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1. Introduction

The U.S. fiscal system relies primarily on the taxation of labor and capital income and very little on the taxation of consumption or real balances. While there has been considerable research on the efficiency of capital and labor income taxes and many studies of the welfare costs of the inflation tax, there have been few attempts to look at these sources of revenue together. In this paper we use the common perspective provided by the neoclassical growth model to evaluate the size of the distortions associated with different monetary and fiscal policies designed to finance a given sequence of government expenditures. We construct an artificial neoclassical monetary economy, calibrate it to match important features of the U.S. economy, and simulate it to provide a quantitative assessment of the welfare costs associated with government policies involving different combinations of taxes on capital and labor income, consumption, and holdings of money. In particular we evaluate the welfare gains from tax reforms that are designed to replace taxes on capital or labor income with other forms of taxation.

In a recent paper, Cooley and Hansen (1989), we estimated the size of the distortion due to the inflation tax in a neoclassical growth model where money is introduced by imposing a cash-in-advance constraint. We found the distortion to be quite small, about .45% of GNP for a 10% annual inflation rate. In this paper we use a somewhat different model which allows us to evaluate policies that include the inflation tax along with other forms of taxation. In particular, we consider how the distortion associated with policies involving the inflation tax compares to that associated with policies that rely solely on the taxation of labor and capital income. The model economy we study in this paper is based on the cash-in-advance framework of Lucas and Stokey (1983). This economy incorporates a distinction between "cash goods" and "credit goods" , a specification that permits sensitivity of real money balances to changes in the interest rate. In addition, this specification creates a distinction between the inflation tax and a consumption tax.

In such an economy, it is clear that the inflation tax will be inferior to a tax on consumption expenditures. This is because a consumption tax will distort some choices, such as the labor-leisure decision, but the inflation tax will distort along these same margins and, in addition, will distort the cash good-credit good decision.

We assume that the government must finance an exogenous stream of expenditures either through distorting taxes or a combination of taxes and bonds that keep the present value of government revenues equal to the present value of government expenditures. We capture the magnitude of the pure distortions associated with alternative taxes by comparing the welfare costs of distorting taxes with the welfare costs of lump-sum taxes designed to raise the same amount of revenue.

We use this model economy to address three issues. First, we want to provide a quantitative assessment of the size of the distortions associated with different taxes. We examine how the welfare of an economy is affected when different combinations of taxes on labor income and inflation or consumption taxes are used to produce a given revenue. We also analyze different combinations of taxes on capital income and inflation, consumption and labor income taxes. Second, we assess the welfare consequences of replacing the tax on capital income by taxes that are less distorting. Our interest in the latter question is motivated by the argument in Lucas (1989), based on the optimal taxation literature, that the tax on capital income is a bad tax. Finally, we compare the benefits of replacing the capital income tax by policies that are nonstationary, that is policies which involve a tax rates that change over time. Although we do not directly solve an optimal taxation problem we are motivated by the finding from that literature (Chamley (1986), Jones, Manuelli and Rossi (1990), Chari, Christiano and Kehoe (1990), King (1990), Zhu (1990)) that optimal policy sequences involve initial polices that are very different from policies in the limit. We want to assess the magnitude of the welfare gains from nonstationary tax policies.

In the next section of the paper we describe in detail the model economy we are going to study and describe the equilibrium concept to be used. The economy is based on a standard neoclassical growth model where money is valued because it is required to purchase consumption goods. In Section 3 we discuss the computational methods used to solve for a competitive equilibrium, to simulate the transitions from one policy to another and to compute the welfare costs associated with various policies. Section 4 describes how the model is calibrated to features of the U.S. economy.

The quantitative results are presented in Section 5. We consider three kinds of experiments. In the first set of experiments we compare the steady-state welfare costs across economies characterized by different mixes of taxes designed to raise the same total revenue. Our base for comparison is a model economy where all revenue is raised by the taxation of labor and capital income at rates close to those observed in the U.S. economy. Our results suggest that the welfare costs are slightly lower in economies that substitute inflation or consumption taxes for the tax on labor income, but dramatically lower for economies that substitute any tax for the tax on capital income. We then consider the welfare consequences and the dynamic behavior of the economy under policies that involve a transition from capital income taxation to other forms of taxation designed to yield the same amount of revenue. The welfare consequences of replacing the capital tax are dramatic: replacing it with a consumption tax, for example, eliminates 81 percent of the distortion. In the new steady state the capital stock increases by as much as fifty percent. The final set of experiments considers nonstationary policies that involve a transition to a temporary policy followed by a new steady state policy, again designed to support the same level of government expenditure. These results show that nonstationary inflation and consumption tax policies can improve welfare compared to stationary policies.

2. A Cash-in-Advance Economy with Taxes

The model economy we study is populated with a continuum of identical infinitely lived households endowed with k_0 units of capital in period 0 and one unit of time each period that is divided between work and leisure. The households receive income from capital and labor which is used to finance consumption, investment in additional capital, or held in the form of money or government bonds. Some consumption goods, however, can only be purchased with previously accumulated cash balances. This feature insures that money is valued in equilibrium. Output is produced from capital and labor by a single competitive firm with access to a constant returns to scale technology. In addition, the government in our model economy finances a given sequence of expenditures by issuing currency, taxing labor and capital income, taxing consumption expenditures, and issuing bonds. There is no uncertainty in this economy; agents are assumed to have perfect foresight.

An important feature of this model is that asset trading is permitted only at the beginning of the period, before the goods market is open. Households obtain at that time the currency needed to purchase a type of consumption good called "cash goods." In the beginning of any period t, a representative household has currency holdings equal to $m_t + (1+R_t)b_t$, where m_t is currency carried over from the previous period and the second term is principle plus interest from government bond holdings, b_t. Households then acquire bonds that they carry into the next period, b_{t+1}. This leaves the household with $m_t + (1+R_t)b_t - b_{t+1}$ units of currency for purchasing goods--the household has no access to additional currency after this point. Thus, purchases of cash goods, denoted c_1, must satisfy the cash-in-advance constraint,

$$(2.1) \qquad (1+\tau_{ct})P_t c_{1t} \leq m_t + (1+R_t)b_t - b_{t+1} ,$$

where P_t is the price level in period t and τ_{ct} is the consumption tax rate in period t. It turns out that this constraint will hold with equality as long as the nominal interest rate is positive. This requirement will be satisfied throughout our analysis.

In addition to the cash good, households obtain utility from consuming a "credit good," denoted c_{2t}, and leisure, $1 - h_t$, where h_t is hours worked. Previously accumulated currency is not required to purchase credit goods; they can be purchased with contemporaneously earned income. Preferences are summarized by the following utility function:

$$\sum_{t=0}^{\infty} \beta^t(\alpha \log c_{1t} + (1-\alpha)\log c_{2t} - Bh_t) \quad , 0<\beta<1 \text{ and } 0<\alpha<1. \tag{2.2}$$

An important aspect of this utility function is that hours worked enters linearly. This feature follows from the following three assumptions as shown in Rogerson (1988): (1) labor is indivisible, people can either work some given number of hours or not at all; (2) the utility function is separable in consumption and leisure; and (3) agents trade employment lotteries rather than hours of labor. We have incorporated these assumptions because an indivisible labor economy has been shown to more closely mimic features of aggregate time series data, in particular the response of hours worked to a change in productivity, than a similar model without this feature (see Hansen (1985)). In addition, a model with this feature is consistent with the fact that most changes in hours worked are due to changes in the number of workers, not in average hours worked per worker.

Households maximize (2.2) subject to the following sequence of budget constraints:[1]

$$\begin{aligned} (1+\tau_{ct})(c_{1t}+c_{2t}) + x_t + \frac{m_{t+1}}{P_t} + \frac{b_{t+1}}{P_t} &\leq (1-\tau_{ht})w_t h_t \\ &+ (1-\tau_{kt})r_t k_t + \tau_{kt}\delta k_t + \frac{m_t}{P_t} + \frac{(1+R_t)b_t}{P_t} . \end{aligned} \tag{2.3}$$

The household expenditures include purchases of the two consumption goods, investment (x_t), money to be carried into the next period (m_{t+1}), and government issued bonds. The funds

[1] This budget constraint incorporates the fact that both consumption goods and the investment good sell at the same price even though one is a cash good and the others are credit goods. This is because all goods are produced using the same technology and, from the point of view of the seller, sales of both credit goods and cash goods result in cash that will be available for spending at the same time in the following period. Although cash good sales in a given period result in cash receipts in the same period, this cash can not be spent until the next period.

available for these purchases include after tax labor income, where τ_{ht} is the labor tax rate and w_t is the wage rate, and after tax capital income, where τ_{kt} is the capital tax rate, k_t is the capital owned by the household and r_t is the rental rate of capital. The third term on the right side of (2.3) reflects the depreciation allowance built into the tax code. The last two terms are the currency carried from the previous period and the principle and interest from holdings of government bonds.

Investment in period t becomes productive capital in period t+1 according to the law of motion,

(2.4) $$k_{t+1} = (1-\delta)k_t + x_t\,, \quad 0<\delta<1.$$

The firm in this economy produces output, Y_t, using the constant returns to scale technology:[2]

(2.5) $$Y_t = K_t^{\theta}H_t^{1-\theta}\,, \quad 0<\theta<1.$$

The firm seeks to maximize profit, which is equal to $Y_t - w_tH_t - r_tK_t$. The first order conditions for the firm's problem yield the following functions for the wage rate and rental rate of capital:

(2.6) $$w(K_t,H_t) = (1-\theta)\left(\frac{K_t}{H_t}\right)^{\theta}$$

(2.7) $$r(K_t,H_t) = \theta\left(\frac{H_t}{K_t}\right)^{1-\theta}$$

The role of the government is to raise revenue to finance a sequence of government expenditures, $\{G_t\}_{t=0}^{\infty}$. Its monetary policy is to issue money according to the following rule:

(2.8) $$M_{t+1} = (1+\mu_{t+1})M_t\,,$$

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[2] We are employing the convention of using capital letters (such as K and H) for per capita variables that are determined in equilibrium but not chosen by the individual households and small letters (k and h) for variables under direct control of the households. Of course, K = k and H = h in equilibrium. This convention will be particularly useful when we describe a recursive formulation of this economy in section 2.2.

where $\{\mu_t\}_{t=1}^{\infty}$ is a sequence of money growth rates and M_0 is given. It follows that the amount of revenue raised by the government through money creation in period t is equal to $\mu_{t+1}M_t/P_t$.

The fiscal policy of the government consists of the sequence of government expenditures and a sequence of taxes on capital income, labor income and consumption, $\{\tau_{kt},\tau_{ht},\tau_{ct}\}_{t=0}^{\infty}$. These sequences must satisfy the requirement that the present value of the sequence of government expenditures equals the present value of the sequence of revenues. We refer to such a policy as a feasible government policy. To implement this policy, the government must issue bonds each period to satisfy the following budget constraint:

$$(2.9) \qquad G_t = \tau_{ht}w_tH_t + \tau_{kt}(r_t-\delta)K_t + \tau_{ct}C_t + \frac{\mu_{t+1}M_t}{P_t} + \frac{B_{t+1}-(1+R_t)B_t}{P_t},$$

where $C_t = C_{1t} + C_{2t}$. We assume that the initial stock of bonds, B_0, is equal to zero.

To facilitate solving for an equilibrium, we transform variables so that the household's problem is stationary. In particular, we define $\hat{m}_t \equiv m_t/M_t$, $\hat{P}_t \equiv P_t/M_t$, $\hat{b}_t \equiv b_t/M_t$, and $\hat{B}_t \equiv B_t/M_t$. This has the effect of eliminating M from the model. We now define an equilibrium for this economy:

Given $k_0 = K_0$, $\hat{b}_0 = \hat{B}_0 = 0$, $\hat{m}_0 = 1$, and a feasible fiscal and monetary policy $\{G_t,\tau_{ht},\tau_{kt},\tau_{ct},\mu_{t+1},\hat{B}_{t+1}\}_{t=0}^{\infty}$ satisfying (2.9), a competitive equilibrium is a set of sequences for the price level $\{\hat{P}_t\}_{t=0}^{\infty}$, interest rates $\{R_t\}_{t=0}^{\infty}$, factor prices $\{w_t,r_t\}_{t=0}^{\infty}$, household allocations $\{c_{1t},c_{2t},h_t,x_t,\hat{m}_{t+1},\hat{b}_{t+1},k_{t+1}\}_{t=0}^{\infty}$, and per capita quantities $\{C_{1t},C_{2t},H_t,X_t,K_{t+1}\}_{t=0}^{\infty}$ such that;

(i) Given the sequence of price levels, interest rates and factor prices, the sequence of quantities maximizes (2.2) subject to (2.1), (2.3) and (2.4);

(ii) $\hat{m}_{t+1} = 1$, $\hat{b}_{t+1} = \hat{B}_{t+1}$, $c_{1t} = C_{1t}$, $c_{2t} = C_{2t}$, $h_t = H_t$, $x_t = X_t$, $k_{t+1} = K_{t+1}$ for all t;

(iii) Factor prices satisfy equations (2.6) and (2.7).

2.1 Solving for a Competitive Equilibrium

Given that the cash-in-advance constraint holds with equality, equilibrium sequences for C_{1t}, C_{2t}, H_t, K_{t+1}, $\hat{B}_t$, $\hat{P}_t$ and R_t must satisfy the following set of equations:

(2.10)

$$\text{(i)} \quad (1+R_t) = \frac{(1+\mu_t)C_{1t}(1+\tau_{ct})\hat{P}_t}{\beta C_{1t-1}(1+\tau_{ct-1})\hat{P}_{t-1}}$$

$$\text{(ii)} \quad \frac{(1+R_t)\hat{B}_t - (1+\mu_{t+1})\hat{B}_{t+1}}{\hat{P}_t} = [(1-\theta)\tau_{ht} + \theta\tau_{kt}]K_t^{\theta}H_t^{1-\theta} - \delta\tau_{kt}K_t + \frac{\mu_{t+1}}{\hat{P}_t} + \tau_{ct}C_t - G_t$$

$$\text{(iii)} \quad (1+\tau_{ct})C_{1t} = [(1-\theta)\tau_{ht} + \theta\tau_{kt} + \tau_{ct}]K_t^{\theta}H_t^{1-\theta} - \delta\tau_{kt}K_t + \frac{1+\mu_{t+1}}{\hat{P}_t} - \tau_{ct}(K_{t+1} - (1-\delta)K_t) - (1+\tau_{ct})G_t$$

$$\text{(iv)} \quad (1+\tau_{ct})C_{2t} = [(1-\theta)(1-\tau_{ht}) + \theta(1-\tau_{kt})]K_t^{\theta}H_t^{1-\theta} + \delta\tau_{tk}K_t - \frac{1+\mu_{t+1}}{\hat{P}_t} - K_{t+1} + (1-\delta)K_t$$

$$\text{(v)} \quad (1-\alpha)(1+\mu_{t+1})\hat{P}_{t+1}(1+\tau_{ct+1})C_{1t+1} = \alpha\beta\hat{P}_t(1+\tau_{ct})C_{2t}$$

$$\text{(vi)} \quad (1+\tau_{ct})C_{2t} = \frac{(1-\alpha)(1-\theta)(1-\tau_{ht})}{B}\left(\frac{K_t}{H_t}\right)^{\theta}$$

$$\text{(vii)} \quad (1+\tau_{ct+1})C_{2t+1} = \beta\left[1 + (1-\tau_{kt+1})\left(\theta\left(\frac{H_{t+1}}{K_{t+1}}\right)^{1-\theta} - \delta\right)\right](1+\tau_{ct})C_{2t}$$

The first of these equations is obtained from the first order condition with respect to $\hat{b}_t$ for the household's optimization problem. Equation (ii) is obtained by substituting (2.6) and (2.7) into (2.9). The third equation is the per capita version of the cash-in-advance constraint, (2.1), with (ii) used to eliminate the last two terms. The per capita versions of the budget constraint, (2.3), and the cash-in-advance constraint, (2.1), were used to obtain the fourth equation. Equations (v) through (vii) are obtained from the first order conditions with respect to $\hat{m}_{t+1}$, h_t

and k_{t+1}, respectively. Together, these seven equations, along with a feasible government policy, initial conditions $(K_0,\hat{B}_0)$ and terminal conditions that we have not yet specified, determine the equilibrium sequences for C_{1t}, C_{2t}, H_t, K_{t+1}, $\hat{B}_t$, $\hat{P}_t$, and R_t. We now describe how we obtain the terminal conditions that make it possible to solve these equations.

In this paper, we restrict our discussion to policies under which government expenditures, tax rates and money growth rates are eventually constant. That is, there will always exist some date T such that $G_t = G$, $\tau_{ct} = \tau_c$, $\tau_{ht} = \tau_h$, $\tau_{kt} = \tau_k$ and $\mu_{t+1} = \mu$ for all $t > T$. Before T, the tax rates and growth rates may differ from these values. We then use recursive methods to obtain rules that express H_{T+1+i}, $\hat{P}_{T+1+i}$ and K_{T+2+i} as functions of K_{T+1+i}, for $i \geq 0$, under the assumption that taxes and the money growth rate are set at these constant values. These rules for i equal to zero are used as the terminal conditions required in addition to equations (2.10) to solve for the sequence of per capita quantities and prices from period 0 to T .

More precisely, we use recursive methods to obtain functions that are evaluated at K_{T+1} to deliver the following: $H_{T+1} = H(K_{T+1})$, $\hat{P}_{T+1} = P(K_{T+1})$ and $K_{T+2} = K(K_{T+1})$. These functions are used in equations (iii) and (iv) of (2.10) for $t = T+1$ to obtain $C_{1,T+1}$ and $C_{2,T+1}$ as functions of K_{T+1}. These, in turn, are used to eliminate $C_{1,T+1}$ and $C_{2,T+1}$ in equations (v) and (vii) of (2.10) for $t = T$. After these substitutions, equations (iii)-(vii) of (2.10), for $t = 0,...,T$, comprise $5(T+1)$ equations in $5(T+1)$ unknowns, $\{C_{1t},C_{2t},H_t,K_{t+1},\hat{P}_t\}_{t=0}^{T}$. In addition, the rules obtained from the recursive procedure can be used to simulate beyond period T.

We now proceed to describe a recursive formulation of our model under the assumption that government expenditures, tax rates and money growth rates are constant over time. With this formulation we are able to define precisely the functions determining H_{T+1}, $\hat{P}_{T+1}$ and K_{T+2}. The computational techniques used to obtain these functions will be described in section 3.

2.2 A Recursive Formulation with Constant Taxes

Assuming that nominal interest rates are determined according to equation (2.10 i), guaranteeing that the household's first order condition for bond holdings is satisfied in equilibrium, (2.10 ii) can be substituted into (2.1) and (2.3) to eliminate bonds from the households optimization problem. This is equivalent to replacing government bonds with a particular sequence of lump sum taxes and transfers that leaves household decisions the same as they would be if bonds were issued. Under this interpretation, a household enters a given period with k units of capital when the per capita capital stock is K and currency expressed as a fraction of per capita money holdings equal to $\hat{m}$. The function $V(K,k,\hat{m})$ denotes the equilibrium maximized present value of the utility stream of the representative household as a function of his beginning of period state. This function V must satisfy Bellman's equation (primes denote next period values):

$$V(K,k,\hat{m}) = \max\{[\alpha \log c_1 + (1-\alpha)\log c_2 - B\,h] + \beta\, V(K',k',\hat{m}')\}$$

subject to

$$\begin{aligned}
&(1+\tau_c)c_1 = \frac{\hat{m}}{\hat{P}} + TR \\
&(1+\tau_c)(c_1+c_2) + x + \frac{(1+\mu)\hat{m}'}{\hat{P}} = (1-\tau_h)w(K,H)h + (1-\tau_k)r(K,H)k \\
&\qquad + \tau_k\delta k + \frac{\hat{m}}{\hat{P}} + TR \\
&TR = [(1-\theta)\tau_h + \theta\tau_k]K^{\theta}H^{1-\theta} - \tau_k\delta K + \frac{\mu}{\hat{P}} + \tau_c C \\
&C = K^{\theta}H^{1-\theta} - X - G \\
&K' = (1-\delta)K + X \\
&X = X(K), \quad H = H(K), \quad \hat{P} = P(K)
\end{aligned} \tag{2.11}$$

and (2.4), (2.6), (2.7), c_1, c_2, x, $\hat{m}'$ non-negative and $0 < h < 1$.

For this problem, G, τ_h, τ_k, τ_c and μ are assumed to be known constants. The first constraint in (2.11) is the cash-in-advance constraint and the second is the household's budget constraint. The third expression gives the size of the lump sum transfer required to equate government expenditures and revenues. This is followed by the per capita resource constraint which is used to determine per capita consumption. The next expression is the law of motion for the per capita capital stock. The final line of (2.11) gives the perceived functional relationship between the per capita state, K, and per capita investment, per capita hours worked and the price level.

A recursive competitive equilibrium consists of a set of decision rules for the household, $c_1(s)$, $c_2(s)$, $x(s)$, $\hat{m}'(s)$, and $h(s)$ (where $s = (K,k,\hat{m})$); a set of per capita decision rules, $X(K)$ and $H(K)$; a pricing function $P(K)$; and a value function $V(s)$ such that:

(i) the functions V, X, H, and P satisfy (2.11) and c_1, c_2, x, $\hat{m}'$, and h are the associated decision rules;

(ii) Given the pricing function, P, individual decisions are consistent with aggregate outcomes:

$$x(K,K,1) = X(K),\ h(K,K,1) = H(K), \text{ and } \hat{m}'(K,K,1) = 1\ .$$

The functions H(K), P(K) and the function obtained by substituting the function X(K) into the law of motion for the per capita capital stock are the functions used to determine H_{T+1}, $\hat{P}_{T+1}$ and K_{T+2} as described in the previous subsection.

3. Computational Issues

3.1 Solving for a Competitive Equilibrium

As we have seen, computing a sequence of quantities and prices that satisfy the definition of competitive equilibrium for our economy, given the types of government policies we will consider, involves two steps. We first compute a set of per capita decision rules for H and X (and hence K′) and a pricing function, P, that satisfies the definition of a recursive competitive equilibrium when the government policy is constant over time. In particular, we set government expenditure, the tax rates and the money growth rate to the levels that will hold after period T. The second step is to use these rules and equations (2.10) to obtain the values of the various prices and quantities before T.

In much of the literature on the neoclassical growth model, the real business cycle literature in particular, it is possible to compute a recursive competitive equilibrium indirectly by solving a planning problem. However, in our case distortions force us to solve for an equilibrium using direct methods. The method we use to compute equilibrium decision rules is the approximation method employed in Cooley and Hansen (1989).

This method, which we will not discuss in detail here, involves substituting the nonlinear constraints in problem (2.11) into the utility function, eliminating c_1 and c_2. A quadratic approximation of the resulting objective function is formed around the steady state, using the method described in Kydland and Prescott (1982). Next, an initial quadratic function, V_0, is chosen as a candidate for V and a sequence of approximations, $\{V_i\}$, is computed by successive iterations using the quadratic version of (2.11). At each iteration, linear candidates for the functions X, H and P are formed, making the maximization problem in (2.11) well defined. This process is continued until successive approximations are sufficiently close. The procedure used to form the linear candidates for X, H and P, and to obtain successive approximations of the value function is described in detail in Hansen and Prescott (1990).

Given the linear decision rules and pricing function for H, X and P, the second step of our procedure is to use a nonlinear equation solver to solve for prices and quantities for periods from zero to T exactly as described in the previous section. In practice, we choose T so that the constant government policy has been in effect some number of periods (usually 50) before simulating with the linear decision rules. This insures that the economy will be in the neighborhood of the steady state so that the linear decision rules are accurate approximations of the true decision rules.

Finally, it is necessary to check that the government policy chosen is in fact feasible. The techniques that we have described so far assume that the policy is feasible, but do not guarantee that it is. In the experiments that we study, there is always one revenue source that can be adjusted until the policy is feasible. We start with some guess for that particular tax rate and compute an equilibrium sequence of prices and quantities of at least 2000 periods in length. Next, we evaluate the present value of government revenues and compare it with the present value of government expenditures. Depending on the outcome, we continue to adjust the tax rate until the policy is feasible.

3.2 Calculating Welfare Changes

To study the welfare consequences of distorting taxation, we compute the percentage increase in consumption that an individual would require to be as well off as under the equilibrium allocation without government spending, taxes or inflation.[3] To obtain a measure of the welfare loss associated with a particular government policy in the steady state, we solve for x in the equation

$$\bar{U} = \alpha \log[c_1^*(1+x)] + (1-\alpha)\log[c_2^*(1+x)] - Bh^* . \tag{3.1}$$

In this equation, $\bar{U}$ is the level of utility attained (in the steady state) under the zero tax allocation ($G = \mu = \tau_h = \tau_k = \tau_c = 0$), and c_1^*, c_2^* and h^* are the steady state consumption and hours associated with the government policy in question. From the value of x that satisfies this equation, we compute $\Delta C = x(c_1^* + c_2^*)$. Here, ΔC is the total change in consumption required to restore an individual to the level of utility obtained under the no tax allocation. We typically express ΔC as a percentage of steady state output (GNP) produced under the government policy being considered.

[3] The allocation we use for our welfare comparisons is not the Pareto Optimal allocation. Negative inflation is required for the Pareto Optimal allocation to be a competitive equilibrium allocation for this economy.

We also study experiments which consider the transition from one policy to another. In these cases, we compute the transition path for at least 2000 periods and calculate the welfare costs associated with this transition path. From this simulation we have time series for c_1, c_2 and h beginning with the first period that the new policy is put into effect. The welfare costs are calculated by solving the following equation for x, where $\bar{U}$ is the same as in (3.1):

$$\sum_{t=1}^{2000} \beta^t[\alpha \log(c_{1t}(1+x)) + (1-\alpha)\log(c_{2t}(1+x)) - h_t - \bar{U}] = 0 . \tag{3.2}$$

The welfare cost measure we typically report is the present value of $x(c_{1t}+c_{2t})$ over the 2000 period simulation expressed as a percentage of the present value of GNP over the same simulation.

4. Calibration of the Model

In order to study the behavior of this model economy, values must be assigned to the parameters of technology, preferences and the policy variables. We follow the procedure of choosing values based on observed features of the data. This calibration procedure has been widely applied in business cycle studies based on models similar to ours.[4] The fact that there are distorting taxes in our model has lead us to change some of the parameter values from those used in our previous work. We first describe the values of the policy variables used in calibrating the model, and then the parameters of technology and preferences.

Since the inflation rate has been quite low on average in the U.S. during the postwar period, we chose to calibrate the model assuming a zero inflation rate, which implies setting μ equal to zero. Similarly, we chose to set the tax on consumption expenditures equal to zero

[4] This procedure became popular in business cycle analysis beginning with the work of Kydland and Prescott (1982). An alternative would be to estimate the parameters using maximum likelihood as is done in Christiano (1988) or Hansen, McGrattan and Sargent (1989). Christiano and Eichenbaum (1989) discuss a procedure that is somewhat intermediate, using the data to estimate key moments while specifying other parameters.

($\tau_c = 0$). A number of authors have computed the average marginal tax rates on labor and capital income. Auerbach (1983), Joines (1981), Seater (1982,1985), Barro and Sahasakul (1983) among others have estimated these average taxes. In the simulations reported below we assume the tax rate on labor income is 23% and the tax rate on capital income is 50%, values which were determined by taking the average of the time series reported in Joines (1981).[5] In the remainder of the paper, we refer to this policy ($\mu = 0$, $\tau_h = .23$, $\tau_k = .5$ and $\tau_c = 0$) as the base policy. Government expenditures, G, under the base policy are equal to the steady state revenue obtained each period with this set of taxes.

We now turn to the parameters of technology, θ and δ. The share of total output that is payments to capital, θ in our model, is set equal to .36. Christiano (1988) points out that depending on how proprietors income is assigned, θ can range from .25 to .43 when measured using post war U.S. national income accounts. We have chosen .36, which is in the middle of this range, because it is the value most commonly used in these studies, including our previous work.

The quarterly depreciation rate, δ, is commonly set equal to .025, which corresponds to a 10 percent annual rate. However, we were lead to assign a different value to this parameter in order for the investment-output ratio to match that observed in the U.S. economy. Since in this paper, the tax on capital corresponds to a tax on the income from producer's structures and equipment (not residential capital or consumer durables), the appropriate component of the national income accounts corresponding to investment in the model is fixed nonresidential investment. In addition, the appropriate measure of total output is gross domestic product of corporate business. Using these series, the average investment-output ratio is .17 over the postwar period. By setting δ equal to .02 (corresponding to an eight percent annual depreciation rate), the investment-output ratio for the model economy matches that for the U.S. economy.

5 Many authors distinguish between the direct tax on capital income and the additional tax that operates through the income tax. The tax rate of .50 is intended to incorporate both of these effects.

The preference parameters, β, B and α, remain to be set. The discount factor, β, is set equal to .99, which implies an annual real interest rate of four percent. The parameter B, which appears in equation (2.3), is chosen so that on average households spend one third of their substitutable time working. This implies a value for B equal to 2.6.

The parameter α, which determines the relative importance of the cash and credit good in the utility function, is calibrated by considering two kinds of evidence. First, we take an approach similar to that in Lucas (1988). He considers a cash-in-advance model and shows how the parameters of conventional money demand functions are related to the parameters of preferences. To illustrate this, equations (2.10) (i) and (v) can be used to obtain the following expression:

$$\text{(3.3)} \qquad \frac{C_t}{C_{1t}} = \frac{1}{\alpha} + \frac{(1-\alpha)}{\alpha} R_{t+1}$$

where $C_t = C_{1t} + C_{2t}$. Per capita real money balances held during period t is equal to $(1+\tau_{ct})C_{1t}$, given that the cash-in-advance constraint (2.1) holds with equality. This implies that the velocity of money with respect to consumption (VEL) is the following:

$$\text{(3.4)} \qquad VEL_t = \frac{1}{\alpha(1+\tau_{ct})} + \frac{1-\alpha}{\alpha(1+\tau_{ct})} R_{t+1}$$

To give empirical content to (4.2) one must identify the appropriate measure of consumption and the appropriate measure of money from which to construct the velocity. For consumption we use consumption of non-durables and services, taken from Citibase. Choosing a measure of money presents problems. Conventional monetary aggregates that one might use to capture quantities subject to the inflation tax--the monetary base, or the non-interest bearing portion of M1--have the drawback that they are too large. They imply velocities less than unity which is inconsistent with the model. Instead, we use the portion of M1 that is held by households.[6] To obtain a value for α, we compute the regression implied by (4.2) using these

[6] These data are obtained from the Flow-of-Funds Accounts. Unfortunately these data are also flawed because of the way they treat currency. Currency held by households is treated as the residual of total currency outstanding and

data.[7] For the sample period from 1970-1986, the estimated equation is:

$$\begin{array}{lll} VEL = & 1.1392 \;+ & 0.1165 * RTB \\ & (0.0265) & (0.0133) \\ & & \\ \multicolumn{2}{c}{D\text{-}W=0.297} & R^2 = 0.549 \end{array}$$

where RTB is the rate on three month Treasury bills stated on a quarterly basis.

The intercept of this regression implies an estimate of $\alpha = 0.88$. But, it must be noted that the conclusions of this regression analysis are sensitive to the choice of sample period.

An alternative way to approach this calibration problem is to estimate α from survey studies of how people actually make their transactions. In 1984, and again in 1986, the Federal Reserve commissioned surveys of consumer transactions. The purpose of these surveys was to determine how people use cash and other means of payment in making their transactions. The proportions for 1984 and 1986 are virtually identical. We take as our estimate of the "cash goods" transactions, those purchases made with cash, main checking, other checking and money orders. This constitutes 84% of all transactions. If we denote this percentage by υ then the relation between the preference parameter α and this percentage υ is given by the expression:

$$\alpha = \frac{(1+\mu)\upsilon}{\beta(1-\upsilon)+(1+\mu)\upsilon}\,. \tag{3.5}$$

This expression is obtained from the steady state version of equation (2.10,v). Using $\beta = .99$, $\mu = 0$ and $\upsilon = .84$ implies an estimate of $\alpha = 0.84$. Since 0.84 is close to the number obtained from the regression above, this is the number we will use in the following experiments.

currency held by businesses and governments. The resulting figure is undoubtedly way too high.

[7] The data reveal a strong trend in velocity. For this regression to be valid it would have to be matched by a trend in interest rates. We test the null hypothesis that velocity and nominal interest rates are cointegrated. We cannot reject the null hypothesis that velocity and interest rates are cointegrated at the 5% level using Park's (1989) test. Unfortunately there is also evidence of a remaining spurious trend in the residuals of this regression.

We summarize our parameter choices in the following table:

β	B	α	θ	δ	μ	τ_h	τ_k	τ_c
0.99	2.60	0.84	0.36	0.02	0.00	0.23	0.50	0.00

5. Quantitative Analysis of Alternative Government Policies.

5.1 Steady State Analysis

In this section we provide a comparison of the steady state welfare costs associated with alternative tax policies designed to raise a given amount of revenue. By holding revenue constant and calculating the welfare costs associated with different mixes of capital taxes, labor taxes, inflation taxes and consumption taxes we can quantitatively assess the differences in the long run distortions associated with each of these revenue sources. The results of these steady state experiments are summarized in Figure 1 and Table 1. [8]

The Columns of Table 1 show the tax rates (for the inflation tax we show the money supply growth rate) and the welfare cost as a percent of GNP associated with several different policies. The first row of Table 1 shows the welfare cost of the base policy to be 31.139% of GNP. In our model these revenues are not rebated to the households in any way and government spending does not enter preferences. Consequently, there is a wealth effect confounded with the pure distortion of the taxes. The second policy illustrated in Table 1 replaces the capital and labor taxes with lump sum taxes. The welfare cost of this policy is 14.961% of GNP. Since there are no distortions associated with the lump sum taxes the difference between the two gives us an estimate of the pure distortion associated with the base

[8] We have also conducted the same set of experiments for an economy in which the indivisible labor assumption is replaced by a divisible labor assumption. The results are quantitatively and qualitatively very similar.

policy, 16.178 % of GNP. This is virtually identical to the numbers reported in Cooley and Hansen (1990).[9]

We next consider policies that replace the tax on labor income, either in whole or in part, with other sources of revenue. The third row of Table 1 shows what happens when the tax is completely replaced by lump sum taxes. The welfare cost falls to 25.677% of GNP implying that the distortion due to the labor tax is about 5.5% of GNP. When the labor income tax is replaced by an inflation tax (row 4) the required inflation rate is 29% per quarter and the welfare cost is 30.268%, an improvement on the base policy of less than 1% of GNP. When the labor tax is replaced by a consumption tax of 23% (row 5) the welfare cost is 29.815% of GNP, a slightly larger improvement. The consequences of these extreme policies, as well as various mixes of labor taxation and inflation or consumption taxation, are illustrated in the top part of Figure 1. Overall, the welfare consequences of these policy variations are small. The distortions resulting from the labor income tax are similar to those resulting from an inflation tax or a consumption tax designed to raise the same amount of revenue.

Policies designed to eliminate the tax on capital income have a major impact on economic welfare in this economy. Rows 6 through 9 of Table 1 show the consequences of policies designed to achieve this objective. Replacing the capital income tax with lump sum taxation lowers the welfare cost of the policy to 19.157% of GNP, a decrease of nearly 12 percent. Replacing the capital tax with the labor income tax would require that the labor income tax be increased from 23% to 34.3% to keep revenue constant, but the welfare cost would decline to 23.18% of GNP. Replacing the capital income tax with the inflation tax would require a quarterly inflation rate of 14.5%, or nearly 60% annually, and the welfare cost would decline to 22% of GNP. Finally, implementing a consumption tax of 11.9% would replace the revenues from capital

[9] As noted above, we compute the welfare costs of these policies relative to the no tax case in which all taxes and the money growth rate are zero rather than relative to the Pareto Optimum. There is some very small distortion associated with the difference between the two but we ignore this.

income taxation and reduce the welfare cost to 21.9% of GNP, resulting in nearly a one third decline in welfare costs over the base policy. Figure 1 shows the welfare consequences of various mixes of capital income taxes and these other taxes.

These results support the view that the major improvements in economic welfare are likely to come from policies designed to replace the tax on capital income, and that the welfare benefits of replacing the labor income tax are relatively minor. These conclusions are based on comparing the steady states associated with different tax policies. In the next section, we consider the behavior of economies that make an unanticipated transition from one policy regime to another. Based on the findings of this section, we consider only policies designed to replace the capital income tax.

5.2 Stationary Policies

The policy changes we consider in this section are assumed to be unanticipated, but agents have perfect foresight once the changes are implemented. We focus on the welfare gains from replacing the capital income tax with inflation taxes, consumption taxes and labor income taxes, taking into account the transition from the steady state of the base case to the new steady state. The policies considered are designed to keep the present value of the revenue stream equal to the present value of government expenditures. Government expenditures are held constant across all experiments and are equal, period by period, to the government expenditures in the base case. The welfare gains from these alternative policies are reported in Table 2. The transition paths of revenue, consumption, hours, utility and the capital stock under the alternative policies are displayed in Figures 2-4.

The results in Table 2 are very similar to those based on comparing different steady states. Replacing the revenue from the capital income tax with an inflation tax requires a monetary growth rate (and therefore an inflation rate in the new steady state) of 15.2% per quarter. This is somewhat higher than the 14.5% from the steady state experiment reported on in Table 1 and the welfare cost of this policy is 21.59% of GNP, which is somewhat smaller. The difference is accounted for by the transition path. Replacing those revenues with the consumption tax requires a tax rate of 12.5% and leads to a welfare cost of 21.47% of GNP. An increase in the labor income tax is the least efficient way to replace these revenues. It requires that the tax rate on labor income jump to 34.2% and results in welfare costs of 22.56% of GNP. The third column of Table 2 shows the steady state capital stock associated with each of the policies. The alternative tax structures have a dramatic impact on the capital stock. Replacing the capital income tax increases the capital stock in the new steady state by as much as 50%. These figures are consistent with those reported by Lucas (1989).

Figures 2 through 4 show how these policies affect several variables of interest. The initial impact of both the consumption and inflation taxes is to cause household to consume less and to work and invest more. Utility falls initially, but the resulting increase in the capital stock permits consumption to be higher and hours of work lower in the long run. The increase in the labor income tax has effects that are much the same. Hours of work increase somewhat less and consumption decreases somewhat more in the short run. Again, it is the dramatic increase in the capital stock that improves welfare in the long run.

5.3 Nonstationary Policies

One of the important insights to be derived from the literature on optimal taxation is that the tax rates employed in the limit under an optimal policy may be very different from the tax rates employed during the transition to the new steady state. This particular feature is a consequence of the fact that optimal taxation is characterized by two principles: goods in inelastic supply should be taxed heavily and consumption at different dates should be taxed evenly. Reconciling these two principles requires policies that are nonstationary. As Chamley (1986) and

Lucas (1989) have pointed out, this implies heavy initial taxation of capital and zero taxation in the limit. In this section, although we do not compute an optimal tax policy, we illustrate how welfare can be improved by considering nonstationary versions of policies designed to eliminate capital taxation. In particular, we consider policies that set the tax rate on capital to zero and replace the revenue by other taxes where the tax rates change in two stages: there is one set of tax rates that are effective for the first four quarters followed by a different set of taxes effective from the fifth period on. As before, the policy change is unanticipated but agents have perfect foresight once the policy has been implemented. In particular, the agents are aware of how the tax rates will change over time.

Table 3 shows the welfare consequences of replacing the capital tax using three different nonstationary policies. The first policy in Table 3 replaces capital taxation with an inflation tax. This policy was designed by first constructing a new stationary policy, (μ = 0.133, τ_h = 0.23, τ_k = 0.0, τ_c = 0.0), such that an unanticipated change from the base policy to this policy would replace 90% of the revenue lost by eliminating the capital tax. Next, the money growth rate in effect during the first four quarters was increased so that all of the revenue is replaced--that is, so that the present value of the revenue stream is equal to the present value of government expenditures. This required setting μ equal to 0.694, as shown in the second column of Table 3. Columns three and four show the welfare cost of the nonstationary policy and the capital stock associated with the new steady state. These results indicate that a policy which sets the inflation rate very high initially, followed by a lower inflation rate improves welfare and leads to a higher steady state capital stock than the corresponding stationary policy described in Table 2. Figure 5 illustrates the transition path associated with this policy. The high initial inflation rate, 69.4% per quarter for four quarters, leads to a dramatic drop in consumption and utility in the first four periods and a sharp increase in revenue relative to the initial policy. This is accompanied with a more dramatic increase in investment, relative to the corresponding stationary policy, which results in the higher steady state capital stock.

The nonstationary consumption tax policy is constructed in precisely the same way. In the initial four periods the tax rate is set at 46.7% and in the new steady state the tax rate is 11.1%. The welfare cost of this policy is only slightly lower than that of the corresponding stationary policy and the steady state capital stock is slightly higher. The dynamic response of the economy to this sequence of tax rates, shown in Figure 6, is largely the same as for the inflation tax policy. A sharper drop in consumption and sharper increases in hours and investment lead to a higher steady state capital stock then under the corresponding nonstationary policy. An interesting conclusion emerging from these last two experiments is that the gains from high temporary inflation rates seem larger than the gains from high temporary consumption taxes, holding revenue constant.

The final experiment in Table 3 replaces capital taxation with increased taxes on labor income, where labor taxes are lower during the first four periods than after. This is opposite of the pattern we have used in the previous two experiments. The policy, ($\mu = 0.0$, $\tau_h = 0.329$, $\tau_k = 0.0$, $\tau_c = 0.0$) was chosen, as before, to replace 90% of revenue lost by setting the capital tax to zero. It turned out to be impossible to replace the remaining revenue by setting the labor tax rate higher during the first four periods. Intertemporal substitution in this model is such that having a higher initial tax rate followed by a lower subsequent tax rate does not produce the desired gain in revenue since households simply postpone work effort. Instead, we increased the steady state labor tax rate to 0.342 to accomplish this. The third row of Table 3 and Figure 7 illustrate the consequences of this nonstationary policy. This produces an initial increase in work effort and decrease in consumption, but the effect on the capital stock and welfare is negligible compared with the corresponding stationary policy.

6. Conclusions.

This paper has quantified the welfare costs of monetary and fiscal policies designed to support an exogenous level of government spending in a neoclassical monetary economy. To address this issue we have put aside a number of very real issues including the effects of uncertainty and the possibility of strategic behavior by the government and households.[10] We have provided a quantitative assessment of the distortions associated with the inflation tax, the consumption tax, the labor income tax and the capital income tax in a simple neoclassical economy. Taxes levied against consumption goods, either through the inflation tax or the consumption tax, are the least distorting. Taxing the income from labor has distortions that are larger but quantitatively similar to taxing consumption or real balances. The taxation of income from capital produces the greatest distortions, nearly 12% of GNP at a 50% tax rate. These results suggest that major improvements in economic welfare follow from a change in the tax structure of an economy that taxes the income from capital heavily. Replacing the capital income tax by a consumption tax eliminates 81 percent of the distortion due to the former. Our experiments show exactly how these improvements would come about. When the tax on capital income is replaced by an alternative tax, consumption would be lower, and work effort and investment higher for an extended period resulting ultimately in a higher level of the capital stock.

Fiscal policies that are efficient in the sense of Ramsey (1926) have the feature that the initial policy may be quite different from the policy that is converged to in the long run. This implies that a nonstationary sequence of policies may produce lower distortions. Our quantitative results confirm this basic principle for inflation and consumption taxes. A very high initial inflation rate followed by a somewhat lower inflation rate in the limit improves welfare in our model economy. Nevertheless, for the policies we considered we find that the welfare

[10] Many others are discussed in Judd (1989).

consequences of these changes in timing and pattern of taxes are very small compared the gains from policies that replace the capital tax with a stationary policy.

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Table 1

Steady State Welfare Consequences of Alternative Policies

Policy	τ_h	τ_k	μ	τ_c	τ	Welfare Cost (% of GNP)
Base Policy	0.23	0.50	0.0	0.0	0.0	31.139
Replace All Taxes with Lump Sum	0.0	0.0	0.0	0.0	0.263	14.961
Replace Labor Tax:						
with Lump Sum	0.0	0.50	0.0	0.0	0.1416	25.677
with Inflation Tax	0.0	0.50	0.293	0.0	0.0	30.268
with Consumption Tax	0.0	0.50	0.0	0.234	0.0	29.815
Replace Capital Tax:						
with Lump Sum	0.23	0.0	0.0	0.0	0.065	19.157
with Labor Tax	0.343	0.0	0.0	0.0	0.0	23.180
with Inflation Tax	0.23	0.0	0.145	0.0	0.0	22.014
with Consumption Tax	0.23	0.0	0.0	0.119	0.0	21.901

Table 2

Welfare Gains From Replacing Capital Income Tax
Including Transition From Steady State

	Welfare Cost % of GNP	Capital Stock in New Steady State
Original Policy $\tau_k=0.5$	31.138	9.903
Replacing τ_k with:		
Inflation Tax $\mu=0.152$	21.591	14.742
Consumption Tax $\tau_c=0.125$	21.472	14.742
Labor Income Tax $\tau_h=0.342$	22.563	14.327

Table 3

Welfare Gains From Replacing Capital Income Tax
Nonstationary Policies

Replacing τ_k with:	First Four Periods	New Steady State	Welfare Cost % of GNP Entire Policy	Capital Stock New Steady State
Inflation Tax	$\mu=0.694$	$\mu=0.133$	20.978	14.890
Consumption Tax	$\tau_c=0.467$	$\tau_c=0.111$	21.086	14.873
Labor Income Tax	$\tau_h=0.329$	$\tau_h=0.342$	22.570	14.322

Figure 1 Welfare Gains From Replacing Labor and Capital Taxes

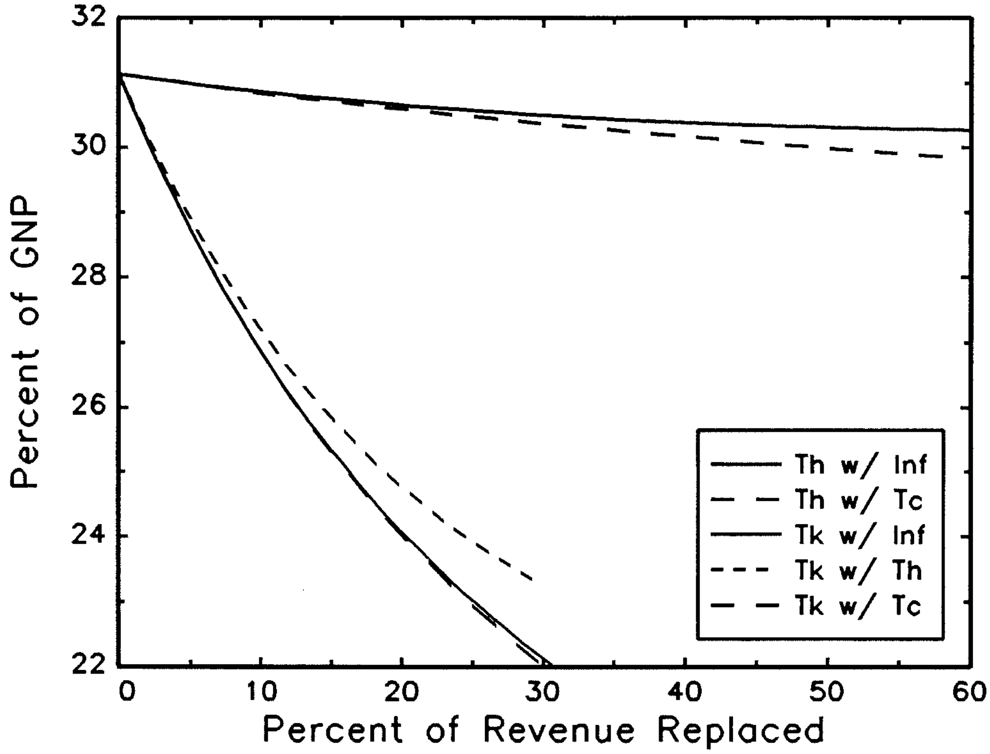

Figure 2 Replacing Capital Tax with Inflation Tax

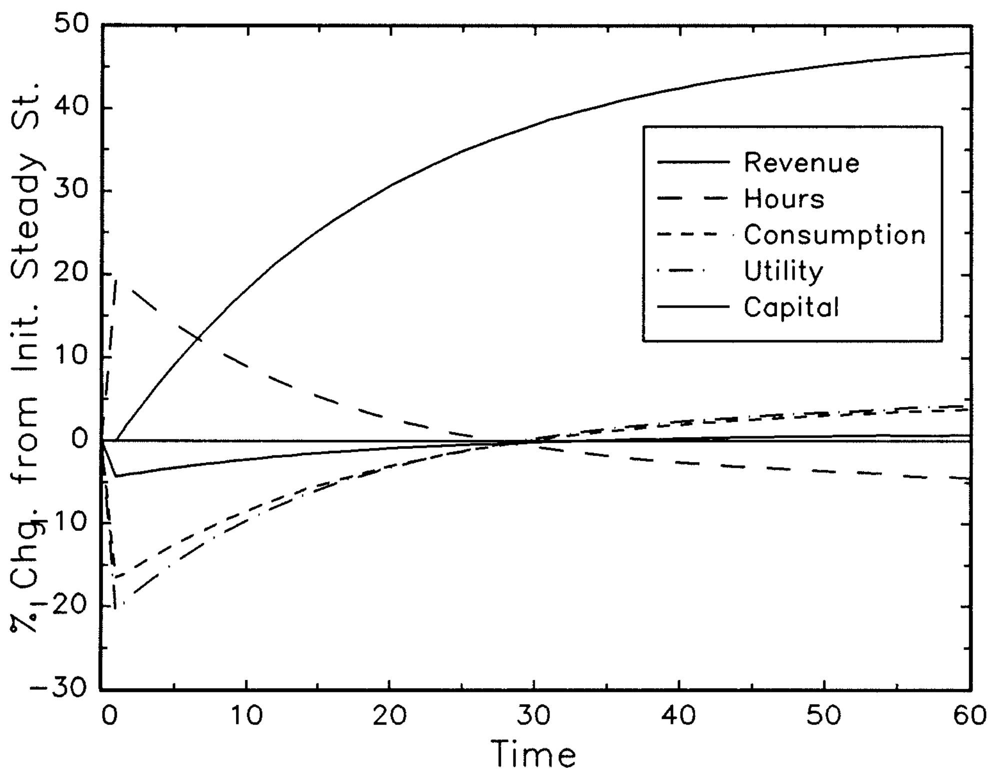

Figure 3 Replacing Capital Tax with Consumption Tax

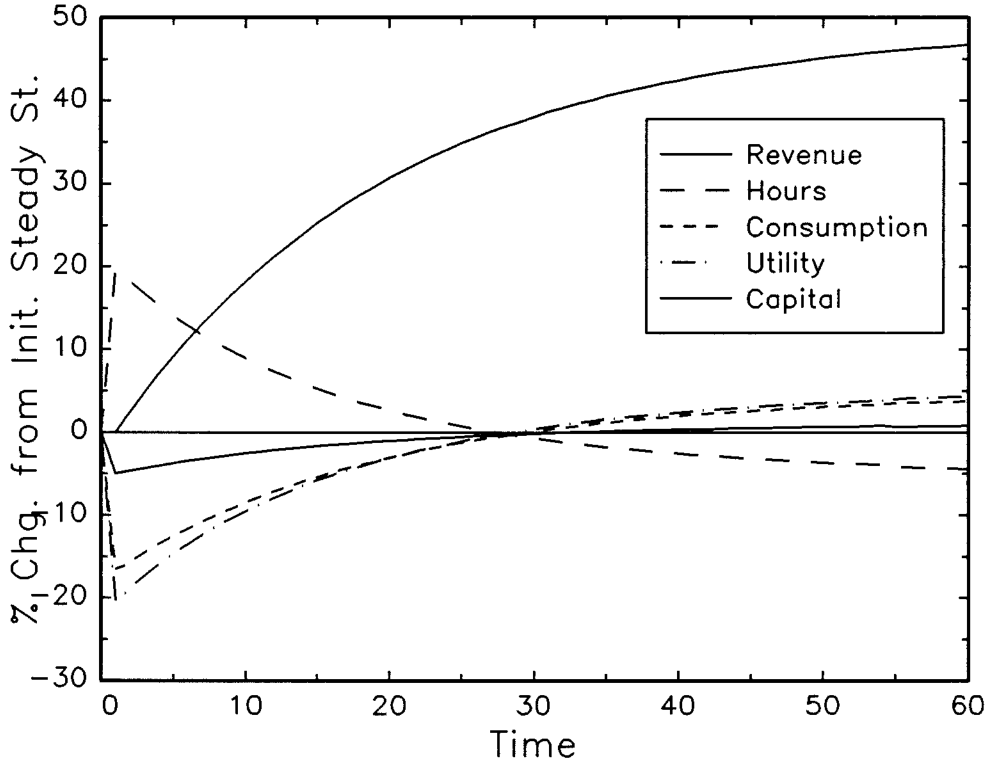

Figure 4 Replacing Capital Tax with Labor Tax

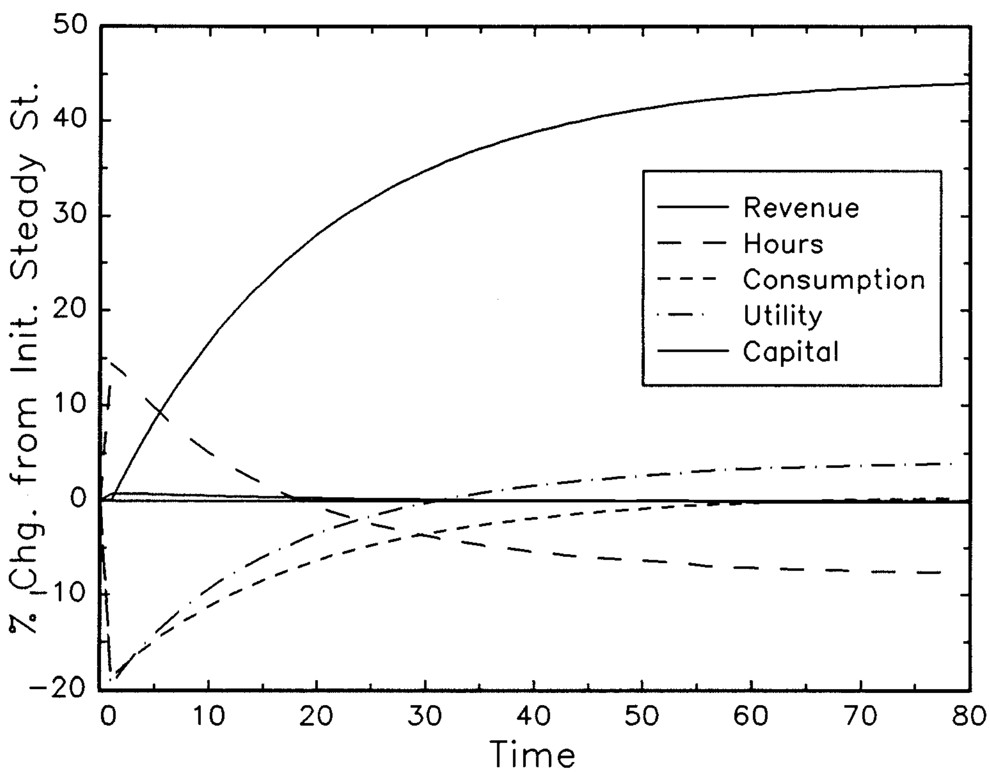

Figure 5 Replacing Capital Tax with Inflation Tax (Nonstationary)

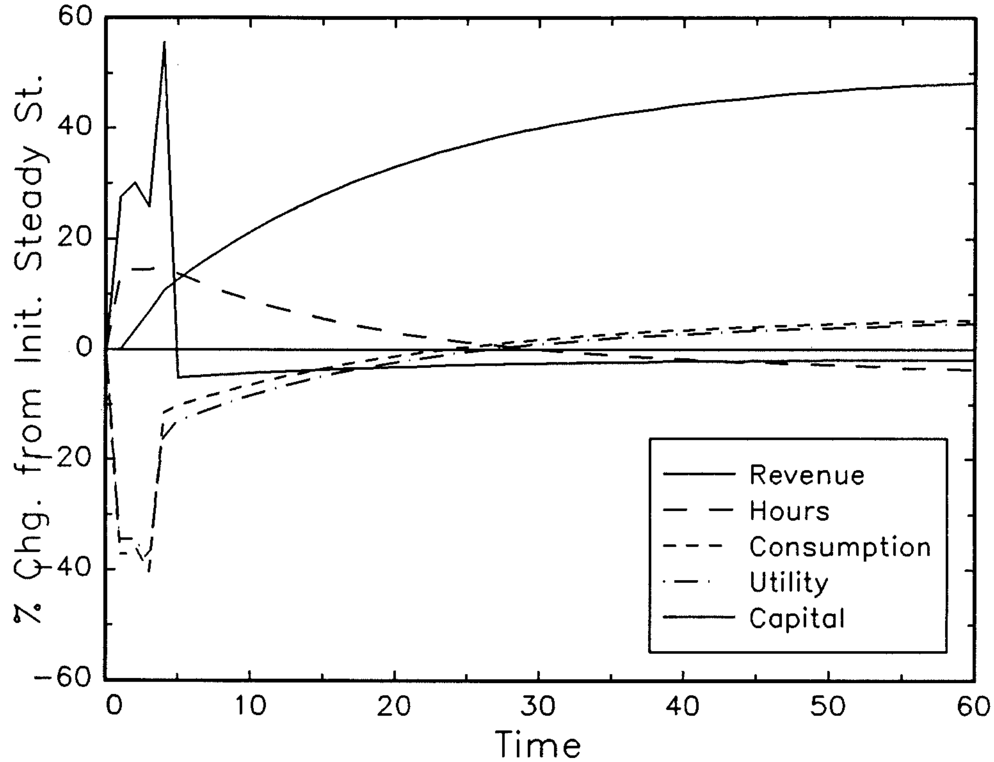

Figure 6 Replacing Capital Tax with Consump. Tax (Nonstationary)

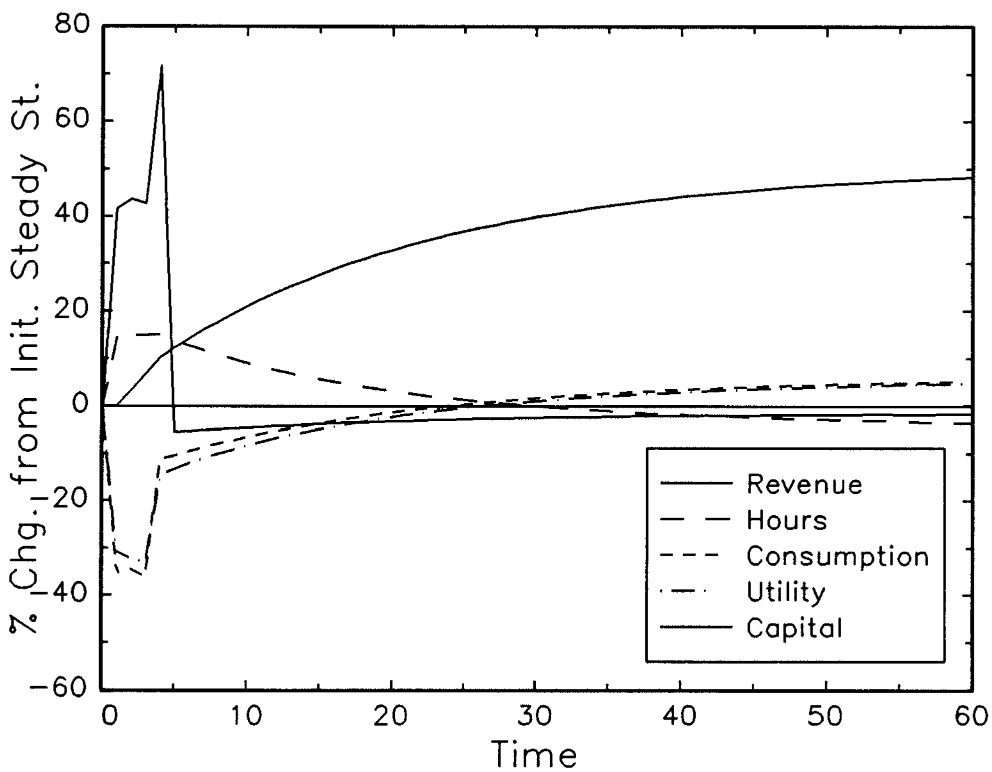

Figure 7 Replacing Capital Tax with Labor Tax (Nonstationary)