capital income, as well as the need for additional savings in retirement to offset the heavier tax burden faced by retirees who no longer escape taxation. The magnitude of the increase in average savings is similar to other recent work (see, e.g., Fuster, Imrohoroglu, and Imrohoroglu [2008], Table 3). In the cases with lower persistence, when assets are more useful for self-insurance, the increase in savings when switching to a pure consumption tax is even larger. That is, a move to a consumption tax regime under low income shock persistence induces a larger response in aggregate savings than with higher persistence. This makes clear that the size of the distortion created by a capital income tax depends on the shock process faced by households.[6] Of course, the increased savings means increased resources

[6] Changes in the persistence of the shock alter the unconditional variance of the shock. However, given that productivity is a log-normal random variable, changes in the varriance affect the mean of the level of productivity. When we lower the persistence of shocks, we therefore increase the variance of the transitory component such that the mean level of income always remains constant. Part of the effect on savings seen is due to the higher variance of transitory shocks under lower persistence.

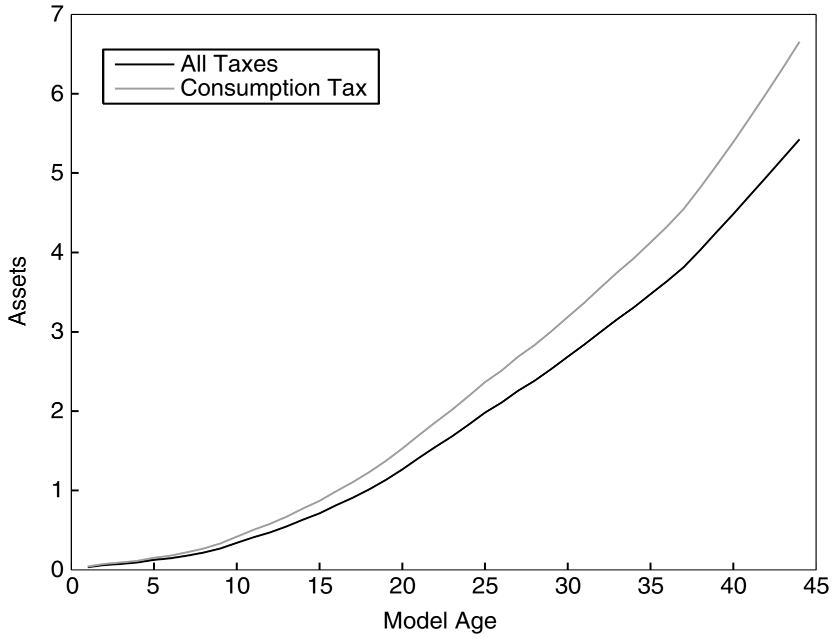
Table 2 Aggregate Results

	ρ	α	τ_l	τ_k	τ_c	E(l)	CV, l	E(x)	CV, x	E(c)	CV, c	E$\left(\frac{c}{ES}\right)$	CV, $\frac{c}{ES}$.	E (Lab. Inc)	CV Lab. Inc
Case 1	0.99	3	0.173	0.35	0.055	.503	0.188	1.958	2.114	0.606	1.088	0.530	1.062	0.908	1.396
Case 2	0.99	3	—	—	0.338	.503	0.188	2.351	2.012	0.580	1.108	0.507	1.082	0.905	1.379
Case 3	0.99	2	0.173	0.35	0.055	.503	0.194	1.650	2.344	0.605	1.082	0.530	1.057	0.910	1.410
Case 4	0.99	2	—	—	0.338	.502	0.195	1.948	2.238	0.579	1.102	0.506	1.077	0.907	1.394
Case 5	0.8	3	0.173	0.35	0.055	.528	0.265	1.984	1.449	0.579	0.890	0.507	0.864	0.885	1.395
Case 6	0.8	3	—	—	0.35	.527	0.268	2.616	1.363	0.547	0.904	0.479	0.878	0.885	1.383
Case 7	0.8	2	0.173	0.35	0.055	.525	0.265	1.659	1.653	0.578	0.899	0.506	0.874	0.885	1.400
Case 8	0.8	2	—	—	0.35	.524	0.269	2.219	1.543	0.545	0.912	0.477	0.887	0.887	1.388
Case 9	0.5	3	0.173	0.35	0.055	.538	0.282	1.994	1.254	0.578	0.864	0.506	0.834	0.889	1.448
Case 10	0.5	3	—	—	0.35	.538	0.284	2.635	1.191	0.545	0.876	0.478	0.846	0.890	1.437
Case 11	0.5	2	0.173	0.35	0.055	.535	0.283	1.670	1.448	0.577	0.875	0.505	0.846	0.890	1.453
Case 12	0.5	2	—	—	0.35	.535	0.286	2.238	1.366	0.544	0.886	0.476	0.856	0.892	1.442

Table 3 Gini Coefficients

	Annual Lab Inc.	Annual Cons.	Wealth	Lifetime Lab Inc.	Lifetime Cons.
$\rho = 0.99,\ \alpha = 3,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	0.5342	0.4462	0.7574	0.4129	0.38
$\rho = 0.99,\ \alpha = 3,\ \tau_c = .338,\ \tau_l = 0,\ \tau_k = 0$	0.5319	0.4494	0.7483	0.4101	0.3834
$\rho = 0.99,\ \alpha = 2,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	0.5356	0.4464	0.7895	0.4129	0.3802
$\rho = 0.99,\ \alpha = 2,\ \tau_c = .338,\ \tau_l = 0,\ \tau_k = 0$	0.5332	0.4499	0.7806	0.41	0.3836
$\rho = 0.8,\ \alpha = 3,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	0.5487	0.3992	0.6599	0.219	0.1975
$\rho = 0.8,\ \alpha = 3,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	0.5483	0.3999	0.6438	0.217	0.1997
$\rho = 0.8,\ \alpha = 2,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	0.5477	0.4032	0.7073	0.2188	0.1982
$\rho = 0.8,\ \alpha = 2,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	0.5476	0.4032	0.6904	0.2169	0.2004
$\rho = 0.5,\ \alpha = 3,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	0.5591	0.3851	0.6145	0.1454	0.1271
$\rho = 0.5,\ \alpha = 3,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	0.5589	0.3854	0.6004	0.144	0.1287
$\rho = 0.5,\ \alpha = 2,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	0.5585	0.389	0.6683	0.1455	0.1276
$\rho = 0.5,\ \alpha = 2,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	0.5585	0.3886	0.6528	0.1441	0.1292

Figure 1 Average Asset Position, by Age



taken into retirement. However, under a pure consumption tax regime, the ability of households to use these resources to finance consumption will be altered. Figure 1 shows that the removal of the intertemporal distortion in savings ultimately aids substantially the ability of households to transfer resources into retirement.

In contrast to outcomes under pure consumption taxes, the persistence of shocks to productivity does not play an important role in aggregate savings when income is taxed. The intuition here is that, with capital income taxes in particular, arranging for consumption in the distant future (e.g., at retirement) is more expensive than without a capital income tax. As a result, even though lower persistence makes self-insurance more effective, the distortion created by capital income taxation makes future consumption expensive enough to make the net increase in aggregate savings small.

With respect to wealth inequality, the coefficients of variation and Gini Coefficients for wealth show that a move to a consumption tax *lowers* wealth inequality and variability, irrespective of persistence and risk aversion. This is an important observation for those concerned with the long-run equity implications of consumption taxation. We also see that, for a given tax regime, low persistence leads to low wealth inequality. This occurs as lower persistence makes lengthy runs of good or bad luck less likely. Conversely, lower risk aversion, by making households more willing to allow for variation in their consumption, creates a wealth distribution with a lower mean and higher coefficient of variation for any given tax regime.

Turning next to effective consumption, we see that a move to a consumption tax has a significant effect. In all economies under study, our model predicts that a move to a pure consumption tax leads to about a 6 percent drop in average effective consumption, while leaving the coefficient of variation largely unchanged. Persistence matters for mean effective consumption only at the highest value, $\rho = 0.99$. However, a move from the benchmark tax regime to pure consumption taxation does not substantially affect the variability of consumption, as seen from the coefficient of variations (cv) shown in Table 2.

As a symptom of the effectiveness of self-insurance under transitory income risk, we see that consumption inequality falls substantially when the persistence drops below 0.99. This result does not depend on tax regime or risk aversion. Looking at Table 3, we see that the Gini Coefficients for consumption show a similar pattern of inequality as the coefficients of variation. When measured at an annual frequency, the consumption Gini decreases as persistence falls, indicating that inequality is higher in states with more persistent shocks regardless of tax regime or risk aversion. This result is accentuated when consumption is reported as a lifetime measure.

Unlike its effects on wealth accumulation and effective consumption, a move to consumption taxes has little impact on labor supply. Moreover, this is robust as it occurs for all levels of risk aversion and shock persistence that we consider. This is important, as the elimination of labor income taxation might have been thought to induce greater labor supply. However, recall equation (15), which shows that the optimal mix of consumption and labor depends on the ratio $\frac{1+\tau_c}{1-\tau_l}$. A move to a pure consumption tax increases both the numerator and the denominator, potentially undoing much of the change created by a jump in the consumption tax. This happens in the model on average. We see in Table 2 that, although consumption falls, leisure remains more or less constant. We also see that, regardless of tax regime and risk aversion, the mean and coefficient of variation of leisure rise with lower persistence. With higher persistence, each shock changes potential future earnings by more than if shocks were transitory. This means that the only way to keep consumption smooth over the life cycle is to work hard in both bad times and good times, which makes leisure less volatile. The result that labor supply does not move much with a consumption tax reform is somewhat telling. Recent work has made clear that household labor supply can be an important smoothing device (e.g., Pijoan-Mas [2006] and Blundell, Pistaferri, and Preston [2008]). Yet, in our experiments, labor hours and earnings respond very little in response to the elimination of income taxes in favor of consumption taxes. The behavior of labor supply, therefore, provides an additional source of evidence that consumption taxes do not expose households to increased risk.

Given the relative invariance of labor supply across economies, the induced stochastic process for labor income is also similar across economies. For example, we see only a slight increase in inequality as persistence decreases, which is reflected in the annual labor income Gini Coefficient, as well as small changes in response to risk aversion. With respect to persistence, our finding stems from the increased volatility in labor supply in low persistence states, which leads to more volatile income for agents. However, labor income inequality depends heavily on whether it is measured annually or over the lifetime. Given any combination of risk aversion and persistence, we see that annual income inequality is substantially higher than lifetime income inequality, as realized lifetime productivity will be much less volatile than its annual counterpart. Moreover, as the persistence of income grows, the level of annual income inequality decreases slightly, while lifetime income inequality increases dramatically. This is because the variance of realized productivity over the lifetime will be much larger when shocks are persistent.

Measured Progressivity and its Relation to Consumption Smoothing

Having laid out the aggregate implications of a move to a consumption tax, we now turn to the central questions of our article regarding the measurement of the incidence of consumption taxes and the relationship of these statistics to direct measures of consumption smoothing. To measure the progressivity of a given tax regime for a given economy, we use the Suits Index (Suits 1977). Let S_x represent the Suits index for a given tax regime and state, and $T_x(y)$ represent the cumulative tax burden for a given level of accumulated household income, y, then:

$$S_x = 1 - \int T_x(y)dy.$$

A Suits index can therefore range between -1 and 1. A positive index implies a progressive tax, while a negative index implies regressivity in the tax regime. An index of 0 is proportional. Table 4 reports the value of the Suits index across experiments and for three reference variables: realized annual income, realized lifetime income, and wealth. Our preferred "direct" measures of consumption smoothing are the coefficient of variation of consumption and the Gini Coefficient for consumption.

The basic input to the Suits index is a function mapping the relative contribution of households ranked by a given reference variable to tax revenues. However, instead of plotting tax contributions by accumulated percentages of households, as is the case with the Gini index, which is based on a Lorenz

Table 4 Suits Indexes

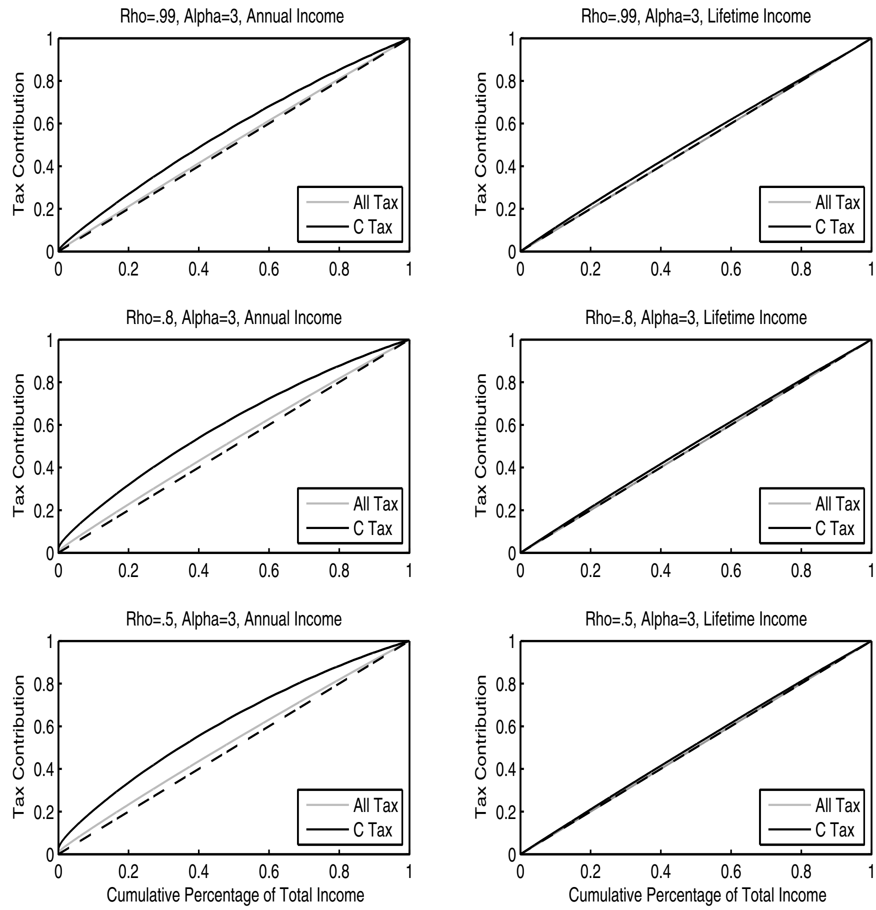
	By Annual Income	By Lifetime Income	By Wealth
$\rho = 0.99,\ \alpha = 3,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	−0.02	0.00	−0.41
$\rho = 0.99,\ \alpha = 3,\ \tau_c = .338,\ \tau_l = 0,\ \tau_k = 0$	−0.12	−0.03	−0.42
$\rho = 0.99,\ \alpha = 2,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	−0.02	0.00	−0.47
$\rho = 0.99,\ \alpha = 2,\ \tau_c = .338,\ \tau_l = 0,\ \tau_k = 0$	−0.12	−0.03	−0.49
$\rho = 0.8,\ \alpha = 3,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	−0.04	0.00	−0.44
$\rho = 0.8,\ \alpha = 3,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	−0.19	−0.02	−0.44
$\rho = 0.8,\ \alpha = 2,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	−0.04	0.00	−0.50
$\rho = 0.8,\ \alpha = 2,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	−0.19	−0.02	−0.51
$\rho = 0.5,\ \alpha = 3,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	−0.05	0.00	−0.46
$\rho = 0.5,\ \alpha = 3,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	−0.22	−0.02	−0.46
$\rho = 0.5,\ \alpha = 2,\ \tau_c = .055,\ \tau_l = .173,\ \tau_k = .35$	−0.05	0.00	−0.53
$\rho = 0.5,\ \alpha = 2,\ \tau_c = .35,\ \tau_l = 0,\ \tau_k = 0$	−0.22	−0.02	−0.53

curve, the Suits index relies on a curve constructed by plotting the cumulative percentage of the reference variable against the cumulative percent of total tax burden on the vertical axis. A given point on the x-axis of the more familiar Lorenz curve refers to a household whose realization of the reference variable (e.g., income) lies above a given fraction of households. By contrast, a given point on the x-axis of the Suits index function gives the accumulated percentage of the reference variable. For example, a value on the x-axis of 0.3 for a Lorenz curve of tax contributions by income refers to a household whose income is above 30 percent of *households*. A value on the x-axis of 0.3 under the Suits index refers to the entire set of households whose *collective contribution to total income is 30 percent*. In particular, unless the reference variable is distributed uniformly, these two measures will not coincide.

Our main finding is that the measured frequency of income is important for the assessment of the progressivity of consumption taxes, both in absolute terms and relative to that obtaining under income taxes. By contrast, measured income frequency matters very little in the assessment of progressivity under income taxes. This result is robust as it survives across varying levels of income shock persistence as well as risk aversion. Each row in Figure 2 displays the Suits function under annual and lifetime measures of income for a given level of income shock persistence. Risk aversion is held fixed at $\alpha = 3$. Since productivity is risky, income is a random variable. Therefore, we measure income ex-post. In the case of lifetime income, we compute, using our simulated income histories, realized lifetime labor incomes for a large sample of households. As seen in Figure 2, the Suits function for annual incidence lies significantly above the 45° line for the consumption tax regime. However, the Suits function for lifetime incidence is essentially proportional. This finding echoes the earlier finding of Metcalf (1997) and suggests that the presence of uninsurable productivity risk does not alter the implications for regressivity of a consumption tax. The measurement of income also affects the *relative* regressivity of consumption taxes versus income taxes. Figure 2 shows that, under annual measures of income, the consumption tax appears much more regressive when compared to a regime with income taxes.

As mentioned at the outset, the more transitory is productivity risk, the more labor earnings are likely to respond to a change in productivity. This is because the ability of a household to generate earnings over its remaining lifetime is relatively less affected when shocks to its productivity are transitory. As a result, the household smooths both consumption and its complement, leisure, quite effectively. In turn, households often consume amounts that are large in relation to their earned income when young and small relative to their earned income when old. As seen in Figure 2, the lower is persistence, the more annual incidence suggests that consumption taxes are regressive. Table 4 presents the numerical values of the Suits indexes.

Figure 2 Suits Functions by Labor Income



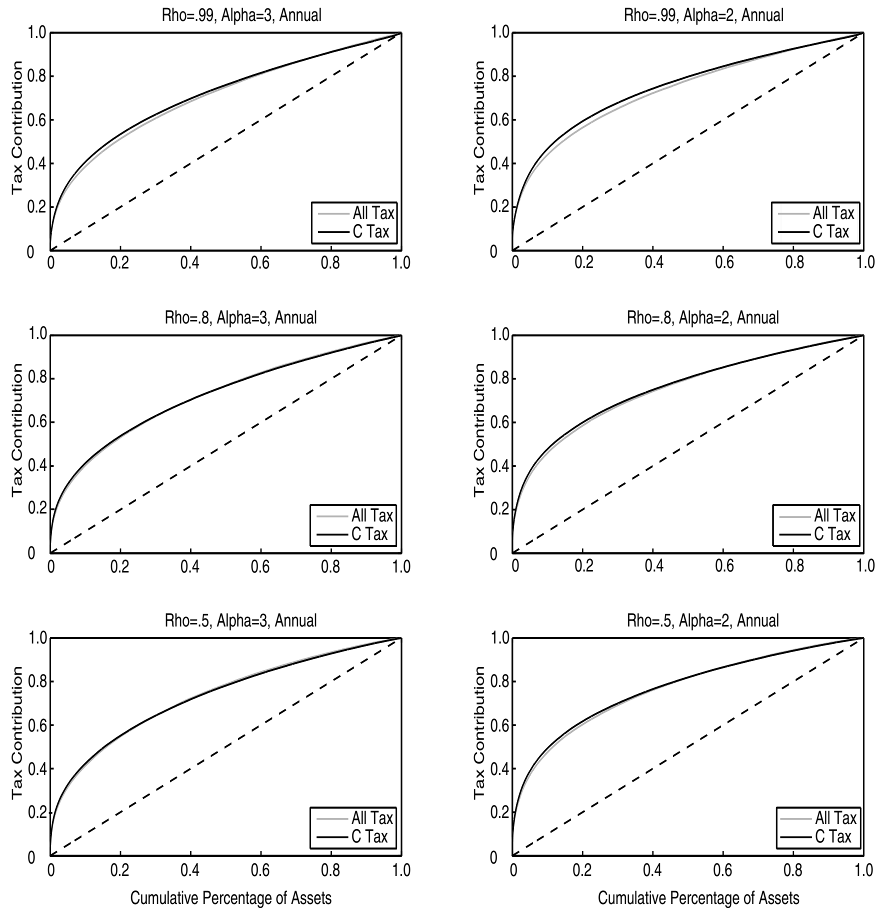
When measured by annual income, a move to a consumption tax from the benchmark tax system leads to more regressivity, and the measure of regressivity increases as income persistence falls. This is because transitory shocks are effectively smoothed via both asset accumulation or decumulation and changes in labor supply. However, as the persistence of productivity shocks rises, such smoothing becomes more difficult. Table 2 shows that the variability of both consumption and effective consumption rise systematically with persistence. Similarly, Table 3 shows that when computed either using lifetime or annual consumption, the Gini Coefficient remains remarkably stable across tax regimes. As with the coefficient of variation, the consumption Gini falls substantially as persistence falls. The preceding makes clear that measures of regressivity that are based on annual income may be misleading for household well-being because they *rise*, while two independent and direct measures of consumption smoothing indicate an improvement in insurance. In sharp contrast, lifetime incidence measures show little variation with shock persistence. It is also important to note that we disallow borrowing in the model; more ability to issue debt would further exaggerate the measured regressivity of consumption taxes. Lastly, while not shown here for brevity, the results in Figure 2 are nearly replicated when risk aversion is lowered below $\alpha = 3$. While we have focused on consumption, notice that in Table 1 the mean and coefficient of variation in labor effort are very similar across tax regimes for all the values of income persistence and risk aversion we consider. Therefore, consumption taxes are unlikely to damage household well-being along this dimension.

Taxes that fall disproportionately on households with low wealth may also be seen as regressive. Therefore, we turn now to measures of regressivity based on rankings of households by wealth. Wealth is a "stock" variable and so there is no "frequency" dimension to its measurement, but the issue of progressivity remains: Do the relatively wealthy pay disproportionately more than those who have fewer assets? As seen in Figure 3, the answer is no under either tax regime. In fact, the Suits index for tax progressivity shown in Table 4 indicates that when measured by wealth, both income and consumption taxes are quite regressive. The measured regressivity of taxes when the Suits function is constructed using wealth does respond to changes in risk aversion. As seen in both Figure 3 and Table 4, higher risk aversion implies lower measured regressivity. This is an implication of the increased precautionary savings motive under higher risk aversion, which leads low-wealth households to increase their savings disproportionately more than their high-wealth counterparts. Therefore, any given quantile of wealth represents a larger number of households under low risk aversion than under high risk aversion. As seen earlier in Table 2, neither mean consumption nor mean income changes substantially with risk aversion. Therefore, the contribution to total tax revenues of the lower wealth quantiles will be greater under low risk aversion. In addition to the preceding, comparing the columns within each row of Figure 3 shows that risk aversion has essentially no effect on the relative progressivity of income and consumption tax regimes. In terms of the overall regressivity of consumption taxes relative to current tax policy, the preceding results make clear that consumption is not inherently more regressive, especially when a lifetime perspective is taken.

5. CONCLUDING REMARKS

The smoother is consumption for a household, the more its tax burden remains invariant to its income. Ironically, this implies that when insurance and credit

Figure 3 Suits Functions by Assets



markets are most successful in delivering intertemporally and intratemporally smooth consumption, tax incidence using high frequency income measures (such as annual income) will, all else equal, imply the greatest regressivity. In this article, we have constructed and simulated a rich model of consumption, savings, and work effort over the life cycle. We have argued that while annual incidence suggests that consumption taxes are regressive, lifetime incidence suggests proportionality. Moreover, for a given level of income shock persistence, consumption taxes do not matter substantially for the variability of consumption. Lastly, we show that lifetime incidence is similar across tax regimes, labor productivity persistence, and risk aversion levels.

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