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THE OPTIMAL COLLECTION OF SEIGNIORAGE
Theory and Evidence

N. Gregory MANKIW*

Harvard University and NBER, Cambridge, MA 02138, USA

This paper presents and tests a positive theory of monetary and fiscal policy. The government chooses the rates of taxation and inflation to minimize the present value of the social cost of raising revenue given exogenous expenditure and an intertemporal budget constraint. The theory implies that nominal interest rates and inflation are random walks. It also implies that nominal interest rates and inflation move together with tax rates. United States data from 1952 to 1985 provide some support for the theory.

1. Introduction

Throughout most of recent history, nominal interest rates, inflation, and money growth have been highly persistent. They show little or no tendency to revert to any normal level. Mankiw and Miron (1986) show that the three-month nominal interest rate has been approximately a random walk since the founding of the Federal Reserve System in 1914. Fama and Gibbons (1984) and Barsky (1987) report findings of non-stationarity in the rate of inflation over the post-war period. The purpose of this paper is to show that the optimal collection of seigniorage over time implies that these series should be approximately random walks.

Inflation is one form of taxation. It is a tax on holding money balances. Beyond the traditional deadweight losses of a tax, inflation also imposes many other social costs [Fischer and Modigliani (1978)]. In a first-best world, there would be no inflation, and perhaps deflation [Friedman (1969)]. Once distortions are introduced, including the need to raise public revenue, a positive rate of inflation may be optimal [Phelps (1973)].

If the marginal social cost of raising revenue is increasing in the tax rate, as one would typically expect, optimal fiscal policy entails the smoothing of tax rates over time [Barro (1979, 1986)]. Just as the smoothing of consumption by consumers makes consumption a random walk [Hall (1978)], the smoothing of tax rates by the government makes tax rates a random walk. This general

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principle applied to the case of seigniorage implies that nominal interest rates and inflation should be smoothed as well and that such smoothing makes these series approximately random walks.

The model presented here to formalize these ideas is completely classical. In particular, monetary policy is assumed to have no effect on output or real interest rates. The model can be interpreted in two ways. Those readers who view economic fluctuations through the lens of real business cycle theory can consider the model as a description of both short-run and long-run fluctuations in nominal variables. Yet there are surely many readers who believe that monetary policy has real short-run effects because of temporary misperceptions or nominal rigidities. These readers can interpret the model as applying to the longer run in which the economy maintains output and employment at the natural rate.

After presenting the model, I examine one key implication, that the nominal interest rate and inflation are determined by the government revenue requirement. Using data since 1952, I find that an increase in federal government revenue of 1 percent of GNP raises the nominal interest rate by 1.1 to 1.4 percentage points. Although there is a highly significant positive relation between the average tax rate and the nominal interest rate, the theory explains only one third of the variation in changes in the nominal interest rate.

2. The theory of optimal seigniorage

I examine here the optimal intertemporal monetary and fiscal policy of a government that must satisfy a budget constraint in present value. The government budget constraint requires

$$\int_0^\infty e^{-\rho s} G(t+s)\,\mathrm{d}s + B(t) = \int_0^\infty e^{-\rho s} T(t+s)\,\mathrm{d}s, \tag{1}$$

where

$G(t)$ = real expenditure at time t,
$T(t)$ = real revenue at time t,
$B(t)$ = real government debt at time t,
ρ = real discount rate, assumed constant over time.

Expenditure is here taken to be exogenous, so as to highlight the issue of revenue mix. Future expenditure is a random variable; the government thus receives new information on its revenue requirement as time passes.

The government raises revenue from two sources. The first source of revenue is a tax on output, such as an income tax or a sales tax. The second source of revenue is seigniorage, the printing of new money. Both ways of raising revenue cause deadweight social losses. The government chooses its use of these two instruments to minimize the present value of these social losses.

Denote the exogenous level of output as $Y(t)$ and the tax rate on output as $\tau(t)$. The revenue raised by this tax is thus $\tau(t)Y(t)$. The deadweight social losses induced by the tax are denoted $f(\tau)Y$, where $f' > 0$ and $f'' > 0$. The deadweight social losses are assumed homogeneous in output.

For the moment, suppose that the demand for money is described by the quantity equation

$$M(t)/P(t) = kY(t), \tag{2}$$

where

$M(t)$ = outside money at time t,
$P(t)$ = the price level at time t,
k = a constant.

The real revenue raised from seignorage is

$$\frac{\dot{M}}{P} = \frac{\dot{M}}{M} \cdot \frac{M}{P} = (\pi + g)kY, \tag{3}$$

where

$\pi = \dot{P}/P$ is the inflation rate,
$g = \dot{Y}/Y$ is the growth rate of output.

Total revenue is therefore

$$T = \tau Y + (\pi + g)kY, \tag{4}$$

the sum of the receipts from direct taxation and seigniorage.

The social cost of inflation is denoted $h(\pi)Y$, where $h' > 0$ and $h'' > 0$. As with the cost of taxation, the cost of inflation is assumed homogeneous in output. The nature of these inflation costs is discussed by Fischer and Modigliani (1978). These social losses include direct costs, such as increased menu costs. But they also include the losses associated with the disruption of the efficient functioning of markets, as emphasized by Okun (1975) and Carlton (1982).[1]

[1] It is sometimes argued that unanticipated inflation is non-distortionary and thus equivalent to a lump-sum tax. For simplicity, this formulation rules out such non-distortionary inflation by including the same variable (π) in both the budget constraint and the social cost function.

The goal of the government is to minimize the expected present value of the social losses

$$E_t \int_0^\infty e^{-\rho s} [f(\tau) + h(\pi)] Y \, ds, \tag{5}$$

subject to the budget constraint

$$\int_0^\infty e^{-\rho s} G \, ds + B(t) = \int_0^\infty e^{-\rho s} (\tau + \pi k + g k) Y \, ds, \tag{6}$$

where some time arguments are omitted to simplify the notation. The two choice variables of the government are the tax rate τ and the inflation rate π.[2]

As in much recent work studying dynamic optimization [e.g., Hall (1978), Hansen and Singleton (1982), Mankiw, Rotemberg and Summers (1985)] I do not solve for the decision rule but rather examine the first-order conditions necessary for an optimum. The first-order conditions are

$$E_t \{ f'[\tau(t+s)] \} = f'[\tau(t)], \tag{7}$$

$$E_t \{ h'[\pi(t+s)] \} = h'[\pi(t)], \tag{8}$$

$$h'[\pi(t)] = k f'[\tau(t)]. \tag{9}$$

The optimal fiscal and monetary policy satisfies these three equations. The intertemporal first-order condition (7) equates the marginal social cost of taxation today and in the future. It expresses the 'tax smoothing' of optimal fiscal policy investigated by Barro (1979, 1986). The intertemporal first-order condition (8) equates the marginal social cost of inflation today and in the future. The static first-order condition (9) equates contemporaneously the marginal social cost of raising revenue through direct taxation and the marginal social cost of raising revenue through seigniorage.

Eq. (7) implies that the marginal cost of taxation is a martingale, while eq. (8) implies that the marginal cost of inflation is a martingale. If $f(\cdot)$ and $h(\cdot)$ are quadratic, then the tax rate and the inflation rate are themselves martingales. Since the real interest rate is assumed constant, the nominal interest rate is a martingale as well.

Eq. (9), which relates the tax rate to the rate of inflation, expresses a crucial implication of the theory. An increase in the government revenue requirement increases the use of both instruments. Hence, the level of taxation moves together with inflation and nominal interest rates.

The theory as developed so far assumes that real balances do not respond to the level of inflation. More generally, one could make k a function of the rate

[2] The government actually chooses the money stock, but given output, this is equivalent to choosing the rate of inflation.

of inflation. This emendation of the model leads to slightly different first-order conditions:

$$\mathrm{E}_t\{f'[\tau(t+s)]\} = f'[\tau(t)], \tag{7'}$$

$$\mathrm{E}_t\{\psi[\pi(t+s)]\} = \psi[\pi(t)], \tag{8'}$$

$$\psi[\pi(t)] = f'[\tau(t)], \tag{9'}$$

where $\psi(\pi) \equiv h'(\pi)/[k(\pi) + (\pi + \rho)k'(\pi)]$. These first-order conditions have roughly the same interpretation as in the basic model. Hence, introducing feedback from inflation to real balances has little effect on the fundamental theoretical implications.

There are at least two issues that the theory presented here does not address. First, I have not explained the mechanics of how the monetary authority achieves its target for inflation and the nominal interest rate. It is sometimes argued that such a target cannot be permanently maintained or that it would lead to indeterminacy of the price level. Recent work by Barro (1987), Goodfriend (1987), and McCallum (1986), however, shows how a nominal interest rate target can be achieved.

Second, I have not presented an explicit model of the transactions process and the role of money. Faig (1986), Kimbrough (1986), and Lucas (1986) suggest that explicit modeling of money as an intermediate good can overturn the traditional conclusion that the inflation tax should be used in a second-best world. Yet Romer (1985) presents a model of the transactions process in which use of the inflation tax is appropriate. Moreover, as Barro (1987) points out, the inflation tax may be the only way of taxing economic activity in the underground economy. The precise circumstances under which use of the inflation tax is second-best optimal remain an unsettled issue.

3. Evidence

The theory of optimal seigniorage can be interpreted as prescriptive. As such, the theory is common. For example, Tobin (1986, p. 11) writes:

> The ability of the government to finance expenditures by issuing money is the 'seigniorage' associated with its sovereign monetary monopoly. Both explicit and implicit taxes are distortionary. The distortion of the inflation tax is the diversion of resources or loss of utility associated with the scarcity of money, already mentioned. But there are also distortions in explicit taxes; lump-sum taxes are not available. *The problem is to optimize the choice of taxes, given the necessity of government expenditure.*

> *This formulation correctly connects the money-supply process to the government budget.* (Emphasis added)

This sort of theory is thus often recommended for the conduct of monetary policy.

It is natural to ask whether the government (including the monetary authority) heeds these recommendations. In other words, can the theory of optimal seigniorage be interpreted as at all descriptive? As I pointed out in the introduction, the data confirm the implication of eq. (8) that inflation and nominal interest rates are highly persistent. This prediction, however, is probably not unique to this theory and thus may not provide a powerful test.

Perhaps the most distinctive feature of the theory of optimal seigniorage is that money growth, inflation, and nominal interest rates are determined by the government revenue requirement. In this section, therefore, I examine this prediction of the theory. If one could obtain reliable estimates of the marginal social cost of inflation, the marginal social cost of direct taxation, and the interest elasticity of money demand, then eq. (9′) could be used to relate the level of taxation to the levels of inflation and the nominal interest rate at any given point in time. Not knowing of such reliable estimates, however, I undertake a more modest test of the theory. I estimate a linear approximation to eq. (9′) using United States time series data. The goal is to test the implication of the theory that over time higher tax rates are associated with higher inflation rates and higher nominal interest rates.

In its purest form, as presented in section 2, the theory of optimal seigniorage implies that the revenue requirement is the sole determinant of inflation and nominal interest rates. That is, the static first-order condition, eq. (9′), holds without any error. In practice, of course, the tax on real money balances depends on a variety of economic and political forces, as does the tax on gasoline, cigarettes, or any other commodity. Nonetheless, if the theory of optimal seigniorage is useful as a positive theory, increases in the government revenue requirement should tend to increase the tax on real money balances.

The first nominal variable I examine is the nominal three-month Treasury bill rate (INT). As a measure of the average tax rate, I use federal government receipts as a percentage of GNP (TAX). Table 1 presents these series annually between 1951 (the year of the Accord between the Federal Reserve and the Treasury) and 1985 (the most recent year available).[3]

Table 1 shows an upward drift in both the interest rate and revenue over this thirty-five-year period. While these trends are consistent with theory, they provide only weak evidence. To abstract from this secular change, all the regressions I report either include a time trend or are in differenced form.

[3] Fama (1975) shows that from 1952 to 1972 almost all variation in nominal interest rates is due to expected inflation. While the post-1972 period shows some variation in real rates, much of the variation in nominal interest rates is still the inflation premium. See Fama and Gibbons (1984).

Table 1

Year	Three-month Treasury bill rate (*INT*)	Federal government receipts as percent of GNP (*TAX*)
1951	1.518	19.376
1952	1.723	19.255
1953	1.891	18.945
1954	0.937	17.235
1955	1.727	18.009
1956	2.628	18.333
1957	3.223	18.293
1958	1.772	17.360
1959	3.386	18.273
1960	2.883	18.805
1961	2.354	18.546
1962	2.773	18.656
1963	3.158	19.048
1964	3.547	17.882
1965	3.946	17.841
1966	4.853	18.588
1967	4.302	18.692
1968	5.333	19.816
1969	6.658	20.718
1970	6.388	19.242
1971	4.328	18.382
1972	4.072	19.146
1973	7.032	19.400
1974	7.830	19.955
1975	5.775	18.450
1976	4.974	19.077
1977	5.269	19.297
1978	7.188	19.620
1979	10.069	20.134
1980	11.434	20.271
1981	14.025	20.949
1982	10.614	20.066
1983	8.611	19.376
1984	9.523	19.296
1985	7.479	19.679

3.1. Basic results

The regression of the Treasury bill rate (*INT*) on the federal revenue percent of GNP (*TAX*) and a time trend (*TIME*) for 1952 to 1985 yields (with standard errors in parentheses)

$$\begin{aligned} INT = \underset{(5.9)}{-26.1} + \underset{(0.03)}{0.19}\, TIME + \underset{(0.33)}{1.43}\, TAX, \\ N = 34, \quad \bar{R}^2 = 0.84, \quad D.W. = 0.98, \quad s.e.e. = 1.27. \end{aligned} \tag{10}$$

The coefficient on *TAX* appears large. It implies that an increase in federal revenue of 1 percent of GNP is associated with a 1.43 percentage point increase in the nominal interest rate.[4]

The small Durbin–Watson statistic prevents any valid inference from regression (10) regarding statistical significance. I present two remedies for serial correlation. First, I quasi-difference the equation, applying the filter $(1-0.5L)$, which is indicated by the Durbin–Watson in regression (10).[5] The results after quasi-differencing are (standard errors again in parentheses)

$$\begin{aligned} &(1-0.5L)INT = \underset{(2.8)}{-11.3} + \underset{(0.02)}{0.09}\,TIME + \underset{(0.31)}{1.25}\,(1-0.5L)TAX, \\ &N=34, \quad \bar{R}^2=0.66, \quad D.W.=1.55, \quad s.e.e.=1.10. \end{aligned} \tag{11}$$

The Durbin–Watson statistic no longer indicates statistically significant serial correlation. The coefficient on *TAX* is only a little smaller. The impact of federal revenue on the nominal interest rate appears positive, substantial, and statistically significant.

As Granger and Newbold (1974) and Plosser and Schwert (1978) emphasize, the problem of spurious regression can be severe when the variables in a regression are random walks. In our case, the variables are approximately random walks both in theory and in practice. To ensure that the relation between *INT* and *TAX* is not spurious, I estimate the equation in differenced form:[6]

$$\begin{aligned} &\Delta INT = \underset{(0.2)}{0.2} + \underset{(0.28)}{1.13}\,\Delta TAX, \\ &N=34, \quad \bar{R}^2=0.31, \quad D.W.=1.82, \quad s.e.e.=1.22. \end{aligned} \tag{12}$$

The relation between *INT* and *TAX* remains significant. An increase in federal revenue of 1 percent of GNP increases the nominal interest rate by

[4]The theory has no prediction regarding the magnitude of this coefficient. See eq. (9).

[5]Since the Durbin–Watson statistic is about 1.0, applying this filter is a non-iterated Cochrane–Orcutt serial correlation correction. Iterating yields a first-order autoregressive parameter of 0.52 with coefficient estimates essentially unchanged.

[6]While differencing may be a good way of dealing with serial correlation of the error, it also emphasizes higher frequency fluctuations. To the extent one expects a relationship to hold only in the long run, differencing may obscure an empirical relationship. In the present application, this problem does not appear serious. But it may explain why the coefficient falls somewhat when the data are differenced.

1.13 percentage points. Changes in the average tax rate explain 31 percent of changes in the nominal interest rate.[7]

3.2. Subsample stability

To investigate how robust is the relation between the nominal interest rate and the average tax rate, I split the sample evenly into two subsamples. The second period, 1969–1985, is different from the first period, 1952–1968, in many ways. In approximately 1969, the economy entered a period that is widely noted for increased macroeconomic volatility, frequent supply shocks, a slowdown of productivity, and the breakdown of many empirical macroeconomic relationships.

The regression of *INT* on *TAX* estimated in differenced form with data from 1952 to 1968 yields

$$\begin{gathered} \Delta INT = \underset{(0.1)}{0.2} + \underset{(0.20)}{0.72}\,\Delta TAX, \\ N = 17, \quad \bar{R}^2 = 0.43, \quad D.W. = 2.46, \quad s.e.e. = 0.59. \end{gathered} \tag{13}$$

The 1969 to 1985 subsample yields

$$\begin{gathered} \Delta INT = \underset{(0.4)}{0.1} + \underset{(0.52)}{1.52}\,\Delta TAX, \\ N = 17, \quad \bar{R}^2 = 0.32, \quad D.W. = 1.96, \quad s.e.e. = 1.62. \end{gathered} \tag{14}$$

In both subsamples, there is a significant positive relation between *INT* and *TAX*.

While the sign of the relation is the same in both subsamples, the coefficient estimate is very different. In particular, the coefficient is twice as large in the second subsample. This increase in the coefficient may be evidence against the linear specification. A log-linear specification yields, for the entire 1952 to 1985 sample,

$$\begin{gathered} \Delta \log(INT) = \underset{(0.04)}{0.04} + \underset{(1.0)}{5.1}\,\Delta \log(TAX), \\ N = 34, \quad \bar{R}^2 = 0.42, \quad D.W. = 2.32, \quad s.e.e. = 0.23, \end{gathered} \tag{15}$$

[7] Even in the second differences the relation is significant,

$$\begin{gathered} \Delta^2 INT = \underset{(0.29)}{-0.03} + \underset{(0.25)}{0.90}\,\Delta^2 TAX, \\ N = 34, \quad \bar{R}^2 = 0.27, \quad D.W. = 2.44, \quad s.e.e. = 1.67. \end{gathered}$$

for the 1952 to 1968 subsample,

$$\begin{aligned} &\Delta \log(INT) = \underset{(0.06)}{0.07} + \underset{(1.5)}{6.4}\,\Delta \log(TAX), \\ &N = 17, \quad \bar{R}^2 = 0.52, \quad D.W. = 2.07, \quad s.e.e. = 0.25, \end{aligned} \tag{16}$$

and for the 1969 to 1985 subsample,

$$\begin{aligned} &\Delta \log(INT) = \underset{(0.05)}{0.02} + \underset{(1.4)}{3.7}\,\Delta \log(TAX), \\ &N = 17, \quad \bar{R}^2 = 0.28, \quad D.W. = 2.01, \quad s.e.e. = 0.22. \end{aligned} \tag{17}$$

With this log-linear specification, the coefficient *falls* from the first to the second subsample. Hence, this functional form appears to overcompensate for the non-linearity.

3.3. *Alternative hypotheses*

The results presented so far indicate there is a significant positive relation between the average tax rate and the nominal interest rate. It is possible that this correlation is proxying for some other omitted variable. In this section I consider whether the addition of other variables changes the apparent relation between *INT* and *TAX*.

One alternative hypothesis is that deficits tend to induce monetization. Under this view, higher tax receipts should, holding constant expenditure, lower money growth, inflation, and nominal interest rates. To test this view, I include federal government expenditure as a fraction of GNP (*EXP*) in this equation. This alternative view predicts that once *EXP* is included, the sign on *TAX* should be negative. The theory of optimal seigniorage [eq. (9)] implies that current expenditure should play no independent role and that its inclusion should not affect the *TAX* coefficient.

Another alternative hypothesis is that interest rates and receipts passively respond to the business cycle. To examine whether the correlations I find are merely business cycle phenomena without any additional structural interpretation, I include the rate of unemployment (*RU*) as an additional regressor.

When these two variables are included in the regression for the entire sample (1952–1985), the results for the specification in levels are

$$\begin{aligned} &INT = \underset{(6.9)}{-28.9} + \underset{(0.05)}{0.18}\,TIME + \underset{(0.40)}{1.75}\,TAX - \underset{(0.21)}{0.23}\,EXP + \underset{(0.23)}{0.31}\,RU, \\ &N = 34, \quad \bar{R}^2 = 0.84, \quad D.W. = 1.11, \quad s.e.e. = 1.27. \end{aligned} \tag{18}$$

When the filter $(1-0.5L)$ is applied, one obtains

$$\begin{aligned}(1-0.5L)INT = &-9.76 + 0.11\,TIME + 1.28\,(1-0.5L)TAX \\ &\;\;(3.80) \quad (0.03) \qquad\quad (0.40) \\ &-0.22\,(1-0.5L)EXP + 0.06\,(1-0.5L)RU, \\ &\;\;(0.22) \qquad\qquad\qquad (0.26)\end{aligned} \tag{19}$$

$$N=34, \quad \bar{R}^2=0.65, \quad D.W.=1.52, \quad s.e.e.=1.12,$$

and in differences,

$$\begin{aligned}\Delta INT = &\;0.23 + 0.86\,\Delta TAX - 0.20\,\Delta EXP - 0.21\,\Delta RU, \\ &(0.21) \quad (0.38) \qquad\quad (0.22) \qquad\quad (0.27) \\ N=34, &\quad \bar{R}^2=0.32, \quad D.W.=1.57, \quad s.e.e.=1.21.\end{aligned} \tag{20}$$

In all three specifications, neither the expenditure variable nor the unemployment rate appears significant. Moreover, the relation between the interest rate and the average tax rate remains positive and strong.

Another hypothesis that relates the tax rate to inflation and nominal interest rates is 'bracket creep': to the extent that a progressive tax system is not indexed, inflation tends to cause tax rates to rise. This hypothesis, however, cannot easily explain the phenomenon reported here. Bracket creep relates the tax rate to the price level, not to the inflation rate. A period of positive but falling inflation would be associated with increases in tax rates under the bracket creep hypothesis, but decreases in tax rates under the theory of optimal seigniorage. Since the rate of inflation is positive throughout the sample period, the bracket creep hypothesis predicts constantly rising tax rates. In contrast, the theory of optimal seigniorage is consistent with the disinflationary periods, such as from 1981 to 1983, in which the tax rate fell with inflation and the nominal interest rate.

3.4. Regressions for inflation

The theory presented here in principle applies to both inflation and nominal interest rates. Nominal interest rates, however, have the advantage of being measured accurately and with little conceptual ambiguity. Moreover, inflation depends on a variety of transitory forces that are beyond the control of policymakers and outside the theory of optimal seigniorage. Despite these reservations, I also examine whether a higher average tax rate is associated with higher inflation.

The measure of inflation I use is the percentage change in the CPI (all urban consumers) from December to December (INF). The regression of INF on TAX yields

$$\underset{}{INF} = \underset{(11.4)}{-33.1} + \underset{(0.06)}{0.14}\, TIME + \underset{(0.64)}{1.80}\, TAX,$$

$$N=34, \quad \bar{R}^2=0.54, \quad D.W.=0.67, \quad s.e.e.=2.45. \tag{21}$$

The estimates imply that a 1 percent increase in receipts as a fraction of GNP raises inflation by 1.80 percentage points. This estimate is very close to the 1.43 estimate from the nominal interest rate regression.

As before, I use two corrections for serial correlation. Quasi-differencing yields

$$(1-0.5L)INF = \underset{(5.0)}{-13.7} + \underset{(0.04)}{0.08}\, TIME + \underset{(0.56)}{1.48}\,(1-0.5L)TAX,$$

$$N=34, \quad \bar{R}^2=0.35, \quad D.W.=1.08, \quad s.e.e.=1.97, \tag{22}$$

and differencing yields

$$\Delta INF = \underset{(0.4)}{-0.1} + \underset{(0.49)}{1.44}\, \Delta TAX,$$

$$N=34, \quad \bar{R}^2=0.19, \quad D.W.=1.45, \quad s.e.e.=2.13. \tag{23}$$

The estimates here of 1.48 and 1.44 are very similar to the estimates of 1.25 and 1.13 obtained with nominal interest rates. The fit of these equations is somewhat worse, as indicated by either the adjusted R^2 or the standard errors of estimate. This reduction in fit is to be expected, since inflation is a 'noisier' time series.

3.5. *An alternative tax measure*

The regressions reported above relate the nominal interest rate and inflation to federal government receipts as a percent of GNP. An alternative tax measure is the average marginal tax rate on labor income (including social security) as estimated by Barro and Sahasakul (1983). I therefore now examine whether this average marginal tax rate (MAR) also positively covaries with the nominal interest rate and inflation.[8]

[8] I am grateful to Robert Barro for providing the updated series.

It is not clear *a priori* which of the two tax measures, TAX or MAR, is preferable. One might argue that the average marginal tax rate is the best measure of the marginal social cost of raising revenue. Yet consider what makes these two variables different.[9] Changes in the mix of taxes, such as a shift between personal and corporate taxes, would change MAR without changing TAX. It is not obvious whether such a change in the tax mix should be associated with a change in the reliance on seigniorage as a source of revenue. Resolving this issue requires a model more extensive than that presented here.

The variable MAR is available up to 1983, so the sample here is two years shorter. Regressing the change in the nominal interest rate on the change in MAR yields

$$\underset{(0.2)}{\Delta INT = 0.1} + \underset{(0.16)}{0.50\,\Delta MAR},$$

$$N=32, \quad \bar{R}^2=0.22, \quad D.W.=1.80, \quad s.e.e.=1.29. \tag{24}$$

The relation between inflation and the average marginal tax rate is

$$\Delta INF = \underset{(0.4)}{-0.2} + \underset{(0.30)}{0.34\,\Delta MAR},$$

$$N=32, \quad \bar{R}^2=0.01, \quad D.W.=1.45, \quad s.e.e.=2.43. \tag{25}$$

The average marginal tax rate is positively related to both the nominal interest rate and inflation, but only the relation to the nominal interest rate is statistically significant.

4. Conclusion

It is well-known that fiscal considerations are important for understanding the money creation leading to many hyperinflations [Sargent (1982), Dornbusch and Fischer (1986)]. I have suggested in this paper that fiscal considerations may be important also for understanding less extreme fluctuations in nominal variables. The theory of optimal seigniorage can explain the non-stationary behavior of nominal interest rates and inflation. The theory also explains the empirical observation documented in this paper that nominal interest rates and inflation positively covary with government receipts as a percent of GNP.[10]

[9] The correlation of ΔTAX and ΔMAR is 0.70.

[10] My empirical results are consistent with those of Evans (1987), who examines 18 tax cuts and 27 tax hikes enacted since 1908. Evans finds (p. 49) that interest rates fall in anticipation of tax cuts and rise in anticipation of tax hikes.

The conservative economic ideology is usually thought to embrace smaller government, lower taxes, and less inflation, while the liberal ideology is prone to larger government, higher taxes, and more inflationist monetary policy. These combinations of monetary and fiscal policies are precisely predicted by the theory of optimal seigniorage. Seen in this light, it is perhaps less surprising that these combinations of policies also appear in United States time series data.

There are a variety of avenues open for future research. One might relax the assumption maintained here that the real interest rate is constant. This extension would require specifying whether high inflation rates or high nominal interest rates are socially costly. 'Menu' costs point toward making inflation costly, while the 'shoeleather' costs associated with trips to the bank point toward making positive nominal interest rates costly.

Future research could also use cross-national data to test the theory of optimal seigniorage. The theory predicts that, *ceteris paribus*, economies with high levels of expenditure and taxation also have high inflation and nominal interest rates. Implementation of such a test, however, would likely require taking into account the cross-national variation in the efficacy of the system of taxation.

Finally, it would be useful to study in more detail the government's choice of the mix of taxes in raising revenue. My empirical results suggest that the revenue requirement can explain approximately one third of the variation in the nominal interest rate. One could probably do no better explaining fluctuations in the gasoline tax or the cigarette tax. There are clearly substantial fluctuations that the theory cannot explain. The theory of optimal seigniorage as presented here is only a partial explanation for fluctuations in money growth, inflation, and nominal interest rates.

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