Some Not-So-Unpleasant Monetarist Arithmetic

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T he motivation for this article is the well-known and controversial work of Sargent and Wallace (1981), who show the potential importance of the government's budget constraint for the behavior of nominal variables. The government's lifetime budget constraint can place restrictions on the behavior of future money growth and thus influence current economic magnitudes through expectational channels. Some of Sargent and Wallace's results are indeed striking, and indicate that tight monetary policy can lead to the unpleasant outcome of both higher expected inflation and a higher price level. Theoretically, they highlight important intertemporal considerations, but one wonders if these considerations are quantitatively meaningful in reality.

In order to investigate the quantitative significance of monetarist arithmetic, I develop a dynamic stochastic model in which the government's budget constraint has nontrivial implications. In particular, I use the methodology of Dotsey (1994) and Dotsey and Mao (1996). Here both money growth and taxes are stochastic, but one or both must endogenously respond to government debt if the government is to maintain budget balance. When the monetary authority does not respond to debt, I term its policy *independent* monetary policy, and when it does respond to debt, I call it *dependent* monetary policy. The primary focus of the article is on the behavior of nominal variables and involves a comparison of their behavior when the monetary authority is and is not independent. The main result is that, for reasonable parameterizations, and when the tax authority responds to the level of debt, the underlying nominal behavior of the economy does not significantly depend upon whether the monetary authority reacts to government financing considerations. In this sense the monetarist arithmetic is not so unpleasant.

The considerations addressed in this article are also similar to those discussed in Aiyagari and Gertler (1985), Leeper (1991), and Woodford (1995). These authors are all concerned with the relationship between the behavior of money and nominal variables in models that emphasize the importance of the government's budget constraint. The article proceeds as follows. Section 1 reviews the key elements of the above-cited papers that are most relevant to the experiments carried out in this article. Section 2 describes the behavior of taxes and money growth as well as the underlying economic model. Section 3 investigates parameterizations that produce the spectacular example presented in Sargent and Wallace, in which current inflation increases under contractionary monetary policy. These parameterizations do not accurately characterize the U.S. economy and the spectacular example does not occur under realistic behavioral assumptions. Section 4 analyzes a model economy that is more consistent with that of the United States. For this case, data are generated under both independent and dependent monetary policy rules. Only minor differences are found in the behavior of nominal variables. Section 5 concludes.

1. LITERATURE SURVEY

Sargent and Wallace (1981) present a model economy that satisfies the monetarist assumptions that the monetary base is closely connected to the price level and that the monetary authority can raise seignorage through money creation. They show that under certain conditions the monetary authority's ability to control inflation is limited. The major condition responsible for this result is the exogeneity of the process for the government's deficit. Given this exogeneity, tight money today leads to higher inflation in the future and may even lead to higher inflation today.

Leeper (1991) extends the Sargent and Wallace analysis to a stochastic environment. Leeper's model is, however, somewhat different in that the monetary authority uses an interest rate instrument and reacts, in some cases, to the rate of inflation. The monetary authority does not react specifically to debt as it does in the model presented below. Also, another distinction between Leeper's model and my model is that I use money as the policy instrument.[1] This modeling is more directly related to Sargent and Wallace.

Like Leeper, I find that when monetary policy is independent, fiscal disturbances in the form of lump sum taxes have no influence on either nominal or real variables. Also, as in Leeper, when the monetary authority responds to debt, fiscal disturbances do affect the economy. Both the price level and the nominal

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[1] One could always make the money supply rule more realistic by including elements of interest rate smoothing. For a detailed discussion on interest rate instruments in a rational expectations model, see Boyd and Dotsey (1996).

interest rate are positively related to debt. Contrary to his analysis, however, I find that a monetary contraction does not generally cause the nominal interest rate to rise. This difference is a result of the more general stochastic process that governs monetary policy, a process that allows for varying degrees of persistence in policy. A current decline in money growth need not be offset by an immediate increase in next period's money growth as occurs in one of the examples emphasized in his paper.

The analysis here is also related to the work of Aiyagari and Gertler (1985) and Woodford (1995). These authors indicate that when monetary policy is influenced by the government's intertemporal budget constraint, nominal variables are sensitive to debt. In contrast to the results in Aiyagari and Gertler, the model considered here indicates that the nominal interest rate and inflation are not necessarily higher when monetary policy depends on the level of government debt. The difference in results occurs because the stochastic process for money growth implies that low money growth rates are more likely when the debt is low. Thus, the possible values of the nominal interest under a dependent monetary policy span the values that occur when monetary policy is independent.

Much of the work in this area adopts the confusing terminology of Ricardian and non-Ricardian monetary policy. I choose not to use this terminology and instead use the terms independent and dependent monetary policy. As Aiyagari and Gertler point out, Ricardian monetary policies do not necessarily imply that the Ricardian equivalence theorem holds. Also, different authors appear to have somewhat different interpretations of what constitutes a Ricardian monetary regime. Aiyagari and Gertler adopt Sargent's (1982) definition, which refers to whether or not government bonds are fully backed by taxes. That is, the fiscal authority commits to a tax process with a present discounted value equal to the present discounted value of government spending and the current value of outstanding government debt. Woodford's definition is somewhat different. It refers to the transversality condition on debt and whether that condition holds independently. Thus, in Woodford's terminology, a model can be Ricardian even though seignorage revenues respond to changes in government debt. His definition, therefore, allows money to respond to debt in a Ricardian world. In all the models considered below, the real value of the debt is bounded, and hence its present discounted value approaches zero. Yet debt does have real and nominal effects in some of the models. Therefore, I prefer to use the terminology of independent and dependent monetary policy.

2.   THE MODEL

In this section I depict the fiscal and monetary policy process as well as the technology and behavioral assumptions that characterize the economic environment relevant to this study.

Fiscal and Monetary Policy Processes

The monetary and fiscal policy processes analyzed here are stochastic and satisfy the government's budget constraint. Monetary policy is defined over changes in base growth rather than in terms of setting the nominal interest rates. This depiction of policy is consistent with previous literature relating deficit finance and inflation.[2] This modeling of monetary policy also allows one to investigate the consequences of money growth's dependence on debt while incorporating the empirically relevant behavior of taxes responding to debt (see Bohn [1991]). Interest rate smoothing could easily be incorporated by allowing the monetary authority to respond to unexpected movements in the nominal interest rate without affecting the existence or uniqueness of the solutions (see Boyd and Dotsey [1996]).

Money, M_t, is introduced through open market operations and behaves according to

$$M_t = M_{t-1}(1 + \eta_t), \tag{1}$$

where η_t is the stochastic rate of money growth.

Taxes are proportional to output. Thus, tax revenues, T_t, are given by

$$T_t = \tau_t Y_t, \tag{2}$$

where Y_t is current nominal output and τ_t is the current tax rate. The government's nominal debt, B_{t+1}, therefore, follows

$$P_t^B B_{t+1} = G + B_t - T_t - \eta_t M_{t-1}, \tag{3}$$

where G represents fixed transfer payments, and P_t^B is the price of a bond at date t that pays one dollar at date $t+1$. The real value of debt relative to ouput, $B_{t+1}/Y_{t+1} = b_{t+1}$, can be written as

$$b_{t+1} = R_t[g + b_t - \tau_t - (\eta_t/(1 + \eta_t))(M_t/Y_t)](Y_t/Y_{t+1}), \tag{4}$$

where R_t is the gross one period nominal interest rate.

A sufficient condition for the government to obey its lifetime budget constraint is for the tax and money growth processes to behave so that the debt-to-GNP ratio is bounded. For that to happen, either one or both processes must depend on government debt. When money and tax rates respond to debt they are modeled as two-state Markov processes with endogenous transition probabilities. Thus the processes are time varying. In particular, let the transition probabilities for taxes be

$$prob(\tau_{t+1} = \tau_l | \tau_t = \tau_l) = \begin{cases} 1 & if \ b_t < 0 \\ (1 - \phi b_t)^{1/\nu} & if \ 0 \le b_t \le 1/\phi \\ 0 & if \ b_t > 1/\phi \end{cases} \tag{5}$$

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[2] For example see Sargent and Wallace (1981), Liviatan (1984), McCallum (1984), Drazen (1985), Aiyagari and Gertler (1985), and Woodford (1995).

$$prob(\tau_{t+1} = \tau_h | \tau_t = \tau_h) = \begin{cases} 0 & \text{if } b_t < 0 \\ \phi b_t^{1/\nu} & \text{if } 0 \le b_t \le 1/\phi, \\ 1 & \text{if } b_t > 1/\phi \end{cases}$$

and those for money growth be

$$prob(\eta_{t+1} = \eta_l | \eta_t = \eta_l) = \begin{cases} 1 & \text{if } b_t < 0 \\ (1 - \phi b_t)^{1/\psi} & \text{if } 0 \le b_t \le 1/\phi \\ 0 & \text{if } b_t > 1/\phi \end{cases} \tag{6}$$

$$prob(\eta_{t+1} = \eta_h | \eta_t = \eta_h) = \begin{cases} 1 & \text{if } b_t < 0 \\ \phi b_t^{1/\psi} & \text{if } 0 \le b_t \le 1/\phi, \\ 0 & \text{if } b_t > 1/\phi \end{cases}$$

where the subscripts l and h refer to low and high, respectively.

As long as the debt-to-GNP ratio rises when both taxes and money growth rates are low and falls when tax rates and money growth rates are high, the debt-to-GNP ratio is bounded and will only rarely lie outside the interval $[0,1/\phi]$. As b_t approaches $1/\phi$, both taxes and money growth will be high with probability one. Similarly, as b_t approaches 0, both taxes and money growth will be low. The parameters ν and ψ control the persistence of the two processes. For any given debt-to-GNP ratio, as ν and ψ increase, the probability of remaining in the current state increases. The above specifications of policy imply that current realizations of taxes and money growth have implications for the entire future path of policy through their effect on debt.

It is important to note that both the unconditional mean and the persistence of money growth do not depend on the debt-to-GNP ratio. If instead the monetary authority had no control over the mean and over persistence of money growth rates, it would be trivial to show that the nominal behavior of the economy depended on fiscal policy. Instead I explore the more difficult question of whether conditional dependence of monetary policy on debt affects nominal magnitudes.

Alternatively, cases in which one of the processes is invariant to debt can be analyzed. I allow for the invariance of tax rates when investigating parameterizations that yield the spectacular case of Sargent and Wallace. I also compare the nominal behavior of an economy when the money growth process does and does not depend on debt.

Technology and Preferences

Since I am primarily concerned with the nominal behavior of the economy, I treat real output as fixed at a constant level, y. Agents derive utility from consumption, c, and real balances, m. Specifically, they maximize

$$U = \max E \sum_{t=0}^{\infty} \beta^t [c_t^{-\rho} + \theta m_t^{-\rho}]^{-1/\rho}$$

subject to the per-period budget constraint

$$M_t^d + P_t^B B_{t+1}^d + p_t c_t \leq (1 - \tau_t) p_t y_t + M_{t-1} + B_t + G_t,$$

where p is the price level and E is the expectations operator conditional on time 0 information. This specification of preferences allows one to look at a range of interest elasticities of money demand and to freely parameterize the ratio m/c.

The first-order conditions determining the demand for money and the optimal consumption-saving decision by individuals are given by

$$\left(\frac{m_t}{c_t}\right) = \left(\frac{\theta(1 + r_t)}{r_t}\right)^{1/(1+\rho)} \tag{7}$$

and

$$\left(\frac{1}{1 + r_t}\right) \left[1 + \theta \left(\frac{c_t}{m_t}\right)^\rho \right]^{-(1/\rho)-1} =$$

$$\beta E_t \left\{ \left[1 + \theta \left(\frac{c_{t+1}}{m_{t+1}}\right)^\rho \right]^{-(1/\rho)-1} \left(\frac{p_t}{p_{t+1}}\right) \right\}, \tag{8}$$

where r_t is the net nominal interest rate and E_t is the expectations operator conditional on time t information. Agents are assumed to know all contemporaneously dated variables as well as the nominal value of end-of-period government debt. Equation (7) implies that money demand is unit elastic with respect to the scale variable consumption and has an interest elasticity of $-(1/(1 + \rho))(1/(1 + r))$. Also, for a given steady-state interest elasticity the parameter θ determines the velocity of money. For example, as ρ goes to infinity $m = c$ and the model approaches a cash-in-advance specification, while as ρ goes to zero money demand becomes unit elastic. Equation (8) governs the optimal consumption-saving decision. Note that real money balances influence intertemporal consumption choices through their effect on the marginal utility of consumption. Higher current real money balances increase the marginal utility of consumption and, holding expected future consumption and money balances constant, imply a higher real interest rate.

Equilibrium

The equilibrium conditions for this economy are

$$c_t = y, \tag{9}$$

$$M_t/p_t = m_t, \tag{10}$$

and

$$B_{t+1}^d = B_{t+1}, \tag{11}$$

along with the first-order conditions (7) and (8), the agent's budget constraint, and the government's budget constraint (3). The three equations (9)–(11) merely state that demand equals supply in the goods, money, and bond markets, respectively. Substituting (7) into (8) and using (9) and (10), these four equations can be used to derive a functional equation for the nominal interest rate. Combined with the law of motion for real government debt (equation [4]) and the stochastic processes for taxes and money growth, the equilibrium functions for the nominal interest rate $r(b, \tau, \eta)$ and next period's real debt $b'(b, \tau, \eta, \tau', \eta')$ can be solved (where the symbol " $'$ " refers to next period value of a variable). Using the solution for r, one can readily derive the solutions for real balances, prices, and expected inflation. Thus, equilibrium is a set of functions for r, b', p, c, and m that satisfy equations (4), and (7)–(11). Because there is no closed form solution, I obtain the solution numerically by solving for the relevant functions along a grid of real debt levels and at the values of taxes and money growth.

3.   THE SPECTACULAR CASE

In their spectacular example, Sargent and Wallace showed that it is possible for lower current money growth to cause both higher expected inflation and a higher price level. The higher expected inflation occurs because lower money growth increases the government's indebtedness, implying that money growth must be, on average, higher in the future. The higher expected future money growth leads to higher expected inflation. Also, the higher expected inflation reduces the current demand for real balances. If the reduction in demand is large enough, the price level must rise to clear the money market. As Drazen (1985) points out, this latter result requires an interest elasticity of at least one in absolute value. Using the model of the previous section, we are able to produce a spectacular example. To do so requires some additional assumptions that are extreme when compared to actual economic behavior in the United States. Besides the unusual responsiveness of money demand to nominal interest rates, the ratio m/c must be higher than one observes in the data, and rates of money growth in the high money growth state must be somewhat higher than commonly observed in the post-war United States. Both of these counterfactual parameterizations must be made in order to bound the debt-to-GNP ratio. That is, both the tax base and the tax rate on money balances in the high money

growth state must be sufficiently high to pay off the increased debt burden that accrues in the low money growth state.

The policy functions for the spectacular example are depicted in Figure 1. To produce this example, the interest elasticity of money demand was set at -1, the steady-state ratio m/c was set at 0.25, and the low and high money growth rates were selected to be -1.25 percent and 13.5 percent, respectively. Also, money growth is quite persistent with $\psi = 5$. This parameterization corresponds to an autocorrelation of roughly 0.65. The model is calibrated at an annual frequency and $\beta = 0.98$. With these parameter values, the debt to GNP ratio lies between -0.46 and 0.58. As shown in the top panel of Figure 1, the nominal interest rate is higher when money growth is low, even though the money growth process is characterized by substantial persistence.[3] This persistence is depicted in the middle panel of Figure 1, which shows that agents expect substantially higher future money growth when money growth is currently high. One also observes, in the bottom panel, that the price level is higher when money growth is low.

To highlight the necessity of the high interest elasticity, I also examine the case in which the interest elasticity is -0.20. This value is representative of money demand in the United States (see Dotsey [1988]). As shown in Figure 2, both the nominal interest rate and the price level are higher when current money growth is high. Thus, the spectacular case is reversed. Additional insight into the important role that the interest elasticity plays in producing the spectacular result can be found in Table 1. This table shows the interest rates that would occur under the high and low money growth rates for various elasticities of money demand. These interest rates are obtained from the following thought experiment. Suppose that the transition probability for money growth is 0.8 and independent of the debt. Also suppose that the tax authority adjusts taxes to bound the level of debt. Then high current money growth always implies higher future money growth. The interest rates that solve equation (8) can be calculated for various values of the interest elasticity and a value of $m/c = 0.25$. As depicted in the table, the difference between the nominal interest rate when money growth is high as opposed to when it is low narrows substantially as the interest elasticity increases in absolute value.

The narrowing of the spread between interest rates under high and low money growth along with the implication that current low money growth leads to higher average future money growth produce the spectacular example. Furthermore, the high interest elasticity implies that money demand falls by more than one-for-one with the money supply and the price level must rise to equilibrate the money market.

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[3] The policy function for expected inflation is qualitatively identical to that of the nominal interest rate. It is, therefore, omitted.
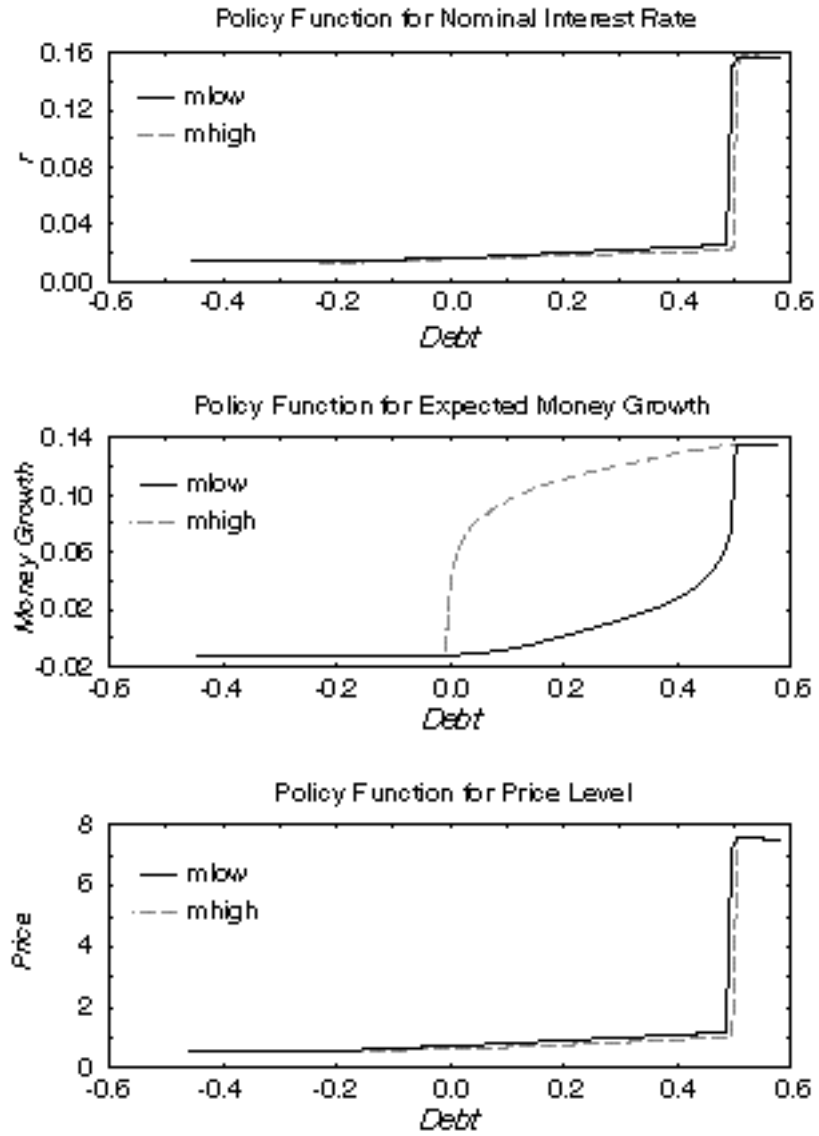
Figure 1

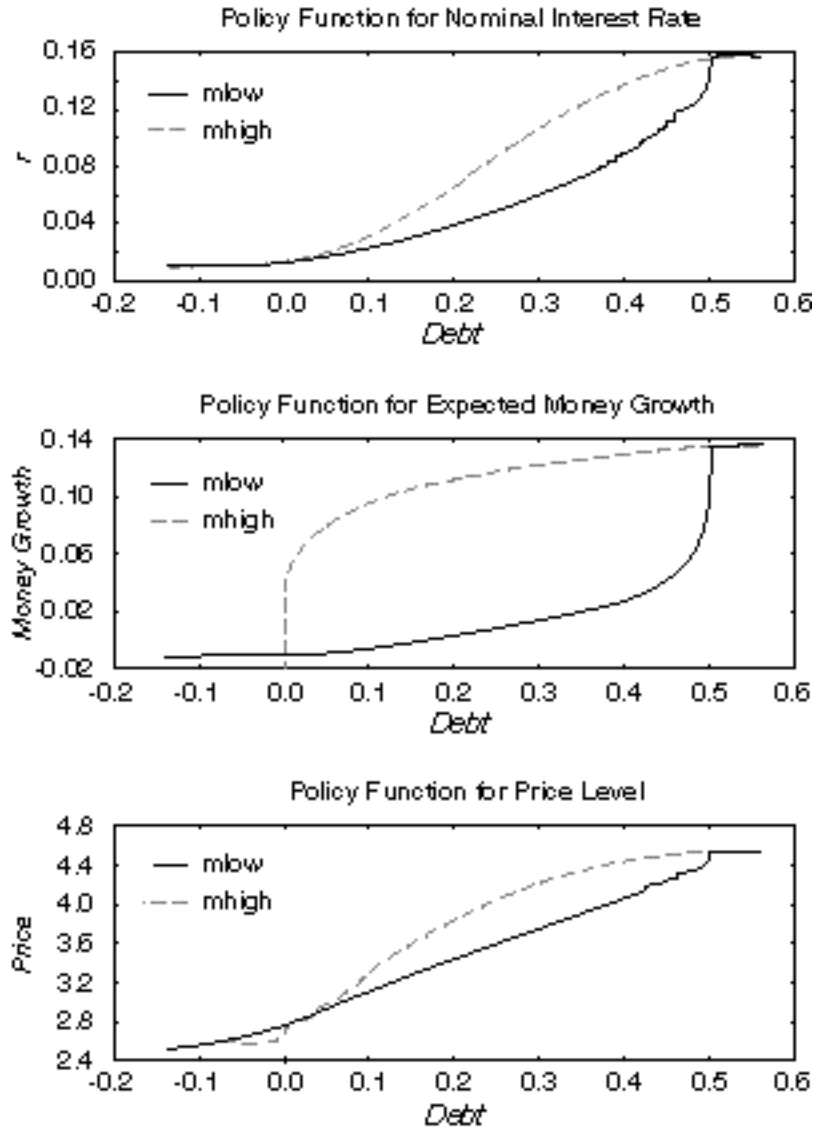Policy Function for Nominal Interest Rate

Policy Function for Expected Money Growth

Policy Function for Price Level

Figure 2

Table 1 Interest Elasticity Effects on Interest Rates

Interest Elasticity of Money Demand	R_l	R_h
−0.10	0.051	0.119
−0.25	0.063	0.100
−0.50	0.068	0.092
−0.75	0.071	0.088
−1.00	0.072	0.086

Note: In this example money growth takes on the values −0.0055 and 0.142, and the transition probability of remaining in the same state is 0.8.
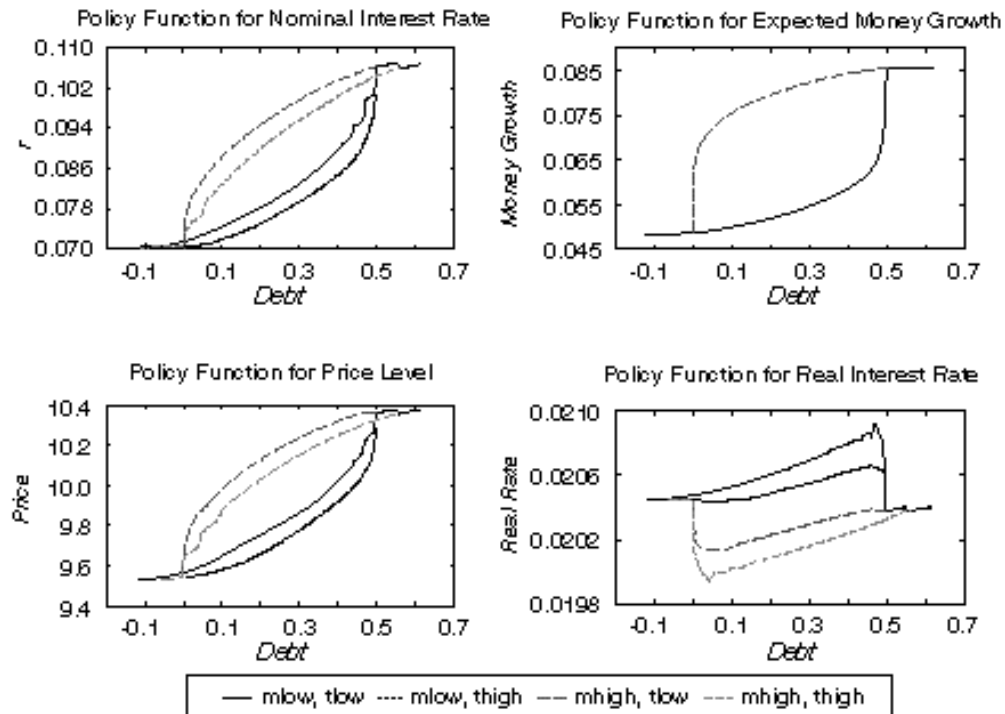
4.   MONETARIST ARITHMETIC IN A CALIBRATED MODEL

To explore the empirical significance of monetarist arithmetic, I calibrate two related models and compare the behavior of nominal variables and expected lifetime utility. In both models, endowment is fixed at one unit and government transfers are equal to 0.189. The models are calibrated to produce a steady-state interest elasticity of money demand of −0.20 and a ratio of money to consumption of 0.10. At an annual frequency, both of these values are consistent with U.S. data. The discount factor is set at 0.98, implying a steady-state real interest rate of two percent. The money growth rates are 0.049 and 0.086, while the tax rates are 0.17 and 0.229. The debt-to-GNP ratio lies within the interval [−0.12, 0.62]. The two models are similar in that the tax authority responds to the debt-to-GNP ratio as described in equation (5). The persistence parameter, v, is set at 3.5. The first model considered depicts a dependent monetary policy as described by equation (6) with a persistence parameter, ψ, equal to 5.0. The second model allows monetary policy to be independent and the transition probability of remaining in the same state of money growth is 0.85. These parameterizations of tax rates and money growth produce realizations that are consistent with U.S. experience over the period 1961 to 1995.

Policy Functions

The policy functions for the case in which monetary policy responds to debt are depicted in Figure 3. One sees that expected money growth is positively related to government debt. As government debt approaches one half of GNP, the probability of both taxes and money growth being high approaches one. Similarly, as debt approaches zero, the probability of both taxes and money growth being low approaches one. Thus, the policy functions for the different states converge as debt approaches its upper and lower bounds. The positive

Figure 3

relationship between money growth and debt leads to a positive relationship between debt and both the nominal interest rate and the price level. The persistence of the money growth process also implies that higher rates of money growth lead to higher nominal interest rates and a higher price level. Also, for any given rate of money growth, higher taxes imply lower nominal interest rates and lower prices. This result occurs because higher taxes reduce the debt and, therefore, imply a lower average rate of future money growth. Consequently, like Leeper (1991) and Aiyagari and Gertler (1985), the model implies that fiscal policy affects nominal variables through its influence on the path of future money growth.

The real interest rate in this model is also related to the level of debt, monetary policy, and fiscal policy. Higher rates of money growth are associated with lower real balances and with a lower marginal utility of consumption. In the case where money growth is high, the expected value of next period's money growth will be less than its current rate. Hence, next period's real balances are

expected to be higher and next period's expected marginal utility will be greater than current marginal utility. This relationship between current and expected future marginal utility implies that the real interest rate will be lower when money growth is currently high. Also, for any given rate of money growth, higher taxes imply lower expected money growth in the future. This lower expected future money growth is associated with higher expected future real balances and a higher expected future marginal utility of consumption. Thus, the real interest rate is lower when taxes are high. Similarly, because lower debt implies lower future money growth, the real interest rate is low when debt is low.

When monetary policy is independent, the policy functions look very different. As shown in Figure 4, debt and fiscal policy no longer have any effects on economic variables. This invariance occurs because taxes and debt do not influence the path of money growth. The policy functions, therefore, take on only two values, one is associated with low money growth, and the other with high money growth. As in the previous case, high money growth results in higher interest rates and a higher price level. Comparison of Figures 3 and 4 reveals that the interest rate and the price level are not necessarily always lower under independent monetary policy. This latter result contrasts with the findings of Aiyagari and Gertler (1985) and occurs because conditional on the debt being low, money growth is much more likely to be low with a dependent monetary policy. Their results, therefore, are sensitive to the actual stochastic specification of policy.
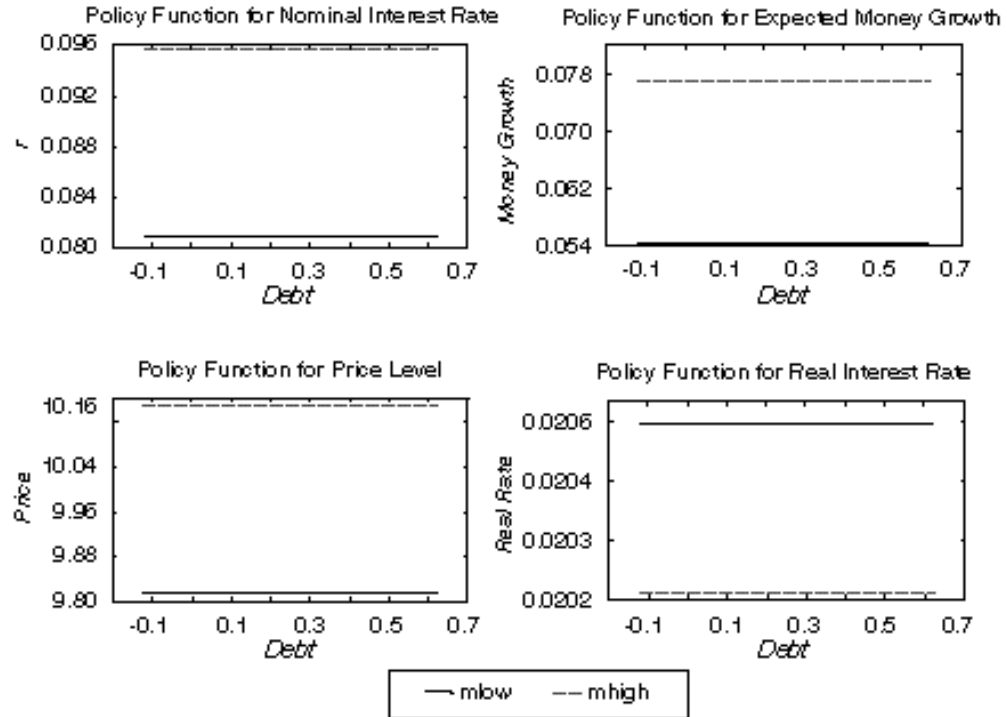
Further Comparison of the Two Policies

To further contrast economic consequences of independent and dependent monetary policies, I examine time series from model simulations. Each simulation is 100 periods long and the results are averaged over 500 simulations. With respect to dependent monetary policy, the simulated tax process has a mean of 0.187 and a standard deviation of 0.027. These values compare with an actual mean of average tax revenues over the period 1961 to 1995 of 0.189 and standard deviation of 0.0074. The simulated tax process is somewhat more variable than the historical series on average tax rates but shows about the same degree of variability as the average marginal tax rate series computed using the methodology of Barro and Sahasakul (1986).[4] The mean of money growth is 0.06 and its standard deviation is 0.017. These values are similar to the actual values for the growth rate of the monetary base, which had a mean of 0.067 and a standard deviation of 0.020.

A further comparison between the generated processes for taxes and money growth and their empirical counterparts can be obtained by examining the

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[4] The Barro and Sahasakul series was taken from DRI, and its standard deviation is 0.0260.

Figure 4

following linear regressions. For generated data under a dependent monetary policy, the regressions are given by

$$\tau_t = 0.070 + 0.561\tau_{t-1} + 0.073b_{t-1}, \tag{12}$$
$$(0.014) \quad (0.082) \qquad (0.023)$$

$$\eta_t = 0.017 + 0.700\eta_{t-1} + 0.007b_{t-1}, \tag{13}$$
$$(0.005) \quad (0.109) \qquad (0.014)$$

while for an independent monetary policy the corresponding regressions are

$$\tau_t = 0.064 + 0.600\tau_{t-1} + 0.067b_{t-1}, \tag{14}$$
$$(0.014) \quad (0.083) \qquad (0.023)$$

$$\eta_t = 0.024 + 0.663\eta_{t-1} - 0.010b_{t-1}, \tag{15}$$
$$(0.007) \quad (0.080) \qquad (0.015)$$

where standard errors are in parentheses. From these regressions alone, it would be difficult to distinguish between the two regimes. All the comparable coefficients differ insignificantly from each other and in neither regime does monetary policy appear to depend on debt. The reason for the insignificant coefficient on debt in the money growth regression (13) is that taxes are doing the bulk of the work in controlling debt. The money growth process is highly persistent (see Figure 5), even at the bounds of the debt space, and taxes are more likely to change states in order to reduce the debt when it is high or increase the debt when it is low. Thus, a simple econometric exercise to test whether seignorage is influenced by debt would fail to uncover this feature in the dependent monetary regime.

Based on actual data over the period 1961 to 1995, the corresponding regressions are
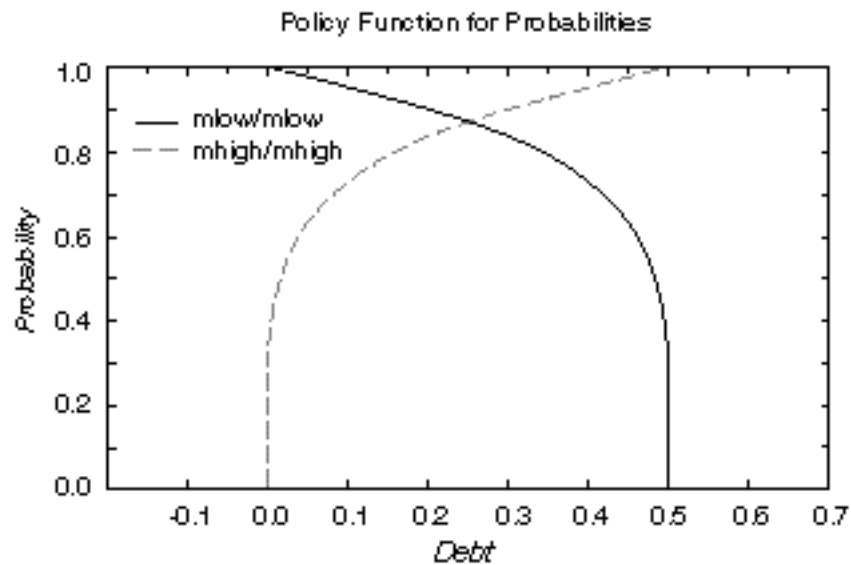
$$\tau_t = 0.070 + 0.62\tau_{t-1} + 0.005b_{t-1}, \tag{16}$$

$$(0.027) \quad (0.14) \qquad (0.0097)$$

$$\eta_t = 0.028 + 0.68\eta_{t-1} - 0.013b_{t-1}. \tag{17}$$

$$(0.015) \quad (0.095) \qquad (0.021)$$

Figure 5

Policy Function for Probabilities

mlow/mlow
mhigh/mhigh

Probability

Debt

With the exception of the insignificance of debt on average tax rates, the regressions on actual and generated data are quite similar.[5] The calibrated processes, therefore, seem to be fairly representative of actual processes.

To compare the influences of monetary policy in the two model economies, I examine impact effects and correlations. For the chosen parameterization the steady-state value of the nominal interest rate is 0.0887, the real interest rate is 0.020, and the price level is $10M$. With low taxes, low money growth, and a dependent monetary policy, the nominal interest rate falls to 0.0807 and the price level declines to 9.810. If taxes were high, then the interest rate would decline to 0.0770 and the price level would fall to 9.719. With an independent monetary policy, low money growth results in a nominal interest rate of 0.0809 and a price level of 9.814. Here, unlike the finding in Aiyagari and Gertler (1985), monetary policy in a dependent regime does affect the price level. Furthermore, although fiscal policy also affects the price level, the effect is much less than one-for-one. For example, under low money growth and high taxes, inflation is 4.3 percent as opposed to 5.0 percent when taxes are low. These contrary results occur for two reasons. One is the explicit stochastic process for policy and the other is the lower interest elasticity of money demand. As the interest elasticity approaches zero, so that $m = c$, prices must move one-for-one with money regardless of the regime.

The preceding example shows that the impact effects of monetary policy differ somewhat across regimes. It remains to ask whether the correlations between policy and nominal variables are very different across regimes. The correlations are depicted in Table 2. The top panel shows the correlation coefficients that occur under a dependent monetary policy and the bottom panel depicts the same correlations under an independent monetary policy. With respect to the correlations between money growth, η, and other nominal variables or between money growth and real balances, the correlations are somewhat smaller under a dependent monetary policy, but by-and-large the correlations are quite similar. The only quantitatively significant differences occur with respect to correlations involving the real interest rate. However, as shown by the policy functions, the real interest rate shows very little variation. Given the presence of measurement error, it would be difficult in practice to identify the monetary regime through the use of data on ex ante real interest rates. Thus, the data generated by the two different models are very much the same.

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[5] Although taxes do not seem to respond to debt over the short sample period considered here, fiscal policy does seem to respond to debt over longer time horizons (see Bohn [1991]) and at lower frequencies (see Dotsey and Mao [1996]).

Table 2 Correlation Coefficients

Dependent Monetary Policy

	m	r	π^e	π	rr
η	-0.848	0.854	0.862	0.864	-0.900
m		-0.998	-0.999	-0.759	0.577
r			1.000	0.765	-0.586
π^e				0.770	-0.599
π					-0.742

Independent Monetary Policy

	m	r	π^e	π	rr
η	-1.00	1.00	1.00	0.88	-1.00
m		-1.00	-1.00	-0.88	1.00
r			1.00	0.88	-1.00
π^e				0.88	-1.00
π					0.88

Note: η is money growth, m is real balances, r is the net nominal interest rate, π^e is expected inflation, π is actual inflation, and rr is the ex ante real rate of interest.

5.   CONCLUSION

This article analyzes the economic effects of a monetary policy that responds to debt and compares those effects with ones that arise under an independent monetary policy. A principal finding is that the nominal behavior of the two calibrated economies is not very different under the two types of monetary regimes. Indeed, linear regression analysis is unable to distinguish between the two economies. It would be even more difficult to distinguish econometrically between independent and dependent monetary policy if dependent monetary policy only reacted to debt at the boundaries of the debt-to-GNP ratio rather than continuously as it does in the above example. Thus, the monetarist arithmetic is not overly unpleasant.

My analysis also indicates that in explorations of the interrelationship between monetary and fiscal policy, the exact form of the stochastic processes is important. Characteristics of the processes, such as persistence, are crucial in gauging the economic effects of policy. Policy, both fiscal and monetary, need not react immediately to changes in government debt, and the timing of the reaction is important. The empirically based persistence of the process for monetary policy is one feature of the model that leads to results that differ from those of other authors.

In addition to demonstrating the importance of the stochastic processes, the results in this article also indicate that behavioral parameters play an important

role in determining the different effects that occur under the two types of monetary policy. In particular, the interest elasticity of money demand is a crucial parameter. The interest elasticity employed in this article is much lower than that used in the papers of both Leeper (1991) and Aiyagari and Gertler (1985). The lower interest elasticity is partly responsible for the influence exerted by dependent monetary policy on the nominal interest rate in my model, which is contrary to the results presented in Aiyagari and Gertler's model. Furthermore, a realistic parameterization of the interest elasticity implies that the spectacular example of Sargent and Wallace is implausible. Thus, it appears that although the intertemporal considerations highlighted by Sargent and Wallace are important theoretically, they appear to be less so in practice.

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