Working Paper 9102

INFLATION, PERSONAL TAXES, AND REAL OUTPUT: A DYNAMIC ANALYSIS

by David Altig and Charles T. Carlstrom

David Altig and Charles T. Carlstrom are economists at the Federal Reserve Bank of Cleveland. This paper is a revised version of one prepared for the Conference on Price Stability held at the Federal Reserve Bank of Cleveland, November 8-10, 1990. The authors would like to express their deep gratitude to their discussants, Alan Auerbach and Finn Kydland, who of course bear no responsibility for any remaining errors and deficiencies. They would also like to thank, without implicating, Rao Aiygari, Steve Davis, Mike Dotsey, Ed Gamber, Dick Jefferis, Charles Steindel, Alan Stockman, Ellis Tallman, David Wildasin, their colleagues at the Federal Reserve Bank of Cleveland, and seminar participants at Indiana University, the 1990 Western Economic Association annual meeting, and the 1990 Federal Reserve System's Business Analysis Group meeting for many helpful comments on earlier versions of this work. Kent Smetters and Josh Rosenberg provided outstanding programming and research assistance.

February 1991

I. Introduction

In the not-too-distant past, examining the policy implications of specific fiscal-monetary policy mixes meant entering a game with fairly well established ground rules. These rules stressed the relative effectiveness of fiscal versus monetary policy instruments in the context of an IS-LM paradigm in which the causal relationship between high-frequency real economic activity and "demand-management" policies was taken for granted. The foundation of empirical policy analysis in this tradition was the reduced-form econometric model. The models were sometimes quite small (the "St. Louis" model, for example) and sometimes quite large (the DRI model, for example), but the general notion of specifying reduced-form aggregate demand and supply curves remained at the core of most empirical strategies.

Arguing within this tradition, Martin Feldstein (1982) pointed to a specific problem with the common prescription of tight fiscal policy (low deficits) and easy money -- the failure to recognize the potentially important consequences of interactions between inflation and the type of nominally based tax system that has existed in the United States for most of the postwar period. Feldstein argued that

> the traditional policy mix reflects not only its optimistic view about the feasibility of government surpluses, but also its overly narrow conception of fiscal policy. In the current macroeconomic tradition, fiscal policy has been almost synonymous with variations in the net government surplus or deficit and has generally ignored the potentially powerful effects of taxes that influence marginal prices.

Implicit in this reasoning is the assertion that the traditional policy mix also conceived of monetary policy in an overly narrow way, ignoring the potentially important effects on long- and short-run economic activity that can arise through the interaction of inflation and nominal tax schemes.

As several of the papers presented at this conference verify, an alternative approach to policy analysis has emerged that differs in significant ways from the approach implicit in Feldstein's remarks. In place of the "traditional approach," we find policy analysis conducted in the context of general-equilibrium models in which preferences and technologies are explicitly characterized and equilibria are obtained by aggregating the decisions of individual firms and households operating in competitive markets. "Empirical" policy analysis in this new approach typically involves analyzing the simulated responses of artificial economies to particular policy choices, sometimes in conjunction with formal econometric analysis, sometimes not.

Feldstein's remarks, however, are as salient as ever. Even when monetary phenomena are explicitly modeled, as in Huh (1990), Kydland (1989), and Cooley and Hansen (1989), general-equilibrium simulation models fail to find a significant explanatory role for monetary policy in the genesis of business cycle fluctuations. But these models typically ignore the "Feldstein channel" -- monetary effects that occur through the interaction of inflation and distortionary nominal tax systems.

This paper addresses the issue implied by Feldstein's argument in a framework that is consistent with the new generation of policy analysis models. In particular, we ask the following question: What consequences do interactions between inflation and the nominal taxation of capital income have for the cyclical behavior of the macroeconomy?

Our analysis utilizes the well-known overlapping-generations simulation framework exemplified by Auerbach and Kotlikoff (1987), henceforth AK.[1] We have chosen this approach because our general orientation is towards examining the value of extending the AK type of fiscal policy analysis to stochastic environments. With respect to the specific question at issue here, our model

[1] An extension of the AK framework to the study of business cycle phenomena has also been developed independently by Rios-Rull (1990).

provides a natural framework for fully endogenizing marginal tax rates in a world with a progressive tax structure.[2]

We do not explicitly model a monetary sector (inflation is introduced as exogenous changes in an arbitrary unit of account), nor do we consider nonzero levels of government expenditure. We assume that lump-sum adjustments in taxes and transfers maintain balance in the government's budget constraint and guarantee the absence of wealth effects on individual households. Also, we focus solely on the personal tax code and generally ignore distortions associated with corporate taxation of capital. These choices are obviously not made because we think these elements are unimportant, but because we wish to isolate the effects arising purely from distortions of "marginal prices" created by the interaction of inflation and the personal tax code.

Two empirical observations that become important in our analysis are demonstrated in figures 1 and 2: Over the 1955-1988 period, the per capita capital stock tended to be above its growth-adjusted mean and aggregate per capita hours tended to be below its mean in periods when inflation tended to be above its sample average.[3] Our numerical model generally mimics this pattern, a surprising result given that we allow inflation to distort capital income tax liabilities and we fully index wage income.

---

[2] McGrattan (1989) considers the cyclical consequences of stochastic "average" marginal tax rates in a variant of the model developed by Kydland and Prescott (1982). In her analysis, marginal tax rates are partially endogenous in that the stochastic process for the average marginal tax rate depends on realizations of lagged aggregate variables. They are not determined, however, as the outcome of individual decisions made under a structural tax regime.

[3] The capital stock measure is private fixed nonresidential capital, measured at the end of the year (net of depreciation) and detrended by the deterministic growth rate of per capita consumption expenditures on nondurable goods and services. Total hours is calculated by annual average hours worked in nonagricultural establishments multiplied by the total civilian population. The consequences of choosing these particular measures will be dealt with briefly in our concluding remarks.

In a mechanical sense, our simulations yield these counterintuitive results for the following reasons. The level of the capital stock is dominated by shocks to the model's "technology variable": Given the behavior of technology shocks, inflation-induced variations in taxes on capital income have only a small effect on the cyclical behavior of the capital stock. But because the preference specification we use in our simulations implies that technology growth exerts offsetting substitution and income effects on the household leisure choice in the long-run, aggregate hours tend to exhibit greater sensitivity to inflation shocks than does the capital stock.

The effect on hours occurs for two reasons. The first is that individuals are taxed on nominal asset income. Because inflation is persistent, an inflation shock decreases the after-tax rate of return on savings, causing individuals to substitute intertemporally toward current consumption and current leisure. That is, higher inflation causes hours worked to decrease and current consumption to increase. This drives the model's relationship between inflation and aggregate hours.

The second is due to a kind of "bracket creep": Even though we assume wage payments are indexed when determining taxable income, the effect of overstating real capital income in an inflationary environment causes inflation-induced increases in marginal tax rates. With flat taxes, the variability of hours is not affected by the introduction of variable inflation. With progressive taxes, however, the variability of hours increases substantially and the covariance between hours worked and output falls substantially with the introduction of variable inflation. Introducing inflation/tax interactions also appears to have some effect on the output/hours correlation.

The conclusions of our investigations are considerably different from what we had conjectured a priori. Despite the fact that the model predicts "significant" steady-state effects of inflation/nominal-tax interactions, we find that although variable inflation does appear to increase the variability of consumption and decrease the variability of investment somewhat, there is little indication in our model that these types of interactions are necessary to explain the broad statistical characteristics of the postwar U.S. economy. Furthermore, to the extent that inflationary biases from capital-income mismeasurement affect cyclical behavior, the effects appear to affect labor more than capital.

II. A Brief Look at Inflation and the U.S. Economy

Table 1 presents selected sample moments for several key macroeconomic variables over the 1955-1988 period. Most of the variables, all of which are described in the table, are expressed in logarithms and as deviations from a common deterministic trend. The exceptions are aggregate hours, the average marginal tax rate, and inflation. In accordance with our simulation framework, aggregate hours and inflation (which is expressed in levels) are treated as trendless stationary variables. A separate trend was estimated for the average marginal tax rate.

Most of the information in table 1 is recognizable from almost any real business cycle study. However, our detrending procedure differs from the more common approach of filtering the data using the method first suggested by Hodrick and Prescott (1980).[4] Relative to the population moments obtained

[4] As Kydland and Prescott (1990) note, the Hodrick-Prescott filter can be thought of as an approximation to stochastic variation in trend. Although we have chosen to use a log-linear deterministic trend as a first pass at the data, we plan to examine the consequences of alternative filtering techniques at a later time. Even though the exact nature of "stylized facts" may be filter dependent (see, for instance, Nelson and Kang [1981] and Cogley [1990]), the

using the Hodrick-Prescott filter, the deterministic log-linear filter reverses the relative size of the standard deviations of hours and productivity and substantially increases the relative standard deviation of the capital stock.

For purposes of this investigation, we focus on the behavior of tax variables and the correlations of aggregate variables with inflation. We can see from table 1 that, for the chosen sample period, personal tax revenues are roughly two and one-half times as variable as GNP, while average marginal tax rates are roughly half as variable as GNP. Inflation has a much stronger contemporaneous correlation with tax revenues than with average marginal tax rates. The contemporaneous correlation of personal tax revenues with output is positive, although small, while the correlation between output and average marginal tax rates is strongly negative.

The correlations of inflation and investment and inflation and the capital stock are .6 and .67, respectively. The correlations of inflation with output and consumption are both positive (.1 and .26, respectively), but much lower than the investment/inflation correlation. The correlation of hours and inflation, on the other hand, is negative and equal to -.36. Attempting to understand these patterns in the context of inflation/tax interactions is the primary goal of our dynamic simulations in section VII.

III. The Simulation Framework

A. Households and Preferences

Our model is an overlapping-generations framework with a basic structure

---

ability of the simulation model to mimic population moments should be independent of the filtering technique if the model is indeed a useful characterization of the real economy.

similar to that of AK. In the basic AK framework, the economy is populated by a sequence of distinct cohorts that are, with the exception of size, identical in every respect. Each generation is 1+n times larger than its predecessor, and like AK, we assume that individuals live for 55 periods with perfect certainty.

In our version of the AK model, individuals alive in calendar time s choose expected consumption and leisure paths to maximize the expected value of a time-separable utility function given by

$$U_t = E_s \sum_{j=t}^{55} \beta^{j-t} \left(\frac{c_{j,s+j-t}^{1-\sigma_c}}{1-\sigma_c} + \alpha \frac{l_{j,s+j-t}^{1-\sigma_l}}{1-\sigma_l} \right), \qquad (1)$$

where t indicates cohort age at time s and $c_{j,s+j-t}(l_{j,s+j-t})$ is the consumption (leisure) of an age j individual at time s+j-t. The preference parameters β, σ_c, σ_l, and α represent, respectively, the individual's subjective time-discount factor, the inverse of the intertemporal elasticity of substitution in consumption (c), the inverse of the intertemporal elasticity of substitution in leisure (l), and the utility weight of leisure.

The operator E_s is a mathematical expectation conditional on the information set Ω_s. We assume throughout that Ω_s includes the realizations of all stochastic variables up through time s. Since all of our simulation experiments assume fixed statutory tax codes, Ω_s also includes knowledge of the nominal tax structure for all s.[5]

The time s budget equation for individuals aged t is given by

$$a_{t,s} = \frac{1+R_s}{1+\pi_s} a_{t-1,s-1} + \epsilon_t w_s (1-l_{t,s}) - c_{t,s} - T_{t,s}, \tag{2}$$

where $a_{t,s}$ refers to nonhuman asset acquisitions and $T_{t,s}$ refers to personal tax payments. The pre-tax market wage at time s is given by w_s, and the variable ϵ_t is an exogenous productivity endowment of an individual in the t^{th} period of life.

Nonhuman assets represent claims to physical capital that earn a nominal one-period rate of return R_s. We assume the existence of a single homogeneous asset class, thus eliminating the potential consequences of tax-induced portfolio adjustments that would occur in a model with heterogeneous assets.

Personal tax payments in the model arise from a progressive income tax supplemented by a system of lump-sum transfers. Total tax payments are thus given by

$$T_{t,s} = \int_{y=0}^{y^*} g(y)\, dy + \tau_{t,s}, \tag{3}$$

where y is the tax base, $g(\cdot)$ is a function relating the tax base to marginal tax rates, and $\tau_{t,s}$ is a lump-sum tax (or transfer). We assume throughout

[5] Rate structures and personal exemption levels in the personal tax code were relatively stable until the late 1970s. Similarly, changes in the treatment of income from capital gains and personal deduction provisions were relatively infrequent until the early to middle 1970s. Since that time, however, the frequency of structural changes in the personal tax code has increased dramatically. The assumption that individuals take the tax structure as fixed is therefore a better approximation for the first 20-25 years of the post-World War II era than for the period since the mid-1970s (in the United States, at least). Bizer and Judd (1989) discuss some of the consequences of stochastic tax structures in the context of a tax structure with exogenous marginal tax rates.

that lump-sum taxes and transfers are used to offset all revenues raised through the income tax. In so doing, we concentrate our attentions on the pure distortionary effects of the tax system.

We define the tax base y^* as

$$y^*_{t,s} = \epsilon_t w_s(1-l_{t,s}) + \frac{R_s a_{t-1,s-1}}{1+\pi_s} - D_{t,s}, \tag{4}$$

where $D_{t,s}$ represents adjustments to gross income such as allowable deductions and personal exemptions. By defining taxable income in this way, we are implicitly adjusting tax brackets for inflation in a manner that is roughly consistent with the indexing provisions in the current tax code (see Tatom [1985] and Altig and Carlstrom [1991] for a discussion of those provisions).

Our definition of the tax base means that, for any s, real capital income is overstated by an amount equal to $\pi_s a_{s-1}/(1+\pi_s)$.[6] This overstatement causes inflation to have real effects that can arise through two separate channels. The first is a pure capital-income mismeasurement effect that lowers the after-tax real return to capital when nominal interest rates rise. The second is a type of bracket creep effect that occurs under a progressive tax system when overstatement of real capital income pushes individual taxpayers into higher marginal tax brackets. We will see that both of these effects can affect the behavior of aggregate hours, a result alluded to in the introduction.

In addition to equation (2), we impose the initial condition $a_{0,s}=0$ for all s, and the terminal condition that the present value of lifetime resources not exceed the present value of lifetime consumption plus tax payments. In

---

[6] Real capital income is given by $(R_s-\pi_s)a_{s-1}/(1+\pi_s)$. Deflating nominal income by $1+\pi_s$ thus overstates real income by $\pi_s a_{s-1}/(1+\pi_s)$.

the absence of a bequest motive and lifetime uncertainty, the wealth constraint implies that $a_{55,s}=0$.

Equations (1)-(4) yield the first-order conditions

$$c^{-\sigma_c}{}_{t,s} = \beta E_s\left(c^{-\sigma_c}{}_{t+1,s+1}\cdot\frac{1+R_{s+1}}{1+\pi_s} - \frac{\partial T_{t,s}}{\partial a_{t,s}}\right) \tag{5}$$

and

$$l_{t,s} = \alpha^{\frac{1}{\sigma_l}}\left(\epsilon_t w_s - \frac{\partial T_{t,s}}{\partial l_{t,s}}\right)^{-\frac{1}{\sigma_l}} c_{t,s}^{\frac{\sigma_c}{\sigma_l}}, \tag{6}$$

or, in more familiar terms,

$$c^{-\sigma_c}{}_{t,s} = \beta E_s\left[c^{-\sigma_c}{}_{t+1,s+1}\frac{1+R_{s+1}(1-\rho_{y^*})}{1+\pi_s}\right] \tag{7}$$

and

$$l_{t,s} = \alpha^{\frac{1}{\sigma_l}}\left[\epsilon_t w_s(1-\rho_{y^*})\right]^{-\frac{1}{\sigma_l}} c_{t,s}^{\frac{\sigma_c}{\sigma_l}}, \tag{8}$$

where ρ_{y*} is the marginal tax rate of an individual with taxable income y^*.

B. Firms and Technology

Output in the model is produced by competitive firms that combine capital (K) and labor (L) using a neoclassical production technology. The aggregate production technology is Cobb-Douglas, defined over aggregate capital and labor supplies as

$$Y_s = AK_s^{\theta}(\exp^{\mu s+z_s}L_s)^{1-\theta}. \tag{9}$$

The parameter θ is capital's share in production, A is an arbitrary scale factor, μ is the deterministic growth rate of effective labor units, and z_s is the realization of a stochastic labor-augmenting "technology variable."[7] In what follows, we normalize A to one.

We follow Prescott (1986) and assume that z_s is generated by the process

$$z_s = \eta z_{s-1} + \xi_s, \tag{10}$$

where ξ_s is the realization of an independent and identically distributed (iid) normal random variable with mean zero. We further assume that the absolute value of η is strictly less than one.

Aggregate capital and labor supplies are defined from individual supplies as

$$K_s = (1+n)^{s-1}\sum_{t=1}^{55}\frac{a_{t,s-1}}{(1+n)^{t-55}} \tag{11}$$

and

$$L_s = (1+n)^{s}\sum_{t=1}^{55}\frac{\epsilon_t(1-l_{t,s})}{(1+n)^{t-55}}. \tag{12}$$

Note that equations (11) and (12) are just the capital- and labor-market

[7] The debate over the exact nature of this "technology variable," which empirically is just the part of GNP that cannot be explained by measured labor and capital inputs under the maintained aggregate production technology, is well known and need not be rehashed here. We refer interested readers to the discussions in Prescott (1986), Summers (1986), McCallum (1989), and Eichenbaum (1990).

adjusted aggregate labor supply given in equation (12) and the technology parameter z_s. Dividing both sides of equation (9) by $\exp(\mu s+z_s)L_s$ yields a stationary relationship in terms of the effective capital-labor ratio, given by

$$\frac{Y_s}{\exp^{\mu s+z_s}L_s} = k_s^{\theta}. \tag{13}$$

Under the standard assumption of competitive markets, the pre-tax real wage and nominal interest rates are given by

$$w_s = (1-\theta)\,k_s^{\theta}\exp^{\mu s+z_s} \tag{14}$$

and

$$R_s = (\theta k_s^{\theta-1}-\delta)\,(1+\pi_s) + \pi_s, \tag{15}$$

where δ is a constant real rate of depreciation on physical capital. We assume throughout that, for tax purposes, capital income is calculated exclusive of real depreciation costs.[8]

Finally, we complete our description of the model by including the goods-market clearing condition given by

[8] The effect of inflation on investment decisions under historical cost depreciation rules is of course central to any complete discussion of inflation/tax-system interactions. The literature that specifically examines this issue is quite large. A few examples that concentrate on quantitative aspects of the issue are Feldstein and Summers (1979), Auerbach (1983), and King and Fullerton (1984).

$$Y_s = C_s + K_{s+1} - (1-\delta)K_s, \tag{16}$$

where

$$C_s = (1+n)^s \sum_{t=1}^{55} \frac{c_{t,s}}{(1+n)^{t-55}}. \tag{17}$$

Note again that we do not explicitly model a monetary sector. Inflation is introduced into our framework by the addition of an arbitrary unit of account. We thus ignore the effects of seigniorage and any distortions that arise through monetary channels per se.

IV. Solving the Model

The steady state of the model is solved by setting the values of the stochastic variables z_s and π_s equal to their unconditional means and applying the iterative procedure described in AK (chapter 4). This section briefly describes the procedure we use for simulating what we loosely refer to as the stochastic path of the economy.

The steady-state calculations provide us with endpoints for the stochastic transition path simulations. The behavior of the economy along the stochastic path is derived by calculating a sequence of transitions to deterministic steady states arising from a sequence of inflation and technology "shocks." The stochastic path of the economy is given by the envelope of the first-period observations obtained from each of these transition paths. Specifically, we proceed as follows:

(i) Starting from the initial steady state, we set the realization of z_1 and π_1 equal to the actual values calculated for the U.S. economy in 1951. Given assumed stochastic processes for inflation and the technology variable (described in the next section), these realizations imply conditional expectations for the time paths of z_s and π_s for $s = 1 \ldots \infty$. The implied expected values of inflation and the technology variables are then substituted into individual first-order conditions and wealth constraints to obtain certainty equivalent transition paths to the deterministic steady state.[9] Assuming no further shocks to the inflation or technology process, these transition paths correspond exactly to the perfect foresight transition paths calculated in the typical AK simulation exercise. The initial element of the transition path calculated in this way gives us our observations of the economy for s=1.

(ii) The asset levels obtained for the s=1 calculations are used as inputs for the second stochastic path observation, s=2. For example, the assets accumulated by the age t cohort at s=1 would be those brought into the period by the cohort that is age t+1 at time s=2. From equation (11), aggregate asset accumulation at s=1 provides the capital stock for the calculations at time s=2.

(iii) Given the initial conditions implied by the s=1 calculations, the 1952 values of inflation and the technology variable are used to repeat the procedure described in step (i). Specifically, the new values of z and π imply a revision in the expected path of inflation and the technology variable. Based on the revisions of this expected path and the period's initial conditions, a new transition to the deterministic steady state is calculated, the initial observation of which describes the economy at s=2.

(iv) The entire sequence of stochastic path observations is obtained by repeating steps (i)-(iii) using observations of the calculations at s-1 as

---

[9] Because we assume stationary processes for both inflation and the technology parameter, the steady state is invariant to specific realizations of these processes. In the actual simulations, we allow the model 110 periods to converge to the steady state.

initial conditions for time s and the realized values of inflation and the technology variable for the U.S. economy from 1951 through 1988. This procedure is represented schematically in figure 3.[10]

V. Parameterizing the Model

Once values are chosen for the model's parameters, solutions are obtained using the numerical methods just described. Our benchmark values for most of the preference and technology parameters are reported in table 2. These values are generally consistent with those found in other simulation studies (see, for example, AK and Prescott [1986]) and are motivated by independent empirical studies.[11]

The sensitivity of our simulations to selected parameter assumptions is partially addressed in the next section. The main focus of the balance of this section is the motivation for three elements not described in table 2: the personal tax code, the stochastic processes for the technology variable, and the rate of inflation. We base each of these parameterizations on simple regression analysis.

A. The Personal Tax Code

We model marginal tax rates as a linear function of taxable income. Thus, g(y) in equation (3) is given by

---

[10] It is not possible in general to guarantee that the model will converge to a unique equilibrium. The best that can typically be done is to hope for convergence and examine the sensitivity of the model's solutions to starting values. See, for example, the discussions in Rios-Rull (1990) and Laitner (1990).

[11] An exception is the preference parameter α, which measures the utility weight of leisure. Our choice of $\alpha=.5$ implies that the average individual allocates approximately 24 percent of his or her total time to labor-market activity in the steady state. This amounts to an average workweek of just over 40 hours.

$$g(y) = g_0 + g_1 y, \tag{18}$$

where y is defined as in equation (4). As a benchmark case, we obtained the parameters g_0 and g_1 by regressing marginal tax rates for married persons filing jointly on the taxable income levels mandated by the 1965 tax code (in 1988 dollars). This procedure yields the values g_0=.146 and g_1=.0000023.

The 1965 personal tax rate structure was chosen for three reasons. First, the 1965 rate structure, which was designated in the Revenue Act of 1964, was in effect longer than any other postwar rate structure. Second, a linear function seems to fit the 1965 rate structure reasonably well.[12] Third, linear approximations of the 1965 rate structure yield values of g_1 that are smaller than those obtained by performing analogous regressions with other postwar rate structures. Since the benchmark tax structure turns out to be too progressive in some important ways, our results would not be improved by imposing tax structures that are more progressive (in the sense of yielding larger values of g_1).

In addition to choosing the tax parameters g_0 and g_1, it is necessary to convert the gross income figures determined by the model into taxable income values to be used in determining marginal tax rates. We proceed in two steps, first scaling the absolute levels of gross income and then adjusting gross income to arrive at taxable income values (by specifying levels for deductions

[12] By "reasonably well" we mean that a linear function is a good choice among the class of continuous, differentiable functions. It is unclear how our results would be biased by approximating the discrete tax code with a continuous (and differentiable) function. On one hand, the discreteness of the true rate structure means that many people face constant tax rates at the margin, a feature that is obviously not captured by the linear rate structure we impose. On the other hand, changes in marginal tax rates in the true personal tax code are much larger for affected individuals than changes implied by our hypothetical tax code. We are currently working on extensions of the model that we hope will shed light on this issue.

and personal exemptions). The details of our calculations are described in an appendix.

B. The Inflation and Technology Processes

As noted in section III, our stochastic path simulations use realized values of inflation and the technology variable for the U.S. economy over the period 1951-1988. The inflation variable is simply the growth rate in the CPI-U. The technology variable z is calculated from the relationship

$$z_s = \ln(Y_s) - [\ln(A) + \mu s + (1-\theta)\ln(L_s) + \theta\ln(K_s)], \qquad (19)$$

which comes directly from equation (9).

Equation (19) is made empirically operational by letting Y equal annual GNP, K equal the fixed nonresidential capital stock, and L equal total hours calculated from data on hours and total employment (see table 1 for exact definitions and data sources). We set θ=.36 in constructing the series described by equation (19).

Note that we eliminate the deterministic trend when calculating the value of the technology variable. This allows us to solve the simulation model assuming zero growth per capita. In particular, this approach avoids problems presented by the growth in the real wage indicated by equation (14).[13]

Parameterizing expectations requires choosing specific processes for inflation and the technology variable. The latter is provided by taking the series calculated according to equation (17) and estimating the model given in

[13] This clarification was prompted by the remarks of Alan Auerbach. See Hansen (1989) for a detailed discussion of the technical issues associated with growth in real business cycle models.

equation (9) over the sample period 1952-1988.[14] This procedure yields the estimated value $\hat{\eta}=.80$.[15]

A second-order autoregressive process is estimated for the inflation rate over the period 1953-1989. We assume the absence of trend in the inflation rate and find that a second-order process is sufficient to eliminate serial correlation in the residuals.[16] The estimated inflation model is

$$\pi_s = .012 + 1.007\pi_{s-1} - .296\pi_{s-2}. \tag{20}$$

Note that the intercept implies a steady-state annual inflation rate of just over 4 percent.

VI. Steady-State Experiments

The steady-state output effects of distortions arising from inflation/tax-system interactions (specifically, from capital-income mismeasurement) are reported in table 3. The experiments reported therein use the benchmark parameterization described in table 2. In addition to the linear tax scheme described in the previous section (which we designate the Progressive I case), we consider a less progressive case and a flat-tax-rate

---

[14] Because A and μ are not directly observable, we first construct the variable $Z_s = \ln(Y_s)-(1-\theta)\ln(L_s)-\theta\ln(K_s)$. Estimations of η and the residual series ξ_s are then obtained by regressing the Z on a constant, a time trend, and its own values lagged once.

[15] This is the value we would expect to find at an annual frequency if the autoregressive parameter found from a regression on quarterly data was roughly .95. Having said this, we note that the properties we assume for the ξ_s process are not appropriate if the true process is iid at a quarterly frequency. In fact, the residual series that we estimate exhibits some serial correlation, which indicates the possibility of time aggregation bias in the annual data.

[16] Trend terms are statistically insignificant when added to the regression model.

case. The parameterizations of each of the separate regimes are chosen to yield steady-state average marginal tax rates of about 23 percent.[17]

In each of the cases reported in table 3, the steady-state output losses due to capital-income mismeasurement are relatively large: Even in the flat-tax case, a 4 percent steady-state rate of inflation results in steady-state output levels that are only about 95 percent of the levels that would be realized in a zero-inflation steady state.

The lower panel of table 3 reports the value of output losses per dollar of revenue raised through the income tax system. The losses range from 4.7 percent (in the flat-tax case) to 5.2 percent (in the Progressive I case) when the steady-state annual inflation rate is 4 percent. Although not reported in table 3, almost all of the reduction in output results from a reduction in the capital stock, not from a large reduction in hours worked.

We emphasize that comparisons across the experiments reported in table 3 are inappropriate, since no attempt has been made to standardize tax revenues under the different tax codes. In addition, the figures reported in table 3 provide no information about welfare impacts or the relative efficiency of raising revenue through inflation/tax interactions relative to statutory tax changes in a zero-inflation environment.[18] The figures in table 3 are useful

---

[17] The 23 percent figure is obtained from the calibration exercise described in the appendix, which uses the Progressive I tax scheme. Although the Progressive I tax structure was not a priori chosen to yield this value, it is gratifyingly close to the average value of 25 percent reported by Sahasakul (1986) for effective marginal tax rates on personal income over the period 1951-1982.

[18] Naturally, the relative efficiency of raising revenue through inflation/tax interactions depends on the nature of the alternative being contemplated. The life-cycle nature of our model implies that individual saving is high when income is high. Tax schemes with lesser degrees of progressivity therefore tend to result in lesser degrees of "crowding-out" of steady-state capital and output for a given revenue requirement.

only as a means of demonstrating that the long-run consequences of the inflation/tax interactions we are modeling are significant.

Table 4 reports the results obtained by repeating the steady-state experiments after changing selected values of the benchmark parameters reported in table 2. The picture that emerges from table 4 is that greater steady-state output losses are associated with an increased willingness of individuals to shift resources intertemporally (that is, smaller values of σ_c, σ_1, and β), smaller rates of depreciation and population growth, and stronger preferences for leisure. In general, these are elements that tend to increase per capita saving rates.

The numbers reported in tables 3 and 4 assume the absence of tax arbitrage opportunities that would allow individuals to partially escape the distortionary effects of inflation on capital income by changing the way in which claims to capital are structured. We think particularly of shifts between debt and equity in a tax environment where nominal interest payments on debt are fully deductible but equity is tax preferred. The last row of table 4 gives results derived from the case where debt and equity instruments with these tax characteristics are introduced. This extension of the model, which essentially follows Miller (1977), is otherwise identical to the basic model used in the main body of this paper.

In the reported simulation, corporate tax rates are set to 16.5 percent, and 65 percent of equity income is tax sheltered. Although introducing tax arbitrage opportunities does substantially reduce steady-state output losses from capital-income mismeasurement, simply stating the assumptions of this experiment suggests a problem with implementing this particular extension of the model: The corporate tax rate necessary to generate an equilibrium with both debt and equity is extremely small -- much smaller than most estimates of the effective corporate tax rate.

We could, of course, attempt to justify the low corporate tax rate by appealing to bankruptcy risk or losses of nondebt tax shields. Also, higher corporate tax rates could be introduced into the model by increasing the fraction of equity income that can be excluded from the calculation of taxable income. However, neither of these strategies seems likely to overcome the essential problem we face with our current model choice; that is, the particular life-cycle structure of our model does not provide enough heterogeneity to generate equilibria with realistic tax arbitrage behavior, a weakness that is manifested in a very small parameter space over which both debt and equity are held in the steady-state equilibrium.[19]

To counter this problem, we are currently working on extensions of the model with intracohort heterogeneity. We note for present purposes that one of the implications we derive from the dynamic simulations reported in the next section is the relatively small effect that inflation/tax interactions seem to have on, say, the variability of output in our model. In this sense, excluding tax arbitrage opportunities strengthens our result.

VII. "Stochastic Path" Simulations

The results of simulating the model using the method described in

---

[19] This weakness is manifested in two related ways. First, the debt-equity ratio is extremely sensitive to the rate of inflation. For the parameterization reported here, the steady-state debt-equity ratio falls from .734 to .225 as the steady-state rate of inflation increases from 0 to 4 percent. (Note also that the negative relationship between the debt-equity ratio and inflation is counterfactual.) Second, small changes in the corporate tax rate push all individuals to corners with respect to their desired holding of particular assets. Holding all else constant, decreasing the corporate tax rate by 1 percent results in steady-state equilibria in which only equity is held. Increasing the corporate tax rate by 1 percent results in equilibria in which only debt is held.

section IV are reported in tables 5-7. Each of the simulation exercises assumes the benchmark parameterization given in table 2 and either the flat-tax scheme (table 5), the Progressive I scheme (table 6), or the intermediate Progressive II scheme (table 7). The simulations are conducted for the sample period 1951-1988 with actual technology shocks (ξ_s) as inputs. In addition, for the variable inflation case, we include actual CPI-U inflation rates as inputs. In order to minimize the effect of the initial conditions, we calculate simulated sample moments for the observations obtained for the period 1955-1988.

Looking first at the constant inflation cases, we find that the standard deviations of output, consumption, and investment are largely invariant to the tax regime. The standard deviation of output is very close to the standard deviation found in the data, with increases in the progressivity of the tax code inducing slightly less volatility in output. The relative standard deviation of consumption is also very close to that found in the data (e.g., .73 for the Progressive II case versus .71 for the U.S. data). Investment, however, is somewhat smoother (relative to variation in output) than suggested by the data (2.06 for the Progressive II case versus 2.23 for the actual data). The model also exhibits variation in the capital stock that is smaller than that in the U.S. economy (as measured by nonresidential fixed capital). The relative standard deviation in the Progressive II case is .95, versus 1.15 for the U.S. economy. Productivity has slightly too much variability (.91 for the Progressive II case versus .85 found in the data). Again, the relative standard deviation is not substantially affected by the tax regime when inflation is constant.

The correlations of output with consumption, investment, and capital are all positive, but tend to be higher than the correlations found in the actual data. This is not particularly surprising given the highly specific nature of the model and the probable magnitude of noise in the actual data. Also, the standard deviation of hours given by the model is much lower relative to the standard deviation of output than is true for the aggregate hours/output relationship in the data. This result is familiar from real business cycle studies with the simple type of labor- and goods-market structures we have assumed.[20]

The ability of the model to mimic the behavior of the U.S. economy is also demonstrated in figures 4 and 5, which plot the actual and simulated paths of hours and capital from 1955-1988.[21]

Although the general trend in aggregate hours is replicated by our model, figure 4 clearly demonstrates the overly smooth behavior of simulated hours relative to actual hours.

The simulated path of capital matches the data quite well until the late 1970s, at which point it begins a decline toward below-mean values that persists through 1988. The capital stock calculated from the data appears to stay above its mean throughout the 1980s, however. As we note in the

---

[20] We do not view our version of the AK framework as a competitor to standard real business cycle models and certainly do not mean to engage in a "horse race" of matching moments. However, given differences in structure and solution approach, we would be concerned if we were not generally able to claim that our approach yields results that are in the ballpark of alternative simulation frameworks. In fact, we believe that they are. Consider, as a basis of comparison, the "basic model" reported in McCallum (1989). The relative standard deviations of consumption, investment, capital, and hours calculated for quarterly data after application of the Hodrick-Prescott filter are .31, 3.14, .26, and .52 in the model versus .73, 3.0, .36, and .94 in the data, respectively. We feel that our results compare favorably to these. (Note, however, the somewhat different patterns that emerge relative to table 3 under the different filtering method.)

[21] The simulated series in figures 4 and 5 assume the Progressive II tax regime and are calculated with variability in both inflation and technology.

conclusion, this divergence seems to be an artifact of the way we have detrended the capital stock data.

Without inflation, the model generates too little variability in personal tax revenues and generally too little variability in average marginal tax rates. The variability of both tax measures does increase as the progressiveness of the structural tax code increases, however. The model also generates a high positive contemporaneous correlation between output and our tax measures, a result that is clearly at odds with the pattern found in the data.

The bottom panels of tables 5-7 display results obtained when inflation is introduced into the model. Inflation increases the variability of consumption and decreases the variability of investment, but has a minimal impact on the standard deviation of output and capital. The introduction of inflation also has little influence on the correlation of these variables with output.

Hours are quite another story. The relative standard deviation of hours almost doubles in the Progressive I tax structure (from .10 to .18) when actual inflation values are used as inputs. Depending on the tax structure, inflation also affects the correlation between output and hours. In the Progressive I case, the contemporaneous correlation of output and hours falls by more than 50 percent, from .52 to .21. In the flat-tax case, however, the relationship between output and hours changes considerably less, from .69 to .57.

The Progressive II case yields a relative standard deviation of the average marginal tax rate and personal tax payments much like the one found in the data (.31 and 2.50, respectively, versus .40 and 2.60 for the actual data). However, with variable inflation, the Progressive II case delivers an hours/inflation correlation that is more negatively correlated than that found in the U.S. economy (-.75 versus -.356 in the data). The lack of a corporate income tax, and hence the lack of tax arbitrage, is one reason inflation has a larger impact on this correlation than seems warranted in the data. In a model with corporate taxes, nominal interest rates will partially reflect a tax-adjusted Fisher effect, which would minimize inflation-induced changes in a consumer's after-tax rate of return.

The model also does a fairly good job of mimicking the positive correlation between output and inflation, consumption and inflation, and productivity and inflation. The correlations of productivity and consumption with inflation are mimicked reasonably well in both the constant and variable inflation models. The output/inflation correlation is closer to the data in the variable inflation case. Only with respect to investment are the results of the model clearly at odds with the data.

Overall, our model seems to be consistent with the phenomena indicated in figures 1 and 2 -- a positive correlation between the level of inflation and capital and a negative correlation between the level of inflation and the level of aggregate hours. This seems surprising at first, because the nature of the tax structure we have imposed on the model is such that inflation-induced tax distortions occur only through capital-income mismeasurement.

Figures 6 and 7, which depict the perfect foresight paths of hours and capital in response to various combinations of one-time unanticipated shocks to the inflation and technology variables, shed light on why the model generates these correlations. Each path is generated by a one-standard-deviation increase or decrease to one or both of the relevant variables. The experiments assume the Progressive I tax regime because it amplifies the tax structure found in the Progressive II tax regime. "Good shocks" are a positive shock to the technology variable and a negative shock to inflation, and "bad shocks" are a negative shock to the technology variable and a positive shock to inflation.

The interesting cases in figures 6 and 7 are those with one good shock and one bad shock. Consider the combination of a positive technology shock and a positive inflation shock. This combination is associated with capital rising above its mean but hours that are below average. Just the opposite is true for the combination of a negative technology shock and a negative inflation shock -- capital moves below average while hours move above average.

The message here is that, with respect to the evolution of the capital stock, changes in the level of the technology variable dominate distortions associated with tax distortions arising from inflation/tax interactions in the personal tax code. We infer that the positive correlation between capital and inflation does not reflect a positive causal relationship from inflation to capital, but rather coincidental correlations between the technology variable and capital and the technology variable and inflation. Indeed, although the contemporaneous relationship between the technology variable and inflation is small, the relationship is stronger -- and positive -- with inflation led one period.

How does the negative correlation between aggregate hours and inflation arise in a model in which the tax liability of labor income per se is protected from inflation by the indexing scheme we have assumed in our calculations? This pattern arises through two channels by which the overstatement of capital income spills over into individual leisure decisions. The first channel is a direct result of the fact that inflation-induced changes in nominal asset income increase an individual's real tax on capital income. In particular, inflation decreases an individual's after-tax rate of return on savings, causing individuals to substitute toward current leisure.

The second channel occurs because, with a progressive income tax, marginal tax rates increase with nominal capital income, which in turn affects both the return to saving and the future after-tax real wage. The fact that the model's output/hours correlation and the standard deviation of hours change substantially when progressivity is introduced into the tax system suggests the importance of this type of phenomenon.

VIII. Concluding Remarks

We originally set out to uncover possible business cycle effects that might arise from inflation/personal-tax interactions working through capital-income mismeasurement in inflationary environments. We suspected that we would find substantial variation in capital accumulation arising from this channel. We did not.

Instead, we found effects in an unexpected place -- the behavior of aggregate hours. We fully believe that understanding the cyclical behavior of labor will involve enriching models in ways not considered here (as in Christiano and Eichenbaum [1990], for instance). Based on our experiments, we suggest another element that may be useful in developing an understanding of the dynamic behavior of aggregate hours -- labor supply distortions that arise specifically through distortions associated with both the direct effects of capital-income mismeasurement and the more indirect effects of bracket creep. Our extension of the AK framework, which easily incorporates structural tax schemes, seems well suited to this task.

Another surprising finding is that the positive correlation between capital and inflation does not reflect any causal relationship, i.e., it seems to arise from the correlation between inflation and the Solow residual found in the data. Our model did a good job of matching the correlation between the model's capital series and the actual inflation rates for the U.S. economy even when we assumed a constant inflation rate.

Further investigation of the mechanisms that yield the results reported here is clearly in order. As noted by the discussants, the "stylized facts" of the inflation/hours and inflation/capital relationships considered here are somewhat puzzling and may not hold up to further scrutiny. Our preliminary investigations, for instance, suggest that the negative inflation/hours correlation may be sensitive to the data used in the construction of the aggregate hours variable, which is based on establishment survey data rather than on the broader household survey data. It is unclear whether the model would match the pattern of hours measured by the household data, since a different measure of aggregate hours would imply a different series for the Solow residuals.

The behavior of the capital stock series does appear to be sensitive to our detrending method. In fact, while the positive inflation/capital correlation remains when capital is detrended by its own deterministic time trend, the time path of the capital stock series behaves much like the simulated series depicted in figure 5.

Despite these caveats, it seems clear that inflation/nominal-tax interactions can have quite unanticipated effects on the macroeconomy, and that the type of simulation framework developed here can aid in understanding what these effects might be.

References

Altig, David and Charles Carlstrom, "Bracket Creep in the Age of Indexing: Have We Solved the Problem?" Contemporary Policy Issues, 1991, forthcoming.

Auerbach, Alan, "Corporate Taxation in the United States," Brookings Papers on Economic Activity, 1983, 451-513.

Auerbach, Alan and Laurence Kotlikoff, Dynamic Fiscal Policy, Cambridge University Press, London, 1987.

Bizer, David and Kenneth Judd, "Taxes and Uncertainty," American Economic Review, Papers and Proceedings, 79, 1989, 331-336.

Christiano, Lawrence and Martin Eichenbaum, "Current Real Business Cycle Theories and Aggregate Labor Market Fluctuations," Discussion Paper 24, Institute for Empirical Macroeconomics, Federal Reserve Bank of Minneapolis, January 1990.

Cogley, Timothy, "Spurious Business Cycle Phenomena in HP Filtered Time Series," Discussion Paper 90-21, University of Washington, Seattle, July 1990.

Cooley, Thomas and Gary Hansen, "The Inflation Tax in a Real Business Cycle Model," American Economic Review, 79, September 1989, 733-748.

Eichenbaum, Martin, "Real Business Cycle Theory: Wisdom or Whimsy?" Working Paper, Federal Reserve Bank of Chicago, July 1990.

Feldstein, Martin, "Inflation, Capital Taxation, and Monetary Policy," in R.E. Hall, ed., Inflation: Cause and Effect, University of Chicago Press, Chicago, IL, 1982.

Feldstein, Martin and Lawrence Summers, "Inflation and the Taxation of Capital Income in the Corporate Sector," National Tax Journal, 32, December 1979, 445-470.

Hansen, Gary, "Technical Progress and Aggregate Fluctuations," Working Paper 546, University of California, Los Angeles, February 1989.

Hodrick, Robert J. and Edward C. Prescott, "Post-War U.S. Business Cycles: An Empirical Investigation," Working Paper, Carnegie-Mellon University, Pittsburgh, PA, 1980.

Huh, Chan G., "Output, Money, and Price Correlations in a Real Business Cycle Model," unpublished manuscript, Federal Reserve Bank of San Francisco, February 1990.

King, Mervyn and Don Fullerton, The Taxation of Income From Capital, University of Chicago Press, Chicago, IL, 1984.

Kydland, Finn, "The Role of Money in a Business Cycle Model," Discussion paper 23, Institute for Empirical Macroeconomics, Federal Reserve Bank of Minneapolis, 1989.

Kydland, Finn and Edward Prescott, "Time to Build and Aggregate Fluctuations," Econometrica, 50, November 1982, 1345-1370.

Kydland, Finn and Edward Prescott, "Business Cycles: Real Facts and a Monetary Myth," Quarterly Review, Federal Reserve Bank of Minneapolis, Spring 1990.

Laitner, John, "Tax Changes and Phase Diagrams for an Overlapping Generations Model," Journal of Political Economy, 98, February 1990, 193-220.

McCallum, Bennett, "Real Business Cycle Models," in R. Barro, ed., Modern Business Cycle Theory, Harvard University Press, Cambridge, MA, 1989.

McGrattan, Ellen, "The Macroeconomic Effects of Distortionary Factor Taxation," manuscript, Duke University, Raleigh, NC, 1989.

Miller, Merton, "Debt and Taxes," Journal of Finance, 32, May 1977, 261-275.

Nelson, Charles and Heejoon Kang, "Spurious Periodicity in Inappropriately Detrended Time Series," Econometrica, 49, May 1981, 741-751.

Prescott, Edward, "Theory Ahead of Business Cycle Measurement," Carnegie-Rochester Conference Series, Autumn 1986, 11-44.

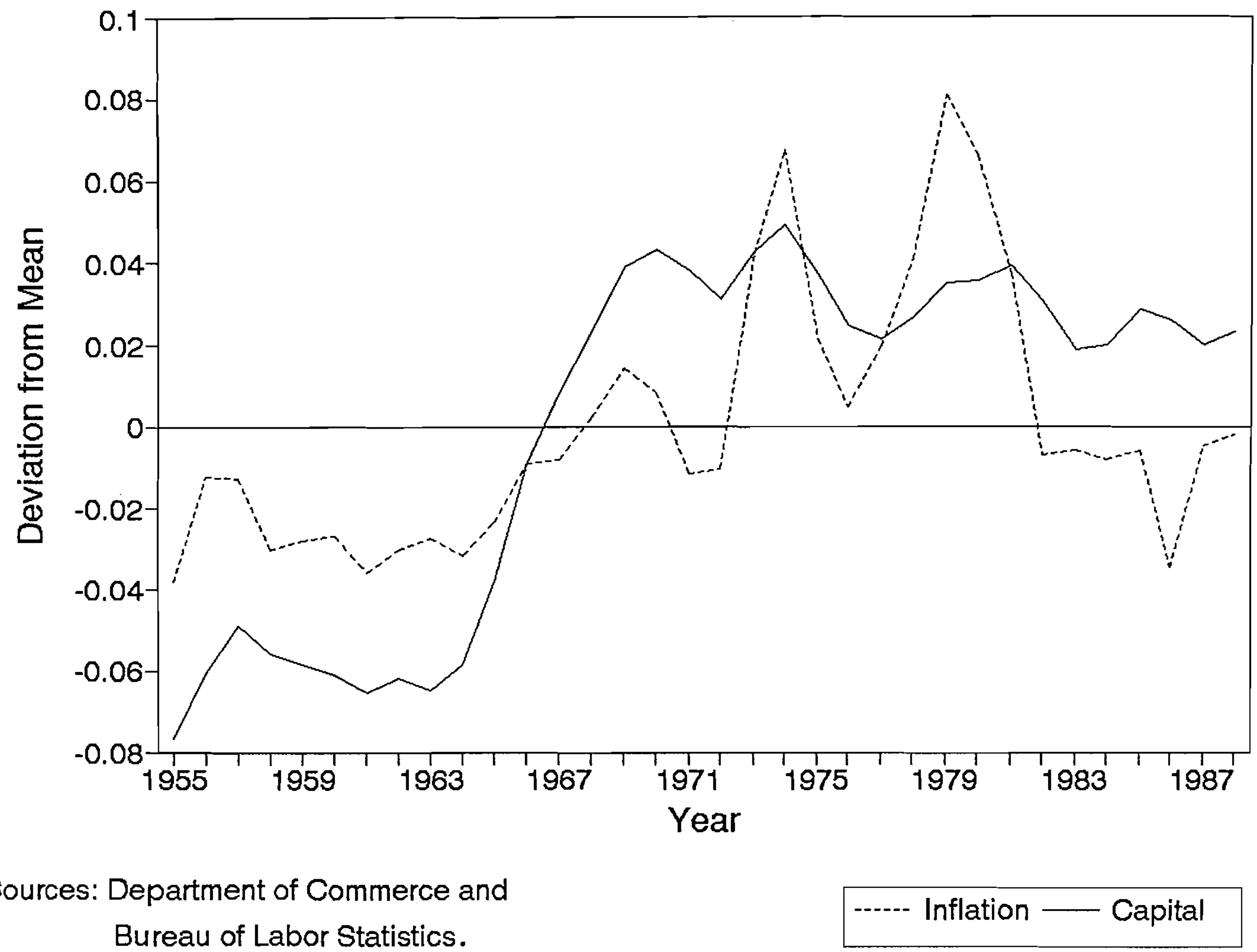
Rios-Rull, Jose-Victor, "Life-Cycle Economies and Aggregate Fluctuations," manuscript, Carnegie-Mellon University, Pittsburgh, PA, 1990.

Sahasakul, Chaipat, "The U.S. Evidence on Optimal Taxation Over Time," Journal of Monetary Economics, 18, 1986, 251-276.

Summers, Lawrence, "Some Skeptical Observations on Real Business Theory," Quarterly Review, Federal Reserve Bank of Minneapolis, 1986.

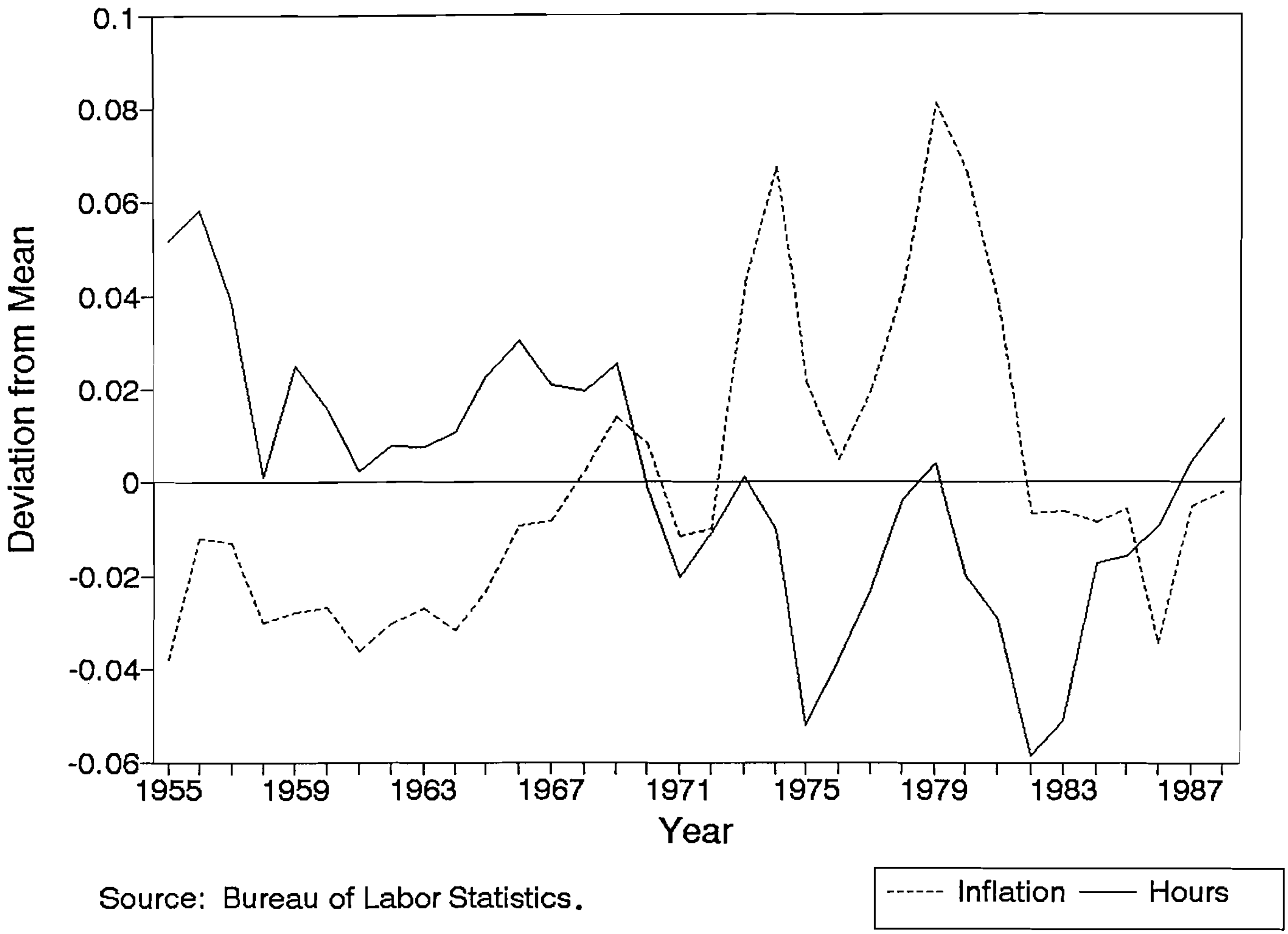
Tatom, John, "Federal Income Tax Reform in 1985: Indexation," Review, Federal Reserve Bank of St. Louis, February 1985.

Figure 1: Inflation and Capital



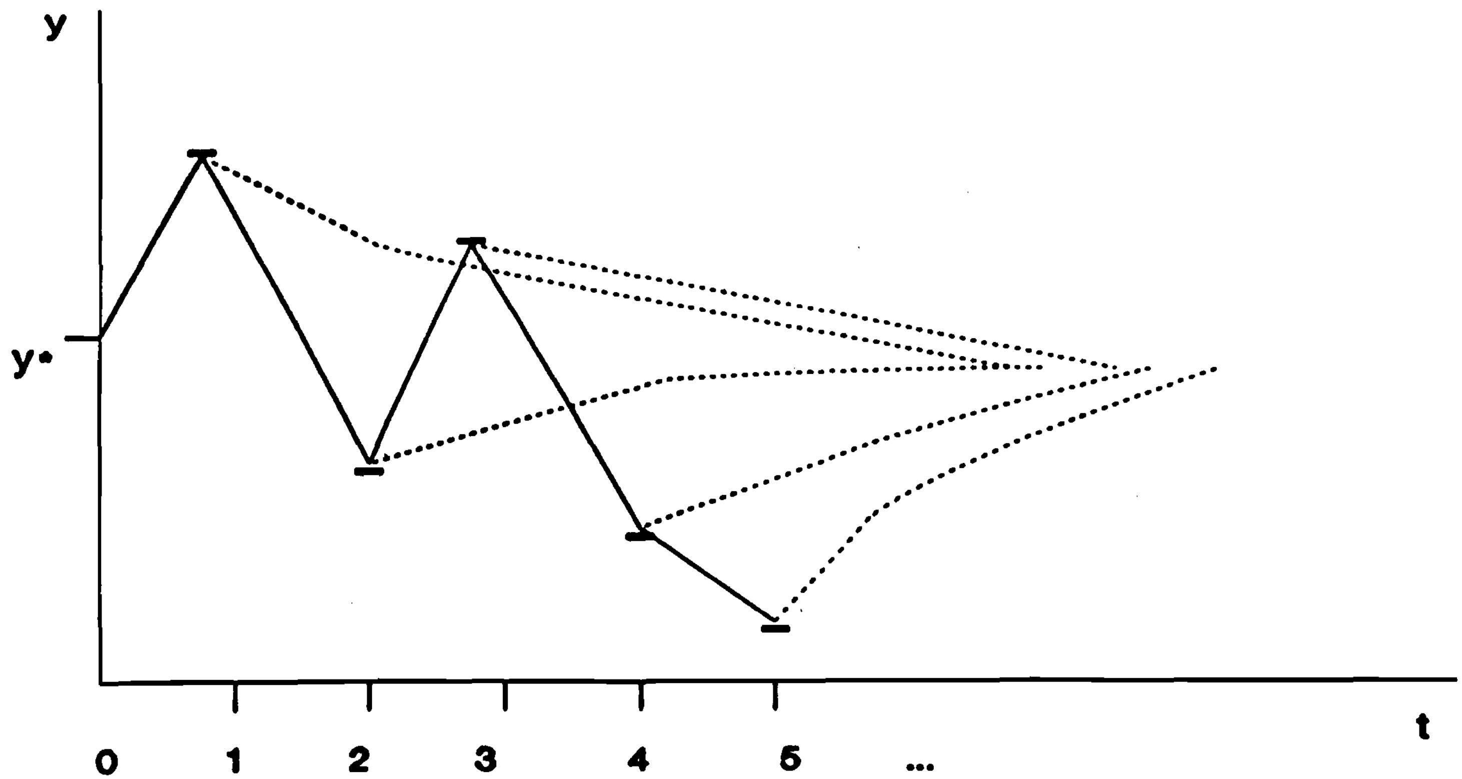
Sources: Department of Commerce and Bureau of Labor Statistics.

Figure 2: Inflation and Hours



Source: Bureau of Labor Statistics.

Figure 3: Schematic Representation of Solution Algorithm

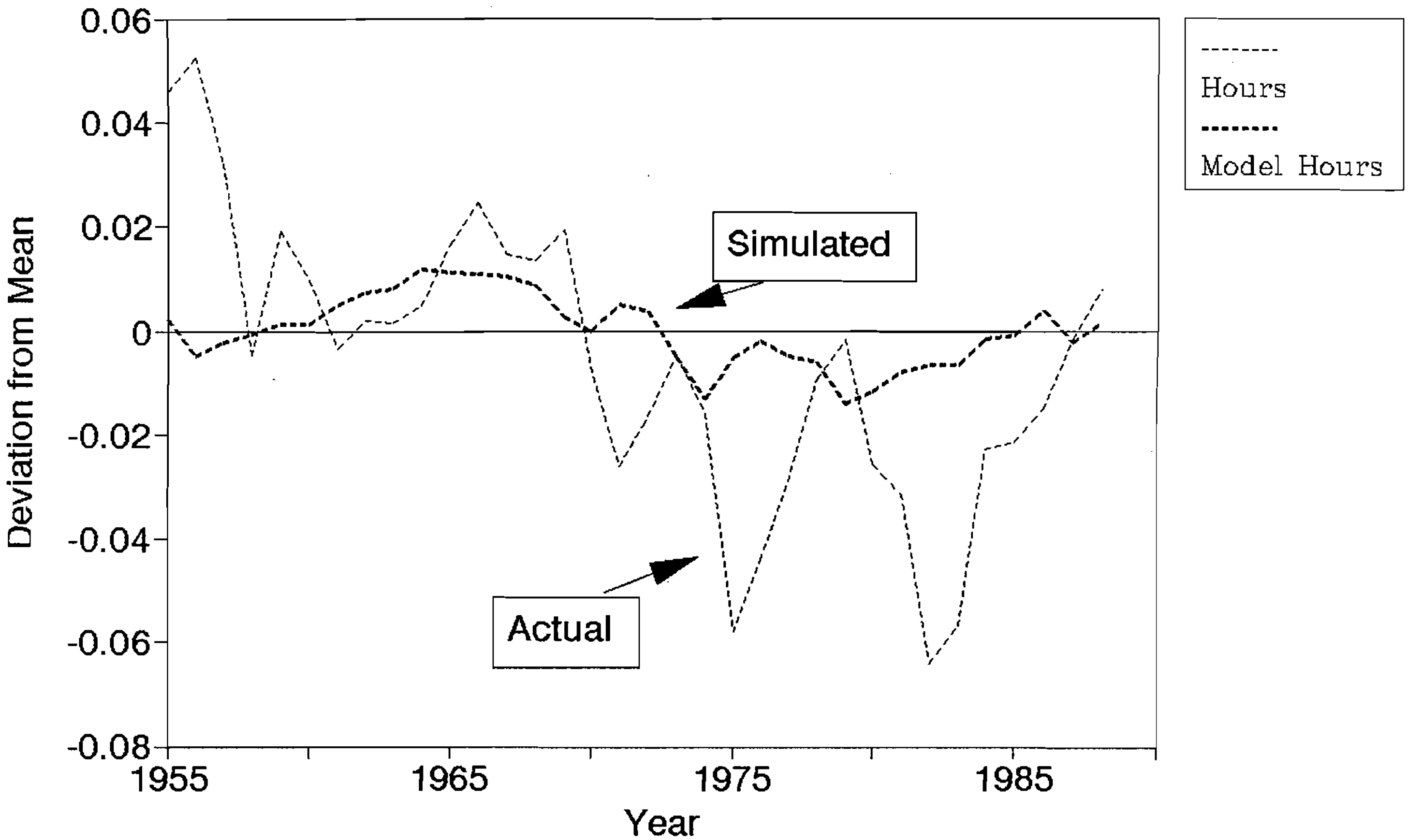


NOTE: The dashed lines represent certainty equivalent output paths conditional on the state of the economy and the realized technology shock at time t. The solid line connects the initial observation of each of these transition paths and represents the cyclical behavior of the economy conditional on the sequence of realized technology shocks.

SOURCE: Authors' calculations.

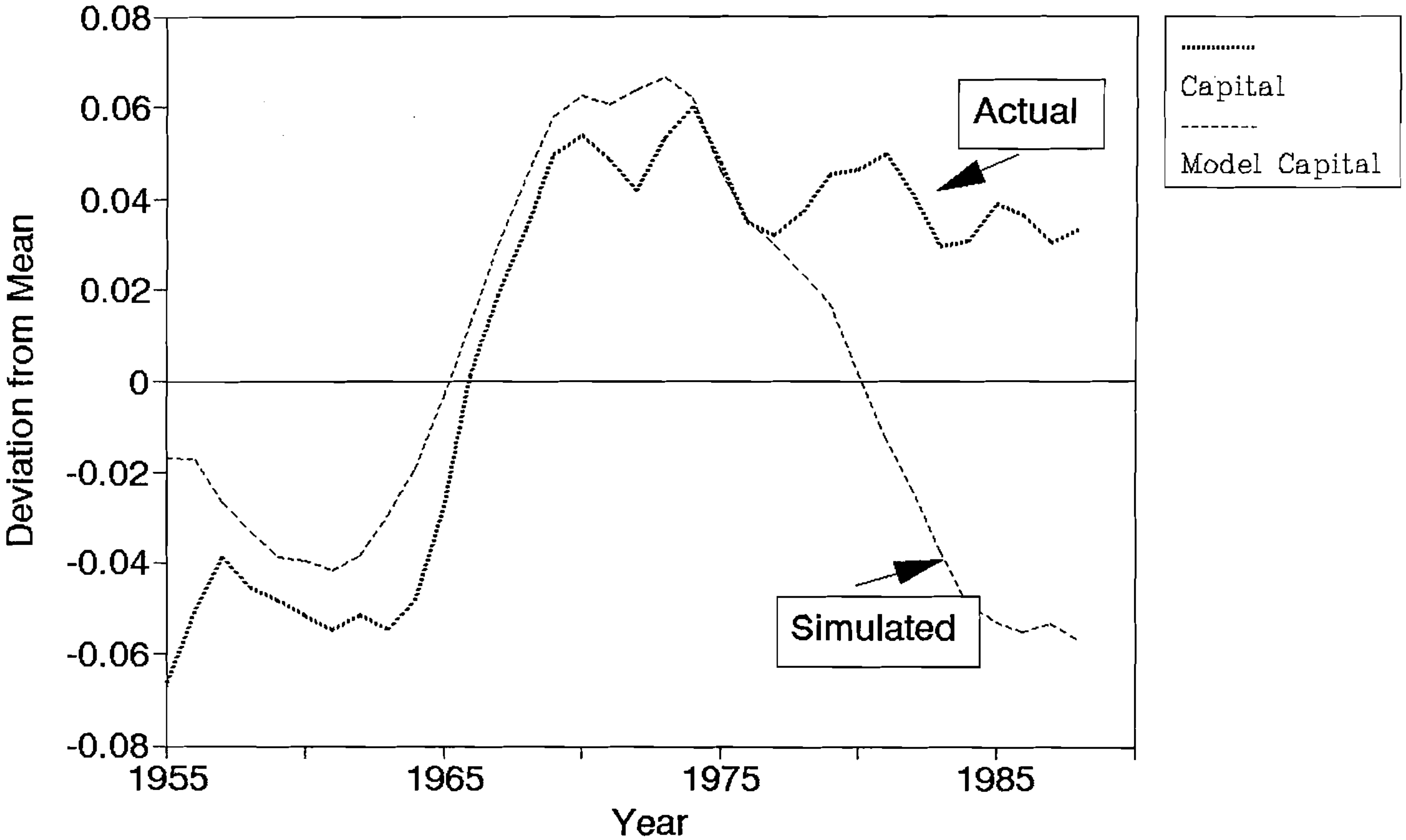
Figure 4: Hours, 1955-1988

Actual and Simulated Hours Series

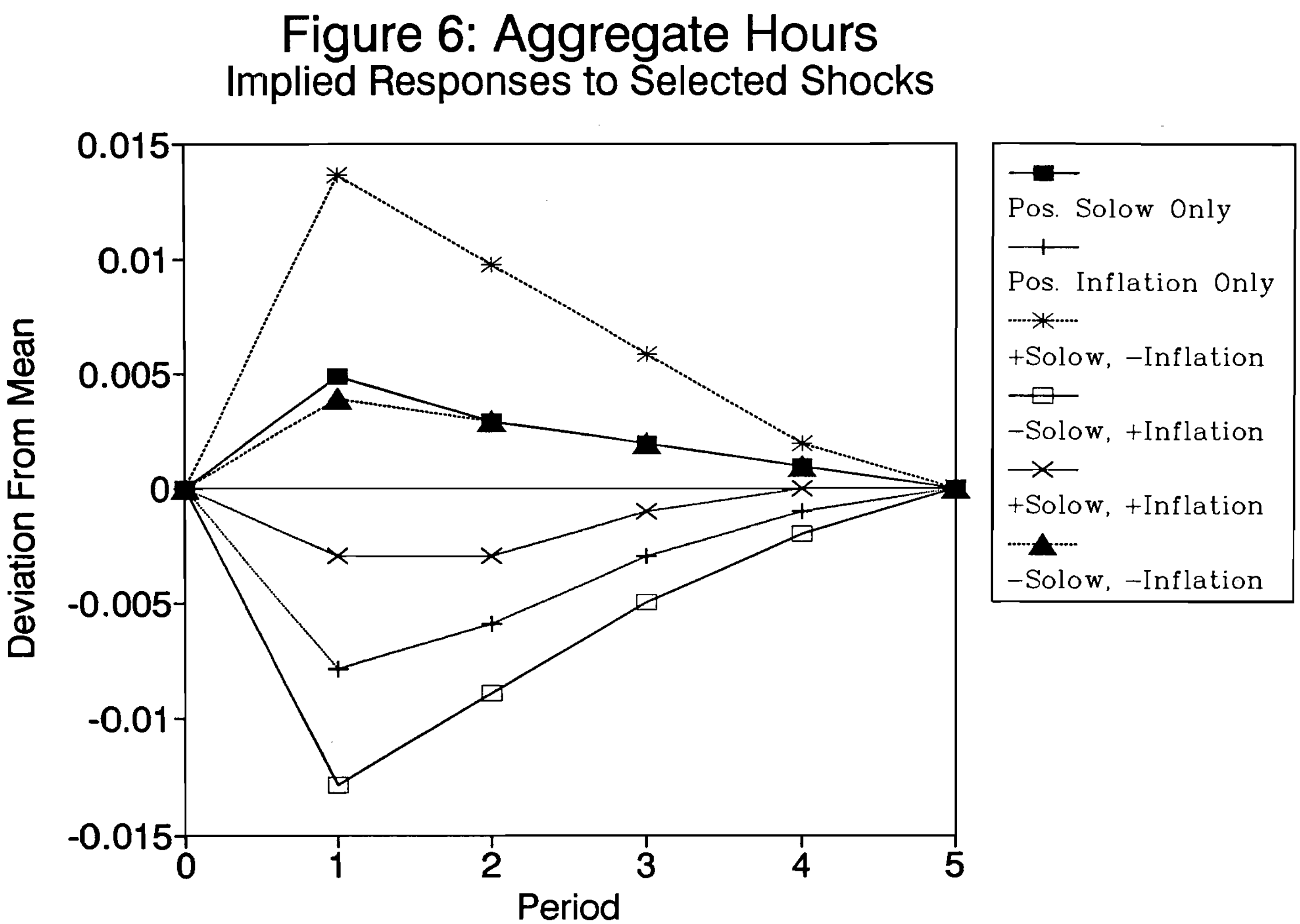


Sources: Authors' calculations and Bureau of Labor Statistics.

Figure 5: Capital, 1955-1988
Actual and Simulated Capital Series

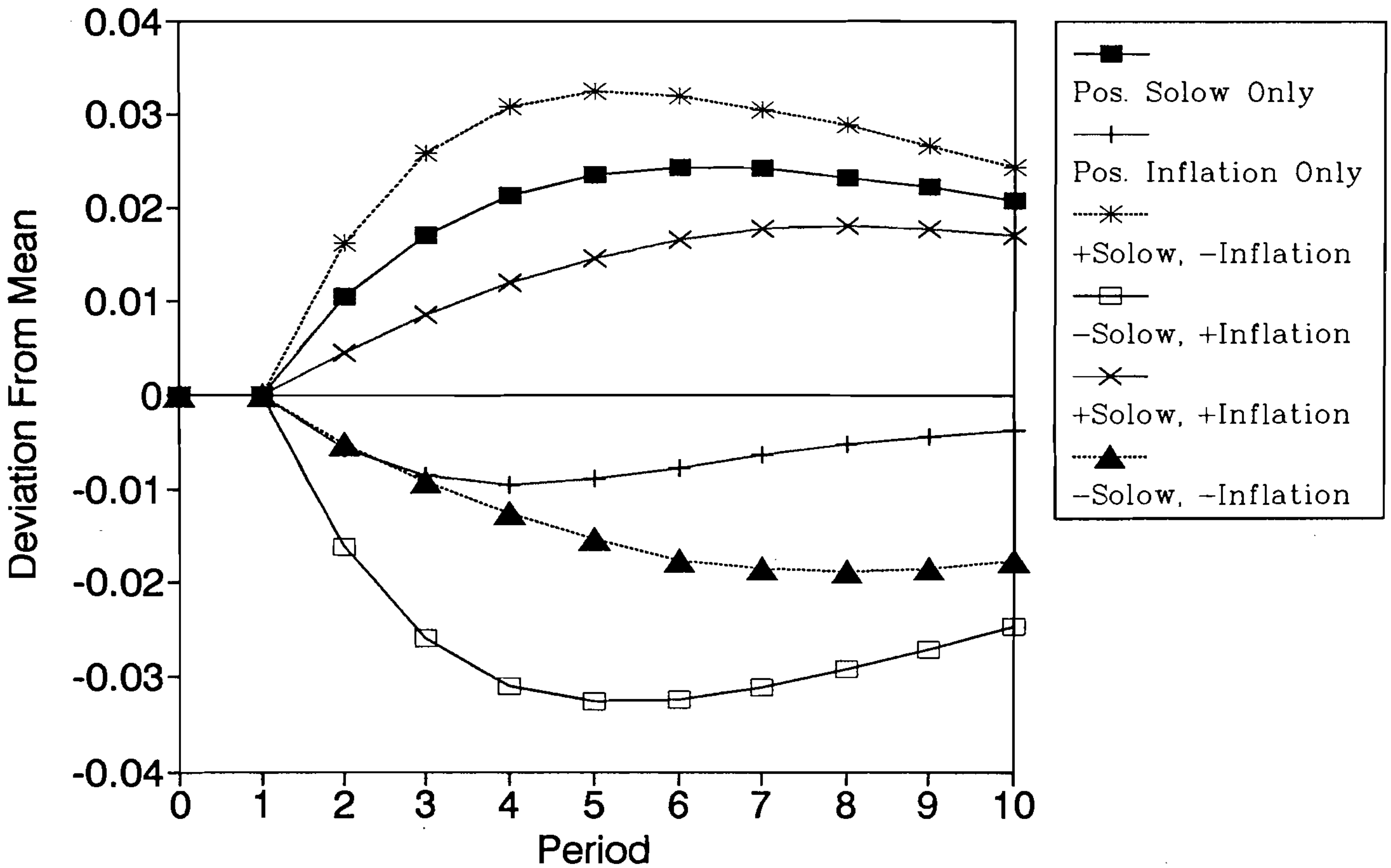


Source: Authors' calculations. See previous figures for sources of actual data.



Each line represents the perfect foresight path given a one-standard-deviation shock to the indicated exogenous variable at time 1.
Source: Authors' calculations.

Figure 7: Capital Stock
Implied Responses to Selected Shocks



Each line represents the perfect foresight path given a one-standard-deviation shock to the indicated exogenous variable at time 1.
Source: Authors' calculations.

Table 1: Sample Moments, U.S. Data 1955-1988, Common Trend*

Variable	Standard Deviation**	Contemporaneous Correlation With Output	With π
Y	4.44	-	.10
C	.71	.88	.26
I	2.23	.43	.60
H	.62	.53	-.356
Y/H	.85	.79	.34
K†	1.15	.13	.58
T	2.60	.14	.65
T'‡	.40	-.77	.07

Key:

Y: Gross National Product. Source: 1990 Economic Report of the President (EROP).
C: Personal Consumption Expenditures, Nondurable Goods and Services. Source: EROP.
I: Gross Private Domestic Fixed Investment. Source: EROP.
H: Total Annual Hours: E*AvgH*52, where E = Total Civilian Employment and AvgH = Total Private Nonagricultural Establishments Average Weekly Hours. Sources: EROP and Bureau of Labor Statistics.
K: Fixed Private Nonresidential Capital, Net of Depreciation. Source: Survey of Current Business, October 1989.
T: Personal Tax and Nontax Payments. Source: EROP.
T': Average Marginal Personal Tax Rate. Source: Sahasakul (1986).
π: Percent Change in the Consumer Price Index for All Urban Wage Earners. Source: EROP.

* All variables except T' and H refer to the logarithm of real per capita values (in 1982 dollars) relative to a common linear time trend. Hours are not detrended. The average marginal tax rate is not expressed in per capita terms, but rather as a deviation from its own trend.

** The standard deviation for output refers to the absolute percentage deviation of the detrended series. All other standard deviations are expressed relative to the standard deviation of Y.

† In an earlier draft of this paper, we mistakenly reported the capital stock correlations using the one-year-ahead stock values. Because reported capital stock figures are end-of-year, the contemporaneous values are the appropriate ones. We are grateful to Finn Kydland for drawing our attention to this point.

‡ The moments for average marginal tax rates are calculated for the sample period 1951-1982.

Table 2: Benchmark Parameters

Parameter	Description	Value
$1/\sigma_c$	Elasticity of Substitution in Consumption	1.0
$1/\sigma_1$	Elasticity of Substitution in Leisure	0.2
β	Subjective Time-Discount Factor	0.97
α	Utility Weight of Leisure	0.5
n	Population Growth Rate	0.013
θ	Capital Share in Production	0.36
δ	Depreciation Rate of Capital	0.10
ϵ_t	Productivity Endowment of an Age t Individual	*

* Given by the formula $\epsilon_t = 4.47 + 0.033t - 0.00067t^2$.

Sources: See text.

Table 3: Steady-State Output Losses

Tax Model*	π = 4%	π = 10%
Absolute Loss**		
Flat	4.7%	10.3%
Progressive I	5.2%	11.4%
Progressive II	4.9%	10.7%
Output Loss Per Dollar Revenue Gained***		
Flat	3.46	3.88
Progressive I	4.06	4.67
Progressive II	3.64	4.13

* Marginal tax rates for an individual with taxable income y are calculated as follows: Flat -- g(y) = .23
Progressive I -- g(y) = .146 + .0000023*y
Progressive II -- g(y) = .20 + .000000789*y

** Absolute losses are given by the percentage reduction in steady-state output relative to the zero-inflation steady state.

*** Losses per dollar of revenue gained are given by $-(Y_\pi - Y_0)/(Rev_\pi - Rev_0)$, where Rev_0 (Y_0) is total revenue raised by distortionary taxation (total output) in the zero-inflation steady state and Rev_π (Y_π) is total revenue raised from distortionary taxation (total output) in the steady state with the indicated inflation rate.

Source: Authors' calculations.

Table 4: Steady-State Output Losses: Alternative Parameterizations*

Parameter Change	Absolute Loss	Loss Per Dollar Revenue Gained
$\sigma_c = 3.0$	3.9%	2.80
$\sigma_c = 5.0$	3.3%	2.31
$\sigma_1 = 1.0$	5.4%	4.39
$\delta = .07$	5.9%	4.11
$\delta = 0.0$	7.9%	4.07
$n = 0.0$	5.1%	3.90
$\alpha = .75$	5.4%	4.27
$\alpha = 1.0$	5.5%	4.45
$\beta = .99$	6.1%	3.87
$\beta = .91$	3.1%	4.13
Equity Model†	1.3%	2.74

** All figures are calculated assuming the Progressive I tax regime and a 4 percent annual inflation rate. See the notes to tables 1 and 2 for further explanation.

† See text for basic description. A more detailed explanation is available from the authors upon request.

Source: Authors' calculations.

Table 5: Model Moments, Flat-Tax Case*

CONSTANT INFLATION

Variable	Standard Deviation**	Contemporaneous Correlation With Output	With π†
Y	1.05	-	.21
C	.72	.95	.43
I	2.08	.91	.004
H	.14	.69	-.22
Y/H	.89	.995	.27
K	.95	.81	.54
T	1.10	.99	.13

VARIABLE INFLATION

Variable	Standard Deviation**	Contemporaneous Correlation With Output	With π
Y	1.07	-	.14
C	.80	.94	.43
I	2.00	.89	-.13
H	.14	.57	-.56
Y/H	.91	.99	.23
K	.92	.86	.45
T	1.92	.82	.46

* Simulated path based on actual realizations of technology variable and inflation rates from 1955-1988. Definitions of the variables correspond roughly to the real data counterparts defined in table 1.

** The standard deviation for output refers to the absolute percentage deviation of the model series relative to the standard deviation of detrended GNP reported in table 1. All other standard deviations are expressed relative to the simulated standard deviation of Y.

† Figures represent the contemporaneous correlations with the indicated variables and actual inflation rates.

Source: Authors' calculations.

Table 6: Model Moments, Progressive I Tax Case*

CONSTANT INFLATION

Variable	Standard Deviation	Contemporaneous Correlation With Output	Contemporaneous Correlation With π
Y	.99	-	.20
C	.73	.95	.41
I	2.02	.91	.00
H	.10	.52	-.41
Y/H	.94	.997	.25
K	.93	.80	.55
T	1.62	.97	.12
T'	.48	.95	.16

VARIABLE INFLATION

Variable	Standard Deviation	Contemporaneous Correlation With Output	Contemporaneous Correlation With π
Y	1.02	-	.07
C	.82	.94	.38
I	2.00	.88	-.22
H	.18	.21	-.93
Y/H	1.00	.99	.22
K	.89	.87	.38
T	2.87	.75	.35
T'	0.91	.73	.71

* Assumes $T' = .146 + .0000023*y$, where y is individual taxable income. For other definitions, see the notes to table 5.

Source: Authors' calculations.

Table 7: Model Moments, Progressive II Tax Case*

CONSTANT INFLATION

Variable	Standard Deviation	Contemporaneous Correlation With Output	With π
Y	1.03	-	.21
C	.73	.95	.42
I	2.06	.91	.002
H	.13	.65	-.27
Y/H	.91	.996	.27
K	.95	.81	.55
T	1.42	.98	.13
T'	.16	.86	.17

VARIABLE INFLATION

Variable	Standard Deviation	Contemporaneous Correlation With Output	With π
Y	1.05	-	.11
C	.81	.94	.42
I	1.99	.89	-.16
H	.15	.43	-.75
Y/H	.94	.99	.23
K	.90	.86	.43
T	2.50	.78	.38
T'	.31	.63	.84

* Assumes $T' = .20 + .000000789*y$, where y is individual taxable income. For other definitions, see the notes to table 4.

Source: Authors' calculations.

APPENDIX: CALIBRATION OF THE TAX CODE

Because our simulation model is geared toward capturing the average effects of life-cycle behavior, we calibrate gross income levels so that the highest level of cohort income in the model roughly coincides with the highest cohort-average income in the data. Taking 1988 as the reference year, the highest level of age-cohort median income is obtained for households with heads age 45-54. The median income for this group is $38,213 in 1988 dollars.[1] We convert this number to an average by scaling according to the ratio of average-to-median income for all households in 1988. Doing so yields an average income for the 45-54 year-old cohort of $47,776.

We chose the 1965 tax code as the basis for our benchmark tax code. Because high income in our model is about $50,000 (by design), we estimate the relationship between marginal tax rates and taxable income for income values through $52,212 (in 1988 dollars). The resulting regression yields the values for g_0 and g_1 given in the text.

The scale of our output measure is chosen so that the highest gross income generated by the model in a steady state with the chosen tax schedule and inflation set to 1.8 percent (the actual inflation rate measured by the CPI-U in 1965) equals $47,766 in 1988 dollars.

Taxable income levels are obtained by adjusting gross income for deductions and personal exemptions. In the benchmark case, we assume that all

* * * * * * * * * * * * *

1 The data used in constructing high cohort income were obtained from the Current Population Reports (Series P-60, No. 166), published by the Bureau of the Census.

taxpayers take a standard deduction equal to $1479 in 1988 dollars.[2] The personal exemption level in 1965 was $600, or $2254 in 1988 dollars. Multiplying by 3.31, the average household size in 1965, yields total personal exemptions of $7460 in 1988 dollars. Taxable income, and hence the tax base, is thus arrived at by subtracting these deduction and exemption levels from gross income levels.

* * * * * * * * * * * * *

2 The 1965 personal tax code provided for a standard deduction equal to the lower of 10 percent of adjusted gross income or $1000. Using the 1965 Statistics of Income for Individual Taxpayers, we calculated that the average standard deduction was $394. The $1479 figure was arrived at by converting the $394 to 1988 dollars using the CPI-U.