The Fiscal Theory of the Price Level - identification and testing for the UK in the 1970s*

Jingwen Fan

(Jinan University, PR China)

Patrick Minford

(Cardiff University and CEPR)

Zhirong Ou†

(Cardiff University)

Abstract

We investigate whether the Fiscal Theory of the Price Level (FTPL) can explain UK inflation in the 1970s. We confront the identification problem involved by setting up the FTPL as a structural model for the episode and pitting it against an alternative Orthodox model; the models have a reduced form that is common in form but, because each model is over-identified, numerically distinct. We use indirect inference to test which model could be generating the VECM approximation to the reduced form that we estimate on the data for the episode. Neither model is rejected, though the Orthodox model outperforms the FTPL. But the best account of the period assumes that expectations were a probability-weighted combination of the two regimes.

Keywords: UK Inflation; Fiscal Theory of the Price Level; Identification; Testing; Indirect inference

JEL Classification: E31, E37, E62, E65

1 Introduction

In 1972 the UK government floated the pound while pursuing highly expansionary fiscal policies whose aim was to reduce rising unemployment. To control inflation the government introduced statutory wage and price controls. Monetary policy was given no targets for either the money supply or inflation; interest rates were held at rates that would accommodate growth and falling unemployment. Since wage and price controls would inevitably break down faced with the inflationary effects of such policies, this period

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†Corresponding author: B14, Aberconway building, Cardiff Business School, Colum Drive, Cardiff, UK, CF10 3EU. Tel.: +44 (0)29 2087 5190. Fax: +44 (0)29 2087 4419. (OuZ@cardiff.ac.uk)

appears to fit rather well with the policy requirements of the Fiscal Theory of the Price Level: fiscal policy appears to have been non-Ricardian (not limited by concerns with solvency) and monetary policy accommodative to inflation - in the language of Leeper (1991) fiscal policy was 'active' and monetary policy was 'passive'. Furthermore, there was no reason to believe that this policy regime would come to an end: both Conservative and Labour parties won elections in the 1970s and both pursued essentially the same policies. While Margaret Thatcher won the Conservative leadership in 1975 and also the election in 1979, during the period we study here it was not assumed that the monetarist policies she advocated would ever occur, since they were opposed by the two other parties, by a powerful group in her own party, as well as by the senior civil service. Only after her election and her actual implementation of them was this a reasonable assumption. So it appears that in the period from 1972 to 1979 there was a prevailing policy regime which was expected to continue. These are key assumptions about the policy environment; besides this narrative background we also check them empirically below.

Under FTPL the price level or inflation is determined by the need to impose fiscal solvency; thus it is set at the value necessary for the government's intertemporal budget constraint to hold at the market value of outstanding debt. Given this determinate price level, money supply growth, interest rates and output are determined recursively as the values required by the rest of the model to permit this price level.

The FTPL has been set out and developed in Leeper (1991), Sims (1994, 1997), Woodford (1996, 1998, 2001) and Cochrane (2001, 2005) - see also comments by McCallum (2001, 2003) and Buiter (1999, 2002), and for surveys Kocherlakota and Phelan (1999), Carlstrom and Fuerst (2000) and Christiano and Fitzgerald (2000). Empirical tests have been proposed by Canzoneri, Cumby and Diba (2001), Bohn (1998), Cochrane (1999), Woodford (1998b) and Davig et al. (2007). Loyo (2000) for example argues that Brazilian policy in the late 1970s and early 1980s was non-Ricardian and that the FTPL provides a persuasive explanation for Brazil's high inflation during that time. The work of Tanner and Ramos (2003) also finds evidence of fiscal dominance for the case of Brazil for some important periods. Cochrane (1999, 2005) argues that the FTPL with a statistically exogenous surplus process explains the dynamics of U.S. inflation in the 1970s. This appears to be similar to what we see in the UK during the 1970s.

With fiscal policy of this type, the financial markets - forced to price the resulting supplies of government bonds - will take a view about future inflation and set interest rates and bond prices accordingly. It will set bond prices so that the government's solvency is assured ex post (i.e. in equilibrium); thus it will be ensuring that buyers of the bonds are paying a fair price. Future inflation is expected because if the bonds were priced at excessive value then consumers would have wealth to spend, in that their bonds would be worth more than their future tax liabilities; this would generate excess demand which would drive up inflation. However this mechanism would only come into play out of equilibrium. We would not

observe it because markets anticipate it and so drive interest rates and expected inflation up in advance; inflation follows because of the standard Phillips Curve mechanism by which workers and firms raise inflation in line with expected inflation. Thus the FTPL can be regarded as a particular policy regime within a sequence of different policy regimes.

Our aim in this paper is to test the Fiscal Theory of the Price Level (FTPL) as applied to the UK in the 1970s episode we described above. Cochrane (1999, 2001, and 2005) has noted that there is a basic identification problem affecting the FTPL: in the FTPL fiscal policy is exogenous and forces inflation to close the government constraint while monetary policy is endogenous and responds to that given inflation. But similar economic behaviour can be consistent with an exogenous monetary policy determining inflation in the 'orthodox' way, with Ricardian fiscal policy endogenously responding to the government budget constraint to ensure solvency given that inflation path - what we will call the Orthodox model. Thus there is a besetting problem in the empirical literature we have cited above, that equations that appear to reflect the FTPL and are used to 'test' it, could also be implied by the Orthodox set-up. To put it more formally the reduced form or solved representation of an FTPL model may *in form* be indistinguishable from that of an orthodox model; this is true of both single equation implications of the model and complete solutions of it.

We meet this problem head on in this paper by setting up both these two models and testing each against the data using Indirect Inference. This procedure, in outline, uses a descriptive model of the data, the 'auxiliary' model, to act as the summary of data behaviour, shared by any structural model that is a candidate to generate the data. Then each candidate model is simulated to see whether it could be the generating mechanism for this data behaviour in its exact quantitative manifestation.

We go in detail below into how this still unfamiliar procedure works. However, before we do so, we should explain why we do not choose alternative, more familiar evaluative procedures. First, we deviate from the popular use of Bayesian methods in evaluating models. Our reason is that Bayesian evaluation (by marginal likelihood and odds ratio tests) does not test any model as a whole against the data; indeed Bayesians dismiss the idea of 'testing models'. What Bayesian evaluation does is estimate the model assuming the truth of the prior distributions and the model structure; then one variant of the model may, on those assumptions, turn out to be more probable. But the model in question may still be rejected, assumptions and all, by the data. Furthermore, a model which is 'less probable' under these assumptions than another model, may not be rejected, or may be rejected at a lower confidence level, than the other by the data. Thus Bayesian methods cannot be used to test whole models against the data - our aim here, where the issue is whether either or both of these two models fit the facts of this episode.

Bayesians may still argue that it is wrong to do what we do here: that one should not test models as a whole against the data but rather only check improvements conditional on prior assumptions which should

not be challenged. However, in macroeconomics it is hard to argue that any set of prior assumptions can be taken for granted as true and beyond challenge. This can be seen from the number of 'schools of thought' still in existence in macroeconomics; this situation of a wide divergence of beliefs has been exacerbated by the financial crisis of the late 2000s. Furthermore, the two models being compared here are so different that it is hard to see what common and unchallengeable prior distributions could be found to impose on them.

Second, as our test of these two models against the data we choose indirect inference over the widely-used direct inference tests based on the data likelihood, such as the Likelihood Ratio test. The reasons for this choice, which we elaborate below, are partly that it tests the model's causality which is of greatest interest to users such as policymakers, rather than its forecasting ability which is of much less interest to them; partly that it has more power than direct inference in small samples and by implication that it will provide more powerful discrimination between the models.

Our paper is organised as follows. We review the history of UK policy during the 1970s in section 2; in this section we establish a narrative that suggests the FTPL could have been at work. In section 3 we set up the model of FTPL that could apply for this UK episode; side by side with it we set out a rival Orthodox model in which monetary policy is governed by a Taylor Rule and fiscal policy is Ricardian. In section 4 we explain the method of indirect inference. In section 5 we discuss the data and the results. Section 6 concludes.

2   The nature of UK policy during the 1970s

From WWII until its breakdown in 1970 the Bretton Woods system governed the UK exchange rate and hence its monetary policy. While exchange controls gave some moderate freedom to manage interest rates away from foreign rates without the policy being overwhelmed by capital movements, such freedom was mainly only for the short term; the setting of interest rates was dominated in the longer term by the need to control the balance of payments sufficiently to hold the sterling exchange rate. Pegging the exchange rate implied that the price level was also pegged to the foreign price level. Through this mechanism monetary policy ensured price level determinacy. Fiscal policy was therefore disciplined by the inability to shift the price level from this trajectory and also by the consequent fixing of the home interest rate to the foreign level. While this discipline could in principle be overthrown by fiscal policy forcing a series of devaluations, the evidence suggests that this did not happen; there were just two devaluations during the whole post-war period up to 1970, in 1949 and 1967. On both occasions a Labour government viewed the devaluation as a one-off change permitting a brief period of monetary and fiscal ease, to be followed by a return to the previous regime.

However, after the collapse of Bretton Woods, the UK moved in a series of steps to a floating exchange rate. Initially sterling was fixed to continental currencies through a European exchange rate system known as 'the snake in the tunnel', designed to hold rates within a general range (the tunnel) and if possible even closer (the snake). Sterling proved difficult to keep within these ranges, and was in practice kept within a range against the dollar at an 'effective' (currency basket) rate. Finally it was formally floated in June 1972.

UK monetary policy was not given a new nominal target to replace the exchange rate. Instead the Conservative government of Edward Heath assigned the determination of inflation to wage and price controls. A statutory 'incomes policy' was introduced in late 1972. After the 1974 election the incoming Labour government set up a 'voluntary incomes policy', buttressed by food subsidies and cuts in indirect tax rates. Fiscal policy was expansionary until 1975 and monetary policy was accommodative, with interest rates kept low to encourage falling unemployment. In 1976 the Labour government invited the IMF to stabilise the falling sterling exchange rate; the IMF terms included the setting of targets for Domestic Credit Expansion. These were largely met by a form of control on deposits (the 'corset') which forced banks to reduce deposits in favour of other forms of liability. But by 1978 these restraints had effectively been abandoned and prices and incomes controls reinstated in the context of a pre-election fiscal and monetary expansion - see Minford (1993), Nelson (2003) and Meenagh et al. (2009b) for further discussions of the UK policy environment for this and other post-war UK periods.

Our description of policy suggests that the role of the nominal anchor for inflation may have been played during the 1970s by fiscal policy, if only because monetary policy was not given this task and was purely accommodative. Thus this episode appears on the face of it to be a good candidate for FTPL to apply.

3 An FTPL Model for the UK in the 1970s

We assume that the UK finances its deficit by issuing nominal perpetuities, each paying one pound per period and whose present value is therefore $\frac{1}{R_t}$ where R_t is the long-term rate of interest. We use perpetuities here rather than the usual one-period bond because of the preponderance of long-term bonds in the UK debt issue: the average maturity of UK debt at this time was approximately ten years. All bonds at this time were nominal (indexed bonds were not issued until 1981).

The government budget constraint can then be written as

(1) $\frac{B_{t+1}}{R_t} = G_t - T_t + B_t + \frac{B_t}{R_t}$

where G_t is government spending in money terms, T_t is government taxation in money terms, B_t is the number of perpetuities issued. Note that when perpetuities are assumed the debt interest in period

t is B_t while the stock of debt at the start of period t has the value during the period of $\frac{B_t}{R_t}$; end-period debt therefore has the value $\frac{B_{t+1}}{R_t}$. Note too the perpetuity interest rate is by construction expected to remain constant into the future.

We can derive the implied value of current bonds outstanding by substituting forwards for future bonds outstanding:

(2) $\frac{B_t}{R_t} = E_t \sum_{i=0}^{\infty} (T_{t+i} - G_{t+i}) \frac{1}{(1+R_t)^{i+1}}$

We represent this equation in terms of each period's expected 'permanent' tax and spending share, t_t and g_t, and assume that $E_t T_{t+i} = t_t E_t P_{t+i} y_{t+i}$ and $E_t G_{t+i} = g_t E_t P_{t+i} y_{t+i}$.

We can then simplify (2) (see Appendix) to:

(3) $\frac{B_t}{R_t \overline{P}_t y_t^*} = \frac{(\bar{t}_t - \bar{g}_t)}{(1+\gamma+\overline{\pi}_t)(r_t^* - \gamma)}$

where $R_t = r_t^* + \overline{\pi}_t$ (respectively the perpetuity real interest rate and perpetuity inflation rate, both 'permanent' variables), γ is the growth rate of equilibrium real GDP, y_t^* (which is a random walk with this as its drift term). All these expected permanent variables are by construction expected to be constant in the future at today's level.

The pricing condition on bonds in equation (3) thus sets their value consistently with expected future primary surpluses. Suppose now the government reduces the present value of future primary surpluses. At an unchanged real value of the debt this would be a 'non-Ricardian' fiscal policy move. According to the FTPL prices will adjust to reduce the real value of the debt to ensure the government budget constraint holds and thus the solvency condition is met. This is to be compared with the normal Ricardian situation, in which fiscal surpluses are endogenous so that fiscal shocks today lead to adjustments in future surpluses, the price level remaining unaffected.

Since the pricing equation sets the ratio of debt value to GDP equal to a function of permanent variables, it follows that this ratio b_t follows a random walk[1] such that:

(4) $b_t = \frac{B_t}{R_t \overline{P}_t y_t^*} = E_t b_{t+1}$ and (5) $\Delta b_t = \eta_t$, an $i.i.d.$ process.

This in turn allows us to solve for the inflation shock as a function of other shocks (especially shocks to government tax and spending). With the number of government bonds issued, B_t, being pre-determined (issued last period) and therefore known at $t-1$, equation (3) could be written as follows (taking logs and letting $\log x_t^{ue} = \log x_t - E_{t-1} \log x_t$, the unexpected change in $\log x_t$)

(6) $\log b_t^{ue} = -\log R_t^{ue} - \log \overline{P}_t^{ue} - \log y_t^{*ue}$ [LHS of equation (3)]

$= \log (\bar{t}_t - \bar{g}_t)^{ue} - \log (1 + \overline{\pi}_t + \gamma)^{ue} - \log(r_t^* - \gamma)^{ue}$ [RHS of equation (3)]

With all the variables in the equation defined to follow a random walk, and making the approximative assumption that the actual and permanent inflation are the same, we can rewrite the above expression

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[1] A 'permanent' variable $\bar{x}_t$ is by definition a variable expected not to change in the future so that $E_t \bar{x}_{t+1} = \bar{x}_t$. Thus $\bar{x}_{t+1} = \bar{x}_t + \epsilon_{t+1}$, where ϵ_{t+1} is an iid error making the process a random walk.

as approximately (note that for small γ, $\log\left(1 + \overline{\pi}_t + \gamma\right)^{ue} \approx \overline{\pi}_t^{ue} = \log \overline{P}_t^{ue}$)

(7) $-\Delta \log\left(\overline{\pi}_t + r_t^*\right) - \Delta \log y_t^* = \Delta \log(\overline{t}_t - \overline{g}_t) - \Delta \log(r_t^* - \gamma)$

Using a first-order Taylor Series expansion around the sample means we can obtain a solution for $\Delta \overline{\pi}_t$ as a function of change in government expenditure and tax rates

(8) $\Delta \overline{\pi}_t = \kappa(\Delta \overline{g}_t - \Delta \overline{t}_t) + \lambda \Delta r_t^* - \mu \Delta \log y_t^*$

where $\kappa = \frac{\overline{\overline{\pi}} + \overline{r^*}}{\overline{\overline{t}} - \overline{\overline{g}}}, \lambda = \frac{\overline{\overline{\pi}} + \gamma}{\overline{r^*} - \gamma}, \mu = \overline{\overline{\pi}} + \overline{r^*}$; $\overline{\overline{\pi}}$, $\overline{r^*}$, $\overline{\overline{t}}$ and $\overline{\overline{g}}$ are sample mean values of the corresponding variables. We can integrate (8) to obtain:

(9) $\overline{\pi}_t = \kappa(\overline{g}_t - \overline{t}_t) + c + \lambda r_t^* + \mu \log y_t^*$

Tax and spending ratios are assumed to deviate from their permanent values according to error processes (which must be stationary by construction). Thus

(10) $(g_t - t_t) = (\overline{g}_t - \overline{t}_t) + \epsilon_t$. Since by construction a permanent variable is a random walk, this gives us:

(11) $\Delta(g_t - t_t) = \Delta(\overline{g}_t - \overline{t}_t) + \Delta \epsilon_t = err_t^{g-t}$

where err_t^{g-t} is a stationary error process. We may now note that there is some unknown error process by which actual inflation is related to permanent inflation: thus $\pi_t = \overline{\pi}_t + \eta_t$. We use (9) for the determinants of $\overline{\pi}_t$ and since we cannot observe $(\lambda r_t^* + \mu \log y_t^*)$ we include this in the total error process, err_t^{pi}, so that finally our FTPL model for inflation is:

(12) $\pi_t = \kappa(g_t - t_t) + c^\pi + err_t^{pi}$

We can now complete the DSGE model by adding a forward-looking IS curve, derived in the usual way from the household Euler equation and the goods market-clearing condition, and a New Keynesian Phillips Curve[2]:

(13) $y_t - y_t^* = E_t(y_{t+1} - y_{t+1}^*) - \frac{1}{\sigma}(R_t^s - E_t \pi_{t+1}) + err_t^{IS}$

(14) $\pi_t = \theta(y_t - y_t^*) + \beta E_t \pi_{t+1} + err_t^{PP}$

Note that the interest rate in the IS curve, R_t^s, is the usual short term rate. Also we can see that since (12) sets inflation, (14) will solve for output and (13) will solve for interest rates. Equilibrium output, y_t^*, approximated in the FTPL derivation as a random walk, is represented empirically by the H-P filter of output and estimated as an I(1) process:

(15) $y_t^* - y_{t-1}^* = c^{y*} + \gamma(y_{t-1}^* - y_{t-2}^*) + err_t^{y*}$

The permanent real interest rate is absorbed into the error term of the IS curve, as it was into that of (12) for inflation.

The FTPL model thus consists of equations (11)-(15).

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[2] One might well argue that for FTPL a more natural assumption would be a New Classical Phillips Curve, in which there is price flexibility. It turns out, as we confirm below in the empirical results section, that it makes virtually no difference. This can be seen if one solves for output from (14); the only difference to the solution will come from having $(\pi_t - E_{t-1}\pi_t)$ on the RHS instead of $(\pi_t - \beta E_t \pi_{t+1})$. These expressions are very similar in practice.

3.1 An Orthodox model:

To construct the Orthodox model we jettison equations (11) and (12) above in favour of a Taylor Rule to set R_t^s and a Ricardian fiscal equation that restores the deficit to some equilibrium level. Thus in place of these we have:

(12)'

$$R_t^s = (1 - \rho)[r^{ss} + \phi_\pi \pi_t + \phi_{xgap}(y_t - y_t^*)] + \rho R_{t-1}^s + err_t^{R^S}$$

and

(11)'

$$\triangle(g_t - t_t) = -\delta[(g - t)_{t-1} - c^{g-t}] + err_t^{g-t\prime}$$

3.2 Model identification

It would be reasonable to ask whether a macroeconomic model of a few equations like the ones here can be considered to be identified. Le et al. (2013) examined this issue for a three equation New Keynesian model of the sort being considered here. They found that it was likely to be heavily over-identified. Thus there were many more coefficients in the reduced form than in the structural model; under normal assumptions this should give several sets of estimates of the structural coefficients from the reduced form. With enough data these sets would coincide and so even a partial reduced form should be sufficient to yield a set of structural parameter estimates. In that paper they went further and sought to find alternative structural parameter sets that could generate the same reduced form; using indirect inference they were able to establish that no other sets could exist. These results suggest that we can regard each of the two models here as over-identified, implying that there is no chance of confusing the reduced form of the one with the reduced form of the other.

We can demonstrate this by a Monte Carlo experiment in which we assume that the FTPL model is true (we give it the parameters similar to those we later estimate for it) and using the FTPL error properties we generate 1,000 samples of data from it (of the same length as in our 1970s sample here - 28 quarters) and calculate the VECM approximate reduced form from it. We now ask whether any Orthodox model could generate the same data and hence the same VECM reduced form, using the indirect inference test at 95% confidence; if indeed it could do so, thus effectively being the same model, then we would reject exactly the same percent of the time as we reject the true FTPL model - namely 5%. In fact we reject it for 51% of the samples; thus it cannot be the same model (table 1. We also did the reverse, and found the same, rejecting about 20% of the time). In doing this check we have searched over a wide range of parameter values using the SA algorithm, starting from the estimated parameters:

Table 1: Identification check: FTPL vs Orthodox Taylor

When the true model is	Rejection rate (at 95% confidence level) of the false model
FTPL	51.3% (Orthodox)
Orthodox	19.7% (FTPL)

This does not contradict the general problem we noted at the start that the two models have similar reduced forms. In particular it is easy to show (see below and Le et al., 2013) that the general solution of these models can in both cases be represented as a VARMA supplemented by coefficients on the exogenous stochastic and deterministic trends. Thus there is no formal difference between the two models' reduced forms; though of course the reduced forms can be distinguished according to particular numerical restrictions on their coefficients. These restrictions will differ according to the details of each model, so that no generic restriction can be proposed that would correspond only to one type of model, such as the FTPL. Thus estimating a particular set of reduced form equations (let alone any single equation forming part of the reduced form) cannot on its own distinguish the two models, as has usually been assumed in empirical work on the FTPL. To distinguish them one needs to know what numerical parameter values would be found in these reduced forms according to each model. It is this that the indirect inference procedure allows us to do, as we now go on to explain.

4 The method of Indirect Inference

We evaluate the model's capacity in fitting the data using the method of Indirect Inference originally proposed in Meenagh et al. (2009a) and subsequently with a number of refinements by Le et al. (2011) who evaluate the method using Monte Carlo experiments. The approach employs an auxiliary model that is completely independent of the theoretical one to produce a description of the data against which the performance of the theory is evaluated indirectly. Such a description can be summarised either by the estimated parameters of the auxiliary model or by functions of these; we will call these the descriptors of the data. While these are treated as the 'reality', the theoretical model being evaluated is simulated to find its implied values for them.

Indirect inference has been widely used in the estimation of structural models (e.g., Smith, 1993, Gregory and Smith, 1991, 1993, Gourieroux et al., 1993, Gourieroux and Monfort, 1995 and Canova, 2005). Here we make a further use of indirect inference, to evaluate an already estimated or calibrated structural model. The common element is the use of an auxiliary time series model. In estimation the parameters of the structural model are chosen such that when this model is simulated it generates estimates of the auxiliary model similar to those obtained from the actual data. The optimal choices of

parameters for the structural model are those that minimise the distance between a given function of the two sets of estimated coefficients of the auxiliary model. Common choices of this function are the actual coefficients, the scores or the impulse response functions. In model evaluation the parameters of the structural model are taken as given. The aim is to compare the performance of the auxiliary model estimated on simulated data derived from the given estimates of a structural model - which is taken as a true model of the economy, the null hypothesis - with the performance of the auxiliary model when estimated from the actual data. If the structural model is correct then its predictions about the impulse responses, moments and time series properties of the data should statistically match those based on the actual data. The comparison is based on the distributions of the two sets of parameter estimates of the auxiliary model, or of functions of these estimates.

The testing procedure thus involves first constructing the errors implied by the previously estimated/calibrated structural model and the data. These are called the structural errors and are backed out directly from the equations and the data[3]. These errors are then bootstrapped and used to generate for each bootstrap new data based on the structural model. An auxiliary time series model is then fitted to each set of data and the sampling distribution of the coefficients of the auxiliary time series model is obtained from these estimates of the auxiliary model. A Wald statistic is computed to determine whether functions of the parameters of the time series model estimated on the actual data lie in some confidence interval implied by this sampling distribution.

The auxiliary model should be a process that would describe the evolution of the data under any relevant model. It is known that for non-stationary data the reduced form of a macro model is a VARMA where non-stationary forcing variables enter as conditioning variables to achieve cointegration (i.e. ensuring that the stochastic trends in the endogenous vector are picked up so that the errors in the VAR are stationary). This in turn can be approximated as a VECM[4]. So following Meenagh et al. (2012)

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[3]Some equations may involve calculation of expectations. The method we use here to initiate the tests is the robust instrumental variables estimation suggested by McCallum (1976) and Wickens (1982): we set the lagged endogenous data as instruments and calculate the fitted values from a VAR(1) – this also being the auxiliary model chosen in what follows. Once the search procedure (effectively indirect estimation) has converged on the best model parameters, we then move to generating the expectations exactly implied by the parameters and the data, and use these to calculate the errors, which are then the exact errors implied by the model and data. The reason we do not use this 'exact' method at the start is that initially when the model is far from the data, the expectations generated are also far from the true ones, so that the errors are exaggerated and the procedure may not converge.

[4]Following Meenagh et al. (2012), we can say that after log-linearisation a DSGE model can usually be written in the form

$$A(L)y_t = BE_t y_{t+1} + C(L)x_t + D(L)e_t \qquad (A1)$$

where y_t are p endogenous variables and x_t are q exogenous variables which we assume are driven by

$$\Delta x_t = a(L)\Delta x_{t-1} + d + c(L)\epsilon_t. \qquad (A2)$$

The exogenous variables may contain both observable and unobservable variables such as a technology shock. The disturbances e_t and ϵ_t are both iid variables with zero means. It follows that both y_t and x_t are non-stationary. L denotes the lag operator $z_{t-s} = L^s z_t$ and $A(L)$, $B(L)$ etc. are polynomial functions with roots outside the unit circle.

The general solution of y_t is

$$y_t = G(L)y_{t-1} + H(L)x_t + f + M(L)e_t + N(L)\epsilon_t. \qquad (A3)$$

where the polynomial functions have roots outside the unit circle. As y_t and x_t are non-stationary, the solution has the p

we use as the auxiliary model a VECM which we reexpress as a VAR(1) for the four macro variables (interest rate, output, inflation and the primary budget deficit, with a time trend and with y_t^* entered as the exogenous non-stationary 'productivity trend' (these two elements having the effect of achieving cointegration). Thus our auxiliary model in practice is given by: $y_t = [I - K]y_{t-1} + \gamma \overline{x}_{t-1} + gt + v_t$ where $\overline{x}_{t-1}$ is the stochastic trend in productivity, gt are the deterministic trends, and v_t are the VECM innovations. We treat as the descriptors of the data all the VAR coefficients and the VAR error variances, so that the Wald statistic is computed from these. Thus effectively we are testing whether the observed dynamics, volatility and cointegrating relations of the chosen variables are explained by the simulated joint distribution of these at a given confidence level. The Wald statistic is given by:

$$(\Phi - \overline{\Phi})' \sum\nolimits_{(\Phi\Phi)}^{-1} (\Phi - \overline{\Phi}) \tag{1}$$

where Φ is the vector of VAR estimates of the chosen descriptors yielded in each simulation, with $\overline{\Phi}$ and $\sum_{(\Phi\Phi)}$ representing the corresponding sample means and variance-covariance matrix of these calculated across simulations, respectively.

The joint distribution of the Φ is obtained by bootstrapping the innovations implied by the data and the theoretical model; it is therefore an estimate of the small sample distribution[5]. Such a distribution

cointegration relations

$$\begin{aligned} y_t &= [I - G(1)]^{-1}[H(1)x_t + f] \\ &= \Pi x_t + g. \end{aligned} \tag{A4}$$

The long-run solution to the model is

$$\begin{aligned} \overline{y}_t &= \Pi \overline{x}_t + g \\ \overline{x}_t &= [1 - a(1)]^{-1}[dt + c(1)\xi_t] \\ \xi_t &= \Sigma_{i=0}^{t-1}\epsilon_{t-s} \end{aligned}$$

Hence the long-run solution to x_t, namely, $\overline{x}_t = \overline{x}_t^D + \overline{x}_t^S$ has a deterministic trend $\overline{x}_t^D = [1 - a(1)]^{-1}dt$ and a stochastic trend $\overline{x}_t^S = [1 - a(1)]^{-1}c(1)\xi_t$.

The solution for y_t can therefore be re-written as the VECM

$$\begin{aligned} \Delta y_t &= -[I - G(1)](y_{t-1} - \Pi x_{t-1}) + P(L)\Delta y_{t-1} + Q(L)\Delta x_t + f + M(L)e_t + N(L)\epsilon_t \\ &= -[I - G(1)](y_{t-1} - \Pi x_{t-1}) + P(L)\Delta y_{t-1} + Q(L)\Delta x_t + f + \omega_t \\ \omega_t &= M(L)e_t + N(L)\epsilon_t \end{aligned} \tag{A5}$$

Hence, in general, the disturbance ω_t is a mixed moving average process. This suggests that the VECM can be approximated by the VARX

$$\Delta y_t = K(y_{t-1} - \Pi x_{t-1}) + R(L)\Delta y_{t-1} + S(L)\Delta x_t + g + \zeta_t \tag{A6}$$

where ζ_t is an iid zero-mean process.

As

$$\overline{x}_t = \overline{x}_{t-1} + [1 - a(1)]^{-1}[d + \epsilon_t]$$

the VECM can also be written as

$$\Delta y_t = K[(y_{t-1} - \overline{y}_{t-1}) - \Pi(x_{t-1} - \overline{x}_{t-1})] + R(L)\Delta y_{t-1} + S(L)\Delta x_t + h + \zeta_t. \tag{A7}$$

Either equations (A6) or (A7) can act as the auxiliary model. Here we focus on (A7); this distinguishes between the effect of the trend element in x and the temporary deviation from its trend. In our models these two elements have different effects and so should be distinguished in the data to allow the greatest test discrimination.

It is possible to estimate (A7) in one stage by OLS. Meenagh et al. (2012) do Monte Carlo experiments to check this procedure and find it to be extremely accurate.

[5]The bootstraps in our tests are all drawn as time vectors so contemporaneous correlations between the innovations are preserved.

is generally more accurate for small samples than the asymptotic distribution; it is also shown to be consistent by Le et al. (2011) given that the Wald statistic is 'asymptotically pivotal'; they also showed it had quite good accuracy in small sample Monte Carlo experiments[6].

This testing procedure is applied to a set of (structural) parameters put forward as the true ones (H_0, the null hypothesis); they can be derived from calibration, estimation, or both. However derived, the test then asks: could these coefficients within this model structure be the true (numerical) model generating the data? Of course only one true model with one set of coefficients is possible. Nevertheless we may have chosen coefficients that are not exactly right numerically, so that the same model with other coefficient values could be correct. Only when we have examined the model with all coefficient values that are feasible within the model theory will we have properly tested it. For this reason we extend our procedure by a further search algorithm, in which we seek other coefficient sets that minimise the Wald test statistic - in doing this we are carrying out indirect estimation. The indirect estimates of the model are consistent and asymptotically normal, in common with FIML - see Smith (1993), Gregory and Smith (1991, 1993), Gourieroux et al., (1993), Gourieroux and Monfort (1995) and Canova (2005).

Thus we calculate the minimum-value full Wald statistic for each model using a powerful algorithm based on Simulated Annealing (SA) in which search takes place over a wide range around the initial values, with optimising search accompanied by random jumps around the space[7]. The merit of this extended procedure is that we are comparing the best possible versions of each model type when finally doing our comparison of model compatibility with the data.

4.1 Comparison of indirect inference with alternative methods of model evaluation

It may be asked why we use Indirect Inference rather than the now widely-used Bayesian approach to estimating and testing DSGE models. We considered this frequently-asked question in the opening section above. As noted there, the Bayesian approach does not test a model as a whole against the data since it operates entirely under the assumptions that the prior distributions and the model structure are correct. It would be appropriate to use this approach if we knew that this was the case so that the assumptions

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[6]Specifically, they found on stationary data that the bias due to bootstrapping was just over 2% at the 95% confidence level and 0.6% at the 99% level. Meenagh et al (2012) found even greater accuracy in Monte Carlo experiments on nonstationary data.

[7]We use a Simulated Annealing algorithm due to Ingber (1996). This mimics the behaviour of the steel cooling process in which steel is cooled, with a degree of reheating at randomly chosen moments in the cooling process—this ensuring that the defects are minimised globally. Similarly the algorithm searches in the chosen range and as points that improve the objective are found it also accepts points that do not improve the objective. This helps to stop the algorithm being caught in local minima. We find this algorithm improves substantially here on a standard optimisation algorithm. Our method used our standard testing method: we take a set of model parameters (excluding error processes), extract the resulting residuals from the data using the LIML method, find their implied autoregressive coefficients ($AR(1)$ here) and then bootstrap the implied innovations with this full set of parameters to find the implied Wald value. This is then minimised by the SA algorithm.

themselves do not need to be tested; but because of well-known controversies in macroeconomics, this is not the case. Even a major model like the Smets-Wouters (2007) model of the U.S., that has been carefully estimated by Bayesian methods, is rejected by our indirect inference test, see Le et al. (2011).

It may then be asked why we use Indirect Inference rather than other available tests of overall specification, given as explained above that Bayesian methods are simply not available for the task here. The alternatives are based on the likelihood of the data, and a widely-used one is the Likelihood Ratio (LR) test ; by contrast our indirect inference test is based on the likelihood of the descriptors of the data. This test is examined carefully in Le et al. (2012) who find that the two measures test quite different properties of the model in their check on its misspecification: the LR test is based on a model's in-sample current forecasting ability whereas the Wald is based on the model's ability to replicate data behaviour, as found in the VAR coefficients and the data variances, reflecting the causal processes at work in the data.

A further finding of Le et al. was that the Wald has substantially more power as a test of mis-specification than the LR. This is presumably related to the nature of the two tests: models that are somewhat mis-specified may still be able to forecast well in sample as the error processes will pick up the effects of mis-specification but mis-specified models will imply a reduced form that differs materially from the true one, and so therefore a VAR approximation to this that similarly deviates from the VAR given by the true model. Le et al.'s comparison related to models that were mis-specified in the sense of having wrong calibrations, even though having the correct model. However in our case here we are concerned with mis-specification in the sense of having the wrong model, since we allow full estimation (so that the calibration mistakes should be eliminated). Thus we did a Monte Carlo experiment to check the power of each test against a mis-specified model, allowing the test to be carried out as here after full reestimation.

For this experiment we assumed that the true model was FTPL and created 1,000 samples of data from it, all of the same small size as here (28). We then checked whether a pure Orthodox model, and thus clearly mis-specified, would if estimated on each data sample then be rejected 5% of the time by this data. With the Indirect Inference Wald (and indirect estimation by Simulated Annealing) the rejection rate was 12%; thus even with such a small sample there was power against model mis-specification. With the LR (and FIML estimation) the rejection rate did not rise above 5%, that of the True model[8].

We then repeated the power experiment the other way round, making the Orthodox model the true one and creating 1000 samples from it. In this case the power is greater, with the Wald test rejecting

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[8]In fact in the case of the LR test we found 4.5%, less than 5%, so that the False model is rejected even less than the True model. We think what may be happening here is that when the false model is freely reestimated for each true sample a process of data-mining occurs whereby for each sample the SA algorithm finds a model and set of errors and AR coefficients such that the in-sample forecast of current data is 'improved' over what even the True model would achieve.

20% of the time and the LR test rejecting 22.5% of the time. Thus here the power of the two tests is comparable.

What we see (tables 2 and 3) is that on average the Wald test has more power against mis-specification with the small sample being used here. Furthermore it is consistent in having power whereas the LR test can fail to have any power at all. Nevertheless, perhaps not surprisingly, with such a very small sample (only 28 observations), the Wald test cannot achieve strong power.

Table 2: Power check of Wald test: FTPL vs Orthodox Taylor

When the true model is	Rejection rate (at 95% confidence level) of the false model
FTPL	11.9% (Orthodox)
Orthodox	19.9% (FTPL)

Table 3: Power check of LR test: FTPL vs Orthodox Taylor

When the true model is	Rejection rate (at 95% confidence level) of the false model
FTPL	4.5% (Orthodox)
Orthodox	22.5% (FTPL)

5   Data and Results

We limit our focus to the period between 1972-1979 during which the FTPL could be a potential candidate given the economic background. We use unfiltered (but seasonally adjusted) data from official sources. We define as R_t^s the Minimum Lending Rates, and as π_t the percentage change in the CPI index, both in quarterly term. We use for y_t the real GDP level in natural logarithm and for y_t^* its trend values as suggested by the H-P filter. The primary deficit ratio $g - t$ is simply the difference between G/GDP and T/GDP, where G and T are respectively the levels of government spending and tax income. In particular, since for model convergence the amount of government spending is required to be less than taxation for government bonds to have a positive value, and that government spending on a capital variety is expected to produce future returns in line with real interest rates, we deduct the trend in such spending from the trend in G/GDP. By implementing this we assume that the average share of expenditure devoted to fixed capital, health and education in the period can be regarded as the (constant) trend in such capital spending; of course the 'capital' element in total government spending is unobservable and hence our assumption is intended merely to adjust the level of g in an approximate way but not its movement over time which we regard as accurately capturing changes in such spending. This adjustment counts for about 10% of GDP. Note that the primary deficit is therefore negative (i.e. there is a primary surplus

Figure 1: UK Data (1972-1979)
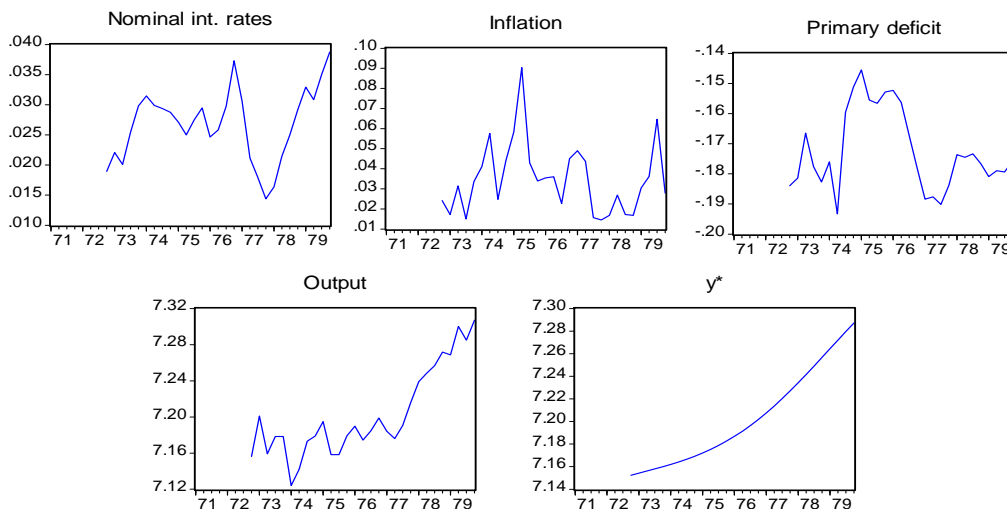
throughout). Figure 1 plots the time series.

We now turn to the empirical performance of the competing models outlined above as suggested by the method of Indirect Inference. We summarise the model estimates (by Simulated Annealing) in table 4 (The Wald test results based on these are shown in table 8 in what follows).

Table 4: Indirect estimates of the FTPL and the Orthodox models

Model parameter	Starting value	FTPL	Orthodox Taylor
θ	2.4	4.07	1.96
β	0.99	fixed	fixed
σ	2.27	0.02	0.46
κ	0.26	0.35	-
ρ	0.5	-	0.76
ϕ_π	2	-	1.31
ϕ_{xgap}	0.125	-	0.06
δ	0.003	-	0.007
c^{y*}	0.0002	fixed	fixed
γ	0.99	fixed	fixed
Shock persistence			
err^{pp}	-	0.43	0.42
err^{IS}	-	0.64	0.84
err^{y*}	-	0.93	0.93
err^{g-t}	-	-0.1	-0.1
err^{π}	-	0.24	-
err^{R^S}	-	-	0.34

The estimates for the two models' shared parameters (θ and σ) are strikingly different. In the FTPL θ is high and σ is low, implying a steep Phillips curve and a flat IS curve. Since inflation is determined exogenously by the exogenous deficit ratio and its own error process, the steep Phillips curve (which

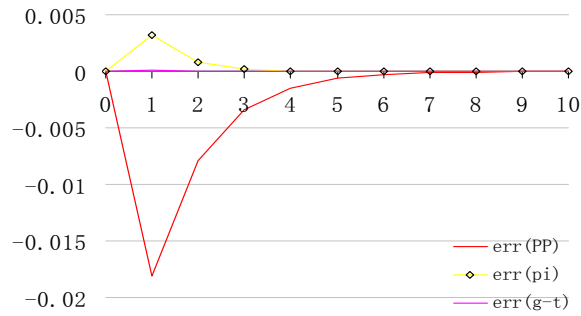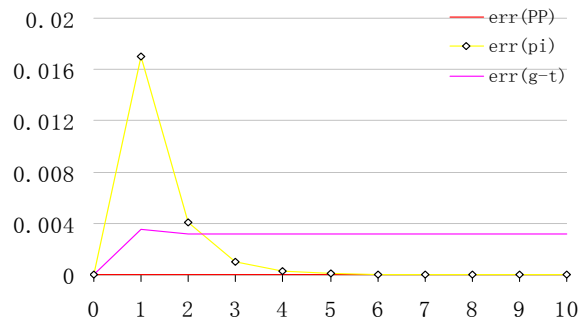Figure 2: IRFs - Output (FTPL)

Figure 3: IRFs - Inflation (FTPL)

determines the output gap) implies that the output gap responds weakly to inflation while the flat IS curve (which sets interest rates) implies that the real interest rate responds weakly to the output gap. The impulse response functions for the FTPL model (figures 2-5) confirm this[9].

Effectively this suppresses most of the simultaneity in the model as can be seen from the variance decomposition in table 5. We find this by bootstrapping the innovations of the model repeatedly for the same sample episode - plainly the variances of non-stationary variables, while undefined asymptotically,

[9]In this model the effect of IS curve shock on output and inflation is nil.
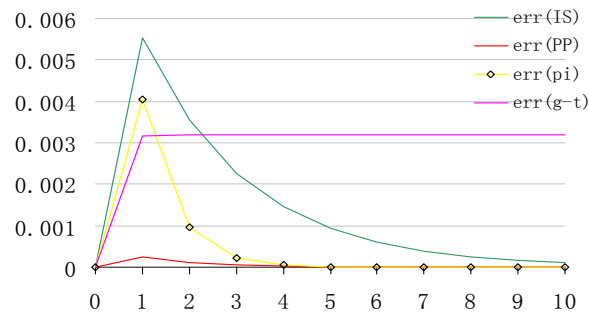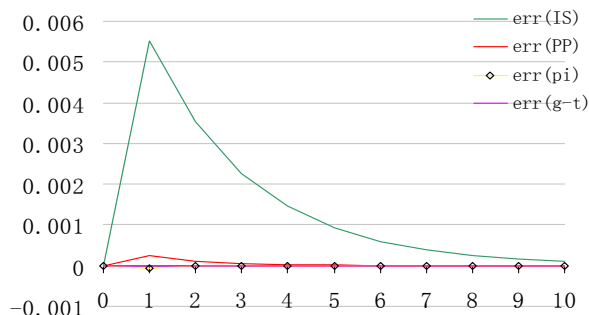
Figure 4: IRFs - Nom. int. rates (FTPL)

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Figure 5: IRFs - Real int. rates (FTPL)

are defined for this (short) sample period. One sees that inflation is disturbed by both the fiscal deficit and its own shock; output by both the productivity trend and the supply (err^{PP}) shock, with a minimal effect from the inflation shock; real interest rates entirely by its own (err^{IS}) shock; nominal interest rates respond to a mixture of shocks because they combine inflation and real interest rates.

Table 5: Variance decomposition (FTPL)

Unit: %	y	π	R	r
err^{IS}:	0	0	23.1	99.9
err^{PP}:	79.1	0	0	0.1
err^{π}:	2.2	67.1	8	0
err^{y*}:	18.7	0	0	0
err^{g-t}:	0	32.9	68.9	0
Total:	100	100	100	100

On the other hand, the estimates for the Orthodox model imply a standard Phillips Curve and also a fairly flat IS curve. The Taylor Rule has fairly standard New Keynesian responses to inflation (1.3) and the output gap (0.06), implying a flat response of interest rates to output gap movement. There is also a weak Ricardian fiscal plan, with the deficit converging extremely slowly ($\delta = 0.007$). In this model the macro-economy is orthogonal to the fiscal deficit but there is considerable simultaneity otherwise. Shocks to demand (IS), supply (PP) and monetary policy (R^S) each move all four macro variables in a relatively normal way, as can be seen from the impulse responses[10] (figures 6-9) and also the variance decomposition (carried out just as for FTPL) in table 6. To replicate the data behaviour in this episode, with its large swings in inflation, the model finds large monetary policy (err^{R^s}) shocks which need to be moderated by Taylor Rule interest rate responses to limit inflation variation; these shocks dominate inflation variance which triggers the Taylor Rule response limiting the effects on real interest rates and output. Demand (err^{IS}) shocks trigger inflation and Taylor Rule responses, so largely affecting interest rate variance. Supply (err^{PP}) shocks trigger sharp inflation responses which are largely neutralised by

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[10]In this model the effect of deficit errors are nil on output, inflation, and both nominal and real interest rates.
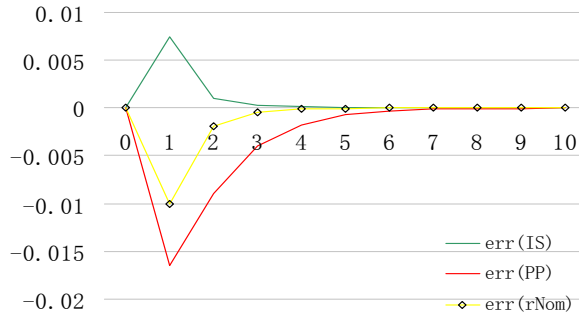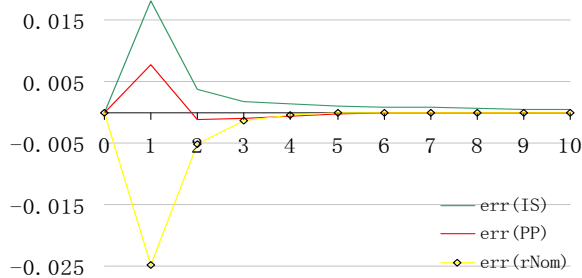
Figure 6: IRFs - Output (Orthodox Taylor)

Figure 7: IRFs - Inflation (Orthodox Taylor)

real interest rate responses; these in turn destabilise output, given the flat IS curve.

5.1 What do the tests show about the two models?

We may now consider the way in which each model replicates the VECM estimates on the data, as shown in table 7.

One thing the table immediately confirms is that both models have VAR representations (plus trend effects and error variances - we will call this VAR+) that are formally similar to each other's and also in

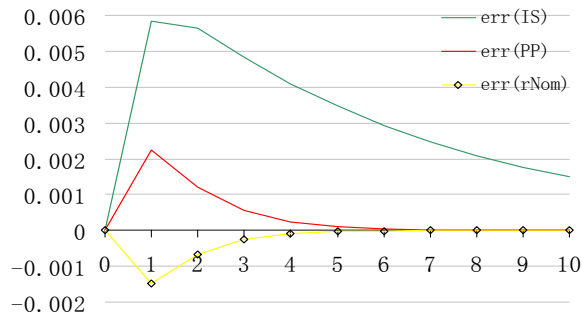Figure 8: IRFs - Nom. int. rates (Orthodox Taylor)
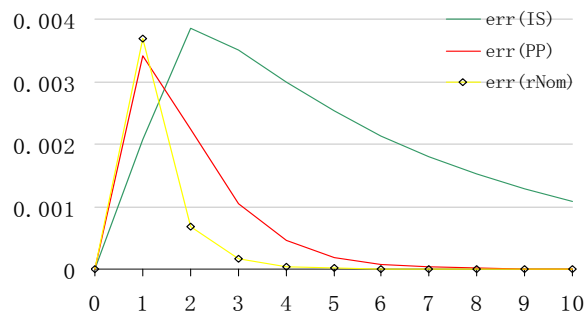

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Figure 9: IRFs - Real int. rates (Orthodox Taylor)

Table 6: Variance decomposition (Orthodox Taylor)

Unit: %	y	π	R	r
err^{IS}:	8.9	33.3	93.2	62.8
err^{PP}:	58.8	6.1	4.9	20.8
err^{R^S}:	16.8	60.1	1.9	16.3
err^{y*}:	15.5	0	0	0
err^{g-t}:	0	0	0	0
Total:	100	100	100	100

general in most cases embrace the actual data coefficients. This illustrates the formal similarity of the two models in terms of their data representation, already noted in our discussion of the identification problem: there is no a priori qualitative or numerical restriction we can apply to any VAR+ coefficient(s) that would reflect one model and not the other. Instead we rely on the joint distribution of all these VAR+ coefficients to differ in numerical detail across the two models, as we know they do from our identification discussion above: we then ask via the Wald test whether the joint distribution of each model could contain the joint values found on the data. These tests are shown in table 8.

The table suggests that when the models are asked to fit all elements of the VAR+, both models pass the Wald test at 95% confidence level. Both models deal very well with volatility. On trend and dynamics, the Orthodox passes comfortably while the FTPL is on the margin of rejection. It is in fact hard to establish much of a difference between the two models; though the p-value of the Orthodox model on the all-elements test is about double that on the FTPL, this is not a wide margin. Both models in effect marginally fail to be rejected overall[11].

However, we know that it is impossible for both models to be true, having checked that they are identified. Thus this interesting result could mean that one of the two models is true but the other one, though false, cannot be rejected because there is insufficient power with the small sample here; or it could mean that both models are false and a third model that lies somewhere between the two is true.

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[11]The results for the FTPL with the New Classical aggregate supply curve in place of the NKPC are essentially the same. We show this comparison in the appendix.

Table 7: VECM estimates: actual vs model simulations

VECM parameter	Actual	FTPL lower	FTPL upper	Ortho. lower	Ortho. upper
y_t on					
y_{t-1}	-0.2740	-0.2835	0.6072	-0.2551	0.6552*
π_{t-1}	-0.3808	-0.6171	0.4384	-0.6558	0.3253
R^s_{t-1}	-0.3502	-1.9803	1.5379	-2.3809	1.0812
$(g-t)_{t-1}$	0.7864	-1.1111	0.8165	-1.0967	0.8337
y^*_{t-1}	3.2576	-2.8302	4.1891	-3.0749	4.0808
$Trend$	-0.0089	-0.0069	0.0082*	-0.0079	0.0074*
π_t on					
y_{t-1}	0.3353	-0.5080	0.4907	-0.3631	0.6922
π_{t-1}	0.3231	-0.4205	0.4520	-0.4481	0.3925
R^s_{t-1}	1.4273	-1.0472	2.1947	-0.8633	2.5227
$(g-t)_{t-1}$	0.2311	-0.5509	1.3207	-0.7512	1.1868
y^*_{t-1}	-0.5633	-2.7752	3.6503	-3.4731	3.1963
$Trend$	0.0011	-0.0072	0.0072	-0.0075	0.0069
R^s_t on					
y_{t-1}	-0.0400	-0.1318	0.1111	-0.0591	0.1801
π_{t-1}	-0.0424	-0.2102	0.0393	-0.1588	0.0612
R^s_{t-1}	0.7967	-0.0015	0.7597*	-0.2494	0.9357
$(g-t)_{t-1}$	0.1672	-0.0162	0.4023	-0.2041	0.2378
y^*_{t-1}	0.3204	-0.8594	0.9110	-0.8656	0.7144
$Trend$	-0.0012	-0.0016	0.0019	-0.0024	0.0011
$(g-t)_t$ on					
y_{t-1}	0.2262	-0.2832	0.3029	-0.3041	0.3116
π_{t-1}	0.1545	-0.3164	0.2785	-0.2908	0.2658
R^s_{t-1}	-0.3739	-1.0098	0.9270	-1.1319	1.0838
$(g-t)_{t-1}$	0.4939	-0.0605	0.8611	-0.1124	0.8305
y^*_{t-1}	-0.6407	-2.9531	2.7286	-3.2408	2.5242
$Trend$	0.0017	-0.0057	0.0060	-0.0062	0.0077
$Var(resid^y)$	$1.80{\times}10^{-4}$	$0.85{\times}10^{-4}$	$3.18{\times}10^{-4}$	$0.74{\times}10^{-4}$	$3.09{\times}10^{-4}$
$Var(resid^\pi)$	$1.27{\times}10^{-4}$	$0.70{\times}10^{-4}$	$2.85{\times}10^{-4}$	$0.59{\times}10^{-4}$	$2.89{\times}10^{-4}$
$Var(resid^{R^S})$	$0.10{\times}10^{-4}$	$0.05{\times}10^{-4}$	$0.15{\times}10^{-4}$	$0.04{\times}10^{-4}$	$0.13{\times}10^{-4}$
$Var(resid^{g-t})$	$0.68{\times}10^{-4}$	$0.18{\times}10^{-4}$	$1.11{\times}10^{-4}$	$0.17{\times}10^{-4}$	$1.15{\times}10^{-4}$

*: number lying beyond the lower/upper bound.

In this case both models could have enough elements of truth in them not to be rejected. This would suggest that some combination of the two, combining these elements, could be closer to the true model than either alone.

This was, as should have been clear from our earlier discussion of the context, a period of great uncertainty in UK economics and politics; in 1975 there was even a proposal by certain Labour politicians led by Tony Benn, a leading minister in the government, to install a siege economy (effectively to insulate an FTPL strategy from external pressures), and this was only narrowly defeated within the Labour government. It may therefore well be that people gave some probability to an FTPL regime continuing and some to an orthodox regime reasserting itself - in the manner described by Leeper (1991).

Table 8: Wald tests of the FTPL and the Orthodox models

Elements tested	FTPL	Orthodox
Trend and dynamcis	95.2	89.4
(VECM coeff. only)	(.048)	(.106)
Volatility	6.4	11.8
(VECM resid. only)	(.936)	(.882)
All elements	93	86.7
(VECM coeff.+resid.)	(.07)	(.133)

Note: p-values in parentheses; p-value = (100-Wald percentile)/100.

5.2 Results for a combined model

The above suggests that inflation behaviour was being influenced by expectations of two potential regimes each with a certain probability. Inflation in this model equals expected inflation because no information lag is assumed. Hence we can think of the FTPL inflation equation as showing the inflation that would be expected (and would also occur) at time t if the FTPL regime was in operation. Similarly for the Orthodox model we can think of the Taylor Rule equation as defining the inflation that would be permitted by the rule (and so would also occur) at prevailing interest rates; thus this would be the inflation expected if the Orthodox regime was prevailing. We can therefore create a model in which inflation expectations are governed by the probability-weighted inflation rate under the two regimes; this will be also the actual inflation, since $actual = expected$. In this model inflation will thus be a weighted combination of the two models' inflation equations - the FTPL and the Taylor Rule equations:

$$
\begin{aligned}
\pi_t &= W^{FTPL}\kappa(g_t - t_t) \\
&+ [1 - W^{FTPL}]\frac{1}{\phi_\pi}[\frac{1}{(1-\rho)}(R_t - \rho R_{t-1}) - \phi_{xgap}(y_t - y_t^*) - \alpha] + err_t^{Weighted\ \pi}
\end{aligned}
$$

Given that inflation is determined by the probability-weighted average of each regime's own inflation outcome, we now have a composite inflation error - which in principle consists of the weighted combination of the two regime error processes plus any temporary deviations of inflation from this weighted combination (e.g. due to variation in the weight). Since we cannot observe what the inflation rate actually was in each regime, only the average outcome, we can only observe a composite error.

All the other equations are the same, with the exception of the fiscal deficit equation which has an AR coefficient that is so close to zero that it cannot resolve the uncertainty about which regime is operating; we allow it to be determined by the model estimation.

When we examine the results of this weighted model (as we report in tables 9 and 10 in comparison to the earlier results), we see that it improves on both models alone, giving a weight on FTPL of 0.34.

The improvement comes in fitting the trend and dynamics, as all the models have little difficulty fitting the volatility in the data. The model now adopts a very flat Phillips Curve, a very steep IS Curve, and a tough Taylor Rule (with high response to inflation and virtually no response to the output gap). The effect of the FTPL deficit mechanism is strong, as the one-third weight allows the direct effect of the deficit on inflation to be about five times as high.

Table 9: Indirect estimates of the models: Weighted vs FTPL Orthodox

Model parameter	FTPL	Orthodox Taylor	Weighted model
θ	4.07	1.96	0.07
β	fixed	fixed	fixed
σ	0.02	0.46	4.38
κ	0.35	-	1.75
ρ	-	0.76	0.69
ϕ_π	-	1.31	3.93
ϕ_{xgap}	-	0.06	0.01
δ	-	0.007	0.005
c^{y*}	fixed	fixed	fixed
γ	fixed	fixed	fixed
$Weight$			0.34
Shock persistence			
err^{pp}	0.43	0.42	0.28
err^{IS}	0.64	0.84	0.47
err^{y*}	0.93	0.93	0.95
err^{g-t}	-0.1	-0.1	-0.1
err^{π}	0.24	-	-
err^{R^S}	-	0.34	-
$err^{Weighted\ \pi}$	-	-	0.26

Table 10: P-values of the models: Weighted vs FTPL Orthodox

Elements tested	FTPL	Orthodox	Weighted model
Trend and dynamcis (VECM coeff. only)	4.8	10.6	11.5
Volatility (VECM resid. only)	93.6	88.2	88.2
All elements (VECM coeff.+resid.)	7	13.3	15.8

Note: p-values in %; Wald percentile = 100 - p-value.

The blend of Orthodox with FTPL is revealed in the IRFs (figures 10-13). The IS and PP shocks affect the economy much as in the Orthodox case. A positive weighted inflation error is a combination of a direct temporary shock to inflation as in the FTPL model with an easing of monetary policy in the Taylor Rule error. The fiscal shock behaves as in the FTPL model, strongly affecting inflation and nominal interest rates.

The resulting variance decomposition (table 11) gives the supply shock and the weighted inflation shocks about an equal role in output variability; the latter includes both monetary policy and exogenous

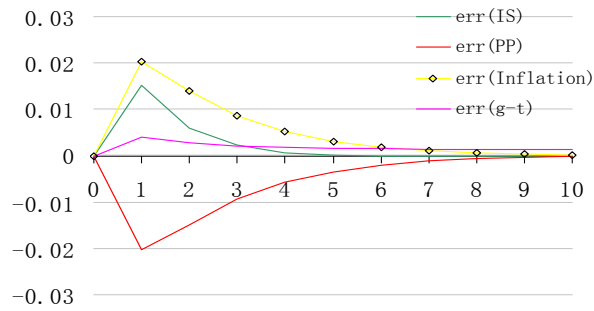Figure 10: IRFs - Output (Weighted model)

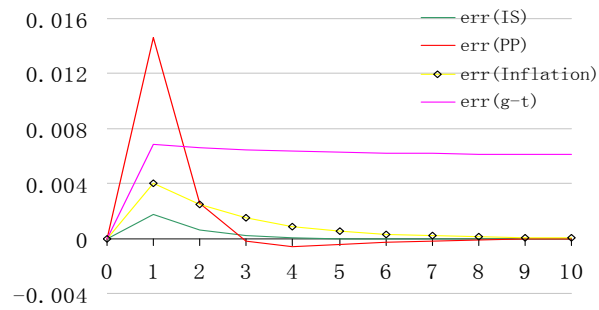Figure 11: IRFs - Inflation (Weighted model)

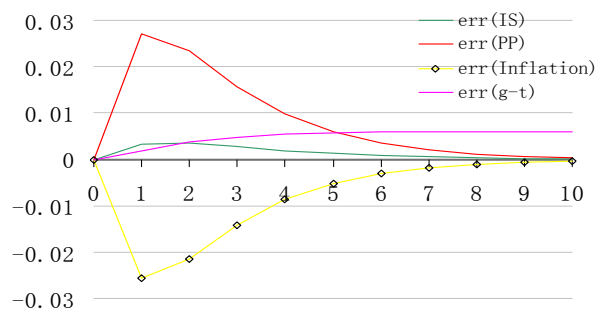Figure 12: IRFs - Nom. int. rates (Weighted model)

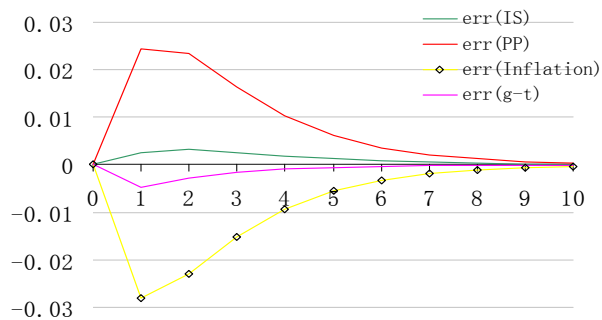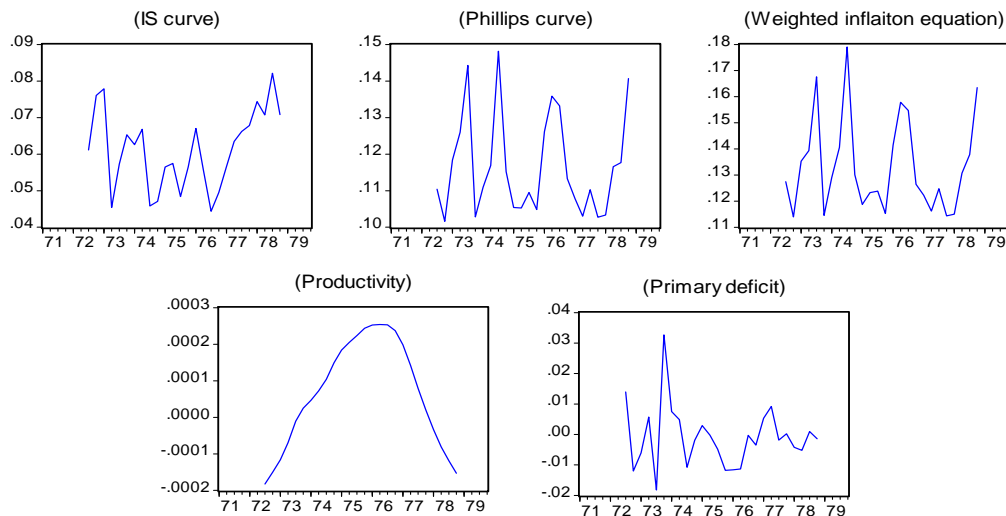Figure 13: IRFs - Real int. rates (Weighted model)

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Figure 14: Structural errors (Weighted model)

inflation shock. These two shocks also share the main role in real and nominal interest rate variability (the fiscal shock also contributes an eighth to the nominal rate). For inflation variability the fiscal shock becomes dominant, with the supply shock providing the rest. What we see here in the weighted model is that the FTPL influences remain important.

Table 11: Variance decomposition (Weighted model)

Unit: %	y	π	R	r
err^{IS}:	14.2	0.4	1	0.9
err^{PP}:	40.4	28.1	46.9	47.6
$err^{Weighted\ \pi}$:	36.8	3.2	40	50.4
err^{y*}:	6	0	0	0
err^{g-t}:	2.6	68.3	12.1	1.1
Total:	100	100	100	100

In the next section we review the implications of this successful weighted model for the causes of what happened quarter by quarter. Clearly, huge errors in policy were made, to permit the large rise in inflation and the prolonged recession both to occur during the mid-1970s. In our final concluding section, we reflect on the policy lessons and how they were absorbed subsequently in UK political choices.

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6   A time-line of the UK 1970s episode according to the weighted models

We see first the errors backed out period by period in figure 14. Begin with the inflation error in the weighted FTPL/Taylor Rule equation. This is some combination of monetary policy and exogenous inflation (notably commodity price) shocks; the 1973 and 1974 peaks were both periods of expansionary money and surging commodity prices. 1977's low point corresponds to the IMF visit, which tightened money sharply. Next, we note that the PP shock mirrors this weighted inflation error closely; this is because with a very flat Phillips Curve movements in inflation are governed almost solely by expected inflation for next quarter; but since the fiscal deficit is close to a random walk this turns out to be very close to current expected inflation which too is dominated by the current fiscal deficit. The IS shock turns negative in the mid-1970s before recovering in the late 1970s. The fiscal deficit shock is large and positive early on before being restrained later in the period.

In the timeline for output (figure 15) we see that all these shocks play a part; the dominant role, as foreshadowed by our variance decomposition, is taken by the supply and inflation shocks but these essentially cancel each other out, leaving the IS shock as the factor creating recession and the productivity shock assisting it in generating later recovery. For inflation (figure 16) the fiscal shock is the key factor generating the sharp inflation explosion from 1973-5, aided by the supply shock. For interest rates (figure 17), fiscal, supply and inflation shocks all three are major factors, but tend to cancel each other out, so that interest rates move little; this is consistent with the model's finding that monetary policy itself had only a small effect on inflation during the period, because although the weight on the Taylor Rule is high at 0.66 the Taylor Rule terms themselves vary little - interest rates move little while the movement in them required to restrain inflation (as implied by the high inflation response coefficient) is large.

Thus the overall picture of the period from our weighted model is that the fiscal deficit was a key factor in driving inflation expectations and that monetary policy in practice did little to moderate these; interest rates varied little. Output was the victim of poor productivity growth and the demand shocks of the mid-1970s, with these both improving somewhat later in the period.

From these timelines it is clear that poor expected macro policy choices, both fiscal and monetary, reinforced the bad results already created by the poor growth of productivity. The two factors together produced economic results so bad that the British voters backed Margaret Thatcher's radical policy changes over a whole decade, embracing not merely macro-policy but also supply-side policy reforms. Whether the voters would have backed her had the economy not been in such a parlous condition in 1979 is a matter of intense interest for political economy but clearly lies well outside the scope of this paper.

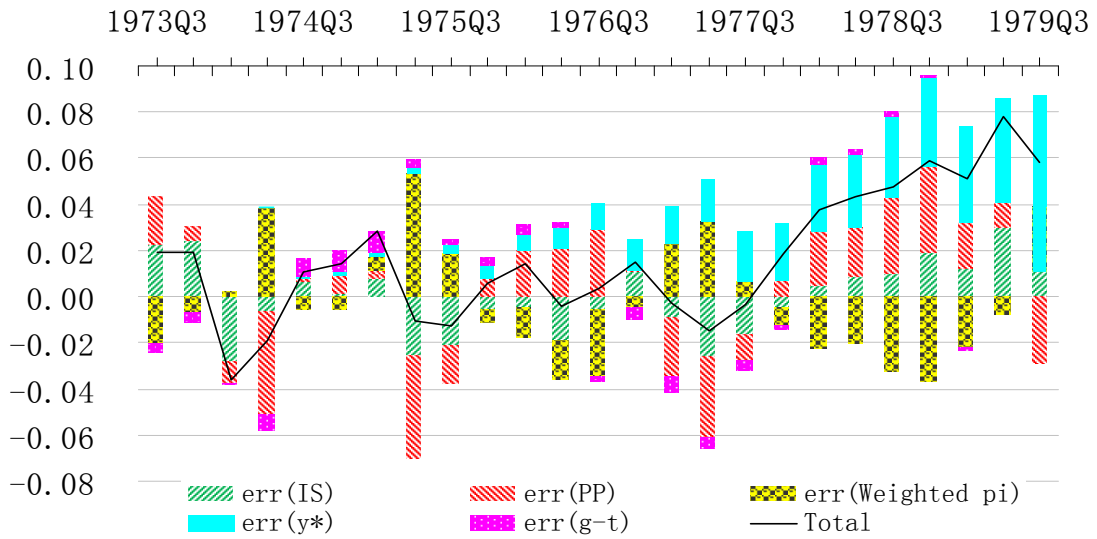Figure 15: Time-line for output (Weighted model)
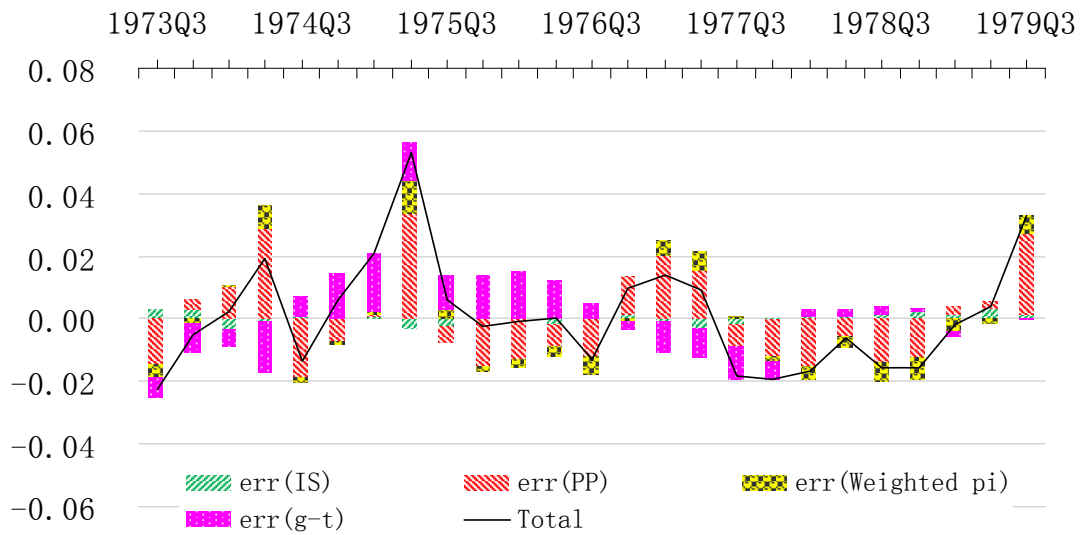

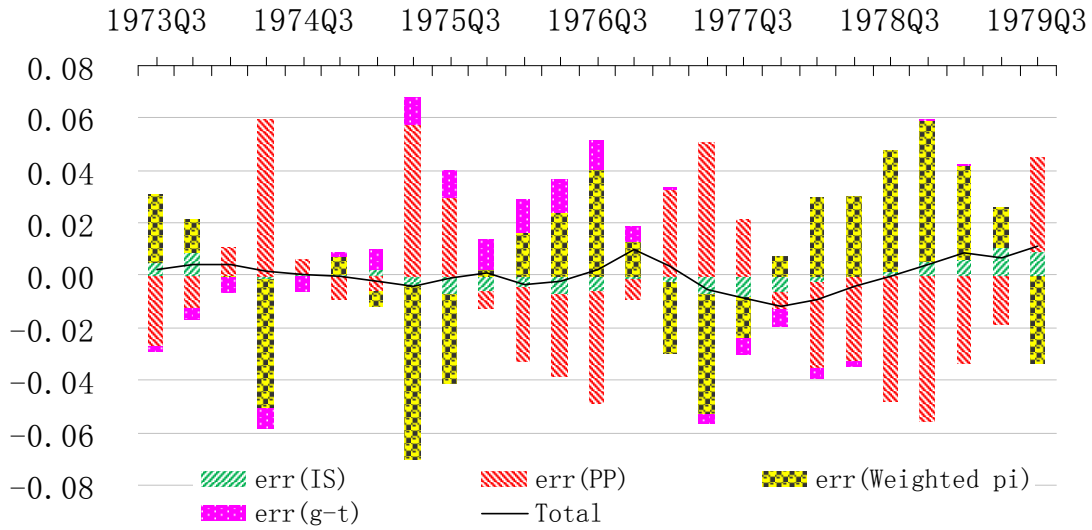Figure 16: Time-line for inflation (Weighted model)

Figure 17: Time-line for nom. int. rates (Weighted model)

7   Conclusions

In this paper we have examined an episode of UK history when fiscal policy may have been set without thought for future solvency implications and monetary policy may have been entirely accommodative - a case of the fiscal theory of the price level. Because the data implications of this theory are qualitatively similar to those of the Orthodox theory in which monetary policy is set by a Taylor Rule to hit an inflation target and fiscal policy is set to achieve solvency at that inflation rate, we have set up the two theories as rival structural models and tested each against the behaviour found in the data, by the method of Indirect Inference. Our finding is that neither model is rejected by the data and that the Orthodox model can account better for the data behaviour than the FTPL; but also that the best account of the period assumes that expectations were a probability-weighted combination of the two regimes. The policies pursued in this episode generated generally high as well as volatile inflation, together with weak productivity growth and a long-lived recession. They paved the way for a decisive change of approach to both fiscal and monetary policy after the election of 1979.

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AppendixA Derivation of Government Budget Constraint

The government budget constraint gives us

$\frac{B_{t+1}}{R_t} = G_t - T_t + B_t + \frac{B_t}{R_t}$

Where,

G_t is the government spending in money terms,

T_t is the government taxation in money terms,

R_t is the amount of nominal interest the government must pay. The value of the bonds outstanding is $B \times \frac{1}{R}$.

We can derive an expression for government budget constraint in the forward direction by substituting forwards for future bonds outstanding, yields

$\frac{B_t}{R_t} = E_t \sum_{i=0}^{\infty} (T_{t+i} - G_{t+i}) \frac{1}{(1+R_t)^{i+1}}$

We approximate this expression by

$\frac{B_t}{R_t} = \sum_{i=0}^{\infty} \frac{(\bar{t}_t - \bar{g}_t)(1+\bar{\pi}_t)^i P_t(1+\gamma)^i y_t}{(1+R_t)^{1+i}}$

where $\bar{t}_t, \bar{g}_t, \bar{\pi}_t, \gamma$ are the currently expected permanent values respectively of the tax/GDP and government spending/GDP ratios, the inflation rate, and the growth rate (assumed constant at all times); $\overline{P}_t, \overline{y}_t$ are respectively the permanent price level and equilibrium output

$= (\bar{t}_t - \bar{g}_t) \overline{P}_t y_t^* \sum_{i=0}^{\infty} \frac{(1+\gamma+\bar{\pi}_t)^i}{(1+R_t)^{1+i}}$

$= (\bar{t}_t - \bar{g}_t) \overline{P}_t y_t^* \sum_{i=0}^{\infty} \frac{(1+\gamma+\bar{\pi}_t)^{1+i}}{(1+R_t)^{1+i}(1+\gamma+\bar{\pi}_t)}$

If γ and $\bar{\pi}_t$ are both small enough,

$\sum_{i=0}^{\infty} \frac{(1+\gamma+\bar{\pi}_t)^{1+i}}{(1+R_t)^{1+i}} = \sum_{i=0}^{\infty} \left(\frac{1}{1+R_t-\gamma-\bar{\pi}_t}\right)^{1+i} = \left(\frac{1}{1-\frac{1}{1+r_{t-}^*\gamma}} - 1\right) = \left(\frac{1}{r_t^*-\gamma}\right)$

Hence, $\frac{B_t}{R_t \overline{P}_t y_t^*} = \frac{(\bar{t}_t - \bar{g}_t)}{(1+\gamma+\bar{\pi}_t)(r_t^*-\gamma)}$.

AppendixB Estimates and Performance of the FTPL Model with New Keynesian and New Classical Aggregate Supply Curves

	Panel A	
Model parameter	FTPL (benchmark NKAS)	FTPL (NCAS)
θ	3.89	3.74
β	fixed	fixed
σ	0.02	0.02
κ	0.34	0.36
Shock persistence		
err^{PP}	0.43	0.43
err^{IS}	0.64	0.64
err^{y*}	0.93	0.93
err^{g-t}	-0.1	-0.1
err^{pi}	0.25	0.24
	Panel B	
Wald test type	FTPL (benchmark NKAS)	FTPL (NCAS)
Directed Wald percentile	89	90.4
(VECM coeff. only)	(0.11)	(.096)
Directed Wald percentile	36.6	33.9
(VECM resid. only)	(.634)	(.661
Full Wald percentile	88.8	91.4
(VECM coeff.+resid.)	(0.112)	(.086)

Note: p-values in parentheses; these are (100-Wald percentile)/100.