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DAE Working Paper No. 0235

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September 2002

Abstract

In this paper, we consider the real-time implementation of a fiscal policy rule based on tax smoothing (Barro (1979) and Bohn (1998)). We show that the tax smoothing approach, augmented by fiscal habit considerations, provides a suprisingly accurate description of US budget surplus movements. In order to investigate the robustness of the policy implications of the rule, we construct a real-time US fiscal data set, complementing the data documented by Croushore and Stark (2001). For each variable, we record the different vintages, reflecting the remeasurements that occur over time. We demonstrate that the easily-constructed rule provides a useful benchmark for policy analysis that is robust to real-time remeasurements.

Keywords: fiscal rules, tax smoothing, fiscal habits, real-time data
JEL Classifications: C82, E62, E66

*We are grateful to participants at the December 2001 ESRC and MMF Workshop on Taxation and Public Debt, and to Peter Tinsley, Jim Nason, Anthony Garratt and Jagjit Chadha for helpful comments on an earlier draft entitled "The Real-time Behaviour of US Budget Surpluses". We thank Henning Bohn and the Philadelphia Federal Reserve Bank for providing the debt and (real-time) output data respectively. Financial support from the ESRC (L38251021) is acknowledged gratefully.

1 Introduction

Simple monetary policy rules, such as those proposed by Taylor (1993) and McCallum (1988), have received a great deal of attention from both academics and policymakers. These rules involve the policymaker setting an operating instrument in response to a number of observable macroeconomic indicators. They are often interpreted as benchmarks by which to evaluate previous policy decisions and the current policy stance. In contrast, the fiscal rules literature has focused largely on politically-driven constraints, such as those associated with the Stability and Growth Pact (see, for example, Canzoneri and Diba (2001)).

In this paper, we examine a fiscal counterpart to monetary policy rules. Our rule contrasts with the fiscal rule proposed by Taylor (1996, 2000) in that it is based on tax smoothing behaviour (see Barro (1979, 1986a and 1986b) and Bohn (1998)). We show that, augmented by fiscal habit or partial adjustment considerations, the rule provides a surprisingly accurate description of the post-1960 behaviour of US budget surpluses. The rule involves setting the primary budget surplus in response to the level of the debt stock, transitory GDP and military expenditure fluctuations, and the surplus in the previous period (all expressed as ratios to GDP). One appealing feature of our approach is that the rule is easy to construct and interpret.

To investigate the robustness of the policy implications of the rule, we construct a real-time US fiscal data set. The Federal Reserve Bank of Philadelphia Real-Time Data Set, documented by Croushore and Stark (2001), provides real-time information on a wide range of macroeconomic variables. Although that data set provides information on total government expenditure, there are no data on government revenue, interest expenditure and military expenditure. Our data set complements this existing source by recording the different vintages for the required fiscal variables—reflecting the remeasurements that occur over time. Our real-time US fiscal data set, together with detailed descriptions, can be downloaded from http://www.econ.cam.ac.uk/dae/research/debt.

We investigate the policy implications of the tax smoothing based fiscal rule in conjunction with the real-time measurements from our data set. We show that calibration of the rule's parameters results in a useful benchmark for policy evaluation. The substantive policy implications of the rule are robust to real-time data remeasurements.

The remainder of the paper is organised as follows. In the following section, we outline the tax smoothing rule. In Section 3, we discuss a number of data issues, and introduce the real-time fiscal data set. In Section 4, we investigate the rule's suitability for real-time policy evaluation. Some conclusions are drawn in the final section.

2 The tax smoothing based fiscal policy rule

Barro's (1979) tax smoothing model is based on the idea that the government minimises the distortion from taxation by allocating taxes over time. The theory is analogous to the permanent income theory of consumption. It assumes implicitly that the government cannot issue bonds directly contingent on the state of the world and that these non-contingent bonds are default free.

The following presentation of the model is based upon Sargent's (1987, p385-88) textbook version. The tax distortion in the current period is assumed to be quadratic in tax rates, $\left[u_1\tau_t + \frac{u_2}{2}\tau_t^2\right]$, where u_1 and u_2 are positive parameters and τ_t is the tax rate in time t. The government chooses a sequence of tax rates $\{\tau_t\}_{t=0}^{\infty}$ in order to finance a stream of exogenous real government expenditure $\{G_t\}$, which follows a stochastic process. Since debt is the only alternative to taxation as a source of revenue, this implies a path for debt, $\{D_{t+1}\}$, through time.

More formally, the government chooses $\{\tau_t, D_{t+1}\}$ in order to minimise:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[u_1\tau_t + \frac{u_2}{2}\tau_t^2\right], \qquad 0 < \beta < 1 \tag{1}$$

where β denotes the discount factor.

Since any expenditure that is not met by taxation must be met by issuing bonds, the government's one-period revenue constraint is given by:

$$D_{t+1} = R\left[D_t + G_t - T_t\right], \tag{2}$$

where T_t denotes government revenue from the average tax rate τ_t, such that $T_t = \tau_t Y_t$ where Y_t denotes real output. The gross interest rate, $R > 1$, is assumed to be fixed. The government takes the government expenditure process, $\{G_t\}$, and the initial stock of debt, D_0, as given. Values of G dated $t+1$ and later are unknown at time t.

The solution to the problem involves smoothing tax rates over time:

$$E_t \tau_{t+1} = -\alpha + (\beta R)^{-1} \tau_t \tag{3}$$

where $\alpha = u_1[1-(\beta R)^{-1}]/u_2$. Assuming that $\beta = 1/R$, tax rates follow a martingale process regardless of the stochastic process for $\{G_t\}$.

In Barro's (1979) model, issuing non state contingent (default free) debt is the mechanism by which the government smooths tax rates. In contrast, in Lucas and Stokey's (1983) model with state contingent debt, optimal Ramsey tax rates follow the serial correlation properties of government expenditures. Aiyagari et al (2001) examine the impact of ruling out state contingent debt in a model similar to that of Lucas and Stokey (1983) and find results broadly consistent with Barro's (given some restrictions on preferences and the quantities of default-free debt).[1]

The tax smoothing model predicts that in the event of a transitory shock to government expenditure, such as a war or a business cycle fluctuation, tax rates will respond permanently by a (small) proportion of the shock. The model implies that the primary surplus-output ratio is determined by the following equation (a derivation is contained in the Appendix):

$$s_t = \rho d_t + \alpha_0 + \alpha_G GVAR_t + \alpha_Y YVAR_t + \epsilon_t \tag{4}$$

where s and d denote the primary surplus and the (start-of-period) debt stock as ratios to output. The variables $GVAR$ and $YVAR$ denote the level of transitory military spending and a business cycle indicator respectively. The parameters are denoted ρ, α_0 and α_i, $i = G, Y$; and ϵ denotes an error term. Bohn (1998) argues

[1] Marcet and Scott (2001) propose an approach to testing for incomplete markets. An application using US data confirms that markets are incomplete.

that (given weak regularity conditions) $\rho > 0$ is sufficient for sustainability, in the sense that the intertemporal budget constraint is satisfied.[2]

We augment the Barro-Bohn approach by allowing for slow fiscal adjustment. The literature on delayed stabilisations (see, for example, Alesina and Drazen (1991) and Alesina et al (1998)) suggests that political influences cause inertia in fiscal policy making. With the aim of capturing this slow adjustment (but without formally modelling the political factors) we consider the partial adjustment model:

$$s_t^* \;=\; \rho d_t \;+\; \alpha_0 \;+\; \alpha_G GVAR_t \;+\; \alpha_Y YVAR_t \;+\; \epsilon_t \tag{5}$$

$$s_t \;-\; s_{t-1} \;=\; \theta(s_t^* \;-\; s_{t-1}), \quad \text{with } 0 < \theta < 1 \tag{6}$$

where s_t^* denotes the desired level of the primary surplus to GDP ratio and θ is the partial adjustment parameter. The partial adjustment mechanism ensures that fiscal behaviour is affected by the desire to avoid volatility in the first difference of s_t. In this sense, the behaviour is similar to that resulting from a one period habit model.[3] Henceforth, we use the terms "habit" and "partial adjustment" interchangeably.

The resulting fiscal policy rule, which is the focus of this paper, can be written as:

$$s_t \;=\; \rho\theta d_t \;+\; \alpha_0\theta \;+\; \alpha_G\theta GVAR_t \;+\; \alpha_Y\theta YVAR_t \;+\; (1-\theta)s_{t-1} \;+\; \theta\epsilon_t. \tag{7}$$

A number of features of this specification are notable. First, we assume that the surplus itself is slow to adjust, not just the tax rate.[4] Second, as noted in the monetary policy literature (for example, Taylor (1993) and Clarida et al (1999)), part of the appeal of using behavioural rules for policy setting is that they are often robust. Although the rule is motivated by a tax smoothing model, it may also

[2] The non-debt component of the deficit must be bounded and GDP finite.

[3] See Fuhrer (2000) for an example of an aggregate consumption multiplicative habit model and Kozicki and Tinsley's (2001) discussion of the relationship between partial adjustment and habits. A statistically significant partial adjustment process may of course also capture other sources of autoregressive fiscal behaviour.

[4] Allowing the rate of adjustment for taxes to differ from that for government expenditures would change the interpretation of the reduced-form parameters in equation (7). But the substantive form of the policy rule would be unchanged.

capture non-tax smoothing behaviour. As long as the surplus responds to the level of debt, the business cycle and temporary government expenditure in a consistent manner, the rule will accurately describe the behaviour of the primary surplus to GDP ratio.

The presence of fiscal habits may reflect the policymakers' concern with model uncertainty. If policymakers are uncertain about the true model, quick policy responses may involve big mistakes which could have been avoided with slow adjustment. Hence, the policymaker may adjust the instrument sluggishly (Brainard (1967)).[5] Of course, if partial adjustment captures the impacts of model uncertainty, an ideal approach would be to model this directly, allowing for learning by the policymaker. This represents an interesting opportunity for subsequent research.

In contrast to our approach, Taylor's (1996 and 2000) fiscal rule is not based on tax smoothing behaviour. He decomposes the (non-primary) budget surplus (as a ratio to GDP) into a countercyclical component and a structural component. He argues that the former is associated with automatic stabilisers and that the latter is dominated by discretionary policy changes. Taylor (2000) shows that the countercyclical component is well characterised by a linear relation with the output gap. He uses the Congressional Budget Office (CBO) measure of the structural surplus to measure the discretionary component.[6] Our proposed rule also includes a term involving the output gap, capturing the cyclical response (of the primary surplus). But the tax smoothing theory is uninformative about the relative proportions of this cyclical effect explained by automatic stabilisers and by the fiscal authorities' cyclical fine-tuning.

In this paper, we focus on whether equation (7) provides a useful basis for normative statements about the overall (cyclical plus non-cyclical components) of the primary surplus. The adopted approach is to compare the actual behaviour of the primary surplus to GDP ratio with the path suggested by the rule. Before this

[5] See Clarida et al (1999) for a discussion of partial adjustment and Rudebusch (2002) for a treatment of model and data uncertainty in monetary policy rules.

[6] Taylor (1996) uses the average (rather than the actual) CBO structural surplus to capture the discretionary component. The CBO measures the structural or standardised surplus by extracting the cyclical components from disaggregate measures of revenues and expenditures.

step can be taken, however, the researcher must specify the parameters ρ, θ, α_0, α_G and α_Y. These can either be estimated or calibrated; but in both cases, the researcher faces a number of measurement problems. We consider these in detail in the subsequent section.

3 Real-time fiscal data

The implementation of a policy rule which relates the primary surplus to contemporaneously dated macroeconomic indicators can be troublesome for a policymaker in practice. Typically, the real-time information set of the policymaker excludes contemporaneous information—the measurements dated t are unknown at time t. The policymaker observes pre-time t observations that are, in effect, measurements with error. These data are subject to repeated revisions, redefinitions and rebenchmarks. The standard approach in macroeconometrics is to use time series measurements taken at the same point in time for all observations for all variables. Researchers typically ignore the impact of data remeasurements in the belief that they are fairly unimportant, perhaps only affecting the most recent couple of observations. In many cases, this approach probably works well. Recent work by Croushore and Stark (2001) for the US has shown, however, that the extent of data remeasurements can be very large. As Orphanides (2001) emphasises, if the measurements confronting a researcher evaluating past policy decisions are very different from those confronting the policymaker in real time, the researcher will misjudge how the policymaker responds to current information.

To examine this issue in the context of fiscal rules, we constructed a real-time US fiscal data set containing the actual measurements in the public domain at (end) December of each year from 1985 to 1995. In common with the earlier work by Bohn (1998), we used calender year measurements pre-dating the 1996 reform of government accounts (which thereafter excluded a measure of capital expenditure from the measured budget surplus).[7] Following the real-time work by Croushore

[7]The change in the definition of the US fiscal year in 1976 from July-June to October-September complicates fiscal year based analyses.

and Stark (2001) and others, we refer to the date of the information set of the policymaker as the "vintage". For example, the measurements in the public domain at the end of 1985 are referred to as the 1985 vintage.

For the primary surplus, we obtained a time series of measurements of the (NIPA, calender year) Federal surplus plus net interest costs from each annual issue of the *Economic Report of The President* (the *Economic Report*). This publication is typically produced in February of a given year and revisions can occur between this date and the end of the calender year. To deal with this intra-year revision issue, we used the measurements reported in the December issue of the Council of Economic Advisors' *Economic Indicators*. This reports only the most recent and therefore the most commonly revised observations. Where the (December) *Economic Indicators* measurements differed from the (typically February) *Economic Report*, we used the former. The 1985-1995 issues of the *Economic Report* only consistently report surplus measurements for the sample period post 1960, hence we restrict our analysis to this period. We obtained GDP measurements in December of each year from the Philadelphia Federal Reserve Real-Time Data Set (see Croushore and Stark (2001)).[8] We used Bohn's (1998) historical data for the level of the debt stock (privately held, at market value, at the start of the year).

We obtained a measure of the transitory component of real government expenditure, $GVAR$, by filtering military expenditure (obtained from the same sources as the surplus data, outlined above). We constructed the $GVAR$ variable as the deviation from an Hodrick-Prescott (1980) (HP) filter-derived trend (with the smoothing parameter, λ, set to 400) divided by the level of output. We constructed the $YVAR$ variable, which measures the transitory component of output, analogously.[9] A number of studies have noted difficulties with using the HP filter for decomposing a time series into a trend and cycle (see, for example, Harvey and Jaeger (1993) and Cogley and Nason (1995)). Orphanides and van Norden (2002) examine the variations in the US output gap that occur from a variety of filtering techniques (using real-time

[8]We used GNP for pre-1992 vintages and GDP subsequently.

[9]For the real-time results, the $GVAR$ and $YVAR$ variables were constructed by filtering recursively.

data). The absence of a theory-based approach to trend-cycle decomposition that is robust to real-time measurements represents an important practical drawback of many policy rules, including ours.[10] By considering the impact of real-time remeasurements on the implementation and interpretation of our proposed fiscal rule subsequently, we shall address the robustness to data uncertainty issue directly (for our given detrending technique).

For each variable in our real-time fiscal data set, the sources outlined above contain only measurements that pre-date the vintage. This lag between the date to which a measurement pertains and the date of the first published measurement complicates the implementation of a policy rule based on contemporaneously dated explanatory variables. For example, for the budget surplus variable, the last measurement contained in the (December) 1985 vintage refers to the calender year 1984. As a result, a policymaker wishing to judge the appropriateness of policy in December 1985 using actual measurements can only examine the behaviour up to and including 1984. A policymaker cannot reach judgements about the appropriateness of current policy if the rule is only informative about the past. In this backward looking form, the policy rule loses its appeal as a practical description of how policy should be conducted in real-time.

Fortunately, the information problem confronting the policymaker is not as bleak as it first appears. In December of each calender year, the policymaker typically knows the preliminary measurements for the first three quarters and, therefore, is able to make projections about the measurements for the calender year ending December with considerable accuracy. To model this conjectured behaviour by the policymaker, for each variable and vintage, we constructed a forecast of the contemporaneous measurements (that is, those referring to the year of the vintage date) using information available from the source publications.[11] We refer to these par-

[10]We experimented with using the Harvey (1985)-Clark (1987) unobserved components approach which Orphanides and van Norden (2002) found to be more robust to real-time measurements than the HP filter. We found that the implied path of the budget surplus and the degree of real-time data generated volatility were similar to the HP case. Details can be obtained from the authors on request.

[11]As one might expect, these partially forecast generated measurements are close to the first

tially forecast based measurements as "real-time" measurements since they reflect the information available to the policymaker in real time. By using forecast information in this way, the fiscal policy rule can be used for current real-time policy analysis.

In the resulting real-time data set, for each variable the data are stored as a matrix, following the convention established by Diebold and Rudebusch (1991). Each successive column vector of this matrix represents a new vintage of data. Within any column, all of the cells are constructed from the actual measurements recorded in the published sources, except the last cell, which refers to the time period dated the same as the vintage date. The last data point, a "real-time" measurement, is based on forecast information. The set of real-time measurements for the period 1985 to 1995 comprise the last elements in the 11 columns, one for each vintage date. Note that all of the figures reported in the data set, real-time and otherwise, are based entirely on information in the public domain at the vintage date shown. More details of the data used and sources for all variables are contained in the Data Appendix and on the website http://www.econ.cam.ac.uk/dae/research/debt/.

Summary statistics for the period 1985 to 1995 are shown in Table 1,

Table 1: Summary Statistics

Variable	AVGE	SD	MIN	MAX
$s_{t/t}$	-0.0021	0.0089	-0.0140	0.0109
$s_{t/95}$	-0.0030	0.0096	-0.0164	0.0109
$d_{t/t}$	0.3881	0.0500	0.3118	0.4529
$d_{t/95}$	0.3844	0.0526	0.3002	0.4523
$YVAR_{t/t}$	-0.0136	0.0132	-0.0295	0.0167
$YVAR_{t/95}$	-0.0039	0.0147	-0.0223	0.0184
$GVAR_{t/t}$	-0.0010	0.0069	-0.0064	0.0150
$GVAR_{t/95}$	0.0017	0.0042	-0.0057	0.0067

where, AVGE is the arithmetic mean, SD is the standard deviation, MIN is the minimum and MAX is the maximum. For each variable x, $x_{t/V}$ is the measurement of x_t at vintage date V. Hence, the data $x_{t/t}$ are the real-time measurements.

actual measurements that are released subsequently.

The major remeasurements in our data occur in the $GVAR$ and $YVAR$ variables, which require real-time filtering. For example, the (absolute) real-time mean of the $YVAR$ variable is more than three times that of the 1995 vintage value. The primary surplus-GDP ratio and the debt-GDP ratio are subject to very little real-time variation. Figures 1a and 1b show the real-time measurements and the 1995 vintage measurements of $GVAR$ and $YVAR$ for t dated 1985 to 1995.

Mankiw et al (1984) and Mankiw and Shapiro (1986) suggest the following categorisation of a remeasurement process. Define a revision for each observation as the difference between the real-time measurement and the final vintage measurement. If the correlation between the real-time measurements and the revisions is high but the correlation between the final measurements and the revisions is low, then the revisions are categorised as "noise". On the other hand, if the correlation between the real-time measurements and the revisions is low but the correlation between the final measurements and the revisions is high, then the revisions are categorised as "news". Table 2 shows these correlation figures for the surplus, debt, $YVAR$ and $GVAR$ variables.

Table 2: Correlations, 1985-1994

	s_t	d_t	$YVAR_t$	$GVAR_t$
Revisions and final	0.409	0.680	0.425	-0.280
Revisions and real-time	-0.147	0.637	-0.287	-0.876

The revisions to the variables in our policy rule are categorised as news, except those to $GVAR$ which appear to be noise. The presence of noise in an explanatory variable implies that estimation of the policy rule using the revised data will yield biased parameter estimates. We shall return to this issue subsequently.

4 Policy evaluation using real-time data

To interpret equation (7) as a fiscal policy rule, we compare the fiscal stance implied by the rule, conditional on the parameters ρ, θ, α_0, α_G and α_Y, with actual surplus behaviour.

4.1 Calibration approach

Taylor's (1993) approach to specifying the unknown parameters of a policy rule involves calibration, rather than estimation. The drawback is that it can be difficult to justify that the parameter values are "reasonable". For our fiscal rule, we assume that θ is approximately 0.5—so that the primary surplus to output ratio moves halfway to the desired level in a given period. Taking Bohn's (1998) upper estimate for ρ, in the region of 0.05, assuming equal weights on the $GVAR$ and $YVAR$ variables (set arbitrarily to 0.25) and using Bohn's intercept (based on post-1960 data) produces the following rule:[12]

$$s_t = 0.03d_t - 0.01 - 0.25GVAR_t - 0.25YVAR_t + 0.50s_{t-1}. \tag{8}$$

Figure 2 shows the fitted and actual plots using the 1995 vintage data for equation (8). Ignoring the real-time data issue for the moment, a normative interpretation of the policy rule involves comparing the actual budget surplus with that implied by the rule. The rule implies that, for example, the fiscal stance was too loose in 1975, in response to the first oil price shock. It was too loose again in the early 1980s, stemming from the Reagan Administration's 1981 Economic Recovery Tax Act, which phased in tax cuts over the successive two years. The relatively small deviation from the tax smoothing path reflects the impact of the military expansion of that administration. Other periods of fiscal imprudence include 1985-86 and the early 1990s. The first of these follows the repeated attempts at deficit reduction following the passing of The Economic Recovery Tax Act and coincides with the Gramm-Rudman-Hollings bill (regarding deficit ceilings and a proposal to eliminate the deficit by 1991, more formally known as The Balanced Budget and Emergency Deficit Control Act). The second follows the Budget Enforcement Act of 1990 and Bush's decision to renege on his earlier campaign promise to avoid raising taxes.

Periods of excessively tight policy include the early 1960s, prior to the implementation of the Kennedy tax plan; and the period 1968-69, associated with deepening

[12] For consistency with Bohn's (1998) earlier work, the variable $YVAR$ is constructed so that a procyclical surplus implies a negative parameter (see the Data Apendix.

military involvement in the Vietnam War.

Normative interpretations of this type can be misleading in the presence of data uncertainty however. Each vintage includes remeasurements to the data that could alter the ex post policy evaluations. Figure 3 shows the range of the primary surplus to GDP ratio implied by the rule using the sequence of vintages from December 1985 to December 1995. Viewing the real-time remeasurements as repeated measurements with error, this range captures the extent of data uncertainty over the 11 vintages on the calibrated rule. For comparison, Figure 3 also shows the real-time measurements of the actual budget surplus.[13] All of the substantive policy conclusions remarked upon above (based on the 1995 vintage data) are robust to this representation of the real-time data uncertainty.[14]

4.2 Estimation approach

An alternative approach to calibration of the parameters is estimation. In Table 3, Column 1, we report the parameters estimated by Ordinary Least Squares for equation (7) over the sample 1960-1994, based on 1995 vintage data, excluding the 1995 real-time data point.

For comparison, in Column 2 we report the same model estimated over the sample 1960-1995, using the same 1995 vintage, but including the 1995 forecast-based data point. In Column 3, we show the estimated parameters for the same model using Bohn's (1998) data over the 1960-1995 sample. Bohn's data include non-filtered measures of $GVAR$ and $YVAR$, taken from Barro's (1986a) earlier work based on single equation methods of identifying unanticipated shocks, and extended to the appropriate sample period.[15] In all cases, the partial adjustment parameter, θ, is positive, significant and large—suggesting that fiscal habits are an important feature of primary surpluses.[16] This result confirms the finding by Canzoneri et al

[13] The measurements shown pre-1985 are from the 1985 vintage.

[14] Using the rule in conjunction with only non-forecast data yields similar policy interpretations.

[15] Bohn (1998) reports results based on a model without habits (equation (4)). He finds strong support for sustainability based on longer samples and selected sub-samples.

[16] In theory, the use of calender year rather than fiscal year data could induce moving average errors. In practice, we found no evidence of this for the habit model. The use of (a variety of)

(2002) of primary surplus persistence in post-WWII US data.

Table 3: Regression results (dependent variable s_t)

Explanatory Variable	Column 1	Column 2	Column 3
d_t	0.031	0.027	0.012
	(0.015)	(0.014)	(0.013)
$INPT$	-0.009	-0.008	-0.007
	(0.005)	(0.004)	(0.004)
$GVAR_t$	-0.407	-0.370	-0.472
	(0.243)	(0.233)	(0.170)
$YVAR_t$	-0.359	-0.351	-1.897
	(0.064)	(0.062)	(0.460)
s_{t-1}	0.495	0.491	0.240
	(0.107)	(0.106)	(0.103)
$\overline{R}^2$	0.61	0.62	0.68
Durbin's h	0.37	0.36	1.54

(Standard errors are shown in parentheses.)

Figure 4 shows the fitted and actual plots for equation (7) with the parameters estimated by OLS using the 1995 vintage data—corresponding to Table 3, Column 2. The fitted line in Figure 4 is very similar to its equivalent using the calibration approach, Figure 2. Hence, the normative interpretations of the rule are close to those for the calibration case. A notable exception is the counterintuitive interpretation of 1981-1982 period as being slightly too fiscally conservative.

Figure 5 shows the variation in the predictions resulting from recursive estimation of the rule, using the sequence of vintages from 1985 to 1995; the policy interpretations are largely invariant to this treatment of the data uncertainty. An important exception to this generalisation, however, is the interpretation of 1982 fiscal policy as too restrictive—that conclusion is not robust to real-time data remeasurements.

The coefficients are vintage dependent in the estimation approach, causing more variation in the implied tax smoothing path than in the calibration case (shown in Figure 3). Figure 6 plots the difference between the range of values implied by

information criteria for model selection suggested that the habit specification is preferable to the no habit model with moving average errors.

the estimated and calibrated models respectively. The estimation approach gives a wider range of policy recommendations, except for the period 1967-1969.

A caveat to the above interpretation is that the parameters reported in Table 3 are likely to be biased. There are two sources of potential bias. First, the noise in the initial measurements of the explanatory variables, in particular $GVAR$, will introduce errors in variables. Second, the contemporaneous explanatory variables are endogenous. Although instrumental variables can deliver consistent estimates of the parameters, we found that in practice lags of the explanatory variables were extremely weak instruments.

5 Conclusions

In this paper, we have examined a fiscal policy rule with explicit links to the theory of tax smoothing. We have constructed a real-time fiscal data set in order to investigate the robustness of the policy conclusions to real-time data remeasurements. We have found that by calibrating the relevant parameters, the rule can be used to provide robust timely policy analysis suitable for practical implementation by a policymaker. The policy implications were slightly less robust to data uncertainty when the parameters of the rule were estimated. We have argued that the empirical validity of fiscal habits may reflect the cautious behaviour of fiscal policymakers when confronted by data uncertainty. Modelling this link formally represents an interesting area for future research.

Appendix

Derivation of equation (4) of the main text

Following Sargent's (1987, p 385-388) textbook presentation, we begin with the two primitives (from the main text):

$$E\sum_{t=0}^{\infty}\beta^t\left[u_1\tau_t+\frac{u_2}{2}\tau_t^2\right],\qquad 0<\beta<1 \tag{1}$$

and:

$$D_{t+1}=R\left[D_t+G_t-T_t\right]. \tag{2}$$

Dividing the second equation by Y_t and assuming constant trend growth, the constraint can be written as:

$$d_{t+1}=\frac{R}{\eta}\left[d_t+g_t-\tau_t\right] \tag{9}$$

where $\eta=\frac{Y_{t+1}}{Y_t}$ and lower case letters denote a ratio of the level to output (eg $d_t=D_t/Y_t$).

Denoting $R_\eta=\frac{R}{\eta}$ and solving equation (9) forward:

$$\sum_{j=0}^{\infty}R_\eta^{-j}E_t\tau_{t+j}=d_t+\sum_{j=0}^{\infty}R_\eta^{-j}E_tg_{t+j} \tag{10}$$

where we assume that $\beta R_\eta^2>1$.

The solution implies the familiar condition:

$$E_t\tau_{t+1}=-\alpha+\left(\beta R_\eta\right)^{-1}\tau_t, \tag{11}$$

where

$$\alpha=\frac{u_1\left[1-\left(\beta R_\eta\right)^{-1}\right]}{u_2}. \tag{12}$$

Assuming that $\beta R_\eta=1$, this implies that tax rates follow a martingale process regardless of the process followed by $\{g_t\}$.

Pursuing the analogy with consumption smoothing, the permanent government expenditure hypothesis ensures that the tax rates follow:

$$\tau_t = \left(\frac{\alpha}{R_\eta - 1}\right) + \left(1 - \frac{1}{\beta R_\eta^2}\right)\left[\sum_{j=0}^{\infty} R_\eta^{-j} E_t g_{t+j} + b_t\right]. \tag{13}$$

Suppose that g_t follows the process:

$$g_t = \bar{g} + \tilde{g}(L)\varepsilon_t, \qquad \tilde{g}(L) = \sum g_j L^j, \qquad \sum_{j=0}^{\infty} g_j^2 < +\infty \tag{14}$$

where $\bar{g}$ is the mean of the government expenditure-output ratio. Then:

$$\varepsilon_t = g_t - E g_t | 1, g_{t-1}, g_{t-2}, ... \tag{15}$$

where ε_t is the innovation process.

In the special case where $\beta R_\eta = 1$, the projection of tax rates on government expenditure-output ratios can be expressed as:

$$(1 - L)\,\tau_{t+1} = \left(1 - \frac{1}{R_\eta}\right)\tilde{g}\left(R_\eta^{-1}\right)\tilde{g}(L)^{-1}\left(g_{t+1} - \bar{g}\right). \tag{16}$$

We assume that:

$$\tilde{g}(L) = \frac{(1 - bL)}{(1 - L)}, \quad 0 < b < 1. \tag{17}$$

In this case, defining $\bar{g} = 0$:

$$\tau_{t+1} = \frac{\left(1 - bR_\eta^{-1}\right)}{1 - bL} g_{t+1}. \tag{18}$$

Notice that:

$$\frac{(1 - bL)}{(1 - L)} = 1 + (1 - b)\sum_{j=1}^{\infty} L^j. \tag{19}$$

From (17) it follows that:

$$g_t = \frac{(1 - bL)}{(1 - L)}\varepsilon_t = \varepsilon_t + (1 - b)\left[\varepsilon_{t-1} + \varepsilon_{t-2} + ...\right]. \tag{20}$$

Using (18):

$$\tau_t = \frac{\left(1 - bR_\eta^{-1}\right)}{1 - bL} g_t = \frac{\left(1 - bR_\eta^{-1}\right)}{1 - bL}\frac{(1 - bL)}{(1 - L)}\varepsilon_t = \left(1 - bR_\eta^{-1}\right)\frac{1}{1 - L}\varepsilon_t. \tag{21}$$

Recalling that $\frac{1}{1-L} = \sum_{j=0}^{\infty} L^j$:

$$\tau_t = \left(1 - bR_\eta^{-1}\right)\left[\varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2} + ...\right]. \tag{22}$$

And for the debt stock ratio (using (2), (20) and (22)):

$$\begin{aligned} d_{t+1} &= R_\eta d_t + R_\eta \left[g_t - \tau_t\right] \\ &= R_\eta d_t + b\left[\varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2} + ...\right] - bR_\eta\left[\varepsilon_{t-1} + \varepsilon_{t-2} + ...\right] \qquad (23) \\ &= b\left[\varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2} + ...\right]. \end{aligned}$$

Hence, the government (primary) surplus-output ratio can be expressed as:

$$\begin{aligned} s_t &= \tau_t - g_t \\ &= \left(1 - bR_\eta^{-1}\right)\left[\varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2} + ...\right] - \varepsilon_t - (1-b)\left[\varepsilon_{t-1} + \varepsilon_{t-2} + ...\right] \\ &= -bR_\eta^{-1}\left[\varepsilon_t + (1 - R_\eta)(\varepsilon_{t-1} + \varepsilon_{t-2} + ...)\right]. \qquad (24) \end{aligned}$$

Approaching the limit $b = 1$ (for purely transitory shocks):

$$s_t = -R_\eta^{-1}\left[\varepsilon_t + (1 - R_\eta)(\varepsilon_{t-1} + \varepsilon_{t-2} + ...)\right] \approx -R_\eta^{-1}\left[\varepsilon_t + (1 - R_\eta)d_t\right]. \tag{25}$$

This implies that in response to a transitory shock to g, such as that resulting from a war, the surplus will respond to the shock itself (by nearly the full amount) and the stock of debt at the start of the period. The transitory shocks are captured by $GVAR_t$ and the debt feedback by d_t in equation (4) of the main text.

A transitory shock to τ_t (uncorrelated with trend output growth), such as that resulting from the business cycle, will (by construction) have no impact on g_t but an immediate impact on τ_t itself. Hence, business cycle shocks captured by $YVAR_t$ should have a one-period contemporaneous impact on s_t as suggested by equation (4) of the main text.

The constant (in equation (4) of the main text) allows for any systematic bias towards deficit or surplus in our post-1960 sample.

Data Appendix

Variable	Source
NIPA: Surplus (S_t) Interest cost (I_t) Defence exp (DEF_t)	*Economic Indicators*, prepared for the Joint Committee by the Council of Economic Advisors December issues, various years. Tables (billions of dollars, calendar year): Federal sector, national income accounts basis. *Economic Report of the President* US Govt Printing Office, Washington DC, various issues. Tables (billions of dollars, calendar year): Federal government receipts and expenditures; national income and product accounts (NIPA).
Non-NIPA: Surplus (S_t) Interest cost (I_t) Defence exp (DEF_t)	*Economic Indicators*, prepared for the Joint Committee by the Council of Economic Advisors December issues, various years. Table (billions of dollars, fiscal year): Federal budget receipts by source and outlays by function; Federal budget receipts and outlays, and debt. *Economic Report of the President* US Govt Printing Office, Washington DC, various issues. Tables (billions of dollars, fiscal year): Federal receipts and outlays, by major category, and surplus or deficit; Government finance.
Nominal output (NY_t) Real output (RY_t)	Federal Reserve Bank of Philadelphia, Real Time Data Set. http://www.phil.frb.org/files/forecast NY_t = 4 quarter average of NOUTPUT (billions of dollars, seasonally adjusted, annual rate). Nom GDP datasets prior to Dec 92; nom GDP thereafter. RY_t = 4 quarter average of ROUTPUT (billions of dollars, seasonally adjusted, annual rate) Real, fixed-weight GNP in all datasets prior to Dec 92; real, fixed-weight GDP in all datasets Dec 92 - Dec 95; real, chain-weight GDP in datasets from Dec 96. 4th quarter observation for current calendar year (forecast) taken from *Greenbook* http://www.phil.frb.org/econ/forecast/scanneddatasets.html
Ratio of public debt to GDP (d_t)	From Bohn (1998). Privately held public debt, at market value, start of year. Assume Bohn uses 1996 vintage data. http://www.econ.ucsb.edu/∼bohn

Real-time measurements

For year t vintage surplus, interest cost and defence expenditure, the most recent observation in the public domain is for Quarter 3 in year t. We use non-NIPA forecast data to create a forecast for calendar year t as follows.

1. Transform fiscal year (runs from 1 October of preceding calendar year to 31 September of current calendar year) non-NIPA measurements to calendar year using the following formula:

$$NN_t^c = 0.75NN_t^f + 0.25NN_{t+1}^f$$

where NN denotes non-NIPA measurements, superscript c denotes calendar year, and superscript f denotes fiscal year.

2. Run the following regression for each vintage (all data are now in calendar year format):

$$N_t^c = \beta_1 + \beta_2 NN_t^c + u_t$$

where N denotes NIPA measurements. Use the resulting estimated coefficients ($\hat{\beta}_1$ and $\hat{\beta}_2$) to create NIPA forecast for the current calendar year.

Variable definitions

$$s_{t/V} = \beta_{0/V} + \beta_{1/V} d_{t/V} + \beta_{2/V} GVAR_{t/V} + \beta_{3/V} YVAR_{t/V} + \beta_{4/V} s_{t-1/V} + \varepsilon_{t/V}$$

For each variable x, $x_{t/V}$ is the measurement of x_t at vintage date V;the coefficients are defined analogously. Note that,

$s_{t/V} = \frac{S_{t/V}+I_{t/V}}{NY_{t/V}}$,

$d_{t/V} = \frac{d_t.NY_{t/96}}{NY_{t/V}}$ (assuming Bohn (1998) data are 1996 vintage)

$GVAR_{t/V} = \frac{(def_{t/V} - trend(def_{t/V}))}{RY_{t/V}}$

with $def_{t/V} = \left(\frac{DEF_{t/V}}{deflator}\right)$, $deflator = \frac{(NY_{t/V}/RY_{t/V})}{(NY_{t/82}/RY_{t/82})}$ and $trend(.)$ the HP filter-derived trend,

$YVAR_{t/V} = \frac{(trend(RY_{t/V}) - RY_{t/V})}{RY_{t/V}}$.

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Figure 1a: GVAR, 1985-1995

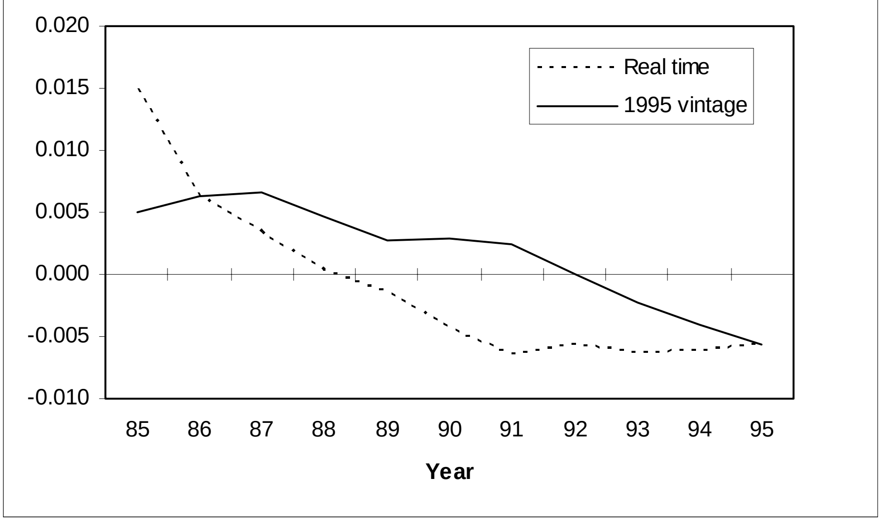


Figure 1b: YVAR, 1985-1995

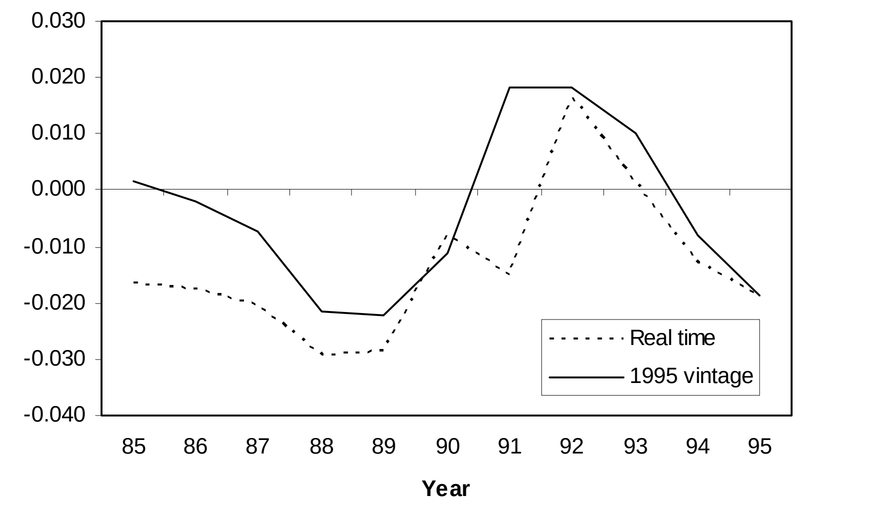


Figure 2: actual and fitted surplus, calibration approach (1995 vintage)

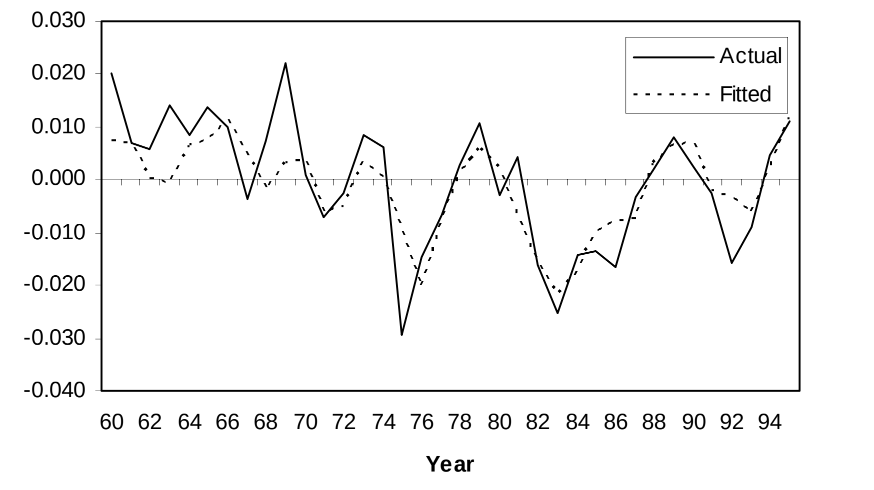
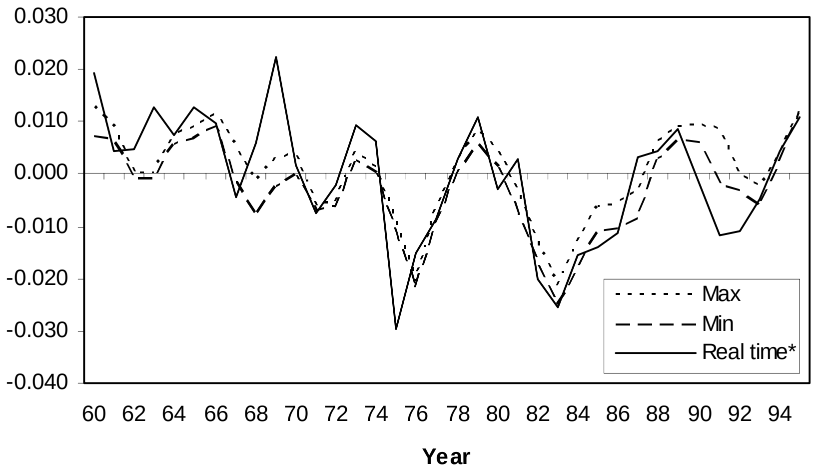


Figure 3: range of fitted surplus, calibrated approach (1985-1995 vintages)



* Real time for 1985-95, 1985 vintage for 1960-84

Figure 4: actual and fitted surplus, estimation approach (1995 vintage)

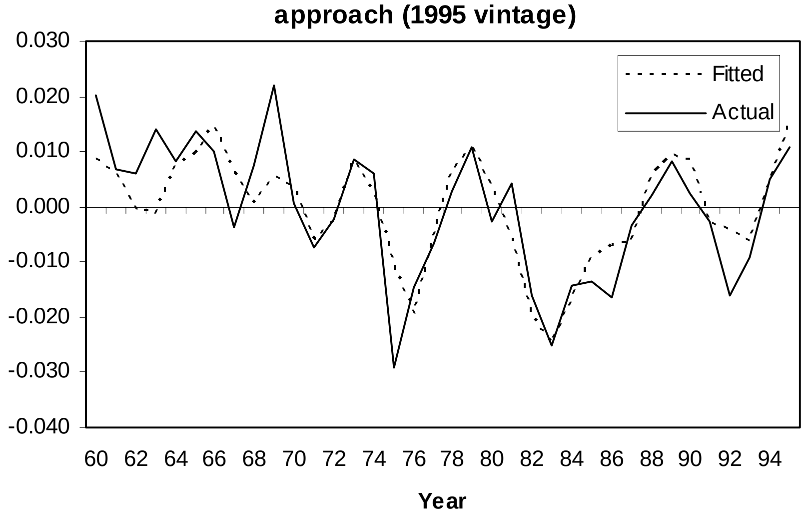
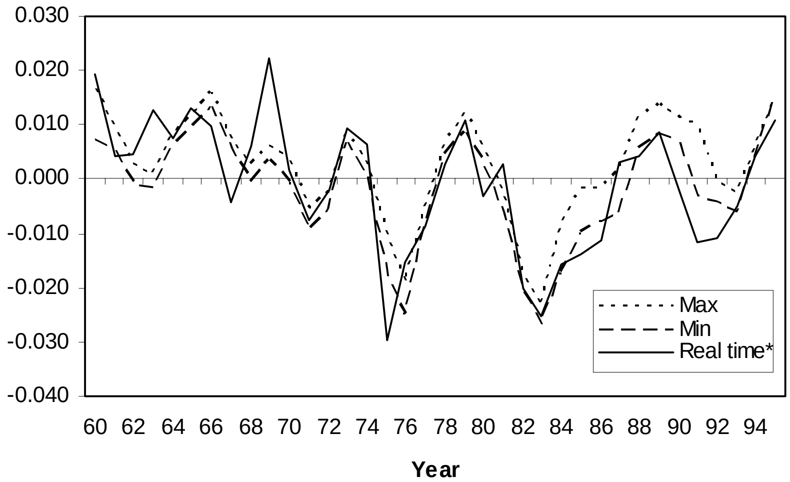


Figure 5: range of fitted surplus, estimation approach (1985-1995 vintages)



* Real time for 1985-95, 1985 vintage for 1960-84

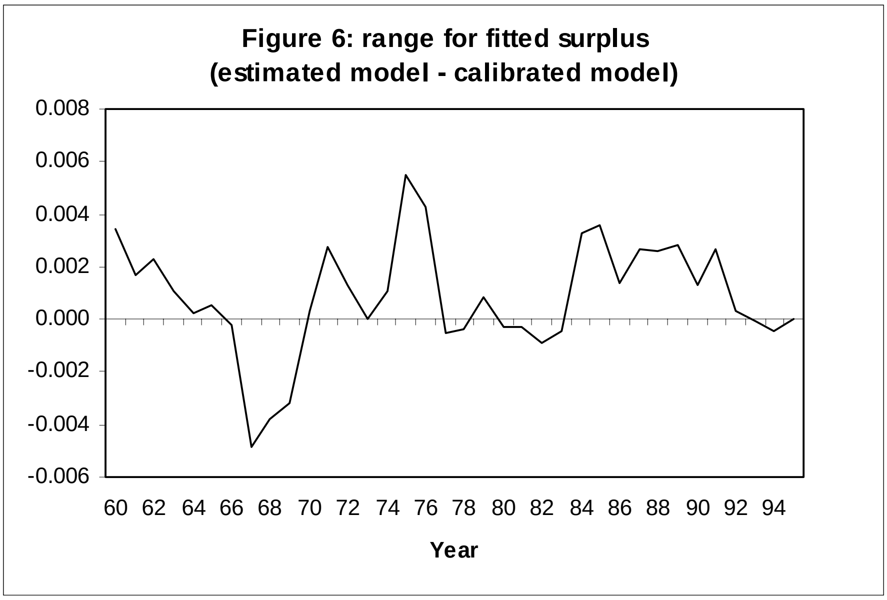


Figure 6: range for fitted surplus
(estimated model - calibrated model)
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94
Year