Consumer Behavior in the United States:

Implications for Social Security Reform

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Abstract

This paper shows theoretically and empirically that an aggregate Euler equation relates the growth rate of per capita consumption to the real interest rate, the ratio of private wealth plus asset income to consumption, and the ratio of social security wealth to consumption. Using the estimated Euler equation, the paper then calculates the steady-state effects of social security reform. Reforms that reduce the ratio of social security wealth to consumption are found to shift the balanced growth paths for the capital stock, output, and consumption upward appreciably.

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I. Introduction

The reform of the US social security system is now attracting much attention. A wide range of proposals for reform have been put forward, ranging from modest modifications to complete privatization.[1] In choosing among these reforms, it is important to quantify how they would affect the aggregate economy. A given reform is presumably more likely to command support, the more favorable its aggregate effects are on net.

In recent years, economists have typically quantified the effects of social security reform in large computational general-equilibrium models based on the lifecycle hypothesis; e.g., Kotlikoff, Smetters, and Walliser (1998). Although the calibration of these models does make use of data, the models are not designed to fit the aggregate data in any very well-defined sense. Rather, the life-cycle structure of the model is simply imposed, and the parameters are chosen in order to match a few select moments of the aggregate data. The lifecycle hypothesis is not the only possible model of consumer behavior, however. Indeed, like all models, it abstracts from many empirically important phenomena.[2] Moreover, computational general-equilibrium models have not typically been validated on data other than those used for calibrating them.[3] One might therefore reasonably doubt the empirical validity of the effects calculated in such models.

An older literature attempted to estimate the effects of social security directly. The seminal study in this literature is Feldstein (1974), who reports that *ceteris paribus*, social security increases consumption and lowers saving substantially. As a result, the balanced growth paths for capital, output, and consumption are lowered substantially. Many other studies followed.[4] They reported mixed results, with perhaps a presumption that social security raises consumption *ceteris paribus*.

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[1] Some examples are Aaron and Bosworth (1997), Advisory Committee on Social Security (1997), Altig and Gokhale (1997), Diamond (1996), Feldstein (1996a), Feldstein and Samwick (1997), Gramlich (1998), Kotlikoff and Sachs (1997), and Mariger (1997).

[2] For example, Attanasio and Weber (1995b) find strong microevidence that changes in family structure across the lifecycle affect the height and slope of the age-consumption profile, Kotlikoff (1988) establishes that bequests and *intervivos* gifts contribute greatly to aggregate wealth, and Zeldes (1989) provides microevidence that some households are borrowing-constrained.

[3] In this regard, the practice in economics lags considerably behind that in engineering, where model calibration is also a widespread practice. Engineers, however, simulate the results of experiments that they subsequently perform. They do not regard a model as validated unless it can accurately predict the data generated in many such experiments.

[4] For example, see Barro (1978); Barro and MacDonald (1979); Burkhauser and Turner (1982); Darby (1978); Evans (1983); Feldstein (1980, 1982, 1996b); Feldstein and Pellechio (1979); Koskela and Viren (1983); Kopits and Gotur (1980); Kotlikoff (1979); Leimer and Lesnoy (1982); Meguire (1996); Modigliani and Sterling (1979); Munnell (1974); and von Furstenburg (1979). Page (1998) exhaustively and critically reviews this literature.

For the most part, this literature investigated the issue by fitting "consumption functions" of the form

$$c_t = \beta_0 + \beta_1 y_t + \beta_2 a_t + \beta_3 s_t + \beta_4' x_t + e_t; \tag{1}$$

where c_t and y_t are per capita consumption and disposable income during period t; a_t and s_t are per capita private wealth and social security wealth at the beginning of period t; x_t is a vector of other variables realized during period t; β_1, β_2 and β_3 are parameters; β_4 is a vector of parameters; and e_t is an error term.[5] If β_3 turns out to be positive and statistically significant, social security is inferred to raise consumption and lower saving *ceteris paribus* and to lower the balanced growth paths for private wealth, output, and consumption. Unfortunately, equation (1) is at best an approximate reduced form of the life-cycle model and at worst bears no relationship to any well-known structural model; see Auerbach and Kotlikoff (1983). If it can be interpreted as a good approximation to a reduced form, its parameters confound structural and expectational parameters. For example, even if Ricardian equivalence holds so that social security is completely neutral, β_3 can be positive if social security wealth is positively correlated with future disposable wage incomes, conditional on the other regressors. Conversely, even if β_3 is estimated to be insignificantly different from zero, social security may still increase consumption appreciably since social security wealth may be negatively correlated with future disposable wage incomes, conditional on the other regressors. In principle, these problems could be overcome by estimating a variant of equation (1) jointly with auxiliary forecasting equations for the components of future disposable wage income while imposing the cross-equation restrictions implied by rational expectations. In practice, this task is too formidable to attempt.

Another problem with equation (1) is that the variables included in it are likely to be difference stationary. If the error term e_t is also difference stationary, least squares is inconsistent. If instead it is mean stationary, the parameters are estimated superconsistently. Nevertheless, unless e_t is also uncorrelated with Δy_t, Δa_t, Δs_t, and Δx_t contemporaneously and at all leads and lags, the standard errors are inconsistent and standard procedures produce invalid inferences.[6] Moreover, correlation is required by the intertemporal budget constraint.

[5] Some of the studies put per capita saving or per capita private assets in the left-hand member in lieu of per capita consumption. Clearly, such regressions can be rewritten in the form (1). Others do not deflate by population, a dubious but probably inconsequential practice.

[6] For proof of the previous three assertions and further discussion, see Hamilton (1994), pp. 557-561, 586-589, 602-608.

In this paper, I also attempt to estimate the effects of social security directly. My starting point is the aggregate Euler equation

$$\Delta \ln c_t = \psi_0 + \psi_1 \ln(1+r_t) + u_t, \tag{2}$$

where r_t is the one-period real interest rate in period t, ψ_1 is the elasticity of intertemporal substitution, and u_t is an error term with a zero mean and finite variance. Under Ricardian equivalence and some separability, aggregation and distributional assumptions, u_t is orthogonal to all lagged information. Consequently, if Ricardian equivalence holds and the augmented model

$$\Delta \ln c_t = \psi_0 + \psi_1 \ln(1+r_t) + \psi_2 \left(\frac{a_t + \pi_t}{c_t} \right) + \psi_3 \left(\frac{s_t}{c_t} \right) + u_t \tag{3}$$

is estimated using lagged instrumental variables, the estimates of ψ_2 and ψ_3 should have zero probability limits. In equation (3), π_t is after-tax asset income in period t and u_t is an error term that has a zero mean and finite variance and is posited to be orthogonal to all lagged information. If instead either ψ_2 or ψ_3 is estimated to be significantly negative, fairly convincing evidence would then exist against either Ricardian equivalence or the other maintained assumptions.[7]

There is a straightforward intuition for why ψ_2 and ψ_3 should be negative. Suppose that Ricardian equivalence does not hold and, in particular, existing households do not fully offset additional government intergenerational transfers in their favor. Suppose further that households experience an unanticipated increase in wealth, which could take the form of a budget deficit, a windfall receipt of asset income, or an increase in the generosity of the social security system. Such an event would induce an instantaneous jump in per capita consumption, followed by decreased growth in per capita consumption over some period of time in order to satisfy the aggregate intertemporal budget constraint. The initially higher and flatter path for per capita consumption would lower the balanced growth path for private wealth. In a closed or large open economy, the balanced growth path for capital stock would also be lower and that for the real interest rate, higher.

This paper fits equation (3) to annual US data over the period 1950-1993, finding strong evidence that ψ_2 and ψ_3 are indeed appreciably negative. The paper then quantifies the steady-state effects on the capital stock, output, and consumption of social security reform defined as a reduction in the steady-state level of s_t/c_t.

[7] My 1988 and 1993 papers and my joint 1994 paper with Hasan pursue a similar approach to investigate the effects of government debt on consumption. These papers omit social security wealth and asset income from the Euler equation.

This paper obtains five noteworthy findings. First, the overidentifying restrictions of equation (3) cannot be rejected even though those who have fitted variants of equation (2) typically reject them at low significance levels; e.g., Hansen and Singleton (1983). Second, using the method advocated by Campbell and Mankiw (1989, 1990, 1991), the paper finds no evidence for binding constraints on borrowing in a variant of equation (3). Third, because the estimates of ψ_2 and ψ_3 are highly significantly negative, Ricardian equivalence is decisively rejected. Fourth, social security reform can raise the balanced growth paths for the capital stock, output, and consumption appreciably. Fifth, the elasticity of intertemporal substitution for consumption is estimated to be a highly statistically significant .63. By contrast, the large literature that has estimated variants of equation (2) has typically obtained estimates less than .1; e.g., Hall (1988).

The remainder of the paper is organized as follows. Section II provides a theoretical explanation for why $(a_t+\pi_t)/c_t$ and s_t/c_t appear in model (3) if intergenerational connectedness is imperfect so that Ricardian equivalence fails. Section III reports the results from fitting models (2) and (3). Section IV investigates the effects of social security reform implied by the empirical model of section III. Finally, section V concludes.

II. Theory

Suppose that households face perfect capital and insurance markets and maximize identical intertemporally separable objective functions characterized by a constant subjective discount rate ρ. Suppose further that their consumption choices are separable from their other choices and that α, the elasticity of intertemporal substitution for consumption, is constant. In that case, the following first-order condition for a maximum holds:

$$E_{t-1}\left(\frac{1+r_t}{1+\rho}\right)\left(\frac{\widehat{c}_t}{\breve{c}_{t-1}}\right)^{-1/\alpha}=1, \tag{4}$$

where r_t is the real rate of return realized between periods t-1 and t on any financial asset and $\widehat{c}_t$ and $\breve{c}_{t-1}$ are the per capita consumptions of the households that inhabit the economy in both periods

t-1 and t. On the assumption that the second- and higher-order conditional moments of $\ln(1+r_t)-\frac{1}{\alpha}\ln(\hat{c}_t/\breve{c}_{t-1})$ are constant,[8] the Euler equation (4) can then be cast in the linear form[9,10]

$$\ln(\hat{c}_t/\breve{c}_{t-1}) = \psi_0 + \alpha\ln(1+r_t) + u_t, \tag{5}$$

where ψ_0 is a constant parameter and

$$u_t \equiv [\ln(\hat{c}_t/\breve{c}_{t-1}) - E_{t-1}\ln(\hat{c}_t/\breve{c}_{t-1})] - \alpha[\ln(1+r_t) - E_{t-1}\ln(1+r_t)]. \tag{6}$$

Equation (6) implies that the error term u_t is orthogonal to all information available in period t-1.

If everyone entering and exiting the economy over time is connected to existing households by operative altruistic bequest or gift motives, $\hat{c}_t$ and $\breve{c}_{t-1}$ can be measured by c_t and c_{t-1}, the per capita consumptions in periods t and t-1. In that case, equation (5) can be implemented by applying the generalized method of moments (GMM) to

$$\Delta\ln c_t = \psi_0 + \psi_1\ln(1+r_t) + u_t, \tag{2}$$

The resulting estimate of ψ_1 should converge in probability to α, the elasticity of intertemporal substitution, when the instrumental variables are dated t-1 or earlier. Furthermore, if equation (2) is augmented with additional variables, the coefficients on these variables should converge in probability to zero. Equation (2) is therefore eminently testable.

Equation (2) need not hold, however, if disconnected households flow into and out of the economy over time. Let d_{t-1} be the fraction of period-(t-1) households that exited then, b_t be the fraction of period-t households that entered then, and c_{t-1}^d and c_t^b be the average amounts that these two groups of households consumed. By definition,

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[8] Carroll (1997) has argued that the variability of these moments is appreciable and persistent, implying that the error term u_t below is not orthogonal to all lagged information. An alternative interpretation of the results of this paper is therefore that these moments are positively and appreciably correlated with $(a_t+\pi_t)/c_t$ and s_t/c_t.

[9] With $x_t \equiv \ln[(1+r_t)/(1+\rho)] - \frac{1}{\alpha}\ln(\hat{c}_t/\breve{c}_{t-1})$, equation (4) can be rewritten as $E_{t-1}\exp(x_t)=1$. Expanding $\exp(x_t)$ in a Taylor series around $\bar{x}$, the unconditional mean of x_t, yields

$$\exp(x_t) = 1 + e^{\bar{x}}(x_t-\bar{x}) + \tfrac{1}{2}e^{\bar{x}}(x_t-\bar{x})^2 + \text{ higher-order terms,}$$

so that

$$1 = E_{t-1}\exp(x_t) = 1 + e^{\bar{x}}E_{t-1}(x_t-\bar{x}) + \tfrac{1}{2}e^{\bar{x}}E_{t-1}(x_t-\bar{x})^2 + \text{ terms in higher-order conditional moments,}$$

which can be rewritten as

$$E_{t-1}x_t = \bar{x} - \tfrac{1}{2}E_{t-1}(x_t-\bar{x})^2 + \text{ terms in higher-order conditional moments.}$$

The assumptions of the text therefore imply that $E_{t-1}x_t = E_{t-1}\{\ln[(1+r_t)/(1+\rho)] - \frac{1}{\alpha}\ln(\hat{c}_t/\breve{c}_{t-1})\}$ must also be a constant. Equation (5) then follows immediately.

[10] If $\ln(\hat{c}_t/\breve{c}_{t-1})$ were directly observable, this distributional assumption could be avoided since the generalized method of moments could then be directly applied to equation (4). Unfortunately, imperfect proxies must be employed, thereby introducing measurement error. The generalized method of moments does not produce consistent estimates in nonlinear models when the regressors are measured with error. Linearizing equation (4) enables this problem to be avoided.

$$d_{t-1}c_{t-1}^{d} + (1-d_{t-1})\breve{c}_{t-1} = c_{t-1} \tag{7}$$

and

$$b_t c_t^{b} + (1-b_t)\widehat{c}_t = c_t. \tag{8}$$

Hence,

$$\ln(\widehat{c}_t / \breve{c}_{t-1}) = \ln[(c_t - b_t c_t^{b})/(1-b_t)] - \ln[(c_{t-1} - d_{t-1}c_{t-1}^{d})/(1-d_{t-1})]$$

or

$$\ln(\widehat{c}_t / \breve{c}_{t-1}) = \Delta \ln c_t + \ln\left[1+\left(\frac{b_t}{1-b_t}\right)\left(\frac{c_t - c_t^{b}}{c_t}\right)\right] - \ln\left[1+\left(\frac{d_{t-1}}{1-d_{t-1}}\right)\left(\frac{c_{t-1} - c_{t-1}^{d}}{c_{t-1}}\right)\right]. \tag{9}$$

Equation (9) implies that except by happenstance, $\ln(\widehat{c}_t / \breve{c}_{t-1})$ differs from $\Delta \ln c_t$ unless the average amounts consumed by the entering and exiting households are identical to the per capita consumptions prevailing at the time.

Olivier Blanchard (1984) and Philippe Weil (1987) consider a special case in which the entry and exit rates are constant and independent of age and the elasticity of intertemporal substitution is one. In this special case, appendix A establishes that to a close approximation, the second and third terms in the right-hand member of equation (9) are increasing linear functions of $(a_t+\pi_t)/c_t$ and s_t/c_t. Equation (5) then implies that to a close approximation,

$$\Delta \ln c_t = \psi_0 + \psi_1 \ln(1+r_t) + \psi_2\left(\frac{a_t + \pi_t}{c_t}\right) + \psi_3\left(\frac{s_t}{c_t}\right) + u_t \tag{3}$$

holds with $\psi_2 < 0$ and $\psi_3 < 0$. This approximation may be adequate, however, even if the entry and exit rates vary to some extent by age and over time and the elasticity of intertemporal substitution differs somewhat from one.

There is a straightforward intuition for why the second and third terms in the right-hand member of equation (9) are related to $(a_t+\pi_t)/c_t$ and s_t/c_t. If all households choose to consume less early in their lifecycles and more late in their lifecycles, they must end up holding a larger stock of assets and receiving more asset income in aggregate. Furthermore, the more social security wealth they have, the more taxes they pay early in the lifecycle and more pension benefits they receive late in the lifecycle. This shift in disposable income from early to late in their lifecycles can leave the aggregate stock of assets and asset income constant only if consumption also shifts from early to late in their lifecycles. As a result, an increase in private wealth plus asset income or in social security wealth is associated with a reduced c^b and an increased c^d.

If the approximations leading to equation (3) are adequate, variables dated t-1 or earlier should be approximately orthogonal to the error term u_t. For this reason, they are appropriate choices as instrumental variables in applying GMM to equation (3). The method outlined by Hansen (1982) can therefore be used to gauge the adequacy of these approximations. Failure to reject the overidentifying orthogonality conditions imposed in fitting equation (3) would then suggest that the approximations are adequate.

Given model adequacy, it is reasonable to suppose that at least approximately, the GMM estimator of ψ_1 converges in probability to the elasticity of intertemporal substitution and those for ψ_2 and ψ_3 converge in probability to negative values. Furthermore, one can test the hypothesis of perfect intergenerational connectedness because the augmented Euler equation (3) nests the standard Euler equation (2). Statistically insignificant estimates for ψ_2 and ψ_3 are consistent with that hypothesis, while significantly negative estimates provide contrary evidence.

III. Empirics

This section reports the results of fitting equations (2) and (3) to annual US data. The ultimate goal is to determine how social security affects the aggregate economy.

According to the theory, period t refers to a discrete point in time. As a result, c_t is ideally a flow realized at the instant t; a_t and s_t are stocks realized at the instant t-1 and predetermined at the instant t; π_t is the asset income earned from the instant t-1, when a_t is realized, to the instant t, when c_t is realized; and r_t is the real after-tax rate of return realized on an asset acquired at the instant t-1 and held until the instant t. In practice, the data on c_t are measured as cumulated flows over intervals of time such as months, quarters, and years. This complication does not cause any problems, however, so long as the interval over which the flows are cumulated extends backward less than one period.[11,12] In that case, the error term u_t in equation (3) retains its property of being uncorrelated with all information lagged at least one period.

[11] Consider a relationship of the form

$$z_t^* = z_{t-1}^* + \beta' x_t^* + u_t^*$$

which relates a variable z^* to a vector of variables x^* and an error term u^*, all measured as flows at the point in time indicated by the subscript. Integrating both members of this equation backward over an interval of length τ yields

$$z_t = z_{t-1} + \beta' x_t + u_t,$$

My measure of c_t is 1.105 times real expenditure on nondurable goods and services in the fourth quarter of year t divided by the mid-quarter resident population. The figure 1.105 is the average ratio of total real expenditures on consumption goods to real expenditures on nondurable goods and services between 1950 and 1993. My use of a series that was cumulated over only one quarter avoids the time-aggregation problem. For a_t, I employ real per capita private wealth at the end of year t-1 divided by the mid-quarter resident population for the fourth quarter of year t-1. The series π_t is after-tax nominal asset income during year t divided by the midyear resident population and the annual deflator for expenditures on nondurable goods and services. I choose an annual time span between observations because private and social security wealth are available only annually.

The theory implies that one may use the real after-tax rate of return on any asset whatsoever to measure r_t so long as its timing conforms with that of $\Delta \ln c_t$. I use the one-year Treasury discount bond as the asset and assume that the marginal tax rate on nominal interest income was 30 percent over the entire sample period.[13,14] The real after-tax rate of return on this asset is calculated with the formula

$$\ln(1+r_t) = \ln(1+.7i_{t-1}) - \Delta \ln P_t, \tag{10}$$

where i_{t-1} is the average nominal annualized and digitized yield on one-year Treasury discount bonds during the fourth quarter of year t-1 and P_t is the deflator for expenditure on nondurable goods and services in the fourth quarter of year t.

Feldstein (1974) pioneered in the daunting task of measuring social security wealth. In each year of his sample, he worked out the implications of the social security system for the present

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where $z_t \equiv \int_0^\tau z^*_{t-v}dv,\ x_t \equiv \int_0^\tau x^*_{t-v}dv,$ and $u_t \equiv \int_0^\tau u^*_{t-v}dv.$ If $\tau < 1,\ E_{t-1}u_t = 0$ since $E_{t-1}u^*_{t-v} = 0$ for all $0 \le v < 1$. Hall (1988) has discussed the case τ=1, showing that $E_{t-1}u_t \neq 0$ but $E_{t-2}u_t = 0$.

[12] This result also requires that the series $\Delta \ln c_t$ be conditionally homoskedastic. Otherwise, the quantity

$$\ln\left(\int_0^\tau c_{t-v}dv\right) - \int_0^\tau \ln c_{t-v}dv$$

would be stochastic.

[13] In agreement with the theory, the estimates for ψ_1, ψ_2, and ψ_3 are virtually identical if one proxies r_t with the real after-tax rates of return calculated from rolling over one-, two-, three-, four-, or six-month Treasury discount bonds. The same is true for the estimates of ψ_2 and ψ_3 obtained using proxies calculated from the nominal one-year holding-period yields on 1¼-, 1½-, 1¾-, 2-, 2½-, 3-, 4-, 5-, 6-, 7-, 8-, 9-, and 10-year Treasury discount bonds. The estimate of ψ_1, however, declines with the term of the bond in this case. This result suggests that households may be less willing to substitute consumption in response to anticipated capital gains and losses than to anticipated real returns paid out as coupons. Such an anomaly would appear to violate Modigliani-Miller neutrality. To the extent that the latter evidence has credence, the calculations in the next section should use a smaller elasticity of intertemporal substitution and obtain larger effects of social security reform on the capital stock, output, and consumption. The empirical results outlined here are available from me upon request.

[14] The empirical results are qualitatively similar for other plausible marginal tax rates.

value of what the current population could reasonably anticipate receiving as net benefits.[15] Many judgments went into his calculation, some of which have proven to be controversial.[16] Subsequent work by Feldstein and others has improved the measurement of social security wealth, though the existing measures no doubt remain appreciably contaminated by systematic as well as random measurement error. It is beyond the scope of this paper, however, to make further improvements. I therefore just use Feldstein's (1996b) measure of net social security wealth, which is available for the postwar period up to the beginning of 1993. Ultimately, it is an empirical question whether his measure is a good proxy for the size of the intergenerational transfer that the social security system induces in favor current households.

I fit equation (2) to the data described above employing GMM. The sample period was 1950-1993, and the instrumental variables were the intercept and two lags each of r_t, $\Delta \ln c_t$, $(a_t+\pi_t)/c_t$, and s_t/c_t. The result was

$$\Delta \ln \hat{c}_t = \underset{(.0020)}{.0218} - \underset{(.197)}{.040} \ln(1+r_t), \quad SEE = .01478, \quad MSLJ = .0872. \tag{11}$$

The elasticity of intertemporal substitution is estimated to be negative, albeit insignificantly so. Furthermore, the marginal significance level of the *J*-statistic is fairly low, providing some evidence against the overidentifying restrictions of the model.

Fitting equation (2) does not produce a reasonable statistical model for a straightforward reason. The first eleven sample autocorrelations of the growth rate of per capita consumption are .17, -.15, .04, .07, -.19, -.12, .16, -.11, -.05, .11, and .09 with a standard error of .16. According to equation (2), this approximately white-noise series is a linear combination of a white-noise error term and a rather persistent real interest rate. (Its first eleven sample autocorrelations are .47, .33,

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[15] In symbols, his measure of social security wealth takes the form

$$\sum_i N_{it}\left[\sum_{j=0}^{J_i}\left(\frac{1}{1+r}\right)^j P_{ijt}B_{ijt}\right],$$

where i is an index indicating the type of household (e.g., distinguished by marital status, age, etc.), N_{it} is the number of households of type i in year t, J_i is the maximum number of years that households of type i can live, r is the discount rate used in the calculation, P_{ijt} is the probability that households of type i in year t survive at least j years into the future, and B_{ijt} is the net benefit that households of type i anticipate as of year t receiving from social security in year $t+j$, conditional on surviving until then. Net benefits equal pensions receipts less payroll tax payments.

[16] In his 1974 endeavor, Feldstein made the following assumptions in specifying B_{ijt}: (i) households anticipated retiring when their heads reached age 65; (ii) they anticipated receiving a pension equal to 41 percent of the per capita disposable income prevailing at that time; (iii) they anticipated paying a fixed fraction θ_{jt} of the per capita disposable income prevailing in the years prior to retirement and nothing in subsequent years; (iv) they anticipated that disposable income would grow at a constant rate g, equal to the average growth rate of disposable income over the sample period; (v) the quantity θ_{jt} is the actual fraction of per capita disposable income paid as social security taxes in years included

.35, .13, .05, -.03, -.24, -.28, -.32, -.35, and -.31 with a standard error of .16.) If the elasticity of intertemporal substitution is to be appreciable, equation (2) must be augmented to include some other persistent regressors in addition to r_t.

Figure 1 illustrates this point in another way. Its upper panel plots five-year centered moving averages of the real interest rate and the growth rate of per capita consumption.[17] The moving average of r_t exhibits long waves, while the moving average of $\Delta \ln c_t$ shows little tendency to be wavelike or to move in the same direction as r_t's moving average. Although per capita consumption did grow rapidly in the mid-1980s when the after-tax real interest rate was high, it did not grow slowly in the early 1950s and mid-1970s when the after-tax real interest rate was low. Consequently, the two moving averages are only weakly correlated with each other as illustrated in the bottom panel.

I used GMM to fit equation (3) to the data over the sample period 1950-1993. The instrumental variables were the intercept and two lags each of r_t, $\Delta \ln c_t$, $(a_t+\pi_t)/c_t$, and s_t/c_t. The result was

$$\Delta \ln \hat{c}_t = \underset{(.063)}{.333} + \underset{(.136)}{.630} \ln(1+r_t) - \underset{(.0119)}{.0568}\left(\frac{a_t+\pi_t}{c_t}\right) - \underset{(.0085)}{.0457}\left(\frac{s_t}{c_t}\right), \tag{12}$$

$$SEE = .01194, \quad MSLJ = .3139.$$

The overidentifying restrictions now pass muster easily. The estimates of ψ_2 and ψ_3 are highly significantly negative, providing strong evidence against Ricardian equivalence. The elasticity of intertemporal substitution is estimated to be .63, a plausible value.[18,19] It is statistically significantly less than one at the .05 level, however, suggesting that the parameters ψ_2 and ψ_3 may not actually be constant as posited in section II.

According to the theory, the rate of growth of consumption for households alive in both periods t-1 and t is within a constant of

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in the sample; and (vi) in years that would occur after the end of the sample, θ_{jt} is the fraction of disposable income paid as social security taxes in the last year of the sample.

[17] For purposes of display, the sample means of the series are removed in Figures 1 and 2.

[18] Many contributors to the real business-cycle literature calibrate α as 1, 1/2, or 1/3; see Cooley (1995).

[19] This result is not surprising given the findings of Attanasio and Weber (1993, 1995a). The latter article formulates a model in which disconnected households flow into and out of the economy at positive rates and then demonstrates that applying GMM to the standard aggregate Euler equation yields a downward-biased estimator for the intertemporal elasticity of substitution. The former article establishes empirically that the bias is appreciable.

$$\Delta \ln c_t + .0568\left(\frac{a_t + \pi_t}{c_t}\right) + .0457\left(\frac{s_t}{c_t}\right). \tag{13}$$

The top panel of Figure 2 plots five-year centered moving averages of the real after-tax rate of return and the adjusted consumption growth rate (13). Both moving averages exhibit similar and closely aligned long waves. The corrections that (13) adds to the aggregate consumption growth rate radically alter its properties. In particular, the adjusted consumption growth rate is much more persistent and is substantially lower in the early 1950s and the mid-1970 than the aggregate consumption growth rate. Consequently, the two moving averages are strongly positively correlated with each other as the bottom panel shows.

The theory of the previous section assumed that households do not face binding constraints on borrowing. Campbell and Mankiw (1989, 1990, 1991) have argued that one can allow for this possibility by including the growth rate of per capita after-tax wage income as an additional regressor in Euler equations.[20] For example, in the context of this paper, one would estimate

$$\Delta \ln c_t = \psi_0 + \psi_1 \ln(1 + r_t) + \psi_2\left(\frac{a_t + \pi_t}{c_t}\right) + \psi_3\left(\frac{s_t}{c_t}\right) + \psi_4 \Delta \ln w_t + u_t \tag{14}$$

in lieu of equation (3), where w_t is real disposable wage income in the fourth quarter of year t divided by the mid-quarter resident population. An appreciable and significantly negative estimate of ψ_4 would then indicate that binding constraints on borrowing have important effects on consumption and asset prices.

I used GMM to fit equation (14) to the data over the sample period 1950-1993. The instrumental variables were the intercept and two lags each of r_t, $\Delta\ln c_t$, $(a_t+\pi_t)/c_t$, s_t/c_t, and $\Delta\ln w_t$. The result was

$$\Delta \ln \hat{c}_t = \underset{(.124)}{.344} + \underset{(.225)}{.648} \ln(1 + r_t) - \underset{(.0221)}{.0581}\left(\frac{a_t + \pi_t}{c_t}\right) - \underset{(.0182)}{.0488}\left(\frac{s_t}{c_t}\right) - \underset{(.0982)}{.0196} \Delta \ln w_t, \tag{15}$$

$$SEE = .01244, \quad MSLJ = .3054.$$

[20] Actually, Campbell and Mankiw estimate regressions with the growth rate of total disposable income though the logic of their approach would call for disposable wage income since borrowing-constrained households do not hold assets and do not receive asset income.

The parameter ψ_4 is numerically small and statistically insignificant at any reasonable level. Therefore, no evidence is found for binding constraints on borrowing.[21]

IV. Effects of Social Security Reform

In this section, I calculate the steady-state values implied by a simple nonstochastic computational general-equilibrium model embedding the estimated equation (12). My purpose is to evaluate the economic significance of the estimates for ψ_2 and ψ_3. The model is highly stylized and calibrated to match only the grossest features of the US economy. Furthermore, it has been validated only to the extent that equation (12) does appear to fit the aggregate data reasonably well. For these reasons, the results are primarily useful in assessing economic significance, though they may give some idea of the size of social security's likely steady-state effects.

I assume that the economy is closed and has the intensive Cobb-Douglas production function

$$\tilde{q} = A\tilde{k}^{1/3}, \tag{16}$$

where $\tilde{q}$ and $\tilde{k}$ are steady-state gross output and capital per efficiency unit of labor. I choose the parameter A so that the capital-output ratio is 2.5 years in the initial steady state in which $\tilde{q}$ is normalized to one per year. The choice of $\frac{1}{3}$ for the elasticity of output with respect to the capital stock is entirely conventional; e.g., Campbell (1994).

I further assume that the owners of capital receive its net marginal product after paying a uniform 30 percent to the government as taxes. The depreciation rate on capital is taken to be 4 percent a year, which is consistent with the assumed capital-output ratio of 2.5 years and the fact that depreciation accounts for roughly 10 percent of GDP. Consequently,

$$\tilde{r} = (1-.3)\left[\tfrac{1}{3}(\tilde{q}/\tilde{k}) - .04\right], \tag{17}$$

where $\tilde{r}$ is the steady-state after-tax real interest rate.

In addition, I assume that the number of efficiency units of labor grows exogenously at a rate of 2.5 percent a year, inducing the capital stock, gross output, and consumption also to grow at

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[21] This result is also not surprising, given the finding of Attanasio and Weber (1995a). In a theoretical model in which disconnected households flow into and out of the economy at positive rates but do not face binding constraints on borrowing, they demonstrate that aggregate consumption growth is nonetheless increasing in predictable wage growth.

that rate in the steady state.[22] I also assume that the government absorbs 18 percent of gross output, roughly its share of GDP in the late 1990s. As a result, in the steady state,

$$(1+.025)\tilde{k} = (1-.04)\tilde{k} + (1-.18)\tilde{q} - \tilde{c}$$

or

$$\tilde{c} = .82\tilde{q} - .065\tilde{k}, \tag{18}$$

where $\tilde{c}$ is steady-state consumption per efficiency unit of labor.

I assume that the government debt policy results in a steady-state ratio of debt to total consumption of .653 years, roughly its value in the late 1990s. Given this assumption,

$$\frac{\tilde{a}+\tilde{\pi}}{\tilde{c}} = (1+\tilde{r})\left(\frac{\tilde{a}}{\tilde{c}}\right) = (1+\tilde{r})\left[\left(\frac{\tilde{k}}{\tilde{c}}\right) + .653\right] \tag{19}$$

since $\pi_t = r_t a_t$.

Finally, I assume that population as well as the number of efficiency units of labor grows at a constant exogenous rate in the steady state. As a result, equation (12) implies that in the steady state,

$$.630\ln(1+\tilde{r}) - .0568\left(\frac{\tilde{a}+\tilde{\pi}}{\tilde{c}}\right) - .0457\left(\frac{\tilde{s}}{\tilde{c}}\right) = B, \tag{20}$$

where *B* is a free parameter selected in order to make equation (20) balance in steady states.[23]

Now, consider the reform of social security. For the purposes of this paper, the reform is taken to be a reduction in the steady-state ratio of social security wealth to consumption with no offsetting increase in the steady-state ratio of government debt to consumption. Although many of the proposals put forward do entail temporary increases in the debt ratio and in practice might entail permanent increases, any such proposal has effects identical to those of a proposal that merely reduces social security wealth less in the first place with no offset. I therefore consider reform proposals that differ only in the ultimate extent to which they reduce the steady-state value of *s*/c.

[22] I am thus abstracting from any benefits that social security reform might have in reducing tax distortions in the labor market. As pointed out by Murphy and Welch (1998), these benefits can in principle be obtained without fundamentally changing the character of social security.

[23] The free parameter *B* is composed of three terms, which I assume to be constant across all steady states. The first is the growth rate of per capita consumption. This term is constant in all steady states for which the growth rates of population and the per capita number of efficiency units of labor are constant. Second, the negative of the intercept in equation (12). Third, the difference between the means of the after-tax marginal product of capital and the real after-tax rate of return on one-year Treasury discount bonds. This term, which is positive and substantial, consists of risk premia.

I solved the model (16)-(20) for each of the following 101 values of *s*/*c*:

$$\tilde{s}/\tilde{c} = 1.78(1-.01i), \quad i = 0, 1, \cdots, 100, \tag{21}$$

where 1.78 years is the value of *s*/*c* observed in 1993 and assumed to obtain in the initial steady state. Figure 3 plots the percentage upward shift in the balanced growth path for the capital stock against *i*, the percentage reduction in the steady-state ratio of social security wealth to consumption effected by the social security reform.[24] The percentage increase in $\tilde{k}$ is essentially linear in the percentage reduction in *s*/*c*, rising about .42 percent for each percent that *s*/*c* is reduced. Equation (16) then implies that $\tilde{q}$ increases by about .14 percent for each percent that *s*/*c* is reduced. As a result, any substantial privatization would shift the balanced growth paths of the capital stock and gross output upward appreciably.

Figure 4 plots the percentage upward shift in the balanced growth path for consumption that the increases in the capital stock plotted in Figure 3 would support. The curve is concave as one would expect from the near linearity of the curve in Figure 3 and is upward sloping, indicating that the US capital stock is well below its golden-rule level. A reform that completely eliminated social security wealth would raise consumption by about five percent in the steady state, a sizeable effect.

How do these effects compare with those found in the literature using computational general-equilibrium models? Kotlikoff, Smetters, and Walliser (1998) simulated the effects of the complete elimination of social security, finding that it would raise the capital stock by about 39 percent in the steady state of their model. Figure 1 implies an effect of 42 percent in the small computational general-equilibrium model of this section. These effects are remarkably close to each other. Apparently, the assumptions underlying the augmented Euler equation (3) have similar implications as the lifecycle assumptions underlying their model. One should not overstate the closeness of these effects, however, since both come from models that are easy to criticize. The important point is that the aggregate effects from social security reform are likely to be large. Even if the true effects were half as large as these, one would still conclude that they are large.

[24] Let $\tilde{k}(i)$ and $\tilde{c}(i)$ be the solutions for $\tilde{k}$ and $\tilde{c}$ corresponding to the *i*th value of $\tilde{s}/\tilde{c}$. Figures 3 and 4 plot $100 \cdot [\tilde{k}(0) - \tilde{k}(i)]/\tilde{k}(0)$ and $100 \cdot [\tilde{c}(0) - \tilde{c}(i)]/\tilde{c}(0)$ against *i*.

V. Conclusions

This paper found strong empirical evidence that social security affects the US economy. The estimated effects are highly significant not only statistically but also economically. In addition, the empirical investigation yielded four important byproducts. First, unlike much of the previous literature, the overidentifying restrictions of the augmented Euler equation fitted here were not rejected. Augmenting the standard Euler equation with wealth terms enables it to pass muster. Second, no evidence was found for binding constraints on borrowing once the wealth terms were included. Third, strong evidence was found for a substantial elasticity of intertemporal substitution. Fourth, Ricardian equivalence was resoundingly rejected.

Appendix A

Without loss of generality, I assume that both the exit and entrance rates are constant so that $b_t = b$ and $d_{t-1} = d$ for every t. On that assumption, the fraction of the population that is age l is $b(1-b)^l$ for $l = 0, 1, 2, \cdots$. Let c_{lt} be the consumption of each household of age l in period t. The assumption of a constant exit probability implies that among unconstrained households, those exiting in period t-1 consume on average the same amount as those surviving from period t-1 to period t. Hence, $c_{t-1}^d = \breve{c}_{t-1} = c_{t-1}$. Equation (9) therefore reduces to

$$\ln(\widehat{c}_t / \breve{c}_{t-1}) = \Delta \ln c_t + \ln\left[1 + \left(\frac{b}{1-b}\right)\left(\frac{c_t - c_{0t}}{c_t}\right)\right] \approx \Delta \ln c_t + \left(\frac{b}{1-b}\right)\left(\frac{c_t - c_{0t}}{c_t}\right) \qquad \text{(A.1)}$$

since $c_t^b = c_{0t}$.

Let w_{lt}, a_{lt}, and π_{lt} be the after-tax wage income, beginning-of-period assets, and after-tax asset income of the households of age l in period t. Because they completely annuitize their assets in perfect insurance markets and face perfect capital markets, their budget constraints take the form

$$c_{lt} + a_{l+1,t+1} = w_{lt} + (1+r_t)a_{lt}/(1-d) = w_{lt} + (a_{lt} + \pi_{lt})/(1-d), \quad l = 0, 1, 2, \cdots. \qquad \text{(A.2)}$$

Solving equation (A.2) forward then yields

$$c_{lt}+\sum_{i=1}^{\infty}(1-d)^i \exp\left[-\sum_{j=1}^{i}\ln(1+r_{t+j})\right]c_{l+i,t+i}=(a_{lt}+\pi_{lt})/(1-d)$$
$$+w_{lt}+\sum_{i=1}^{\infty}(1-d)^i \exp\left[-\sum_{j=1}^{i}\ln(1+r_{t+j})\right]w_{l+i,t+i}. \tag{A.3}$$

From equation (A.3), it follows that

$$c_{lt}=\mu_{lt}\left[(a_{lt}+\pi_{lt})/(1-d)+h_{lt}\right], \tag{A.4}$$

where

$$h_{lt}=w_{lt}+E_t\sum_{i=1}^{\infty}(1-d)^i \exp\left[-\sum_{j=1}^{i}\ln(1+r_{t+j})\right]w_{l+i,t+i} \tag{A.5}$$

and

$$\mu_{lt}\equiv\left\{1+\sum_{i=1}^{\infty}(1-d)^i E_t \exp\left(\sum_{j=1}^{i}[\ln(c_{l+j,t+j}/c_{l+j-1,t+j-1})-\ln(1+r_{t+j})]\right)\right\}^{-1}. \tag{A.6}$$

The assumptions leading to equations (4) and (5) imply that

$$\ln(c_{l+j,t+j}/c_{l+j-1,t+j-1})=\psi_0+\alpha\ln(1+r_{t+j})+u_{t+j}. \tag{A.7}$$

Substituting equation (A.7) into equation (A.6) then yields

$$\mu_{lt}=\mu_t\equiv\left\{1+\sum_{i=1}^{\infty}(1-d)^i E_t \exp\left[-\sum_{j=1}^{i}\{(1-\alpha)\ln(1+r_{t+j})+\psi_0+u_{t+i}\}\right]\right\}^{-1} \tag{A.8}$$

Equation (A.4) reduces to

$$c_{0t}=\mu_t h_{0t} \tag{A.9}$$

for l = 0 since $a_{0t}=\pi_{0t}=0$. Aggregating both members of equation (A.4) produces

$$c_t=\mu_t\left[\left(\tfrac{1}{1-d}\right)(a_t+\pi_t)+h_t\right], \tag{A.10}$$

where $a_t\equiv\sum_{l=0}^{\infty}b(1-b)^l a_{lt}$, $\pi_t\equiv\sum_{l=0}^{\infty}b(1-b)^l\pi_{lt}$, and $h_t\equiv\sum_{l=0}^{\infty}b(1-b)^l h_{lt}$. Equations (A.1), (A.9), and (A.10) then imply that

$$\ln(\hat{c}_t/\breve{c}_{t-1})\approx\Delta\ln c_t+\mu_t\left(\frac{b}{1-b}\right)\left[\left(\frac{1}{1-d}\right)\left(\frac{a_t+\pi_t}{c_t}\right)+\left(\frac{h_t-h_{0t}}{c_t}\right)\right]. \tag{A.11}$$

It is convenient to decompose h_t-h_{0t} into two components. The first is the per capita present value of the current and future net transfers that existing households expect to receive as of period t less the per capita present value of the current and future net transfers that the newly arriving households expect to receive. Equivalently, this component is the average intergenerational transfer in favor of existing households induced by the current system of transfers payments and the taxes that finance them. I denote this component s_t and call it *social security wealth* because the social security system generates the lion's share of such intergenerational transfers and because the empirical analysis of the next section focuses on social security. The second component reflects the shape of the age-earnings profile as well as any systematic relationship between age and the taxes levied to cover government consumption and to service the government debt. I assume that this component is proportional to consumption.[25] Given these further assumptions, equations (5) and (A.11) imply that

$$\Delta \ln c_t = \psi_0 + \alpha \ln(1+r_t) - \mu_t \left(\frac{b}{1-b}\right)\left[\left(\frac{1}{1-d}\right)\left(\frac{a_t+\pi_t}{c_t}\right)+\left(\frac{h_t-h_{0t}}{c_t}\right)\right]+u_t. \qquad \text{(A.12)}$$

For convenience, I use the same symbol to denote the intercepts in equation (A.12) and (5) even though they generally differ.

The quantity μ_t in equation (A.12) is the marginal propensity to consume from wealth. According to equation (A.8), it is constant if α, the elasticity of intertemporal substitution, equals one or if r_t, the real interest rate, is serially independent. In either case, equation (3) holds with $\psi_1 \equiv \alpha > 0$, $\psi_2 \equiv -b\mu/(1-b)(1-d) < 0$, and $\psi_3 \equiv -b\mu/(1-b) < 0$.

Appendix B

Real expenditure on nondurable goods and services is the sum of lines 4 and 5 of NIPA Table 1.2. For 1947-1958, the fourth-quarter nominal interest rate on Treasury one-year discount bonds is the average of the September, October, November, and December values of the one-year simple interest rate on discount Treasury securities compiled by Huston McCulloch and Heon-Chul Kwon (1993).[26] Using the 12-month Treasury bill rate reported in the Federal Reserve Bulletin on a discount basis, I calculated the simple interest rates (yields to maturity) for October, November, and December of 1959-1993 and averaged them together. Note that the data of McCulloch and Kwon are end-of-month observations so that averaging over the September, October, November, and December observations approximates an average over the fourth quarter. By contrast, the data

[25] This assumption has the same effect as Blanchard's assumption that every household receives the same disposable wage income.

from the Federal Reserve are monthly averages of daily figures. Real private wealth comes from Table B-115 of the 1995 *Economic Report of the President*; end-of-year figures for year t-1 are relabeled as beginning-of-year figures for year t. Real disposable wage income is nominal disposable income from line 25 of NIPA Table 2.1 less nominal after-tax asset income divided by the deflator for expenditures on nondurable goods and services. Before-tax asset income is national income minus compensation of employees minus a fraction ω of proprietors' income plus net government interest payments minus government interest payments to foreigners. These series are lines 1, 2, and 9 of NIPA Table 1.14 and lines 13 and 16 of NIPA Table 3.1. The fraction ω is the ratio of employee compensation to national income less proprietors' income. (The assumption being made here is that compensation for proprietors' labor services represents the same fraction of total proprietors' income as compensation is in the rest of national income.) After-tax asset income is before-tax asset income minus corporate profits taxes minus federal inheritance taxes minus other personal state and local taxes minus a fraction ζ of income taxes minus the inflation tax $-(1-CPI_{t-1}/CPI_t)\cdot GNFA_t$, where CPI_t is the consumer price index for December of year t and $GNFA_t$ is government net financial assets. These series are line 3 of NIPA Table 3.1, line 4 of NIPA Table 3.2, line 5 of Table 3.3, the sum of line 3 of NIPA Table 3.2 and line 3 of NIPA Table 3.3, page C-27 of the January/February issue of the *Survey of Current Business* and a printout provided by the Bureau of Economic Analysis, and Table B-114 of the 1995 *Economic Report of the President*. The fraction ζ is the ratio before-tax asset income minus corporate profits taxes to national income plus net government interest payments minus corporate profits taxes. (The assumptions being made here are that asset income is taxed at the same average rate as compensation and that only corporate profits taxes are deductible against income taxes.) All NIPA data come from a diskette provided by the Bureau of Economic Analysis.

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[26] They report their data as continuously discounted rates. The simple interest rates plugged into equation (10) were calculated by exponentiating their series and subtracting one.

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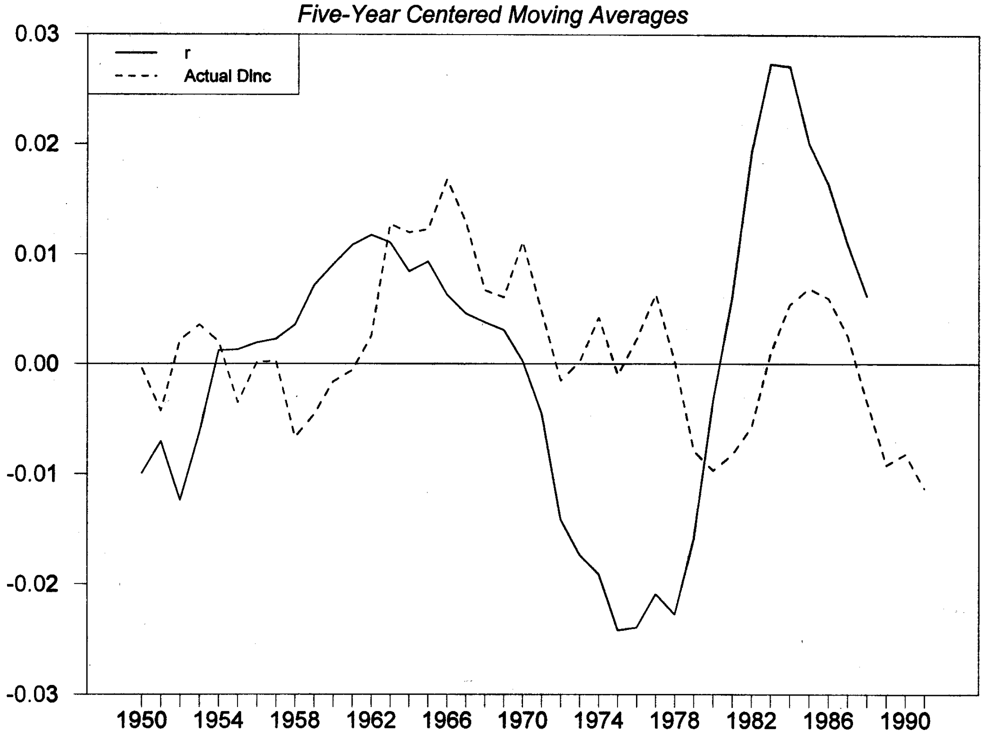
Figure 1. Consumption Growth and the Real Interest Rate

Five-Year Centered Moving Averages



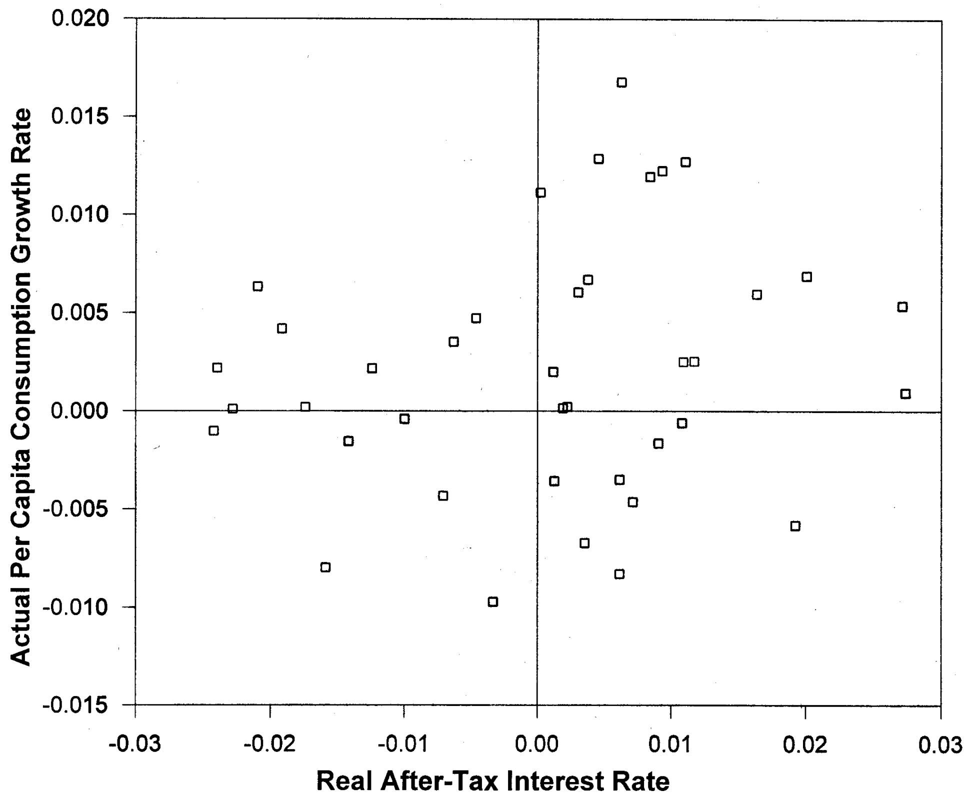
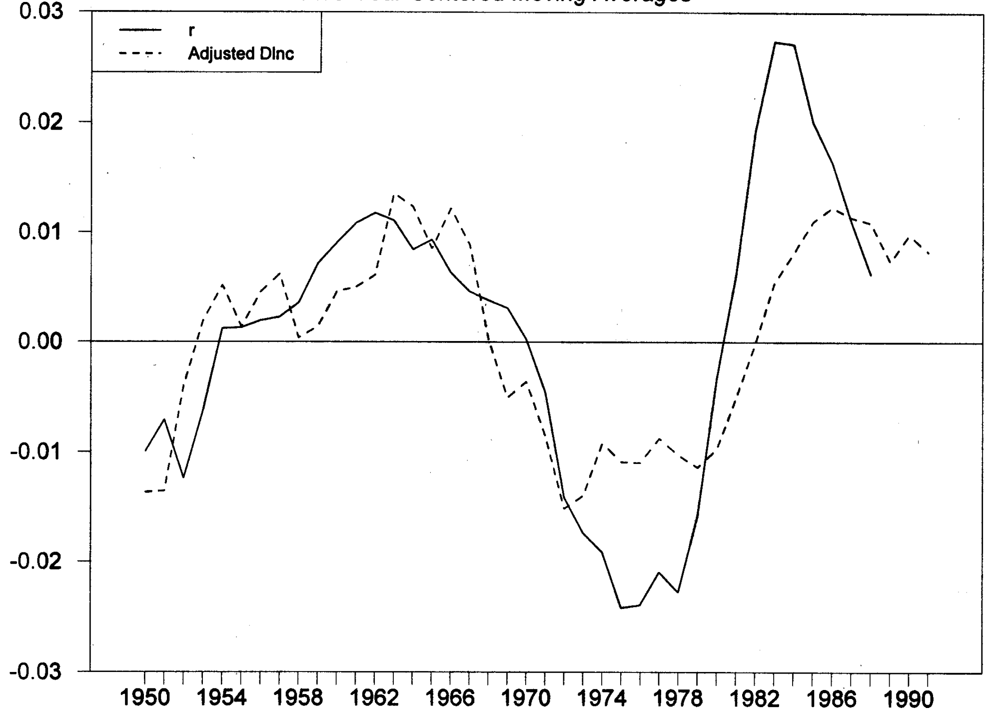

0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
Actual Per Capita Consumption Growth Rate
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
Real After-Tax Interest Rate

Figure 2. Adjusted Consumption Growth and the Real Interest Rate

Five-Year Centered Moving Averages



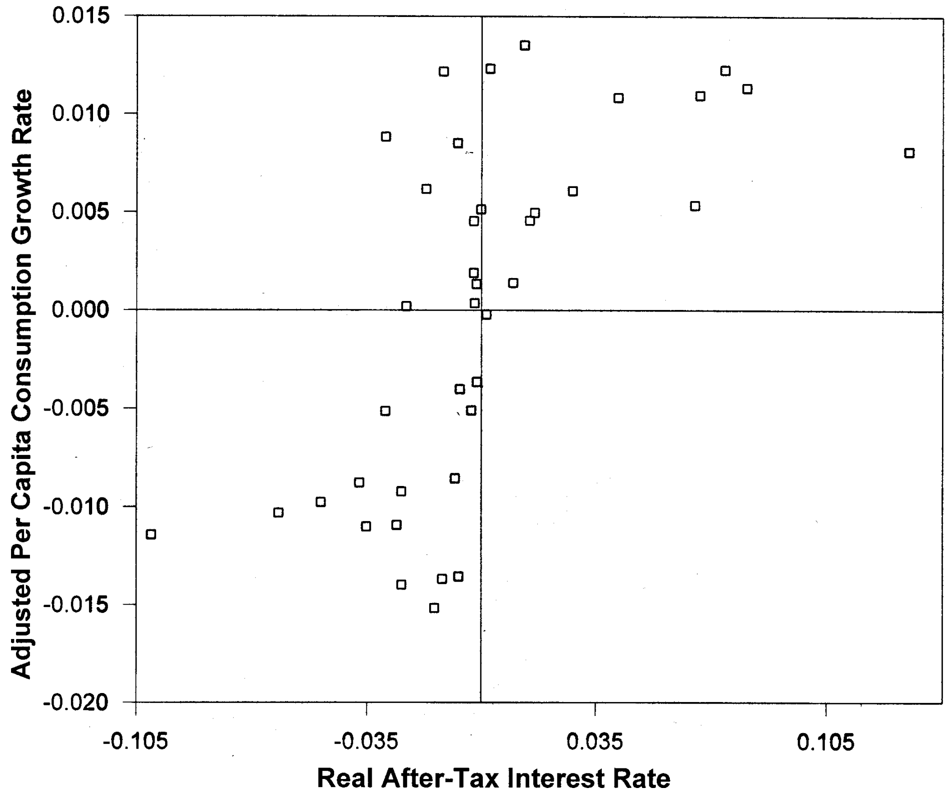

0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
Adjusted Per Capita Consumption Growth Rate
-0.105
-0.035
0.035
0.105
Real After-Tax Interest Rate

Figure 3. Steady-State Effect of Social-Security Reform

on the Per Capita Capital Stock

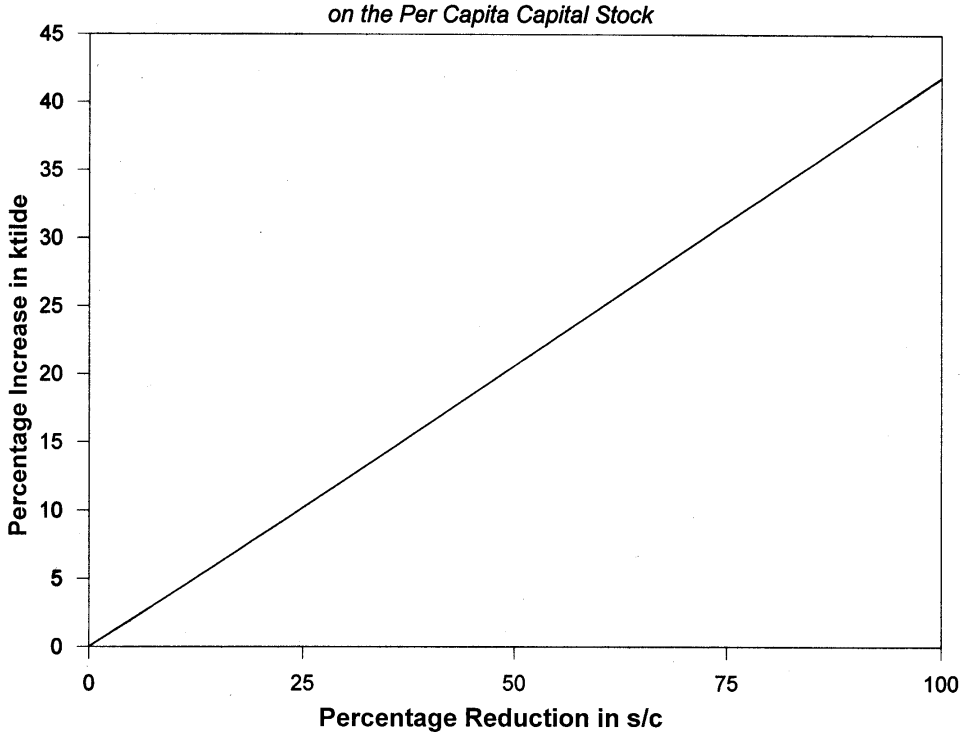


Figure 4. Steady-State Effect of Social-Security Reform

on Per Capita Consumption