Monetary Policy, Taxes, and the Business Cycle

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ABSTRACT

In this paper, we model the interaction of inflation with the tax code, examining the contribution of this interaction to aggregate fluctuations. Our innovation is to combine persistent monetary policy shocks with non-indexed taxes in a model in which the central bank implements policy using an interest rate rule. All three features are necessary for us to generate large effects of monetary policy shocks, but they are also realistic features of the U.S. economy. We find that monetary policy had important effects on the behavior of the business cycle before 1980, but these effects are considerably less in post-1980 calibrations of the model.

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Introduction

Does the interaction of inflation and the tax code contribute considerably to aggregate fluctuations? There is a large body of work showing that the steady-state welfare effects of moderate inflation are large when nominal capital gains are taxed. These include the partial equilibrium analyses of Fischer (1981), Feldstein (1997), and Cohen, Hassett, and Hubbard (1999).[1] The literature also includes the steady-state analysis of general equilibrium models in Abel (1997), Leung and Zhang (2000), and Bullard and Russell (2004). In general equilibrium, the welfare costs arise because, for any given capital income tax rate, an increase in the inflation rate raises the real pre-tax rate of return to capital and lowers the after-tax return. The lower after-tax return causes a decline in the capital stock and a reduction in labor productivity. These analyses are about steady states and only suggestive about the cyclical impacts. This paper examines the impact of the interaction between inflation and the capital gains tax on business cycle fluctuations.

We specify a dynamic, stochastic, general equilibrium model that combines persistent shocks to the inflation trend with taxes on nominal capital gains in a setting where the central bank implements policy using an interest rate rule. All three features are necessary for us to generate large effects of monetary shocks, but they are also realistic features of the U.S. economy.

Cooley and Hansen (1989) and Pakko (1998) show that the real effects of persistent money growth shocks are large relative to money supply shocks, but still small. Studies with models using money supply rules will not find much interaction between the tax system and monetary policy shocks because there is little or no persistence in inflation following a money

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[1] For empirical estimates of the burden of capital gain tax using panel data, see Poterba (1987) and Auerbach (1988). For survey of the tax policy issues and recent evidence, see Auerbach (2004).

growth shock. A persistent money growth shock leads to a large jump in the price level, but inflation does not persist and does not affect expected returns to investment.

Inflation persistence is needed to induce changes in expected tax rates. Dittmar, Gavin, and Kydland (2004) show that inflation persistence is common in models where the central bank uses an interest rate rule. When the central bank is using an interest rate rule, a persistent shock to the inflation trend appears as a shock to the inflation target. It is followed by a persistent deviation of inflation from the steady state and, in the presence of a nominal tax on capital gains, a persistent change in the effective marginal tax rate on capital. Thus, a positive shock to the inflation objective distorts the consumption/saving decision and may have a long-lasting effect on the capital stock.[2]

We begin by describing a model with taxes, including separate taxes for income from labor, capital, bonds, and capital gains. In the United States, the rise of inflation in the 1970s without indexation of tax brackets and exclusion restrictions led the government to index some aspects of the tax code and to make ad hoc adjustments in other aspects. We assume constant statutory tax rates in order to examine the interaction of variable inflation with the nominal tax on capital gains. Then, we discuss the dynamics of the model, showing how inflation affects the business cycle through the tax on nominal capital gains. Finally, we use the model with estimates of persistence in the inflation objective to show what our model predicts for capital, hours, and productivity in the U.S. economy.

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[2] Altig and Carlstrom (1991) use an overlapping-generations model with nominal prices (but without money explicitly included) to show that the lack of perfect indexation for inflation in the tax code could have a large cyclical effect in principle. They find, however, that their model could not account for the magnitude of cyclical variation in hours worked and that it predicts a large decline in the capital stock in the 1980s that never materialized. We find that one crucial assumption in Altig and Carlstrom—the relatively low calibrated value for inflation persistence—is likely to be important for these findings.

A Monetary Model with Nominal Taxes

Technology

Output is produced with a constant returns to scale (CRTS) production technology:

(1) $$Y_t = z_t F(K_t, x_t N_t) = z_t K_t^{\alpha}(x_t N_t)^{1-\alpha},$$

where z_t is a stationary technology shock and x_t is an index of labor-augmenting technical progress that increases at a (gross) growth rate $\gamma_x^{1/(1-\alpha)}$. The implied growth rate for output, capital, and consumption, γ_x, defines a steady-state growth path for the real economy.

The firm sells output at price P_t, and purchases labor and capital services from the household at nominal wage W_t and rental price of capital V_t. Along with the CRTS assumption, profit-maximization under perfect competition implies that the real wage rate, $w_t=W_t/P_t$, and rental price, $v_t=V_t/P_t$, will be equated with the marginal products of labor and capital.

Capital—owned by the household—follows the law of motion

(2) $$K_{t+1} = (1-\delta)K_t + I_t,$$

where I_t is gross investment and δ is the depreciation rate on capital.

Government with a Nominal Tax Code

A government issues money and collects revenues by imposing proportional taxes on nominal income from labor, bond interest, and capital ownership (with possibly differing tax rates). Government revenues, T, from income taxes are

(3) $$T_t = \tau_t^N W_t N_t + \tau_t^B R_t B_t + \tau_t^K (v_t - \delta) P_t K_t + \tau_t^G (P_t - P_{t-1}) K_t,$$

where R_t is the nominal interest rate on bonds from the previous period. The third term in equation (4) represents the revenue from taxes assessed on capital returns net of depreciation charges. The fourth term represents the income from the tax on nominal capital gains.

Revenues from the income taxes are returned to the household via a lump-sum rebate. This allows us to consider the pure distortionary effects of taxation, abstracting from wealth effects associated with reallocations between the public and private sectors. The government transfers money to the public directly.

Households

A representative household maximizes a discounted stream of utility from consumption and leisure,

$$max\ E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t),$$
$$\text{with } u(C_t, L_t) = (C_t^{\theta} L_t^{1-\theta})^{1-\sigma} / (1-\sigma),$$

subject to a nominal budget constraint and a constraint on the allocation of time. The household's nominal budget constraint can be written

$$(4) \quad (1-\tau_t^N) W_t N_t + (1-\tau_t^K)(v_t - \delta) P_t K_t - \tau_t^G (P_t - P_{t-1}) K_t + \overline{T}_t$$
$$+[1+(1-\tau_t^B) R_t] B_t + M_t + \Delta_t = P_t C_t + P_t [K_{t+1} - K_t] + B_{t+1} + M_{t+1},$$

where Δ_t is the transfer of money in period *t*.[3]

The household endowment of time (normalized to 1) can be allocated to leisure, labor input to the production process, or transaction-related activities such as shopping and trips to the bank:

$$(5) \qquad L_t + N_t + S_t = 1.$$

[3] The bar over T_t, the lump sum transfer of government revenue, indicates that the household takes the lump-sum transfer as exogenous to its maximization problem.

Transactions-related costs are minimized via a shopping-time function that is assumed to be increasing in the nominal value of consumption purchases and decreasing in the quantity of money held for facilitating transactions,

$$S_t = \xi \left(\frac{P_t C_t}{M_t} \right)^{\eta}, \tag{6}$$

with ξ, $\eta > 0$. Note that the shopping-time function depends on pre-transfer money—a timing assumption used by Kydland (1989) that is also consistent with cash-in-advance timing. If we included the transfer, then it would be equivalent to end-of-period balances and more comparable with the analysis of models in which money enters the utility function directly. Both variants of shopping-time technology are discussed in Goodfriend and McCallum (1987). The only important result that depends on this timing is the real determinacy of the equilibrium with a contemporaneous policy rule: Carlstrom and Fuerst (2001) show that the determinacy conditions depend crucially on these somewhat arbitrary timing conventions.

Growth Trends and Stationarity

The model contains two sources of nonstationarity: Technological progress implies growth in all real variables, while nominal variables are also subject to growth due to inflation. Allowing for the technology growth rate and inflation to have stochastic components, the stationary representation of the model approximates the dynamics of a difference-stationary economy. The real-valued variables—output, consumption, and investment—share a common trend, γ_x. The price level grows at the (stochastic) trend inflation rate, γ_{pt}, so the nominal values also share a common trend. To ensure that the government's intertemporal budget constraint is satisfied, we impose the condition that the growth rate of bonds and money are cointegrated with the nominal growth trend, $\gamma_x\gamma_p$. In the computational experiments, we treat γ_p as stochastic, allowing for shocks to the inflation trend.

To solve for the model's approximate dynamics, we require a stationary representation, which can be derived by deflating all real variables by $(\gamma_x)^t$ and deflating all nominal variables by a similar index of the trend rate of inflation, $(\gamma_p)^t$.[4] The resulting transformed household optimization problem, in which all nominal and real variables are stationary, can be written

$$max\ E_0 \sum_{t=0}^{\infty} \beta^t (c_t^{\theta} L_t^{1-\theta})^{1-\sigma} / (1-\sigma)$$

subject to

$$(7) \qquad (1-\tau_t^N) w_t N_t + (1-\tau_t^K)(v_t - \delta) k_t - \tau_t^G \left(1 - \frac{p_{t-1}}{\gamma_{pt} p_t}\right) k_t + \frac{\bar{t}_t}{p_t}$$

$$+ [1 + (1-\tau_t^B) R_t] \frac{b_t}{p_t} + \frac{m_t}{p_t} + \frac{\Delta m_t}{p_t} = c_t + [\gamma_{xt+1} k_{t+1} - k_t] + \gamma_{pt+1}\gamma_x \frac{b_{t+1}}{p_t} + \gamma_{pt+1}\gamma_x \frac{m_{t+1}}{p_t}, \text{ and}$$

$$(8) \qquad L_t + N_t + \xi \left(\frac{p_t c_t}{m_t} \right)^{\eta} = 1 .$$

In the transformed problem, lower-case variables represent inflation-adjusted, growth-adjusted stationary values. The timing convention is such that R_{t+1} represents the return on a one-period bond from t to t+1, and γ_{pt+1} represents the nominal trend growth rate from t to $t+1$.

The first-order conditions for this problem with respect to optimal asset allocation can be used to illustrate the effects of tax distortions in the model. (See the Appendix for a complete enumeration of the household's first-order conditions.) Define the gross nominal rate of return on a tax-free bond as

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[4] This transformation also affects the value of the appropriate discount factor as described in King, Plosser, and Rebelo (1988).

(9) $$(1+\widetilde{R}_{t+1}) = E_t\left[\frac{\gamma_x \lambda_t}{\beta \lambda_{t+1}} \pi_{t+1}\right],$$

where the inflation component of nominal returns is $\pi_{t+1} = \gamma_{pt+1} p_{t+1} / p_t$ and λ is the shadow value of a commodity unit—the Lagrange multiplier associated with the household budget constraint. In general equilibrium, equation (9) represents the after-tax nominal interest rate. Relative to the real after-tax interest rate, $(1+\widetilde{r}_{t+1}) = (1+\widetilde{R}_{t+1})/\pi_{t+1}$, the tax distortions affecting asset pricing can be summarized in the following relationships:[5]

(10)
$$\begin{aligned}
(1+\widetilde{r}_{t+1}) &= E_t\{[1+\eta(\omega_{t+1} p_{t+1}/\lambda_{t+1})(S_{t+1}/m_{t+1})]/\pi_{t+1}\} && \text{(Money)}\\
&= E_t\{[1+(1-\tau^B_{t+1})R_{t+1}]/\pi_{t+1}\} && \text{(Bonds)}\\
&= E_t\{1+[(1-\tau^K_{t+1})(v_{t+1}-\delta)]-\tau^G_{t+1}(1-1/\pi_{t+1})\} && \text{(Capital)}
\end{aligned}$$

The distorting effects of taxes on interest and capital income are directly represented in (10) by the tax wedges, $(1-\tau^B)$ and $(1-\tau^K)$. An increase in the tax on interest income lowers the demand for bonds, raising the nominal bond rate. The direct effect of an increase in the capital tax is to lower real after-tax returns, reducing investment demand and capital accumulation.

The last term reflects the taxation of nominal capital gains. A higher inflation rate lowers after-tax returns to capital through this channel, lowering investment demand and capital accumulation. It is this mechanism that primarily drives the model dynamics in response to shocks to the inflation trend.

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[5] In the first line of (10), ω represents the shadow value of time—the Lagrange multiplier associated with constraint (8).

Inflation matters also because it lowers real returns on money and bonds. For a given baseline real return, an increase in inflation requires a higher nominal bond rate and a higher nominal return to money holdings in equilibrium. In the case of money, higher nominal returns are associated with a lower demand for real money balances and an increase in shopping-time costs.

After some substitution from the household's other first-order conditions, the condition for optimal money holdings from (10) can be written in a form that can be interpreted as a money demand function:

$$(11) \qquad \frac{m_{t+1}}{p_{t+1}} = \left[\frac{\eta \xi (1-\tau_{t+1}^{N})(1-\alpha)(y_{t+1} / N_{t+1}) c_{t+1}^{\eta}}{(1-\tau_{t+1}^{B}) R_{t+1}} \right]^{\frac{1}{1+\eta}} .$$

Calibrating the shopping-time function with η=1 implies an interest elasticity of -½ . Note also that because consumption and productivity are cointegrated, the scale variable in the numerator of (11) implies a *long-run* income elasticity equal to 1. Because both consumption and labor productivity tend to be procyclical—but with smaller amplitude than output—the short-run income elasiticity of the money demand relationship will be less than 1. Note that both the tax on labor income and the tax on bond income affect this demand for real money balances. The inflation tax also matters for money demand through its impact on the nominal interest rate in the denominator of (11).

Stochastic General Equilibrium

The first-order conditions from the household's problem, along with optimality conditions from the firm's problem and equilibrium conditions for clearing the markets for goods and labor, determine the endogenous responses of the model to stochastic shocks. All that remains is to specify the behavior of government-controlled variables and other exogenous processes.

With lump-sum rebates of tax revenue and no real government assets, the bond market plays no independent role in terms of equilibrium allocations. Without loss of generality, we will assume that government borrowing is zero in each period. The household's first-order condition with respect to bonds therefore stands as a definition of the nominal interest rate.

Closing the model requires the specification of the policy functions determining the money supply process and tax rates. In this paper we treat the tax rates as constant. We consider two alternative monetary policy strategies—a money growth rule and an interest rate rule aimed at achieving an inflation target. In both cases, we define the monetary policy shock to be a shock to the inflation trend (γ_{pt}). When the central bank is using a money growth rule, we refer to this shock as a shock to money growth; when it is using an interest rate rule, we refer to the shock as a shock to the inflation target.

It is common in the literature on money growth rules to specify the policy shock as a shock to the money growth rate. In the literature on interest rate rules, however, the shock is usually appended to the equation in which the central bank determines the one-period interest rate. We think of this as a shock to liquidity. In the money growth rule, the liquidity shock is an innovation to the level, rather than to the growth rate of the money supply. In this paper we do not consider shocks to short-term liquidity because there is no special role for liquidity except that embodied in the shopping-time function. These effects are small in a model with flexible prices.

Under the interest rate rule, the central bank targets the inflation rate, with the money stock determined endogenously from the money demand relationship (11). As typically written, an interest rate rule specifies that the monetary authority adjusts the nominal interest rate in response to deviations of inflation from a target rate, π^*, and to deviations of output from potential (the output gap). Although we examined some rules with output in them, our model does not include the standard notion of an output gap. In models where prices do not adjust to clear markets, the output gap is defined as the difference between the model's output and the level that would occur in a flexible-price equilibrium. In the past we have defined the output gap as the deviation of output from the steady state. In preliminary results for this study, we found that none of our qualitative results depended on having output in the policy rule.[6] Therefore we focus on policy in which the central bank responds only to inflation:

$$(12) \quad R_{t+1} = \bar{r} + \pi^* + \varphi_\pi(\pi_t - \pi^*).$$

Assuming a constant inflation target, this rule can be written

$$(12') \quad R_{t+1} = (\bar{r} - \varphi_\pi \pi^*) + (1 + \varphi_\pi)\pi_t .$$

In the context of this model, a rule of this type can be specified as

$$(13) \quad (1 + R_{t+1}) = (1 + \bar{r})\pi_t \left(\frac{\pi_t}{\pi^*} \right)^{\varphi_\pi} .$$

In terms of log-deviations from a constant steady state,

$$(13') \quad \hat{R}_{t+1} = (1 + \varphi_\pi)\hat{\pi}_t .$$

Recall that π_t includes both the endogenous rate of change in prices, p_t/p_{t-1}, and an exogenous component representing the inflation trend, γ_{pt}. Interpreting the exogenous component as a target rate of inflation that is subject to occasional deviations from the constant steady state, the rule can be generalized to allow for changes in the inflation target:

$$(14) \quad \hat{R}_{t+1} = (1 + \varphi_\pi)\hat{\pi}_t - \varphi_\pi \hat{\gamma}_{pt} .$$

The remaining exogenous variables—z_t, and γ_{pt}—are similarly assumed to follow independent first-order autoregressive processes that are calibrated from the data:

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[6] We also confirmed the result in Edge and Rudd (2002) that adding taxes to the model restricts the size of the parameter space for which the model has a unique equilibrium. In our model, increasing the weight on output restricts the space even more.

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z, \text{ and}$$
$$\gamma_{pt} = \rho_\pi \gamma_{pt-1} + \varepsilon_t^\pi.$$

The monetary policy shock, ε_t^π, is a shock to the inflation trend. The model's dynamics are simulated in terms of proportional deviations from a baseline, constant steady state.

Steady-State and Model Calibration

The model's dynamics will be approximated as proportional deviations from a baseline steady state, defined by the model parameters (including the baseline growth rates of technology and prices, γ_x and γ_p). The model is calibrated by matching the steady-state values to long-run macroeconomic data (see Table 1).

[Table 1]

Some of the model's parameters are calibrated directly using long-run average values for post-1960 U.S. data: The capital share is set equal to 0.38, and the depreciation $\delta = 0.02$. The discount factor, β, is set to 0.99. We set the relative risk-aversion parameter equal to 2. The shopping-time parameter, η, is set at 1, implying an interest elasticity of money demand equal to -0.5. Steady-state allocations of time are set exogenously, with market labor comprising 30 percent of time, and shopping time equaling 0.3 percent of time and the remaining 69.70 percent of time allocated to leisure. The growth rate parameters are set at $\gamma_x = 1.004$ and $\gamma_p = 1.01$, reflecting the average annual growth rates of productivity growth and inflation equal to approximately 1.6 percent and 4 percent, respectively. The money growth trend is a product of the technology and inflation growth trends.

Several other key ratios and parameters can be calibrated from a steady-state representation of the model's optimality conditions (see Appendix). In particular, share parameters for the consumption/output ratio, labor/leisure shares, and the parameters of the shopping-time function can be related to one another and solved using calibrated values for the technology parameters and time allocations described above.

Steady-state tax rates are all set to equal the average marginal tax rates for 1960 to 2002, calculated using the NBER TAXSIM model and reported in Table 9 of Feenberg and Poterba (2003). They are 24 percent for labor, 26 percent for interest income, 34 percent for capital income, and 20 percent for capital gains. In this paper, we consider only two shocks: The first is to the level of technology and the second is to the inflation trend.[7] We calibrate the technology shock process with a 0.95 first-order autocorrelation parameter and a standard deviation equal to 0.75 percent at a quarterly rate, calibrations widely used in the real business cycle literature.

In principle, the time-series process for the inflation trend can be calibrated using either money growth or inflation data. Because the data were generated in an era in which the central bank usually followed an interest rate rule, the model suggests that we should calibrate the model to the persistence in the inflation data. Gavin and Kydland (2000), among many others, show that the autocorrelation of inflation dropped significantly after the policy change in October 1979. Therefore, we estimate the persistence in the inflation rate separately for pre- and post-1979 periods. Using an augmented Dickey-Fuller method, we estimate the persistence to be 0.97 before 1979 and 0.84 afterwards. The standard deviation of the residual is approximately 0.4 percent at a quarterly rate in both periods. Under this specification, the lower unconditional variance of inflation after 1979 is all due to lower persistence.[8]

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[7] See Pakko (2002) for an analysis of persistent shocks to the growth trend in technology.

[8] Using Bayesian methods, Kim, Nelson, and Piger (2004) find that the posterior mean of the persistence parameter falls from 0.94 before 1979:Q2 to 0.72 afterwards. They also estimate a separate breakpoint for the innovation variance which occurs in 1991.

Steady-State Welfare Costs

The main operative mechanism of the model—the interaction of inflation with the nominal tax code—is illustrated in the steady-state welfare calculations presented in Table 2.

[Table 2]

The small welfare costs of inflation attributable to non-neutrality from the shopping-time function are shown in the first row. These losses are associated with typical "welfare triangle" type calculations: Higher rates of inflation induce households to economize on real money holdings, requiring greater shopping time (at the expense of leisure and work effort). For an inflation rate of 10 percent, output and consumption are only 0.42 percent lower than they would be in a zero-inflation steady state. Leisure is only marginally lower than in the zero-inflation environment. The final two columns of the table show the combined effects of lower consumption and leisure on household utility, using a measure of compensating variation calculated as the κ that solves

(15) $$U(c_t^{10}, L_t^{10}) = U((1-\kappa)c_t^0, L_t^0),$$

where superscripts denote the steady-state inflation rate. For the first row, this value represents a cost of only 0.47 percent of steady-state consumption in the zero-inflation environment.

The second row shows that—with the exception of the capital gains tax—the addition of taxes to the model have no effect on the welfare costs of inflation. In fact, the costs of 10 percent inflation are even smaller in this case because the 0 percent baseline economy is already distorted by taxes on real labor and capital income.

The third row shows the dramatic effect that nominal taxation of capital gains has on the steady state. In the high-inflation environment, output is about 12 percent lower than it would be at zero inflation, while consumption is lower by about 8 percent. The main effect of inflation is revealed in the capital/output ratio, which is nearly 13 percent lower in the 10 percent inflation regime. As a result, wages and employment are lower (so that leisure is actually higher for this case). In terms of the compensating variations, 10 percent inflation represents a cost of about 7 percent of steady-state consumption, or about 5 to 6 percent of output.

These calculations confirm that our model framework captures the effects highlighted by Feldstein, Fisher, and others—namely, that the nominal taxation of capital gains implies that inflation suppresses capital accumulation. In the model dynamics presented below, our interest is in evaluating how this mechanism might generate real fluctuations in response to stochastic inflation.

Model Dynamics

We show how the model economy responds to monetary policy shocks under alternative assumptions about tax policy and the central bank long-run inflation policy. Figure 1 shows the response of inflation to a persistent 1 percent shock to the nominal growth trend, γ_p, with and without a tax on bond income. Note that the bond tax magnifies the effect on inflation. Without the bond tax, a 1 percent shock to the inflation trend causes the inflation rate to jump to 0.66 percent before gradually returning to the steady state. With the 26 percent tax on interest income, the inflation rate jumps to 0.99 percent and decays gradually.

[Figure 1]

The effect on the real economic dynamics of our model is best seen by comparing the response of the capital stock under these alternative regimes. The impulse responses of the capital stock to a monetary policy shock under four tax regimes are shown in Figure 2. The tax regime with the smallest impact is the one with the seigniorage tax only. Here, a persistent 1 percent shock to the inflation target causes capital to decline only a tiny fraction of a percent. When we include all taxes except capital gains taxes, the decline, on impact, is about 0.1 percent.

The decline is entirely due to the bond tax because it drives a larger wedge between the before- and after-tax interest rate. The interesting cases are those with a capital gains tax, with and without a bond tax. Braun (1994) and McGrattan (1994) show that both the labor tax and the capital tax have large welfare effects, but the size of the tax wedges do not change with inflation and do not interact with fluctuations in the inflation rate as does the bond tax.[9] In the third tax regime, we reinstate the capital gains tax but eliminate the tax on bond income. Here the large effect of the capital gains tax is clearly evident. The impact effect is 1.3 percentage points larger than the impact effect with no taxes. When we include all taxes, a 1 percent increase in the inflation target reduces the capital stock by 2.7 percent. The bond tax is important because it raises the impact on inflation by about half and therefore magnifies the increase in the effective tax on nominal capital gains.

[Figure 2]

Figure 3 shows the impulse responses of some key macroeconomic variables following a 1 percent inflation shock. Both output and hours worked decline sharply upon impact with the decline in investment. Output follows capital stock along a protracted path of below-trend growth. Hours converge back to the steady state over time—the rate convergence has a half-life of about 4 years. The model produces a counterfactual increase in consumption because there is no cost of adjusting capital and it is freely consumed if the stock is too high. Figure 4 shows that this effect is quite short-lived compared with the long period of depressed consumption that follows an inflationary shock. Labor productivity also displays a short-lived increase upon impact, followed by a long period of convergence back to the trend.

[Figure 3]

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[9] Chang (1995) considered the capital income tax, but also did not investigate the interaction with inflation.

Business Cycle Effects

This model can also be used to show how much cyclical output variation might be attributed to the interaction of inflation with the tax code. As shown by Gavin and Kydland (1999), Kim, Nelson, and Piger (2004), and others, there has been at least one significant structural break in the inflation process over the sample period. In particular, the persistence of shocks to inflation diminished significantly after 1979. Consequently, we calculate the business cycle effects of inflation innovations under two separate regimes for inflation: In the first regime (corresponding to the pre-1979 period) the autoregressive parameter, ρ_π, is set to 0.97, while for the latter period we use a value of 0.84.[10] In each of the computational experiments, the technology shock is assumed to have a first-order AR parameter of 0.95 and a shock variance of 0.0075.

[Table 3]

Table 3 shows standard deviations and correlations with output for some key macroeconomic variables, comparing versions of the model with and without the nominal capital gains tax. It is clear from the top panel of Table 3 that the interaction between inflation and the nominal capital gains tax has a substantial effect when inflation is highly persistent—as before 1980.

In the early period, the model without capital gains taxes accounts for 72 percent of the variability in the cyclical standard deviation in output. In this simple model without taxes, the variability of hours is low and the comovement between output and other variables far too high relative to the data—particularly for productivity. These moments are nearly identical to those that would obtain in a model without either taxes or inflation. Persistent shocks to the inflation objective have no measurable impact on output in the model without a capital gains tax.

Adding the capital gains tax increases the standard deviation of each of the variables considered. The variability of output rises to account for 80 percent of the variability in the data. The standard deviation of hours is approximately twice as large in the model with a capital gains tax. In addition, the inclusion of capital gains taxes introduces a propagation channel for inflation shocks that lowers the high correlation between output and other macroeconomic variables that is typical of standard RBC models. As we saw in Figure 3, when the shock to inflation is highly persistent, the resulting increase in the expected future effective capital gains tax causes households to consume capital, generating a low contemporaneous correlation with output and very volatile investment. Indeed, in the model with capital gains taxes, the correlation of consumption and output is far too low relative to U.S. data. On the other hand, the short-run dynamics illustrated in Figure 3 also imply a lower correlation of output and productivity, bringing that statistic very close to its observed value in the data.

In the later period, with $\rho_\pi = 0.84$, the qualitative results are similar but much smaller. The standard deviation of output deviations is no higher than it is without the capital gains tax. Both hours and productivity are slightly more volatile and less highly correlated with output. With the lower persistence, the variability of consumption and hours are only slightly higher than in the model without a capital gains tax. The first-order autocorrelations are slightly lower in the

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[10] These values were estimated using Dickey-Fuller regressions for sample periods of 1954:Q1 to1979:Q3 and 1979:Q4 to 2003:Q4. The estimate for the early period should probably be adjusted upward for the bias reported in Stock (1991). If we were to delete the transition years, 1980 to 1982, the estimate of the persistence would fall to 0.72 for the later period.

model that includes capital gains taxes, but the effect is not nearly as pronounced as in the high-persistence case. Overall, except for the volatility of investment, there appear to be no measurable cyclical effects of adding the capital gains tax when the persistence is as low as 0.84.

The statistics for U.S. data reported in Table 3 illustrate the widely documented decline in the volatility of real macroeconomic variables during the 1980s. The analysis of the model suggests that the lower persistence of inflation since 1979 might have played a role in this volatility decrease. With high persistence in the inflation process, inflation shocks interact with the capital gains tax to have large effects on real variables. This impact declines dramatically with the decline in inflation persistence.

Simulations of U.S. Data

The computational experiments suggest that we should see important effects from the interaction of inflation and the capital gains tax before 1980, but the effects may be too small to be measurable afterwards. To illustrate this feature of the model, we use estimated shocks to the inflation trend to see what our model implies for movements of capital, hours worked, and labor productivity for U.S. history with a policy break in 1979:Q3. We use the same calibration for the policy process as was used in Table 3. The contribution of estimated inflation shocks to the real economy are summarized in Figure 4.

[Figure 4]

In the period leading up to 1980, the effects of the interaction between inflation and the capital gains tax are of the same order of magnitude as the effects of technology shocks. As we saw in Figure 2, the effects on the capital stock go on for such a long time that the damage from rising inflation in the 1960s and 1970s continued to have a depressing effect on the capital stock into the 1990s.

The impact on labor input works through the economy quickly. The upward drift of inflation caused hours worked to fall below the steady-state level for most of the 1970s. Corresponding to the inflationary effects of the oil price shocks of the 1970s, the model implies sharp declines in employment associated with those events. Since 1980, the effect on hours worked is insignificant.

The impact on productivity reflects a combination of the effect on the capital stock and on hours worked. The upward drift in inflation combined with the nominal tax on capital gains to exert an increasingly negative impact on labor productivity from the late 1960s until after 1980. Since the 1980s, this effect has helped to raise labor productivity slightly.

Sensitivity Analysis

The goal in this paper is to analyze the business cycle consequences of interaction between inflation policy and a non-indexed tax system. There are reasons that our baseline case may over- or underestimate the effects of inflation operating through the tax code. On the one hand, we may have understated the effects before 1980 because the inflation target may have been more persistent than we assumed. There is a large time-series literature that finds a unit root in the inflation process. In summaries of recent research into the nature of the inflation expectations embedded in the yield curve, Kozicki and Tinsley (2003), Ellingsen and Soderstrom (2004), and Dewachter and Lyrio (2004) all argue that expectations about the Fed's inflation objective follow a random walk.

On the other hand, the results shown above probably overstate the effect of the capital gains tax because we treat it is as an accrual tax. Protopapadakis (1983) argues that accrual-equivalent marginal tax rates were perhaps as low as 5 percent, substantially below the effective marginal tax rates reported by Feenberg and Poterba (2003). Balcer and Judd (1987) use a dynamic overlapping-generations model of portfolio choice to address specific questions about savings and portfolio choice in a model with fixed labor and exogenous returns to capital. They show that there is no accrual-tax equivalent to a deferral tax system in their model. They find that the capital gains tax is fully effective only in the case of households that are in mid-life at the peak of their productivity cycle. They also show that the household's preference for equity versus bond assets (and the capital gains tax liability) depends importantly on the curvature of utility.

In Table 4, we report the sensitivity of our results to alternative assumptions about the capital gains tax rate, the persistence of the process driving the Fed's inflation objective, and the coefficient of relative risk aversion. The top panel reports the sensitivity of output variability to changes in the persistence of the nominal shock, ρ_π, given the baseline calibration for the other parameters. If the persistence is as low as 0.9, then there is no cyclical effect of the capital gains tax, even at 20 percent. On the other hand, if the inflation target really was close to a random walk before 1980, then even the effects of a 5 percent tax rate would have been substantial.

As did Balcer and Judd, we also found that our results were sensitive to the curvature of the utility function. As the degree of risk aversion rises, the effect of the capital gains tax declines. The cyclical effects of persistent nominal shocks operating through the capital gains tax appear to be measurable in specifications where the coefficient of relative risk aversion is below 5.

Conclusion

When the central bank operates with an interest rate, persistent shocks to the nominal growth trend (or, equivalently, the inflation target) can have large real effects on the business cycle if the tax system is not indexed for inflation. In our model, there is a tax on nominal capital gains. The business cycle effects are large when the shocks to the expected inflation objective are highly persistent. We found those effects to be large in the United States before 1980, but not afterwards. The reduction in the persistence of shocks to the inflation target was the critical aspect of the change in monetary policy. Before 1980, the inflation objective appeared to be close to a random walk. After 1980, we estimated the largest root in the inflation process to be no larger than 0.84. At this level, the shocks have no measurable impact on the cycle.

Using a common calibration for all parameters except the persistence in the shock to the long-run inflation objective, we find that bad monetary policy may partially explain the slowdown in productivity growth before 1980. The upward trend in the average inflation rate probably interacted with the tax on nominal capital gains to reduce productivity growth in the 1960s and 1970s. Better policy after 1980 may partially explain the revival of productivity and the lower variability of real variables since then.

Our study is aimed at understanding business cycle effects, not welfare effects. The welfare effects of these taxes may be quite large even if the cyclical effects are negligible. Although treating the capital gains tax as if it were paid on accrual most likely overstates the cyclical effects of inflation, there were many parts of the tax code that were not indexed for inflation until the 1980s and they were not included in this study. The results in this paper suggest that taking account of them would be important for understanding the nature of the U.S. economy, especially before 1980.

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Appendix: First-Order Conditions and Steady-State Calibration

The first-order conditions to the household's optimization problem can be expressed as

(A1) $U_c(\cdot_t) = \lambda_t + \omega_t \eta(S_t / c_t)$

(A2) $U_L(\cdot_t) = \omega_t$

(A3) $\lambda_t (1 - \tau_t^N) w_t = \omega_t$

(A4) $\beta E_t \{[\lambda_{t+1} + \omega_{t+1} p_{t+1} \eta(S_{t+1} / m_{t+1})] / \pi_{pt+1}\} = \gamma_x \lambda_t$

(A5) $\beta E_t \{\lambda_{t+1} [1 + (1 - \tau_{t+1}^B) R_{t+1}] / \pi_{t+1}\} = \gamma_x \lambda_t$

(A6) $\beta E_t \lambda_{t+1} \left\{1 + [(1 - \tau_{t+1}^K)(v_{t+1} - \delta)] - \tau_{t+1}^G \left(1 - \frac{p_t}{\gamma_{pt+1} p_{t+1}}\right)\right\} = \gamma_x \lambda_t$,

where λ_t and ω_t are utility-denominated, present-valued shadow prices of goods and time, and $\pi_{t+1} = \gamma_{pt+1} p_{t+1} / p_t$.

Equation (A1) sets the marginal utility of consumption equal to the shadow goods price plus a factor reflecting the shopping-time cost. Equations (A2) and (A3) determine the shadow value of time and reflect the optimal condition that the marginal utility of leisure is equal to an after-tax wage rate (denominated in utility units).

From the firm's profit-maximization condition, the marginal product of labor is equal to the real wage,

(A7) $w_t = (1 - \alpha)(y_t / N_t)$,

and the firm's demand for capital determines that the real rental price will be equal to capital's marginal product:

(A8) $v_t = \alpha(y_t / k_t)$.

Equations (A1) and (A6), along with a transformed stationary representation of the capital accumulation equation,

(A9) $\gamma_t k_{t+1} = (1-\delta)k_t + i_t$,

imply household demand functions for consumption and real investment—and, hence, the future capital stock, k_{t+1}. The presence of marginal shopping-time costs in the consumption-demand equation (A1), defined by the shopping-time function,

(A10) $S_t = \xi\left(\frac{p_t c_t}{m_t}\right)^{\eta}$,

demonstrates one source of non-neutrality in the model. In addition, the presence of π_t in equation (A6) implies another source of interaction between the goods market and the nominal asset market.

Assuming equilibrium in the nominal asset markets, the condition for equilibrium in the goods market can be derived from the household's budget constraint,

(A11) $y_t = c_t + i_t$,

and the production function,

(A12) $y_t = z_t k_t^{\alpha} N_t^{1-\alpha}$.

Equilibrium in the goods market determines consumption, investment, and output—with the equilibrating price being the shadow value of capital, λ_{t+1}; i.e., the after-tax real interest rate,

$$(1+\tilde{r}_{t+1}) = \frac{\gamma_x \lambda_t}{\beta \lambda_{t+1}}.$$

Steady-State Relationships

Several key steady-state ratios are useful for deriving values for the remaining model parameters and for specifying the linear approximations used to calculate the model's dynamics. First, equations (A6) and (A8) can be used to derive the steady-state capital/output ratio:

$$\text{(A13)}\quad \frac{k}{y} = \frac{\alpha\beta(1-\tau^K)}{\gamma_x - \beta(1-\delta) + \beta\tau^K\left[(\gamma_p - 1)/\gamma_p - \delta\right]}.$$

From (A9) the share of output used for investment will be

$$\text{(A14)}\quad \frac{i}{y} = [\gamma_x - (1-\delta)]\frac{k}{y},$$

and from (A11) the consumption share is

$$\text{(A15)}\quad \frac{c}{y} = 1 - \frac{i}{y}.$$

From (A1) and (A2), the marginal rate of substitution between consumption and leisure is related to the two shadow prices and the parameters of the shopping-time function. Substituting the values of the relative shadow prices from (A3), we can derive the following relationship:

$$\text{(A16)}\quad \frac{\theta}{1-\theta}\left(\frac{L}{N}\right) = \frac{1}{(1-\tau_N)(1-\alpha)}\left(\frac{c}{y}\right) + \eta\left(\frac{S}{N}\right).$$

Given a calibrated allocation of time among labor, leisure, and shopping—along with a value of η (selected to generate money demand elasticities) and the consumption/output ratio from (A15)—equation (A16) determines the value of the parameter θ to be used.

Combining equations (A3) and (A4) yields

$$\text{(A17)}\quad 1 + (1-\tau^N)(1-\alpha)\left(\frac{py}{m}\right)\eta\left(\frac{S}{N}\right) = \frac{\gamma_x\gamma_p}{\beta},$$

which defines the steady-state ratio of nominal output to money (velocity). With this value in hand, we can use the shopping-time definition (6′), along with the consumption-output ratio above, to specify a value for the scale parameter, ξ, consistent with the calibrated allocation of time for shopping.[11]

[11] Alternatively, equation (29) can be used to calibrate S and ξ to be consistent with a preselected value for velocity.

Table 1: Parameter Calibration for the Baseline Case

Parameter	Symbol	Value
Depreciation rate	δ	0.02
Discount factor	β	0.99
Relative risk aversion	σ	2
Labor tax rate	τ^N	0.24
Capital tax rate	τ^K	0.34
Bond tax rate	τ^B	0.26
Capital-gains tax rate	τ^{Kg}	0.20
Steady-state output growth	γ_x	1.004
Steady-state money growth	γ_p	1.01
Shopping-time parameter	η	1
Capital share in production	α	0.38
Steady-state share of shopping time	S	0.003
Steady-state share of time supplying labor services	N	0.3
Fed's reaction to inflation	φ_π	0.5
Fed's reaction to output gap	φ_y	0
Persistence in the technology shock	ρ_z	0.95
Persistence in the money growth shock	ρ_π	0.95
Standard deviation of shocks		
Production technology	σ_z	0.0075
Monetary policy	σ_π	0.0040

Table 2: Welfare Effects of a Steady-State 10 percent Inflation Rate

	Effects on Steady-State Values (Percent)					Compensating Variation As Percent of:	
	Y	C	L	W	K/Y	C	Y
No taxes	- 0.42	- 0.42	- 0.02	0.00	0.00	0.47	0.35
Taxes w/o capital gains	- 0.34	- 0.34	- 0.06	0.00	0.00	0.42	0.33
Taxes incl. capital gains	-11.82	- 8.37	+1.10	- 9.12	-12.73	7.01	5.61

Table 3: Second Moments (HP Filtered)

Panel A: $\rho_\pi = 0.97$

	U.S. data 1954:1 – 1979:3		Model w/o Capital Gains Tax		Model with Capital Gains Tax	
	SD(•)	Corr(•,y)	SD(•)	Corr(•,y)	SD(•)	Corr(•,y)
Output	1.81	1.00	1.30	1	1.44	1
Consumption	0.84	0.83	0.56	0.98	0.99	0.20
Investment	5.18	0.80	4.08	0.99	7.51	0.86
Hours	1.94	0.87	0.55	0.95	1.13	0.77
Productivity	1.22	0.61	0.79	0.98	0.91	0.62

Panel B: $\rho_\pi = 0.84$

	U.S data 1979:4 - 2003:4		Model w/o Capital Gains Tax		Model with Capital Gains Tax	
	SD(•)	Corr(•,y)	SD(•)	Corr(•,y)	SD(•)	Corr(•,y)
Output	1.35	1.00	1.29	1	1.29	1
Consumption	0.71	0.79	0.56	0.98	0.59	0.90
Investment	4.43	0.79	4.08	0.99	4.47	0.97
Hours	1.62	0.89	0.52	0.98	0.56	0.93
Productivity	0.88	0.37	0.79	0.99	0.80	0.97

Table 4
Cyclical Effects of Taxing Nominal Capital Gains
(Standard deviation of the cyclical component of output)

	Capital Gains Tax Rate			
	0%	5%	10%	20%
ρ_π	$\sigma = 2$			
0.9	1.30	1.30	1.31	1.31
0.95	1.30	1.32	1.34	1.37
0.97	1.30	1.33	1.37	1.44
0.99	1.30	1.37	1.45	1.57
0.999	1.30	1.40	1.52	1.69
σ	$\rho_\pi = 0.97$			
0.5	1.45	1.56	1.71	1.93
1	1.37	1.43	1.52	1.65
2	1.30	1.33	1.37	1.44
5	1.24	1.26	1.27	1.28
10	1.22	1.23	1.23	1.24

NOTE: Baseline calibrations are used for the model except as noted for the coefficient of relative risk aversion, σ, and the persistence parameter for the inflation target shock, ρ_π.

Figure 1
Inflation Response to a Persistent 1% Monetary Policy Shock
(with baseline tax rates)

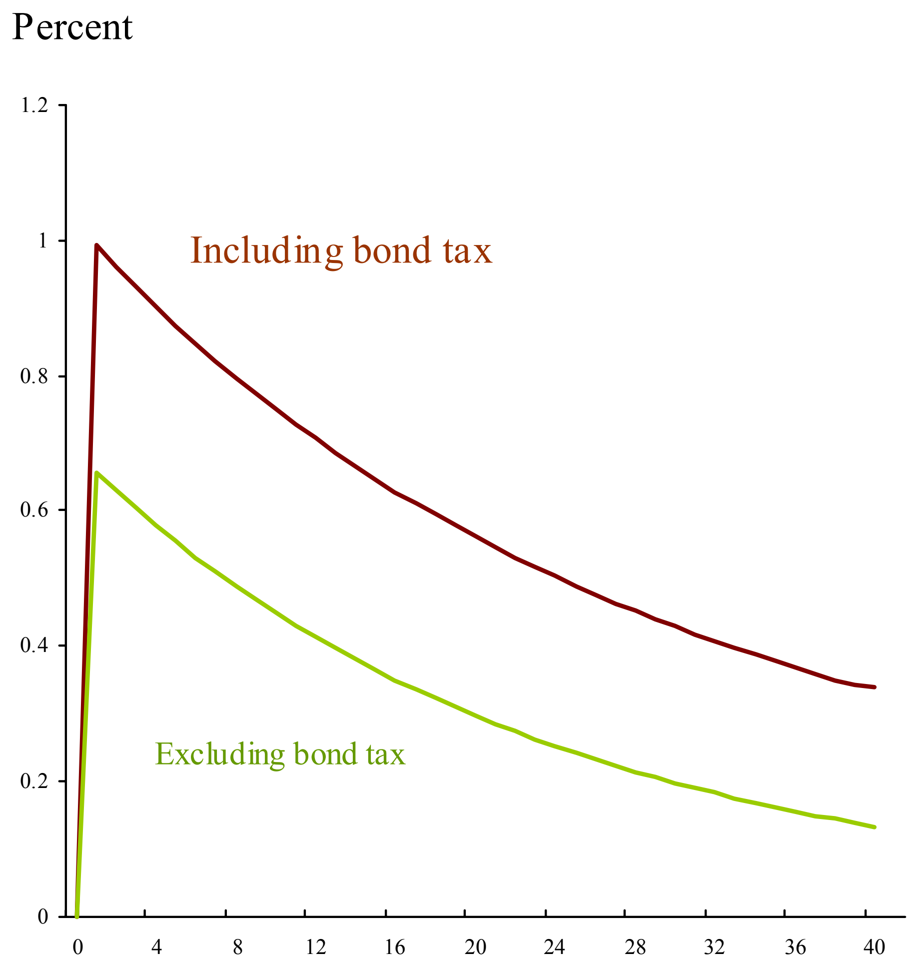

Figure 2: Capital Response to a 1% Monetary Policy Shock
(Effects of different taxes)

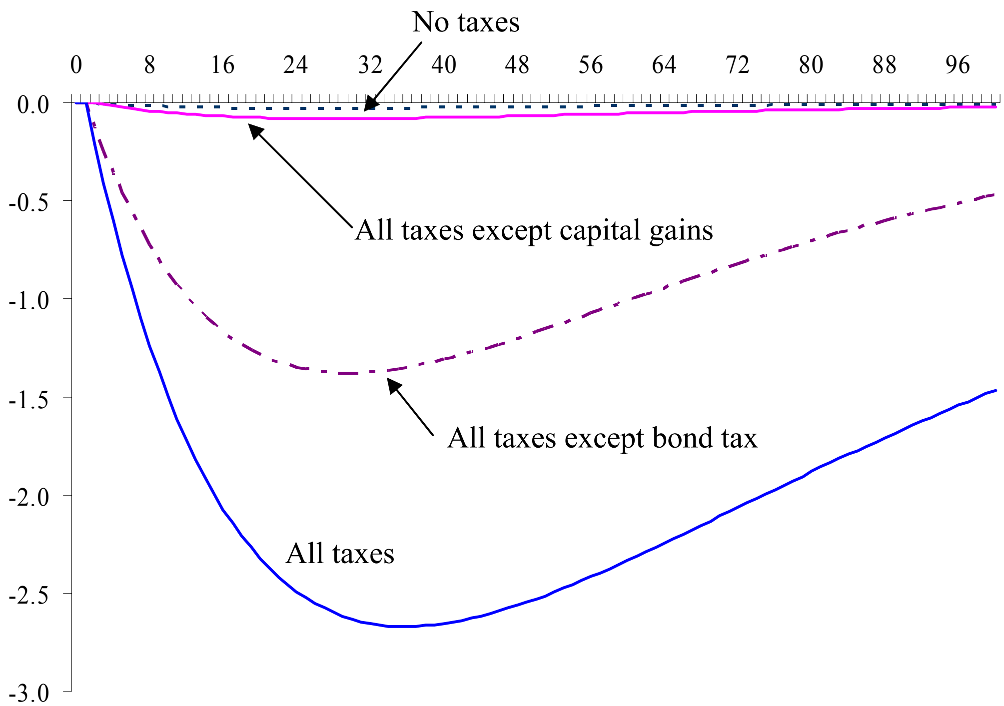

Figure 3: Responses to a 1% Monetary Policy Shock

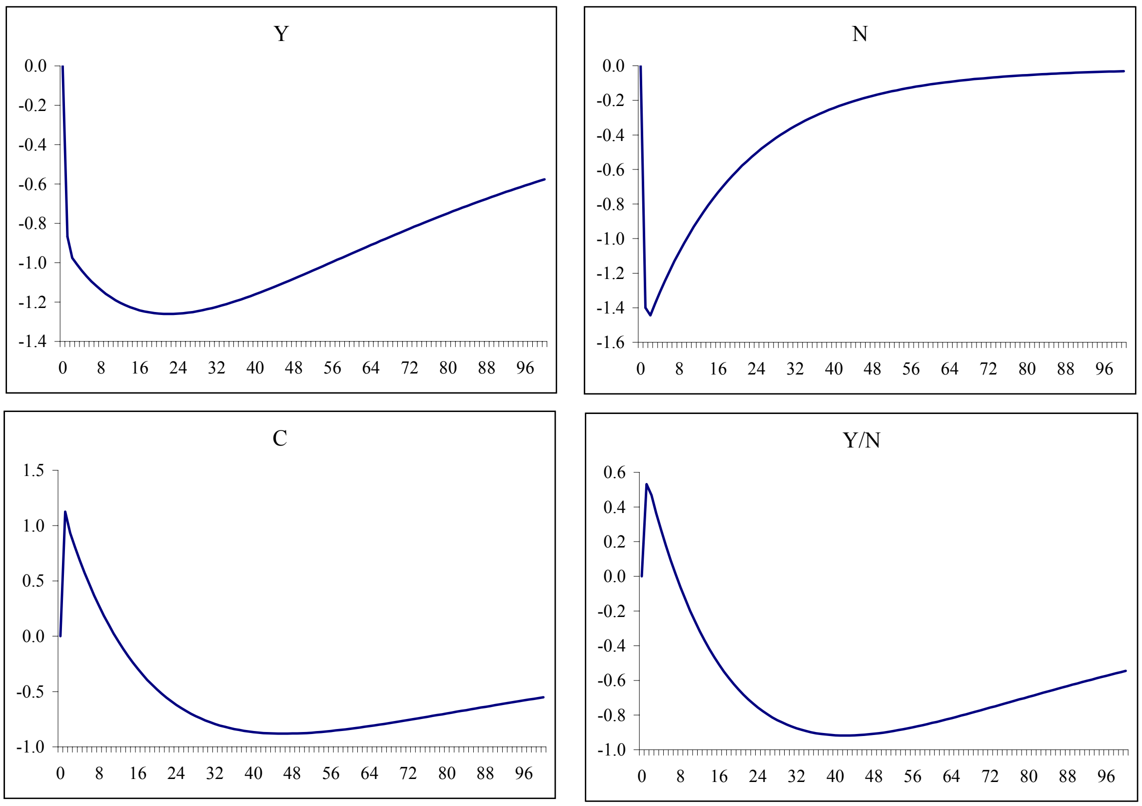

Figure 4: Contribution of Monetary Policy Shocks