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THE WELFARE COSTS OF MODERATE INFLATIONS

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ABSTRACT

In this paper we appraise the revenue and welfare costs of policies designed to reduce moderate inflation rates to zero. We analyze policies in which inflation is simply reduced to zero and policies in which the revenue from the inflation tax must be replaced by increasing the taxes on labor and capital income. The vehicle for analysis is an equilibrium growth model with money. Our results show that policies designed to reduce moderate inflations offer only small improvements in welfare. When the revenues have to be replaced by other distorting taxes, the welfare costs of the new policy are substantially higher than the original policy.

1. Introduction

In the recent past the view that a little bit of inflation was good for the economy was widely held. The Phillips curve, in its earlier incarnations, implied that moderate inflation was worth tolerating because it would permit lower unemployment. This justification for tolerating inflation has long since been abandoned by economists and policy-makers because both theory and experience showed it to be false. Nevertheless, one legacy of this era seems to be a fairly widespread tolerance for moderate inflation. Recently, there has been much discussion of removing this inflationary bias by passing legislation that would require the Federal Reserve to target zero inflation. In this paper we examine some of the consequences of achieving that goal: we appraise the revenue and welfare costs of policies designed to reduce moderate inflation rates to zero.

Much has been written about why government policies may have an inflationary bias. In this paper we don't address the issue of what motivates governments to inflate. Implicit in our analysis, however, is the notion that one important motive for inflation is the revenue raising potential of the inflation tax. It would be difficult to argue that the inflation tax constitutes an important revenue source for the United States. One indirect and very imperfect measure of this would be contributions by the Federal Reserve to the Treasury. In recent years those rebates have amounted to only about 2 to 2.5 % of total revenues or 4.5 to 5% of revenues from individual and corporate income taxes. Nevertheless, we demonstrate that in the model economy considered in this paper, the revenue from the inflation tax can very quickly become an important part of total revenues. The obvious additional advantage of the inflation tax as a revenue source is that it does not have to be legislated.

In addition to the revenue consequences of the inflation tax we consider the welfare costs -- the pure distortions -- caused by this levy. In a recent paper, Cooley and Hansen (1989), we provided estimates of the welfare costs of inflation based on simulations of a neoclassical monetary economy where money is held because of a cash-in-advance constraint. Those estimates ignored several features of the economy that are potentially important in assessing the welfare consequences of policies designed to bring the inflation rate to zero. Most importantly, those estimates ignored the potential interaction of the inflation tax with other distorting taxes. Further, no attention was paid to the revenue consequences of inflationary policies. In this paper we present the results of experiments designed to address these issues. First, we examine how the presence of other distorting taxes affects the welfare costs of inflation and the revenue that can be raised by the inflation tax. Next, we consider the welfare and revenue consequences of policies designed to reduce the inflation rate to zero. We analyze policies in which inflation is simply reduced to zero and policies in which the revenue from the inflation tax must be replaced by increasing the taxes on labor and capital income. Finally, we appraise the dynamic consequences of reducing the inflation rate to zero but having that change be temporary rather than permanent.

The vehicle for analysis in this paper is an equilibrium growth model with money. Money is introduced via a cash-in-advance constraint of the sort considered by Lucas and Stokey (1987). In this economy there are two kinds of consumption goods, a "cash good" and a "credit good". Individuals must purchase the cash good with currency. Both capital and labor income are taxed and money held to purchase the cash good is subject to the inflation tax. There is no uncertainty in this economy and no government debt. Further, we not address any of the optimal taxation problems considered by Chamley (1986), Chari, Christiano and Kehoe (1990) or King(1990).

Some of the key findings of our analysis are as follows. Our results show that the presence of other distorting taxes approximately doubles the estimated welfare cost of the inflation tax and decreases the revenue potential of the tax. A policy that reduces the inflation rate from 5% to zero in an economy with taxes on labor and capital income has the effect of lowering the annuity value of revenue by about 2.4 percent and increase welfare by only 0.33% of

GNP relative to the original policy. When the revenues have to be replaced by other distorting taxes, the welfare costs of the new policy are higher than the original policy with five percent inflation. Moreover, this economy can only replace a limited amount of revenue by increasing the tax on capital income. Finally, we show that policies that reduce the inflation rate to zero only temporarily actually make the economy worse off because of the intertemporal substitution that takes place.

The paper proceeds as follows. In the next section we describe the key features of the model economy and the equilibrium. Section 3 contains a discussion of the computational methods used to solve the economy, to simulate transitions from one policy to another and to estimate the welfare costs. In Section 4 we discuss the calibration of the model. Section 5 presents the results.

2. The Model

The model economy to be studied consists of a continuum of identical infinitely lived households that consume and invest output produced by a single firm with access to a constant returns to scale technology. There is no uncertainty; agents are assumed to have perfect foresight. The households supply labor and accumulate productive capital which they rent to the firm. There is also a government that supplies currency, taxes labor and capital income, and provides lump sum transfers to the households. Money is valued in this economy because it is required in order to purchase some consumption goods.[1] We shall first describe the role of the government, then the problem solved by the households, and finally the firm's problem.

The government issues money according to the following rule:

$$M_t = g_t M_{t-1} . \tag{2.1}$$

Given a price level, p_t, it follows that the amount of revenue raised by the government through money creation in period t is equal to $(g_t-1)M_{t-1}/p_t$.

In addition to seigniorage, the government also raises revenue by taxing labor income at the rate τ_{ht} and capital income at the rate τ_{kt}. Since the focus of this paper is on comparing the distorting effects of various forms of taxation, we assume the government makes no purchases of output. All revenue collected is refunded to agents in the form of real lump sum transfers equal to TR_t.

A policy in this economy consists of a sequence of money growth rates and tax rates, $\{g_t,\tau_{ht},\tau_{kt}\}_{t=0}^{\infty}$. The sequence of lump sum transfers, TR_t, are chosen so that the government budget constraint is satisfied in each period:

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[1] Eckstein and Leiderman (1989) use a model with money in the utility function to examine the seingorage and welfare costs of inflation for Israel.

(2.2) $$(g_t-1)\frac{M_{t-1}}{p_t} + \tau_{ht}w_tH_t + \tau_{kt}(r_t-\delta)K_t \;\; - TR_t$$

In this budget constraint, H_t is total hours worked, K_t is the aggregate capital stock, and w_t and r_t are the real wage rate and rental rate of capital, respectively.[2] The term $\tau_{kt}\delta K_t$, where δ is the rate of depreciation of capital, reflects the depreciation allowance built into the tax code.

Households seek to maximize the following utility function,

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

where $0 < \alpha < 1$, c_{1t} is consumption of the "cash good," c_{2t} is consumption of the "credit good" and h_t is hours worked in time t.[3] We assume that households have one unit of time that can be devoted to work or leisure, so $0 \leq h_t \leq 1$.

An important aspect of this utility function is that hours worked enters linearly. This feature follows from the following three assumptions as shown in Hansen (1985) or 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. An implication of this is that hours worked is proportional to employment in this model. Introducing this feature in a model of aggregate fluctuations enables the model to exhibit large fluctuations in hours worked relative to productivity, as shown in Hansen (1985). In addition, with this feature the model is consistent with the fact that most fluctuations in hours worked are due to fluctuations in the number of workers, not in hours worked per worker.

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[2] We are employing the convention of using capital letters (such as K and H) for economy wide 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.

[3] It is possible to recover the preference specification of Cooley and Hansen (1989) by setting α equal to one.

Households maximize (2.3) subject to the following sequence of budget constraints:[4]

(2.4)
$$c_{1t}+c_{2t} + x_t + \frac{m_t}{p_t} \le (1-\tau_{ht})w_t h_t + (1-\tau_{kt})r_t k_t + \tau_{kt}\delta k_t + \frac{m_{t-1}}{p_t} + TR_t$$

where m_t is money balances held from period t to period t+1 and x_t is investment.

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

(2.5)
$$k_{t+1} = (1-\delta)k_t + x_t\,, \quad 0<\delta<1.$$

Households enter period t with nominal money balances equal to m_{t-1} carried over from the previous period. Holdings of money balances are required in order to purchase the "cash good," c_1. In addition, the government issues new currency in the amount $M_t - M_{t-1} = (g_t-1)M_{t-1}$ that provides additional cash to households that can be used for purchases of cash goods in period t. That is, a household's consumption choice must satisfy the cash-in-advance constraint,

(2.6)
$$p_t c_{1t} \le m_{t-1} + (g_t-1)M_{t-1}.$$

In this paper, attention is focused on examples where this constraint holds with equality. This constraint will always bind if the monetary growth factor, g_t, exceeds the discount factor, β, for all t. Our examples will satisfy this condition.

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

(2.7)
$$Y_t = K_t^{\theta} H_t^{1-\theta}\,, \quad 0<\theta<1.$$

The firm seeks to maximize profit, which is equal to $Y_t - w_t H_t - r_t K_t$. The first order

4 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.

conditions for the firm's problem yield the following functions for the wage rate and rental rate of capital:

$$w(K_t,H_t) = (1-\theta)\left(\frac{K_t}{H_t}\right)^{\theta} \tag{2.8}$$

$$r(K_t,H_t) = \theta\left(\frac{H_t}{K_t}\right)^{1-\theta} \tag{2.9}$$

To facilitate solving for an equilibrium, we transform variables so that the household's problem is stationary. In particular, we define $\hat{m}_t = m_t/M_t$ and $\hat{p}_t = p_t/M_t$. In addition, we let $V(\hat{m},K,k) = V(\hat{m}_{t-1},K_t,k_t)$ be the equilibrium maximized present value of the utility stream of the representative household who enters the period with a fraction of per capita money balances equal to $\hat{m}$ and a capital stock equal to k when the aggregate state is described by K. Implicit in the functional form of V are equilibrium aggregate decision rules for H and X and the equilibrium pricing function, $\hat{p}$. Each of these is a function of the aggregate state, K. The function V must satisfy Bellman's equation (primes denote next period values):

$$V(\hat{m},K,k) = \max\{U(c_1,c_2,h) + \beta\, V(\hat{m}',K',k')\} \tag{2.10}$$

subject to

$$\begin{aligned} c_1 + c_2 + x + \frac{\hat{m}'}{\hat{p}} &= w(K,H)[(1-\tau_h)h + \tau_h H] \\ &+ r(K,H)[(1-\tau_k)k + \tau_k K] + \tau_k \delta(k-K) + \frac{\hat{m}+g-1}{\hat{p}\,g} \end{aligned} \tag{2.11}$$

$$c_1 = \frac{\hat{m}+g-1}{\hat{p}g} \tag{2.12}$$

$$K' = (1-\delta)K + X \tag{2.13}$$

$$X = X(K), \quad H = H(K), \quad \hat{p} = \hat{p}(K) \tag{2.14}$$

and (2.5), (2.8), (2.9), c_1, c_2, x, $\hat{m}'$ non-negative and $0 < h < 1$.

For this problem, tax rates are assumed to be constant. Constraint (2.11) is the household's budget constraint after transforming the variables and substituting in the government budget constraint (2.2). Equation (2.12) is the transformed cash-in-advance constraint, which we assume holds with equality. The aggregate capital stock evolves according to (2.13). Finally, (2.14) gives the perceived functional relationship between the aggregate state, K, and aggregate investment, aggregate hours worked and the price level.

A <u>stationary competitive equilibrium</u> consists of a set of decision rules, $c_1(s)$, $c_2(s)$, $x(s)$, $\hat{m}'(s)$, and $h(s)$ (where $s = (\hat{m},K,k)$), a set of aggregate decision rules, $X(K)$ and $H(K)$, a pricing function $\hat{p}(K)$, and a value function $V(s)$ such that:

(i) the functions V, X, H, and $\hat{p}$ satisfy (2.10) and c_1, c_2, x, $\hat{m}'$, and h are the associated set of decision rules;

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

(iii) $c_1(1,K,K) + c_2(1,K,K) + x(1,K,K) = Y(K)$

3. Computational Issues

3.1 *Solving for an Equilibrium*

In much of the literature on the neoclassical growth model, the real business cycle literature in particular, it is possible to compute an 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).[5]

This method, which we will not discuss in detail here, involves substituting constraints (2.11) and (2.12) into the period utility function given in equation (2.3), eliminating c_1 and c_2. A quadratic approximation of this objective function is formed around the steady state, using the method described in Kydland and Prescott (1982). Given linear guesses for the functions in

[5] This method is described in a fair amount of detail in Hansen and Prescott (1990).

(2.14), problem (2.10) becomes a linear-quadratic dynamic programming problem. The iterative method used to solve for the equilibrium aggregate decision rules and price level in (2.14), and simultaneously the value function in (2.10), is described in our previous paper.

3.2 *Simulating Policy Changes*

The experiments described in this paper all assume that the policy variables (g,τ_h,τ_k) are constant after some date T. The methods described in the previous subsection are used to obtain equilibrium aggregate decision rules that hold under this constant policy. However, we are interested in simulating the effects of policy changes, either temporary or permanent, that occur before T. We use the equilibrium Euler equations from the original nonlinear version of the model to simulate the effects of these policy changes.[6]

To make this more precise, let a policy at date t be denoted by $\tau_t = (g_t,\tau_{ht},\tau_{kt})$. The class of policy sequences we consider have the form, $\{\tau_t\}_{t=0}^{T}$ and $\tau_t=\bar{\tau}$ for $t \geq T+1$, where $\bar{\tau}$ is some policy that is independent of time. The equilibrium Euler equations for the original model are formed from the first order conditions (with respect to h_t, k_{t+1} and $\hat{m}_t$) for a sequence version of the households problem (2.10) after (2.11) and (2.12) have been substituted into the objective. Imposing the equilibrium conditions ($k_t = K_t$, $\hat{m}_t = 1$, $x_t = X_t$, and $h_t = H_t$ for all t), we obtain three sequences of equilibrium Euler equations of the following form:

$$(3.1) \quad \phi(\tau_t,\tau_{t+1},\hat{p}_t,\hat{p}_{t+1},H_t,H_{t+1},K_t,K_{t+1},K_{t+2}) = 0, \text{ for } t = 0, ...,T .$$

After date T, the variables $\hat{p}$, h and k are assumed to be chosen according to the aggregate decision rules obtained from the quadratic approximation when $\tau = \bar{\tau}$. In particular, the

[6] It is also possible to simulate the effects of a policy change using the quadratic approximation described above. However, the quadratic approximation methods may lead to inaccurate results if the economy moves far from the original steady state. This may be a serious problem for some of the experiments we consider.

variables $\hat{p}_{T+1}$, H_{T+1} and K_{T+2}, which enter the Euler equations for period T, are determined in this way. Substituting the aggregate decision rules into the last set of Euler equations produces a system of $3\cdot(T+1)$ equations in $3\cdot(T+1)$ unknowns which can be solved using a nonlinear equation solver. We then use these linear aggregate decision riles to simulate beyond period T. In practice, we choose T so that the policy $\bar{\tau}$ 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.

3.3 *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 Pareto optimal allocation. The Pareto optimal allocation for our economy is equivalent to the equilibrium allocation for the same economy without the cash-in-advance constraint or distorting taxes, or, equivalently, for a version of the model where the money supply grows at a rate such that the cash-in-advance constraint is never binding. It turns out that for the model studied in this paper, the cash-in-advance constraint is not binding if the monetary growth factor is equal to the discount factor, β.[7] To obtain a measure of the welfare loss associated with distorting taxation in the steady state, we solve for x in the equation

$$\bar{U} = \alpha \log[c_1^*(1+x)] + (1-\alpha)\log[c_2^*(1+x)] - Bh^* . \tag{3.2}$$

In this equation, $\bar{U}$ is the level of utility attained (in the steady state) under the Pareto optimal allocation ($g = \beta$, $\tau_h = \tau_k = \tau_c = 0$), and c_1^*, c_2^* and h^* are the steady state consumption and hours associated with the tax 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

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[7] When we set $g = \beta$, the initial price level is no longer uniquely determined. However, the real allocation and rate of inflation are uniquely determined and the allocation is Pareto optimal if there are no other distorting taxes.

restore an individual to the level of utility obtained under the Pareto optimal allocation.

In some of our experiments we consider changes in policy. In those cases we want take into account the effects of the transitional dynamics. The procedure we follow is to compute a 2000 period simulation starting from the steady state of the baseline policy. From this simulation we have time series on 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 (3.2).

$$\sum_{t=1}^{1000} \beta^t[\alpha \log(c_{1t}(1+x)) + (1-\alpha)\log(c_{2t}(1+x)) - h_t - \bar{U}] = 0 \tag{3.3}$$

The welfare cost measure, ΔC, is defined to be the annuity value of $x(c_{1t}+c_{2t})$ over the 2000 period simulation. We will usually express these welfare costs as a percentage of the annuity value of GNP.

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.[8] 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 the then the parameters of technology and preferences.

Since the inflation rate has been quite low on average in the U.S. during the postwar

[8] 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.

period, we chose to calibrate the model assuming a zero inflation rate, which implies setting g = 1.0. 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 income is 23% and the tax rate on capital is 50% (τ_h = .23 and τ_k = .5), values which were determined by taking the average of the time series reported in Joines (1981).[9]

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. Taking total output to be consumption of nondurables and services plus fixed nonresidential investment, 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.

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

[9] 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.

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 1.8.

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, we can introduce a market for nominally denominated bonds which is open at the beginning of the period. Bonds carried from period t to t+1, b_t, must be purchased with cash balances or the return from bonds carried over from period t-1. The gross rate of return on bonds held from t to t+1 is R_t. With this addition, the cash-in-advance constraint (2.6) becomes

$$p_t c_{1t} + b_t = m_{t-1} + (g_t - 1)M_{t-1} + (1+R_{t-1})b_{t-1} \tag{4.1}$$

Similarly, b_t must be introduced into the budget constraint, (2.4). From the first order conditions for b_t and m_t, it is possible to obtain the following expression:

$$\frac{C_t}{m_t/p_t} = \frac{1}{\alpha} + \frac{(1-\alpha)}{\alpha} R_t \tag{4.2}$$

where $C_t = c_{1t} + c_{2t}$.

Equation (4.2) relates the velocity defined in terms of total consumption to the nominal interest rate R_t. To give empirical content to this relation 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 model. Instead, we use the portion of M1 that is held by households.[10] To obtain a value for α, we compute the regression implied by (3.2) using these data.[11] For the sample period from 1970 -1986, the estimated equation is:

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

where RTB is 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 results of this survey are depicted in Figure 1 for 1984. The proportions for 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:

$$(4.3) \qquad \alpha = \frac{g\upsilon}{\beta(1-\upsilon)+g\upsilon}$$

Using $\beta = .99$, $g = 1$ 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 most of the

[10] These data are obtained from the Flow-of-Funds Accounts. Unfortunately these data too are flawed because of the way they treat currency. Currency held by households is treated as the residual of total currency outstanding and currency held by businesses and governments. The resulting figure is undoubtedly way too high.

[11] 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 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.

following experiments. For some of them we will use a value of $\alpha=0.5$, much smaller than the calibrated value.[12]

We summarize our parameter choices in the following table:

g	τ_h	τ_k	θ	δ	β	B	α
1.00	0.23	0.50	0.36	0.02	0.99	1.80	0.84

5. **Policy Experiments**

Our objective in this paper is to analyze the welfare consequences of ending moderate inflations. We begin by describing the steady state properties of the economy for various inflation policies with and without other distorting taxes.

5.1 *Steady State Properties*

Consider first the revenue generated in this economy by different steady state inflation rates. Figure 2 shows total revenues raised by inflation both with and without the taxes on capital and labor income and it shows the change in total revenue when inflation is combined with other taxes. Inflation taxes contribute less to total revenues when other distorting taxes are present. Figure 3 shows seignorage as a fraction of GNP for both of these cases. The observation that inflation tax revenues are a larger fraction of GNP when other taxes are present reflects the fact that GNP is lower in that case. Figures 4 and 5 show the welfare cost of inflation and the welfare cost divided by revenue for various steady state inflation rates, with and without other distorting taxes. The key observation here is that the presence of other taxes nearly doubles the welfare

[12] This extension was suggested by the comments of Benabou and Wright.

cost of inflation. Figure 5 shows that, for moderate inflation rates, the revenue gained is much greater than the welfare cost incurred and this is true regardless of the presence of other taxes.

These steady state results are summarized in Table 1. The top panel shows the consequences of the inflation tax when the policy includes taxation of labor and capital income. The lower panel shows the revenue and welfare consequence of the inflation tax by itself. The third panel of Table 1 shows the welfare costs associated with different policies when we reduce our calibrated value of α, the parameter that captures relative preferences for cash versus credit goods. These latter numbers are included to show the sensitivity of the results to this feature of the model.

Column 2 of Table 1 shows the revenue associated with each steady state inflation rate. Column 3 shows the ratio of that revenue to GNP and so on. The right-most column shows the welfare cost of the entire policy. The first entry in this column gives us an estimate of the pure distortion associated with the taxation of capital and labor income in the base policy. This estimate of 16.843% of GNP is within the range of, but at the low end of estimates that have appeared elsewhere in the literature. To summarize, we find that the presence of other distorting taxes has two pronounced effects: the welfare costs of the inflation tax are essentially doubled and the revenue from a given steady state inflation policy are reduced by one third. When agents have preferences that are less heavily weighted toward cash goods, the revenue potential of the inflation tax and the welfare costs of inflation are both much smaller. The third panel shows that both the revenue and the welfare costs are decreased by nearly one half by this difference in parameters. The welfare cost of the entire policy is not affected very much because most of the distortion is due to the other taxes.

4.2 *Reducing Inflation*

Next we consider the repercussions for this model economy of a policy proposal that has been much discussed: reducing a moderate inflation to zero. In simulating this transition we assume that the new policy will hold forever and that agents have perfect foresight about this. We first estimate the welfare gains of simply reducing the inflation rate from 5% to zero, from 10% to zero and from 20% to zero.

The consequences of these reductions are shown in Table 2. Column 1 of Table 2 shows the inflation rate associated with the initial policy. The taxes on labor and capital income are held at their baseline level for these experiments. The welfare costs associated with these initial policies can be read from the top half of Table 1 (column 7). Column 2 of Table 2 shows the welfare costs from the new policy relative to the original policy (including the effect of the transition).[13] This number is computed as the annuity value of the change in consumption that would yield the same utility as the initial policy (e.g. 5% inflation) stated as a percentage of GNP.[14] Accordingly negative numbers indicate that one is better off under the new policy. This particular way of computing the welfare cost gives us the best direct comparison to the initial distorted policy. Column 3 of Table 2 shows the annuity value of the revenue lost as a consequence of the transition to zero inflation. These results confirm the widely held view that a permanent reduction of the inflation rate to zero has positive welfare consequences. The welfare costs of the distortions in this economy decrease by .34% of GNP, .66% of GNP and 1.28% of GNP as a consequences of eliminating 5%, 10% and 20% inflation respectively. These welfare improvements are not obtained without some cost. From an initial 5% annual inflation the revenue loss is 2.39%, from an initial 10% annual inflation the revenue loss is 4.45% and from an initial 20% inflation the revenue loss is 7.87%. These are very sizeable revenue losses obtained for a small improvement in welfare. In the current budgetary climate even 2% would be important.

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[13] The transitional dynamics have a very minor effect on welfare.

[14] Referring back to equation 3.2

Table 3 shows what would happen in this economy if the revenue losses due to ending a moderate inflation have to be replaced by other distorting taxes. Column 2 displays the welfare cost of the original policy. Columns 3 and 4 display the welfare costs of the new policy when revenue is replaced by the labor income tax. Replacing the revenues from a 5% inflation increases the welfare cost of the policy by .425% compared to the initial policy; compensating for a 10% inflation increases the welfare cost by 1.018%; compensating for a 20% increases the welfare cost by 2.42%. Columns 5 and 6 show the consequences for welfare when the revenue from the inflation tax must be replaced using the capital income tax. Replacing the revenues from 5% inflation with the capital tax increases welfare cost relative to the initial policy by 3.23%. Replacing larger revenue losses with the capital tax is simply not possible. Figures 6 and 7 show, for the 5% inflation case, how the time path of utility, hours, consumption and capital are affected by the transition to a new policy. Consumption and hours initially decline sharply and then gradually approach their new steady state value while the capital stock declines gradually. When the capital tax is used to replace revenue the effect on capital and hours is dramatic. The former falls by nearly 4% in the first period, while the capital stock declines steadily to a level more than 12% below the initial steady state. Consumption initially increases for this policy but then is lower eventually as a consequence of the drop in investment. These results underscore the consequences of replacing the inflation tax with taxes that are more distorting.

5.3 *Temporary Policy Changes*

The set of experiments just discussed all involve transitions from one policy to another that are permanent. Once the transition to zero inflation occurs agents in this economy believe it to be permanent. In this section we suppose the government is unable to commit to a permanent change in inflation policy and instead can only engineer a temporary change and agents know this to be the case.

The results of these experiments are shown in Table 4. All of these assume that the initial policy in this economy involved a 10% annual inflation rate and the new policy is one of zero inflation. Taxes on labor and capital income remain fixed. Table 4 shows the results of experiments in which inflation is zero for one, two and five years. These results suggest that both welfare and revenue are likely to decline as a consequence of temporary changes in policy. The welfare costs of the policy are higher and the revenue is lower. The reason for this can be seen in Figure 8 which shows the time paths of revenue, consumption, hours, capital and utility for a one year change in the inflation policy. The effect of the one year decline in inflation is an immediate and sharp drop in investment (a "credit good" in this economy) and a corresponding increase in consumption over the period that it is untaxed. The consequence of this intertemporal substitution is that consumption is lower in the long run and utility and the present value of revenue are both marginally lower. The implication of these results is that unless there is a commitment technology available that would bind the government to policies that keep the inflation rate at zero then the policies would not have the desired consequences.

6. **Concluding Remarks**

In this paper we have tried to address a current policy issue --the proposal that the Federal Reserve should be required to reduce inflation to zero-- by simulating some of its consequences with a simple equilibrium model. This exercise is in the spirit of a large public finance literature that has looked at taxation this way. Nevertheless, we are mindful of the fact that this simple model abstracts from many of the details of the economy and the fiscal system that may have an important bearing on the consequences of policies to reduce inflation. With that important caveat, however, our results show that, for the model economy studied here, the costs of lowering inflation to zero may well exceed the benefits. This is particularly true if there is no commitment mechanism that would bind the Fed to this policy indefinitely.

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Table 1

Welfare and Revenue Consequences of Alternative Policies

Economy With Capital and Labor Income Taxation

$\alpha = 0.84$

Inflation Rate	Seignorage	Seignorage/GNP	Welfare Cost of Inflation (%GNP)	Change in Total Revenue	Seignorage/Total Revenue	Welfare Cost of Policy (%GNP)
0.0	0.0	0.0	0.2794	0.0	0.0	16.843
5.0	0.0094	0.0083	0.6257	0.0066	0.0239	17.259
10.0	0.0180	0.0161	0.9628	0.0126	0.0448	17.664
20.0	0.0333	0.0304	1.6117	0.0232	0.0792	18.443
50.0	0.0681	0.0652	3.3860	0.0463	0.1464	20.575

Economy With Only Inflation Tax

Inflation Rate	Seignorage	Seignorage/GNP	Welfare Cost of Inflation (%GNP)	Change in Total Revenue	Seignorage/ Total Revenue	Welfare Cost of Policy (%GNP)
0.0	0.0	0.0	0.1048	0.0	1.0	0.1048
5.0	0.0143	0.0077	0.2392	0.0143	1.0	0.2392
10.0	0.0275	0.0150	0.3751	0.0275	1.0	0.3751
20.0	0.0508	0.0282	0.6488	0.0508	1.0	0.6488
50.0	0.1040	0.0605	1.4661	0.1040	1.0	1.4661

Table 1(continued)

Welfare and Revenue Consequences of Alternative Policies

Economy With Capital and Labor Income Taxation

α=0.50

Inflation Rate	Seignor-age	Seignor-age/GNP	Welfare Cost of Inflation (%GNP)	Change in Total Rev-enue	Seignor-age/Total Revenue	Welfare Cost of Policy (%GNP)
0.0	0.0	0.0	0.1669	0.0	0.0	16.707
5.0	0.0056	0.0049	0.3719	0.0039	0.0143	16.954
10.0	0.0107	0.0095	0.5717	0.0075	0.0270	17.194
20.0	0.0198	0.0178	0.9556	0.0138	0.0485	17.655
50.0	0.0405	0.0374	1.9992	0.0275	0.0923	18.909

Table 2

Gains and Losses From a Transition to Zero Inflation

Initial Policy	Welfare Cost of Original Policy	Welfare Cost of New Policy Relative To Original (%GNP)	Annuity Value of Revenue Loss From New Policy
5% Annual Rate	17.259	-0.34%	2.38%
10% Annual Rate	17.664	-0.66%	4.45%
20% Annual Rate	18.443	-1.280%	7.87%

Table 3

Welfare Costs of Reducing Inflation Permanently
Holding Revenue Constant

		Revenue Replaced With Labor Income Tax		Revenue Replaced With Capital Income Tax	
Inflation Rate	Welfare Cost of Original Policy %GNP	Welfare Cost of New Policy %GNP (Tax Rate)	Welfare Cost of New Policy Relative to Original %GNP	Welfare Cost of New Policy %GNP (Tax Rate)	Welfare Cost of New Policy Relative To Original %GNP
5%	17.259	17.771	0.425	21.634	3.231
		(0.24762)		(0.58484)	
10%	17.664	18.926	1.018	NP	
		(0.2673)			
20%	18.443	21.468	2.422	NP	
		(0.30658)			

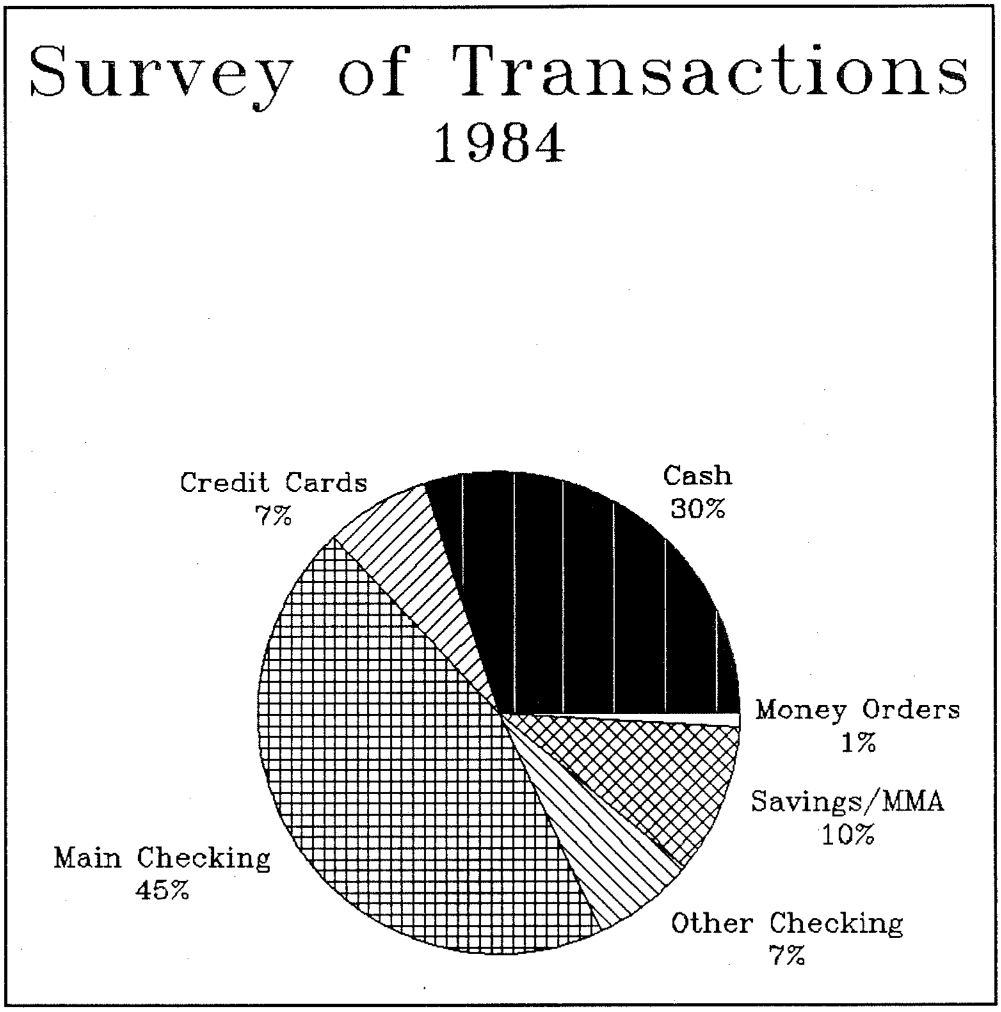
NP - Revenue Replacement not possible

Table 4

Welfare and Revenue Consequences of Temporary Policy
Initial Policy 10% Inflation

Duration of New Policy	Welfare Cost of Original Policy	Welfare Cost Relative To Original Steady State (%GNP)	Percentage Change in Annuity Value of Revenue From Policy
One Year	17.664	.0008	-.239%
Two Years	17.664	.0013	-.448%
Five Years	17.664	.00007	-.966%

Figure 1



Survey of Transactions
1984
Credit Cards
7%
Cash
30%
Money Orders
1%
Savings/MMA
10%
Main Checking
45%
Other Checking
7%

Figure 2 Revenue from Inflation

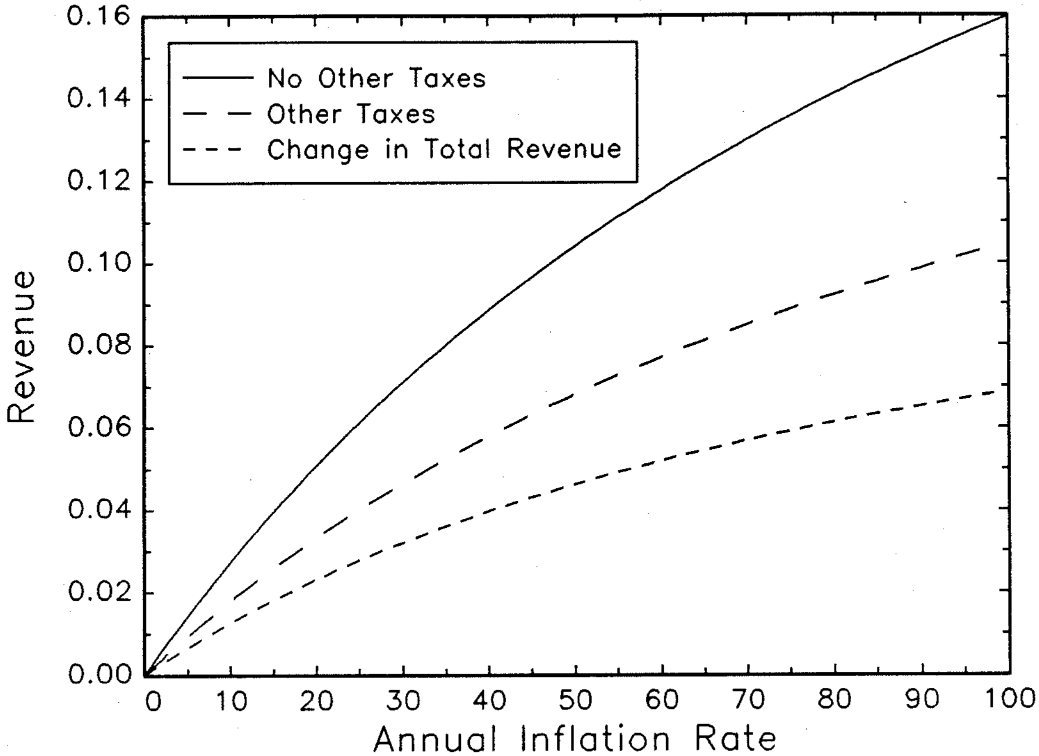


Figure 3 Seignorage as a Fraction of GNP

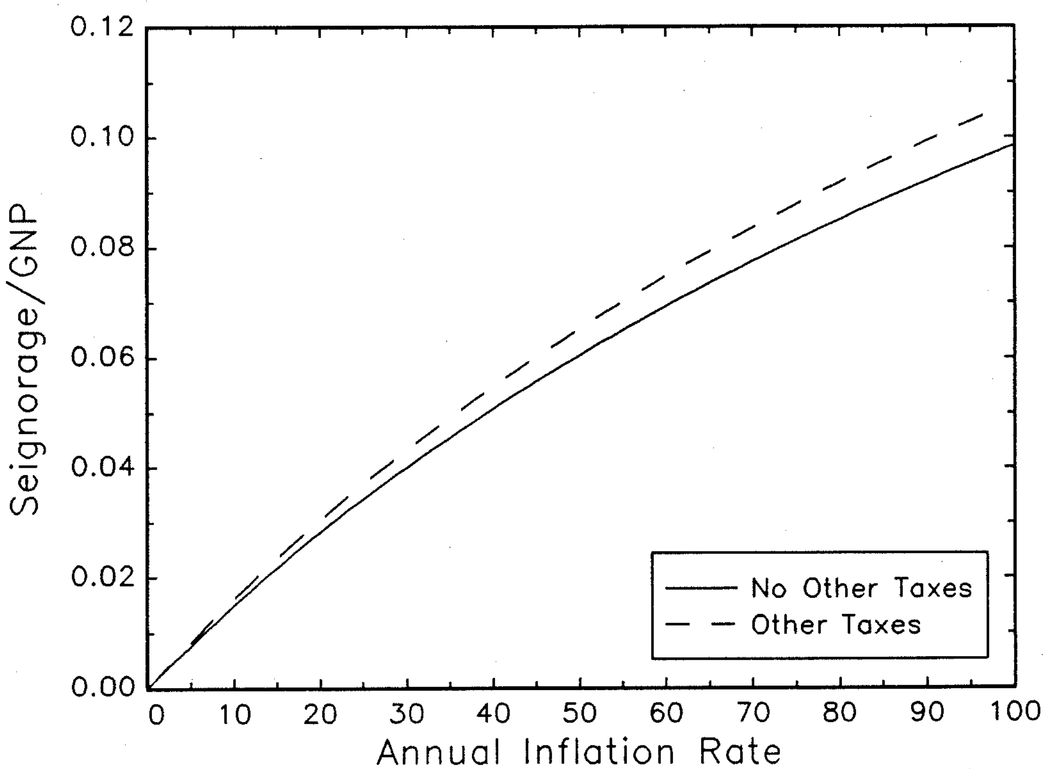


Figure 4 Welfare Cost of Inflation

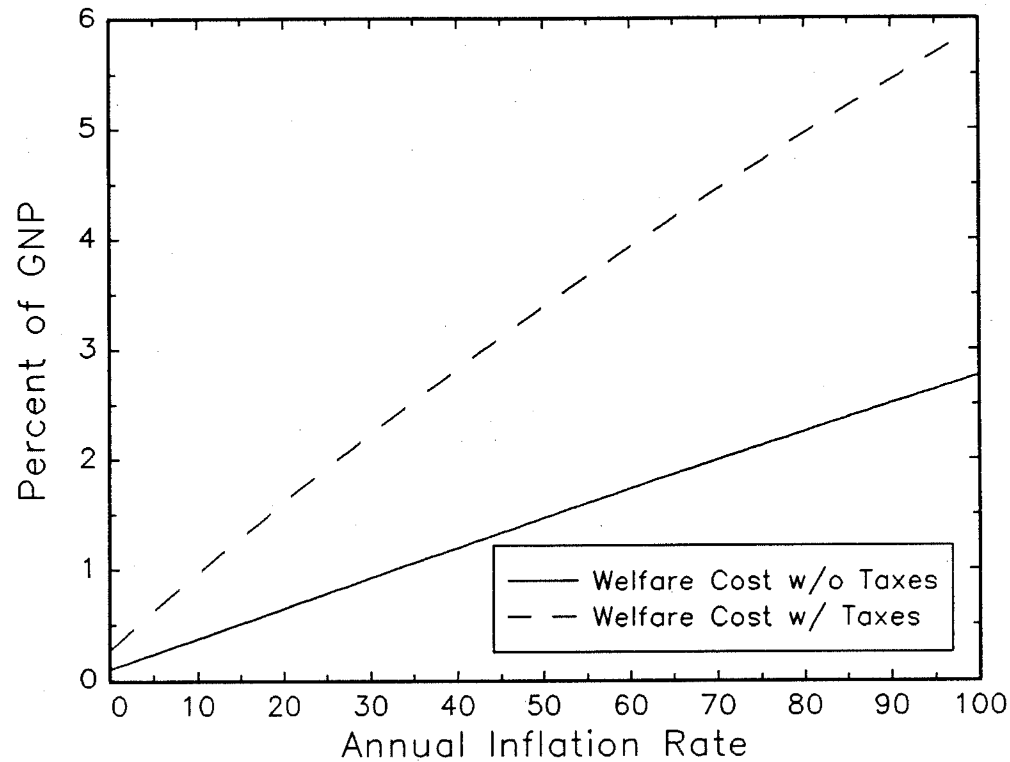


Figure 5 Welfare Cost Divided by Revenue

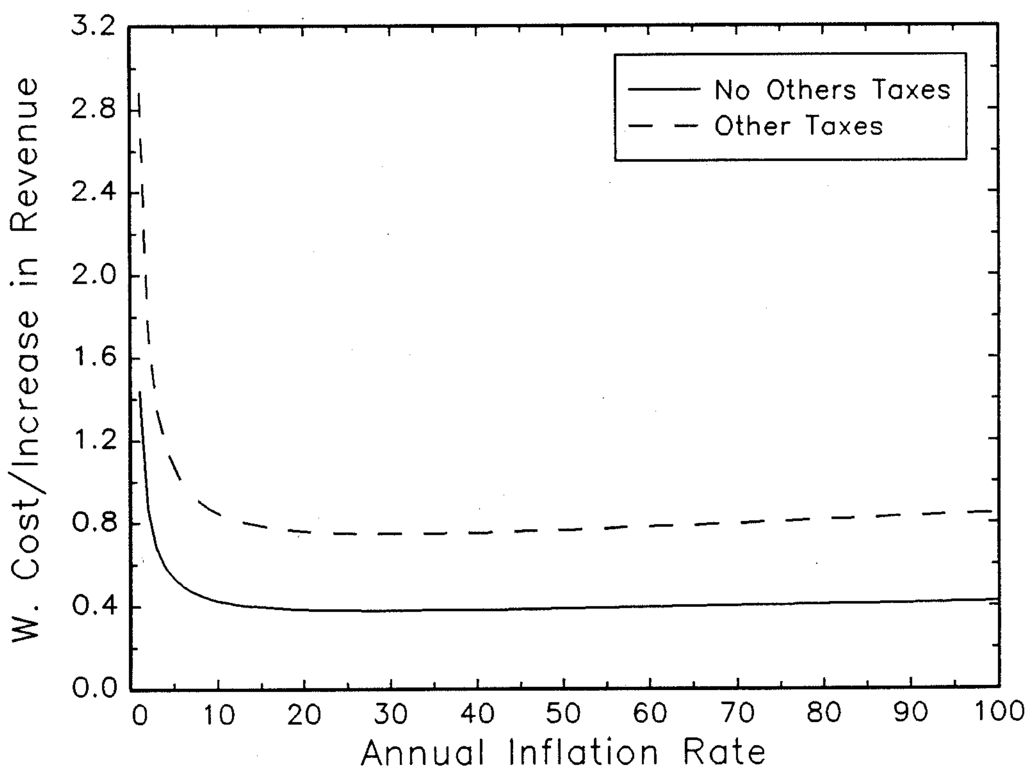


Figure 6 Eliminating 5% Inflation By Raising Labor Tax

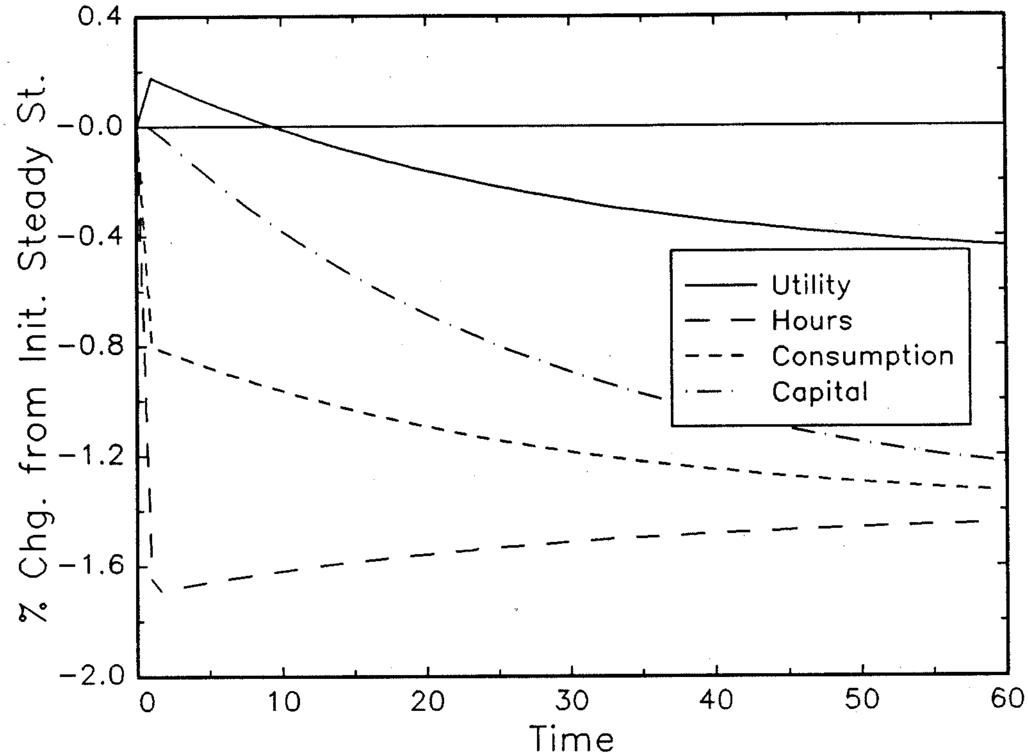


Figure 7 Eliminating 5% Inflation By Raising Capital Tax

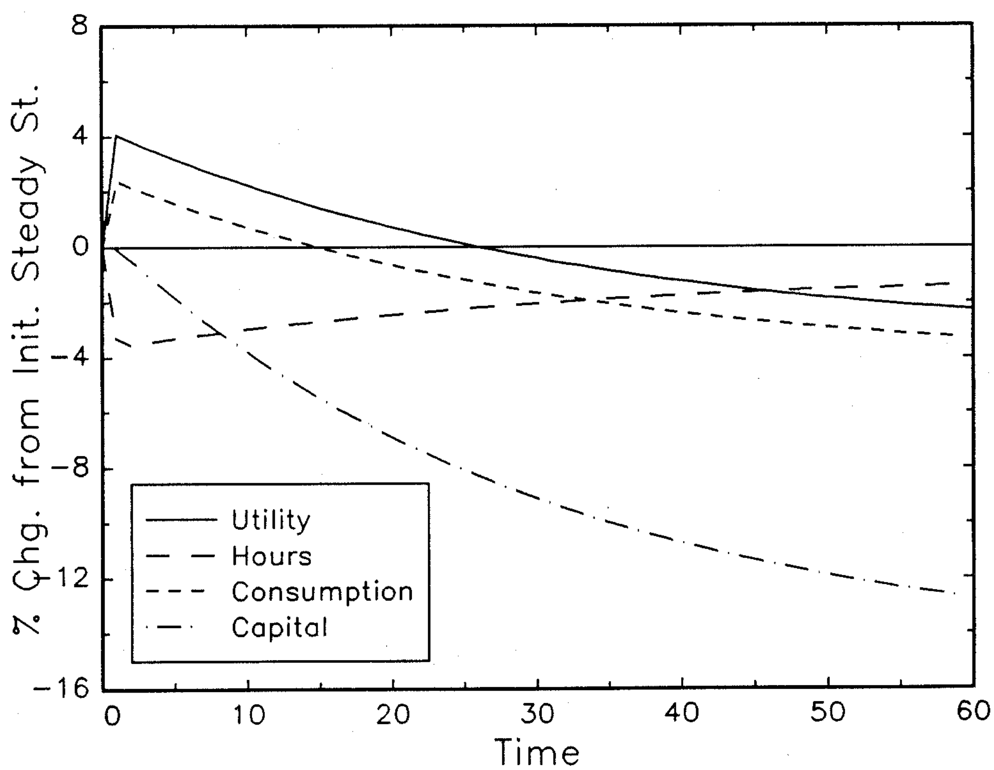


Figure 8 Temporary (One Year) Elimination of 10% Inflation