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INFLATION AS TAXATION: THEORY AND EVIDENCE

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Abstract
The theory of seigniorage is surveyed and reviewed. A theoretical model is developed which nests optimal tax theory and institutional approaches to fiscal and monetary policy. The predictions of this model are tested in three ways: on a large cross-country data set, on a panel of advanced countries, and as a time series for a single country that has undergone a change of regime (South Africa). Reasons are advanced for the poor performance of the optimal tax model of inflation in these and other empirical tests.

Keywords: inflation, interest rates, seigniorage, taxation

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1. INTRODUCTION

The second half of the twentieth century has been the most sustained period of inflation in history. Before 1939, outside wartime, inflation was essentially a zero-mean white noise process (Barsky, 1987). The persistence of inflation since 1945 probably has its roots in structural changes in the economy rather than in the attractions of seigniorage revenue, and some recent attempts to explain cross-country inflation patterns have ignored the revenue aspect altogether (e.g. Bleaney and Fielding, 1999; Bruno and Sachs, 1985; Romer, 1993). Nevertheless the fact that inflation erodes the real value of the government's liabilities, and can also be influenced by the government itself, can scarcely be ignored. The issue is whether the temptation to raise revenue through inflation has or has not ever been a significant factor in the history of prices.

The standard approach to this problem treats inflation as a policy variable and the inflation tax as an alternative to conventional taxation. Both forms of revenue have costs, and the government chooses its fiscal policy so as to equalise these costs at the margin. In its simplest form this theory of optimal taxation suggests a positive correlation between tax rates and inflation rates. The difficulty is that this positive correlation is only occasionally observed in the empirical data (Poterba and Rotemberg, 1990). The theory also implies that inflation rates above the seigniorage-maximising level would never occur, yet the experience of hyperinflations shows that they do (Bruno and Fischer, 1990), although this could be rendered consistent with the model by allowing for the sluggish adjustment of inflationary expectations.

One possible response is that the optimal tax theory is correct in essence but has not yet become sufficiently elaborate. For example, instead of regarding governments as benevolent planners solving an intertemporal optimisation problem based solely on (exogenously given) social costs of tax distortions and inflation, we should perhaps model them as social institutions and endogenise these parameters. A significant branch of research has demonstrated that political and institutional factors help to explain budget deficits and/or seigniorage revenue (Edwards and Tabellini, 1991; Grilli *et al*., 1991; Roubini and Sachs, 1989). A further weakness of the simple model is that, if social welfare is reduced by higher inflationary expectations, and inflationary expectations at time $t+1$ are positively correlated with inflation at time t, then it may pay the government to eschew the inflation tax in order to keep inflationary expectations low, effectively investing in reputation (Barro and Gordon, 1983). If that is the case, then the theory may apply in its simplest version only to situations in which investing in reputation is not worthwhile. Conversely, because a government that invests in reputation is rewarded with low interest rates, governments may be induced to adjust their fiscal policy or debt structure in order to preserve their reputation (Missale and Blanchard, 1994). It is not at all clear, therefore, that rejection of the simplest form of optimal tax theory by the data should be taken to mean that the theory is wrong, rather than merely in need of elaboration.

This paper begins by surveying the theoretical and empirical literature on seigniorage. Theoretically, the contribution of the paper is to integrate research on reputation, debt structure and political institutions into an empirically testable model. In the model developed here, the political factors operate through the authorities' preference parameters and thus influence the choice between reputational and non-reputational solutions (and the inflation rate, conditional on the non-reputational solution being chosen). In the empirical part of the paper, the predictions of this model are tested in three ways: as a cross-section for over 100 countries; as a panel for developed countries; and as a time series for one developing country that has had a marked change of regime (South Africa). The results suggest that even in a refined form the optimal tax model is not as yet very helpful in explaining either the cross-country pattern of inflation rates or the dynamics of inflation over time in a single country or in a number of countries. Possible reasons for this are discussed in the conclusion.

2. THEORY

The basic model is clearly expounded by Mankiw (1987). Inflation is a tax on money balances that can be used as a substitute for conventional taxes. The government must satisfy its intertemporal budget constraint. To finance expenditures that are assumed (for simplicity) to have an exogenously given present value, the government chooses the tax structure so as to minimise the present value of deadweight social losses that are defined as $f(\tau)Y$ for conventional taxes, assuming a tax rate of τ (Y denotes output), and $h(\mathrm{p})Y$ for seigniorage revenue, where p is the rate of inflation. It is assumed that the first and second derivatives of both f and h are positive, the sign of the second derivatives ensuring that the first-order conditions imply smoothing of both conventional and inflation tax rates in the sense of Barro (1979). The tax change in response to any expenditure shock is thus spread over all future time periods.

Formally, the government minimises

$$Z = E_t \int_0^\infty e^{-\mathrm{r}s} [f(\mathrm{t}) + h(\mathrm{p})]\, Y\, ds \qquad (1)$$

subject to the budget constraint

$$\int_0^\infty e^{-\mathrm{r}s} G\, ds + B = \int_0^\infty e^{-\mathrm{r}s} [\mathrm{t} + \mathrm{p}k + gk]\, Y\, ds \qquad (2)$$

where G is government expenditure, B denotes real government debt at time zero, k is the inverse of the velocity of circulation of money and g is the growth rate of real output. Equation (2) simply says that the present value of all future taxes must equal the present value of all future expenditures plus the debt. Maximising (1) subject to (2) yields the first-order conditions

$$E_t\{ f' [\mathrm{t}\,(t+s)]\} = f' [\mathrm{t}\,(t)] \qquad (3)$$

$$E_t\{ h' [\mathrm{p}\,(t+s)]\} = h' [\mathrm{p}\,(t)] \qquad (4)$$

$$h' [\mathrm{p}\,(t)] = k f' [\mathrm{t}\,(t)] \qquad (5)$$

Equations (3) and (4) imply constant tax and inflation rates over all future time periods. Equation (5) is the crucial result from our point of view. Because h' and f' are both positive, this equation implies that any expenditure shock will cause both inflation and conventional tax rates to move in the same direction. The same positive correlation should be observed between tax rates and nominal interest rates, if we assume rational expectations together with a Fisher relationship between nominal interest rates and expected inflation. These are the predictions which Mankiw tests, using United States data from 1952 to 1985. His results are supportive of the theory.

Poterba and Rotemberg (1990) extend the model by allowing for seigniorage revenue on nominal debt. They test the predictions of the optimal tax model for five countries, and find no consistent support for the model, whether or not nominal debt is included in the tax base of the inflation tax. Roubini and Sachs (1989) replicate Mankiw's tests for fifteen OECD countries over the period 1960-85 and find support for the model in only three of them (Finland, Netherlands and United States).

Recent research on the optimal tax model has moved in two directions, both of them implicitly based on the perception that the simple model described above is not supported by the data. One response has been to try to model the relative social cost of inflation and conventional taxation. This approach is founded on scepticism that the social loss functions *f* and *h* remain stable over time, which could explain the failure of the optimal tax model in time-series tests. Casual empiricism suggests that such scepticism is justified. Extreme inflationary experiences are relatively rare and not necessarily associated with high levels of government expenditure, whereas, if social loss functions are stable, such experiences should either be common (because the social costs of inflation are small) or, if rare, should occur only when expenditure and tax rates also reach extreme values. The second strand of recent research allows for a multi-period time horizon. When the social costs of inflation are an increasing function of expected as well as actual inflation, there is an incentive to invest in keeping future inflationary expectations low by delivering low actual inflation. This strand of research focuses on the conditions for investing in low inflationary expectations.

I begin by reviewing research that attempts to model the relative social costs of inflation and conventional taxation. The theme of this work is that the government should be regarded as a social institution rather than as a mechanistic social optimising agency. I then turn to the reputational approach.

Government as a social institution

The central insight of this strand of research is that not all governments are the same. They may differ in the devolution of decision-making to lower levels or functions of government, in the degree of polarisation between political parties, in the constitutional framework (presidential or parliamentary system), in the stability and frequency of change of ruling coalitions, etc. These factors may in turn affect the perceived social costs of conventional taxation and inflation or the discount rate of the politicians in power.

One theory of this kind might be termed a theory of weak central government. In this theory, fiscal decision-making is devolved to a level that does not coincide with the currency area. Thus the model could be applied to a common currency area in which the member governments' fiscal policy is unconstrained, or to a single country in which the central government has little control over the fiscal decisions of lower levels of government (the former Yugoslavia being an archetypal case). Aizenman (1992) develops a model of this kind. The central idea is that fiscal decisions are devolved to *n* regions, each of which maximises the utility of its own citizens. Since the costs of inflation are spread over all *n* regions, but conventional taxes can be raised only within a given region, there is an externality attached to money-financing of expenditure that creates an inflationary bias.

The empirical predictions of such a model are tested by Andrabi (1997). Andrabi considers a game between the *n* fiscal authorities, in which they either co-operate and behave as if fiscal policy were centrally co-ordinated, or exploit the externality and inflate. Non-co-operation yields one-period benefits, but if it occurs, the Nash inflationary solution prevails in all future periods. Since the Nash solution is worse than the co-operative solution, this punishment may be sufficient to deter cheating provided that the fiscal authorities do not have too high a time discount rate. Andrabi shows that, for a given discount rate, cheating is more likely if (a) output has greater variance, (b) government spending is higher, and (c) output growth rates are lower. Greater output variance raises the incentive to cheat in high-output states, since the gains from cheating rise with current output. The growth-rate effect arises because the punishment increases when future output is higher relative to current output. Effect

(b) reflects the fact that the incentive to cheat is higher when the tax rate is higher in the co-operative state.

In his empirical tests, Andrabi (1997) carries out time-series regressions of seigniorage revenue on the transitory component of output for 20 OECD countries using annual data for 1958-92, and finds generally positive coefficients. This result is perhaps not surprising, because the regression amounts to a test of a Phillips curve relationship, and the findings are therefore susceptible to multiple interpretations.[1] Andrabi also finds a negative correlation between average seigniorage revenue over the period 1970-82 (as calculated by Edwards and Tabellini (1991)) and average growth rates for 1970-88 in a sample of 75 countries. This finding is also consistent with the model, but the direction of causality is unclear: many authors have interpreted a similar finding as suggesting that inflation causes slow growth, rather than *vice versa*.

The steady growth of the debt/GDP ratio in most OECD countries during the 1980s stimulated research on political determinants of budget deficits. Roubini and Sachs (1989) find that, in the period 1975-85, budget deficits were significantly greater when there were more political parties in the ruling coalition and when governments had a shorter average tenure. Grilli, Masciandaro and Tabellini (1991) distinguish between "significant" and "insignificant" government changes, and also consider variables such as the share of the legislature held by extremist political parties and political fractionalisation, as measured by the probability that two randomly chosen members of the legislature are from the same party. But should we expect any of these variables to have any effect on seigniorage revenue?

Cukierman, Edwards and Tabellini (1992) develop a theoretical model in which seigniorage revenue is predicted to be higher if a government change is more likely and politics is more polarised (as measured by how different the preferences of a new government are from its predecessor's). In their model, there are two parties with differing preferences over the *composition* of public expenditure (preferences over the

[1] The decision to use time-series rather than cross-section data to test this relationship is questionable. If the variance of output is sufficiently high, then the Nash solution should prevail in all time periods, whatever the realisation of current output, because of the history of cheating in previous periods.

level of public expenditure are assumed to be identical). In each period a government chooses fiscal policy, and also sets the efficiency of the tax system *for the following period*, as measured by the proportion of revenue lost in collection costs. Seigniorage revenue does not suffer any collection costs. For a government that is certain to be in power next period, the optimum choice is to make the tax system as efficient as possible. To the extent that there is a possibility of losing power, however, there is an incentive to reduce the efficiency of next period's tax system in order to discourage public spending which would be "misdirected" (from the point of view of the preferences of the current government) in the event of loss of power. This leads to a prediction that a government chooses a lower value of the tax efficiency variable if (a) there is a greater probability of a change of government and also if (b) there is greater polarisation of the political system (i.e. a greater difference between the preferences of the parties). Because the tax efficiency variable is assumed to affect only conventional taxation, a side effect of setting it at a low value is that it distorts the optimal tax choice towards seigniorage revenue. Thus the model predicts higher inflation when governments change more frequently and have more polarised positions.

Cukierman *et al*. (1992) estimate their model for 79 countries over the period 1971-82. They use a probit model to estimate the probability of government change, and use the average of this measure over the period as a proxy for political instability. For political polarisation, they use several alternative measures: numbers of coups, a dummy for democracy, and a totalitarianism ranking. In all cases, they find the variables to be significant and of the expected sign in a regression model which has the ratio of seigniorage revenue to GDP as the dependent variable.

The structure of debt

Missale and Blanchard (1994) explore the debt-inflation relationship in a repeated-game framework. Like Andrabi (1997), they focus on the conditions under which the one-period gains to inflation exceed the future punishment. Unlike previous work, they claim to allow for the maturity structure of the debt. Indeed the principal motivation of their paper is to explain why, in three OECD countries that have experienced very high ratios of debt to GDP in recent years (Belgium, Ireland and Italy), there appears to have been an inverse correlation between the debt ratio and average maturity. They develop a theoretical model in which debt "maturity" is in effect equated with the proportion of debt that is not indexed against domestic inflation (either through explicit indexation, denomination in foreign currency or bearing a floating interest rate), and they show that, as the debt ratio increases, the temptation to defect from the co-operative zero-inflation solution also rises unless "maturity" falls.

An innovation of the Missale and Blanchard paper is that it recognises the ability of governments to mitigate the cost of loss of reputation by adjusting the debt structure, because they can reduce the effective maturity of debt to zero after inflating. This possibility increases the incentive to inflate when nominal debt is high. The parameter that reflects the costs of fiscal adjustment provides a natural link with the political factors discussed in the previous section, which can be interpreted as determinants of this parameter, as will be seen later. Finally, as with Andrabi (1997), the paper highlights the possibility that reputation leads governments to resist the temptation to exploit seigniorage revenue on debt. For these reasons the model presented here is an adaptation of that developed by Missale and Blanchard (1994). On the other hand, the identification of maturity with the absence of indexation is a weakness of their model. Whereas indexation prevents governments from gaining seigniorage revenue on debt through unanticipated inflation at all, maturity merely determines how long such a strategy can be continued without punishment. Although intuition tells us that greater delay in punishment is in some sense equivalent to having more nominal debt to exploit, these concepts should ideally be kept separate. Accordingly, the model presented below separates the effects of nominal debt and the maturity structure of that debt.

In this model, the intertemporal government budget constraint is simplified into a sustainability condition that the debt/income ratio cannot increase from one period to the next. This device is convenient for analysing a game in which the private sector’s expectations play a major role and exogenous shocks are excluded. With shocks, the principle of tax smoothing implies that debt absorbs much of any shock in the short-run, and the sustainability condition would be violated. There are also many historical examples of governments whose debt followed an unsustainable upward path for many years, only for the trend to be reversed by a sharp fiscal correction (e.g.

Ireland), with no obvious justification in terms of exogenous factors. The issues highlighted by the model are, however, so central to the relationship between debt and inflationary expectations that these limitations are justified in the interests of tractability.

The formal model

The model is described by the following equations. The first is an expectations-augmented Phillips curve linking the deviation of output (y) from its equilibrium value (y^*) to the difference between actual inflation (p) and anticipated inflation at the end of the previous period (p^e):

$$y = y^* + a(\mathrm{p} - \mathrm{p}^e) \qquad a > 0 \qquad (6)$$

The second equation defines the government's objective function, which is increasing in output and decreasing in inflation and the primary budget surplus as a proportion of output (s). To simplify the algebra, only the term in inflation is assumed to be quadratic. This objective function embodies the usual inflation bias, but the term in s implies that the government prefers higher non-interest expenditures and/or lower taxes, other things being equal. The government maximises

$$Z = y - 0.5b\mathrm{p}^2 - cs \qquad b,c > 0 \qquad (7)$$

The government budget constraint is defined by

$$s + H + D = id \qquad (8)$$

where H represents the growth of high-powered money, D the issue of new debt and d the beginning-of-period stock of debt, all as a proportion of output, and i is the nominal interest rate. The growth of high-powered money is proportional to the growth rate of nominal output (g represents the growth rate of real output, and k is the ratio of high-powered money to output):

$$H = k(\mathrm{p} + g) \qquad k > 0 \qquad (9)$$

Equation (10) defines the sustainability condition. Debt cannot grow at a rate faster than nominal output (it never pays the government in this model to allow debt to grow more slowly than this):

$$D = (\mathrm{p}+g)d \qquad (10)$$

How is the nominal interest rate on debt determined? I assume that a proportion (1-n) of debt is indexed to the price level, whilst the remaining proportion n, which consists of nominal debt, has its interest rate determined by the Fisher relation i.e. the interest rate paid is equal to the real interest rate (r) plus inflation over the life of the bond as expected at the date of issue. Denoting p^e as the average expected inflation for the nominal bonds in issue, this yields:

$$i = r + np^e + (1-n)\mathrm{p} \qquad (11)$$

If all nominal bonds are one-period bonds, then p^e is just equal to the expected inflation rate for the current period as determined at the end of the previous period, i.e. $p^e = \mathrm{p}^e$. In the general case where at least some bonds are of longer maturity, this equality no longer holds. In the present context, ($dp^e/d\mathrm{p}^e$) may be thought of as an index of the average maturity of nominal bonds; the lower is ($dp^e/d\mathrm{p}^e$), the longer is average maturity.[2] This implies, for example, that floating-rate bonds are effectively of short maturity, since higher inflationary expectations feed through immediately into the interest rate paid on them.

Substituting (9), (10) and (11) into (8) gives

$$s = (r-g)d - k(\mathrm{p}+g) - n(\mathrm{p}-p^e)d \qquad (12)$$

Equation (12) states that the primary surplus consists of the debt/income ratio multiplied by the difference between the real interest rate and the growth rate, minus seigniorage revenue, minus the nominal debt multiplied by the rate of unanticipated inflation. Since in a one-shot game the government is taking inflationary expectations

[2] This assumes that maturing nominal bonds are not replaced by indexed bonds.

as given, this last term reflects the potential to obtain revenue through unanticipated inflation.

Substituting (6) and (12) into (7) and maximising Z with respect to π, taking both π^e and p^e as given, yields

$$\pi = (1/b)\,[a + c(k+nd)] \tag{13}$$

Equation (13) shows that, if the government chooses the inflation rate so as to maximise Z in a one-shot game, the inflation rate which it selects will be:

- decreasing in the inflation-aversion parameter (*b*);
- increasing in the sensitivity of output to inflation surprises (*a*);
- increasing in the parameter that measures aversion to fiscal correction (*c*);
- increasing in the ratio of high-powered money to output (k);
- increasing in the ratio of nominal debt to output (*nd*).

The two parts of equation (13) correspond to what Cukierman (1992) describes as the employment and the revenue motives for inflation. The first term (a/b) is the standard solution to equations (1) and (2) with c=0. With c>0, the preferred inflation rate is augmented by the element $(c/b)(k+nd)$, of which (c/b) reflects the relative weights attached to fiscal correction and inflation, and $(k+nd)$ represents the tax base for the inflation tax.

In a repeated game, it may pay the government to play π=0 in every period in order to secure π^e=0. The equation for Z, after substitution from (6) and (12), is:

$$Z = y^* + a(\pi - \pi^e) - 0.5\pi^2 - c[(r-g)d - k(\pi+g) - n(\pi - p^e)d] \tag{14}$$

Social welfare is clearly decreasing in expected inflation, so that, if there is a positive correlation between π in period t and π^e in period $t+1$, there may be an incentive to “invest in reputation” by choosing a lower value of π than that indicated by equation (8). Following Missale and Blanchard (1994), assume that in period 1 $\pi^e = p^e = 0$, and that in subsequent periods π^e either stays at zero for ever (so long as the government delivers $\pi=0$ in every period) or takes a positive value for ever (if the government inflates). In the latter case, all new debt issued is indexed debt, because in the non-reputational state having $n>0$ results in higher inflation – both actual and expected – for any given value of d, thus making the government worse off. Nevertheless, if there is some nominal debt of maturity greater than one period, in period 2 the government may still have some old nominal debt on which to exploit seigniorage revenue, and this will continue until all nominal debt has been redeemed.

In order to allow for maturity, let us assume that a proportion m of nominal debt is two-period debt, and the remaining proportion $1-m$ is one-period debt.[3] The choice which the government then faces is the following. Either (1) play zero inflation in all periods, enjoying the benefits of zero expected inflation (the reputational solution); or (2) exploit seigniorage revenue on nominal debt for the first two periods, but suffer positive actual and expected inflation in all future periods, issuing only indexed debt (the non-reputational solution).

In the reputational solution, the primary budget surplus in all periods is given by

$$s = (r-g)d - kg \qquad (15)$$

and the present value of the government's objective function is

$$Z_R = [1 + (1/\delta)]\,[y^* - c(r-g)d + ckg] \qquad (16)$$

where δ represents the discount rate. In the non-reputational solution, we have:

Period 1: $\pi^e = p^e = 0$; $\pi = (1/b)\,[a + c(k+nd)]$

Period 2: $p^e = 0$; $\pi = \pi^e = (1/b)\,[a + c(k+mnd)]$

Period 3 onwards: $\pi = \pi^e = (1/b)\,(a + ck)$

In period 1, the government exploits seigniorage on the full nominal debt, and in period 2 it can still exploit seignorage on a fraction *m* of the period 1 nominal debt, and chooses an inflation rate that is lower than in period 1, but higher than in all subsequent periods. Maturing debt is replaced by indexed debt and labour and goods market fully reflect the fact that the government chose to inflate in period 1. Compared with the reputational solution, there is a gain from reducing the primary surplus in periods 1 and 2, offset by the losses from inflation in all subsequent periods.

The condition for Z_{NR} to be greater than Z_R (i.e. for inflation to be preferable) is given by

$$\mathrm{d}\,[a+c(k+nd)]^2 + \{c^2 mnd\mathrm{d}(2k+mnd) \,/\, [(2(1+\mathrm{d})]\,\} > (a^2 - c^2k^2) \qquad (17)$$

This equation implies that the incentive to inflate is greater

- the higher is the discount rate (d);
- the greater is nominal debt (*nd*);
- the longer is the average maturity of nominal debt (*m*);
- the higher is the ratio of high-powered money to output (*k*); and
- the greater is the authorities' aversion to fiscal correction (*c*).

The intuition behind these results is fairly straightforward. A higher discount rate means that future losses count less relative to present gains from inflation. Nominal debt and the money/output ratio directly affect (positively) the tax base for seigniorage. With more aversion to fiscal correction, the authorities get greater reward for the reduction in the fiscal surplus through seigniorage. Note that with only one-period nominal debt (*m*=0) the second term on the left-hand side of (17) disappears. Note also that neither inflation aversion nor the quantity of indexed debt affects the choice between the reputational and non-reputational solutions.[4]

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[3] Strictly, *m*, which is the nominal debt to GDP ratio in period 2 as a fraction of that in period 1, is a declining function of the first-period inflation rate. For this reason, *m* needs to be interpreted as the proportion of two-period debt, assuming the period-one inflation rate derived below.

[4] If the government's objective function were quadratic instead of linear in *s*, this would still be true to a first approximation.

In considering the predictions of this model, we need to take into account both the condition for the non-reputational solution to be preferred (equation (17)) and the inflation rate that results, conditional on the non-reputational solution being chosen (equation (13)). If the bimodal distribution of inflation rates implied by this model occurred in an empirical sample, enabling one group of observations to be identified with some precision as representing the reputational solution, it would be possible to employ a two-stage strategy, modeling the decision to invest in reputation to test equation (17), and then (for the inflationary sub-sample) modeling the inflation rate to test equation (13). In the real world, the data do not usually permit such a precise identification of the two regimes, and the normal strategy is to apply a simple linear regression model of inflation to the whole sample. In this case, both equations (13) and (17) should come into play.

The simplest tests of optimal tax theory assume that the preference parameters in the government's utility function are the same across time and space. A more complex approach would try to incorporate factors that might account for some of the variation in these parameters. One group of such factors might be labeled "structural", and another group "institutional".

At the structural level, factors such as per capita GDP, size of population and openness deserve consideration. At lower levels of per capita GDP, there may be less inflation aversion, because each additional unit of output is more valuable. Developing countries tend to have higher money/GDP ratios (k), which raises the tax base for seigniorage, but this is more than offset by their low levels of nominal debt, since historically they have borrowed overwhelmingly in foreign currencies (South Africa is an exception that will be considered explicitly in the empirical section). Poorer countries also tend to rely more heavily on trade taxes, for which the tax base is directly related to openness, probably because collection costs are lower. Less open economies at lower per capita GDP levels may have greater aversion to fiscal correction because they have to rely more heavily on non-trade taxes.

In the institutional category, the prime candidates are the political factors considered above. Governments which do not expect to last long probably discount the future more heavily than those which anticipate greater longevity. According to equation (17) such governments, having a low value of d, would be more likely to choose the inflationary solution. It is more difficult to map other political variables onto the government's utility function (equation (2)). Political polarisation in the sense of Cukierman *et al*. (1992) could be measured by the number of political parties or the strength of "extremist" parties. A high degree of polarisation may make fiscal decisions more controversial and thereby render fiscal correction more difficult. On the other hand, it is not clear, for example, whether aversion to fiscal correction is affected by whether a country has a parliamentary or a presidential system of government. The theory of central government weakness is also probably best represented as a high value of c.

Another institutional factor that needs to be taken into account is the exchange rate regime, since there is clear evidence for the whole post-1973 period that floating exchange rates tend to be associated with significantly higher inflation rates than pegged rates (Bleaney, 1999; Ghosh *et al*., 1995). To the extent that pegging the exchange rate can be interpreted as investing in reputation, an effect of this kind is quite consistent with the model developed above.

3. EMPIRICAL TESTS

Previous empirical tests of the above model (or something closely related to it) have consisted of time-series regressions of inflation on the ratio of tax revenue to GDP for a number of industrial countries (Roubini and Sachs, 1989; Poterba and Rotemberg, 1990), or cross-section regressions for average seigniorage revenue 1971-82 across a large sample of industrial and developing countries (Cukierman *et al*., 1992).

Three types of empirical tests are carried out below. The first is a cross-country inflation regression for a large number of countries over two periods, 1973-88 and 1989-98. This regression controls for various structural factors but contains no institutional variables other than the exchange rate regime. The basic specification is as in Bleaney (1999), which builds on Romer (1993) and Lane (1997), but with the share of government revenues in GDP included as an additional regressor.

The second type of test allows for the impact of nominal debt and for the effects of political variables on the model's parameters. This test is based on 1982-98 data for a panel of industrial countries.

The third test focuses on a single country (South Africa), where the change of regime in the early 1990s almost certainly produced significant shifts in the parameters of the model presented in the previous section. The issue here is whether the time-series relationship between inflation, taxes and debt is consistent with the optimal tax model after allowing for these shifts.

The results of the cross-country tests are presented in Table 1. The sample comprises 106 countries for 1973-88 and 92 countries for 1989-98. The average inflation rate (transformed to mitigate the influence of outliers) is regressed on central government revenues as a share of GDP, openness, per capita GDP, population, area and a measure of the exchange rate regime. In neither period does the tax variable have the expected positive sign in the regression (columns (1) and (3)), and there is no evidence of significant interaction effects between tax revenue and per capita GDP, of the sort which might occur if, for example, the optimal tax model applied to developing countries but not industrial countries (columns (2) and (4)). Thus the simple optimal tax model is not supported by these cross-country regressions. It is true that nominal debt is not included (for lack of data),[5] but nominal debt is largely a phenomenon of high-income countries, which in recent years have been characterised by low inflation, so inclusion of nominal debt is not likely to make the results in Table 1 any more consistent with the optimal tax model.

Table 2 shows the results for the panel of industrial countries for the period 1982-98.[6] Regression (5) shows an inflation regression with tax revenue and debt variables as regressors. Both of these variables have a negative sign, which is contrary to the predictions of the basic optimal tax model. In regression (6) various political variables are included and interacted with the debt variable. If the theoretical model presented

[5] There is plenty of information about total debt ratios, but the composition is critical here.
[6] Countries with significant quantities of indexed debt (Iceland and the United Kingdom) were omitted from the sample.

above is correct, then these political variables should affect the choice between the reputational and non-reputational states, and also the inflation rate in the non-reputational state. These political measures (all taken from Grilli *et al*., 1991) consist of government durability, stability and fractionalisation. Durability is the average length of time between changes in government, whereas stability is the average length of time between changes in government defined as 'significant' (involving a change in the party in power). The fractionalisation index is defined as the probability that two randomly chosen members of the legislature belong to different parties. Since durability and stability should be associated with discounting the future less heavily, they would be expected to reduce the debt coefficient, whereas fractionalisation, as a measure of political polarisation, should raise it.[7] It can be seen that, although the political variables improve the explanation, only one of the three interactive terms (durability times debt) has the predicted sign, and that is the one with the lowest *t*-statistic. Regressions (7) and (8) repeat the same exercise using long-term interest rates (as a measure of inflationary expectations) rather than actual inflation rates as the dependent variable. In regression (7) net debt has a positive coefficient, although it is not significant, but tax revenue continues to have a negative coefficient. When the political variables are included (regression (8)), the signs of the interactive terms are the same as for inflation.

These two empirical tests are, then, rather unfavourable to the optimal tax model, even in a more complex version. The third test focuses on a single country: South Africa. South Africa is interesting for a number of reasons. It has good historical data; it has had substantial quantities of nominal debt for decades, unlike many developing countries; and it underwent a significant change of regime in the early 1990s, involving much greater central bank independence but also considerable pressures for correcting historical inequities through government expenditures, pressures which could reasonably be interpreted as an increased preference for budget deficits. South Africa can therefore be used to provide a time-series test of the optimal tax model, after allowing for structural change with the change of regime.

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[7] I have also tested Grilli *et al*.'s measure of political extremism (average percentage of votes taken by parties defined as extremist) as an alternative measure of polarisation, with similar results. For precise definitions of all these variables, see Grilli *et al*. (1991).

The tests are based on annual data from 1970 to 1997.[8] Consumer price inflation rose quickly from under 5% p.a. to over 10% in the early 1970s, and even in the 1990s has not been much below that level. The average rate was 9.6% p.a. from 1970 to 1979, 14.7% p.a. from 1980 to 1991, and 9.5% p.a. from 1992 to 1997. Long-term government bond yields have followed a similar pattern, except that they did not fall in the 1990s, averaging 15.1% from 1992 to 1997, which suggests that long-term expectations of inflation are somewhat above the current inflation rate. This may well reflect political pressures on the government budget. Because of sizeable deficits, the debt/GDP ratio rose rapidly from 40% in 1991 to 56% in 1997, although it has now stabilised, after declining from 42% in 1970 to a minimum of 30% in 1982. Tax revenue has risen steadily from 18% of GDP in 1970 to 27% in 1997, with the steepest rise occurring in the 1980s.

Under the apartheid regime every other objective was subordinate to the survival of apartheid, but the new Constitution enshrines the independence of the Reserve Bank in the pursuit of the stable currency. At the same time the political pressures for redistributive government expenditure have grown. This was reflected in a May 1998 address by the Governor, who said that

"For understandable reasons, the financial disciplines applied by the Reserve Bank in pursuing its objective of protecting the value of the currency are not always appreciated in all quarters. There are strong pressure groups that believe that the new South Africa justifies also a new monetary policy that will provide more funds at lower interest rates for the funding of the massive needs for social reform." (South African Reserve Bank Quarterly Bulletin no. 208, June 1998, p. 42)

A reasonable interpretation of the regime change in the early 1990s would be that aversion to inflation (parameter *b* in the theoretical model) increased with the greater independence of the Reserve Bank, but that aversion to fiscal stringency (*c*) also rose because of the desire to correct historical inequalities between social groups. The rise in *b* implies lower inflation in the non-reputational state, and the rise in *c* should make inflation more sensitive to the level of nominal debt, making the non-reputational state more likely at a given debt level, and also increasing the slope of the

[8] Data from before 1970 are available, but if they are included the residuals tend to become non-

inflation/debt relationship in the non-reputational state (although this latter effect may be more than offset by the rise in *b*).

The results in Tables 3 and 4 show that South African experience is inconsistent with the model. Table 3 shows three regressions for consumer price inflation. Regression (9) allows for no regime change, whereas regression (10) tests for a shift in coefficients starting in 1992. There is strong evidence of such a structural break. Since the tax coefficient becomes negative from 1992 onwards, this coefficient is assumed to be zero after that date. Regression (10) implies a switch to the reputational solution in the 1990s (inflation is lower and is no longer correlated with the tax rate). This is, however, inconsistent with the model, because the rise in *c* should if anything make the reputational solution less attractive, and the change in *b* should not affect the choice between reputational and non-reputational solutions (recall equation (17)). Finally, regression (11) includes debt, but it emerges with a significant *negative* coefficient, whereas the model predicts a positive coefficient. In Table 4 these tests are repeated for government bond yields, with similar results.

In summary, although the empirical tests of this section are more wide-ranging than those carried out previously, and designed to address more complex versions of the optimal tax theory of seigniorage, the results are equally negative.

4. CONCLUSIONS

The simple optimal tax model has undergone significant theoretical refinements in recent years. These refinements suggest the incorporation of political or institutional variables to capture variations in the underlying structure of the authorities' preferences, and greater attention to the incentives to invest in a reputation for low inflation. Nevertheless, even taking these factors into account, the results reported here yield little support for the optimal tax model as an explanation of inflation. The question is why this model should perform so poorly.

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stationary.

A major factor is simply that our expectations of the model are too high. It is unrealistic to expect to be able to explain inflation with a public finance model, when the inflation tax typically represents only a small proportion of tax revenue. If we possessed very good models of the determinants of tax structure and tax rates as a whole, with low standard errors, we might have a chance of modeling the small element of tax revenue represented by seigniorage. As it is, our models of tax structure are crude, and seigniorage revenue is effectively lost in the noise of these models (e.g. Gemmell, 1993).

A second factor is the role of inflationary inertia. At higher rates, inflation tends to have high persistence (Edwards, 1998). This means that the past history of inflation itself plays a significant role in determining current inflation. In a time series one can take that into account by incorporating lagged inflation as a regressor, but this only solves the problem if the dynamics of inflation are relatively simple and structurally stable. In the time series model for South Africa reported in Table 3, for example, adding lags of inflation improves the fit and reduces autocorrelation of the residuals, but does not improve the performance of the optimal tax model. In cross-section tests, taking an average of a number of years helps to address the issue, but makes it difficult to distinguish countries with persistent inflation from others whose average is boosted by a short inflationary episode. These problems are less severe if we use a measure of medium-term inflationary expectations (e.g. government bond yields) rather than current realisations of the inflation rate, but such measures of inflationary expectations are available for only a minority of countries. The complex dynamics of inflation therefore create difficulties. Even if the optimal tax model could provide a good explanation of the origins of a high-inflation episode, it is not likely to offer an adequate account of its subsequent development.

The complex dynamics of inflation also imply that resorting to the inflation tax is a high-risk strategy for any government. Precisely because expectations and institutions may adapt to inflationary experience, the costs of stabilising prices after taking advantage of seigniorage revenue are very uncertain. Once the genie is out of the bottle, it may be very difficult to put it back in again. The risks of switching from conventional taxation to seigniorage revenue are therefore much greater than for, say, a switch from direct to indirect taxation. If politicians are risk-averse, then the occasions on which they deliberately resort to the inflation tax may be rather rare, and tell us more about the exceptional political constraints on doing anything else. Seigniorage may be hard to explain simply because it is the default form of revenue which comes into play if a government cannot bring itself to cut expenditure, raise conventional taxes or issue bonds, and we lack a good model of such paralysis episodes in the politics of fiscal policy.

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Table 1. Cross-country tests of the optimal tax model

Dependent variable	Inflation 1973-88	Inflation 1973-88	Inflation 1989-98	Inflation 1989-98
Regression no:	(1)	(2)	(3)	(4)
Independent variables				
Constant	46.79 (3.07)	51.51 (2.96)	35.89 (2.33)	40.93 (1.80)
Openness	-0.171 (-2.41)	-0.162 (-2.24)	-0.020 (-0.31)	-0.012 (-0.17)
ln (GDP pc)	-0.712 (-0.82)	-1.38 (-0.94)	-2.15 (-2.39)	-2.81 (-1.18)
ln (population)	-2.37 (-3.00)	-2.41 (-3.02)	-1.42 (-1.64)	-1.56 (1.65)
ln (area)	0.728 (1.42)	0.815 (1.52)	1.19 (1.75)	1.28 (1.73)
ER regime	4.80 (3.01)	4.75 (2.96)	3.67 (2.77)	3.70 (2.77)
Tax rev./GDP	-0.100 (-1.32)	-0.375 (-0.77)	-0.253 (-2.34)	-0.511 (-0.60)
Tax rev./GDP x ln(GDP pc)		0.0328 (0.57)		0.0289 (0.30)
Sample size	106	106	92	92
R-squared	0.236	0.238	0.339	0.339
Standard error	6.98	7.00	8.38	8.43

Notes

Dependent variable = 100p/(100+p), where *p* is the average percentage inflation rate over the period. Openness is imports/GDP (%). Exchange rate regime=1 (pegged), =2 (intermediate), or =3 (floating) for each year, averaged over the period. See Bleaney (1999) for data sources. Figures in brackets are *t*-statistics.

Table 2. Inflation and interest rate regressions for OECD countries 1982-98

Dependent variable:	Inflation	Inflation	Long-term interest rates	Long-term interest rates
Regression no:	(5)	(6)	(7)	(8)
	Random Effects	Fixed Effects	Random Effects	Random Effects
Independent variables				
Constant	8.45 (6.64)		11.12 (8.35)	20.31 (10.31)
Tax revenue/GDP	-9.55 (-3.71)	-15.97 (-4.58)	-3.90 (-1.46)	-21.33 (-1.31)
Net debt/GDP	-0.138 (-0.23)	3.81 (3.06)	0.721 (1.14)	-1.67 (-1.31)
Fractionalisat-ion		12.45 (2.46)		12.21 (1.99)
Govt durability		-0.869 (-1.55)		1.12 (1.72)
Govt stability		-0.156 (-3.83)		-0.319 (-6.60)
Fractionalisat-ion times Debt		-37.75 (-5.35)		-27.7 (-3.26)
Durability times Debt		-1.19 (-1.09)		-5.62 (-4.45)
Stability times Debt		0.210 (1.94)		0.482 (3.63)
Hausman stat.	0.00	488	0.00	0.00
R-squared	0.060	0.478	0.017	0.512
No. of observations	224	176	246	195

Note: Figures in brackets are *t*-statistics. Hausman statistic is the chi-squared statistic for fixed versus random effects estimation. Fixed effects estimation is chosen if $p<0.05$ for this statistic.

Table 3. Inflation regressions for South Africa 1970-97

Dependent variable:	Change in log of consumer prices	Change in log of consumer prices	Change in log of consumer prices
Regression no.:	(9)	(10)	(11)
Independent variables			
Constant	0.0539 (1.27)	0.147* (17.8)	0.101* (4.20)
Tax revenue/GDP minus 0.25	0.257 (1.31)		0.678* (5.85)
Ditto up to 1991 only, zero thereafter		0.834* (4.54)	
Government debt/GDP			-0.355* (-8.20)
Dummy 1992-97		-0.0559* (-4.52)	
Sample size	28	28	28
R-squared	0.062	0.515	0.746
Standard error	0.0306	0.0225	0.0163
Durbin-Watson	0.35	0.82	1.09
ADF (1)	-2.52	-4.21*	-4.38*

Notes: Figures in parentheses are *t*-statistics. * denotes $p<0.05$. ADF (1) is the augmented Dickey-Fuller statistic with one lag of the dependent variable.

Table 4. Interest rate regressions for South Africa 1970-97

Dependent variable:	log (government bond yield + 1)	log (government bond yield + 1)	log (government bond yield + 1)
Regression no.:	(12)	(13)	(14)
Independent variables			
Constant	-0.0503* (-3.03)	0.145* (31.6)	-0.0458* (-4.03)
United States real interest rate	0.285* (3.24)	0.200* (2.86)	0.159* (2.47)
Tax revenue/GDP minus 0.25	0.732 (9.22)		0.925* (14.3)
Ditto up to 1991 only, zero thereafter		0.949* (11.9)	
Government debt/GDP			-0.111* (-5.43)
Dummy 1992-97		-0.0115* (-2.57)	
Sample size	28	28	28
R-squared	0.879	0.933	0.946
Standard error	0.0104	0.0080	0.0071
Durbin-Watson	0.98	1.59	2.03
ADF (1)	-3.05	-5.00*	-7.60*

Notes: Figures in parentheses are *t*-statistics. * denotes $p<0.05$. ADF (1) is the augmented Dickey-Fuller statistic with one lag of the dependent variable.