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Does the Fiscal Theory of the Price Level help to explain the US economy? *

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Abstract

We implement a quantitative empirical test of FTPL defined as a non-Ricardian model of fiscal policy (the 'FTPL model'). We used Indirect Inference to compare its match to postwar US data with that of a standard New Keynesian model with Ricardian fiscal policy. The distinguishing feature of this FTPL version of the orthodox New Keynesian model is that government spending and taxation are allowed to evolve according to data-based exogenous processes. Nominal debt accumulates according to the government's budget constraint and at a future date, T, this accumulated nominal debt must be devalued to a sustainable real level by a terminal price level, which in turn defines an average inflation rate to that point from the pre-regime price level. This rate determines expected inflation which then enters the model up to the terminal date. Thus inflation is caused by expected fiscal policy. During this FTPL regime monetary policy has a weak (less than unity) interest rate response to inflation. The FTPL regime is expected to end at T and be replaced then by a Ricardian New Keynesian (orthodox) regime which will generate primary surpluses that back the resulting real debt at T. While this hypothesised FTPL regime was rejected over the whole postwar sample, it was accepted for the post-GFC period alone, with the orthodox regime prevailing otherwise; this regime combination was as probable an explanation of the whole period as the orthodox regime alone. Nevertheless, a more probable model was the New Keynesian model with an orthodox monetary regime throughout and a fiscal regime whose Ricardian commitment was limited by the debt-related probability of a future switch to the FTPL. This model provided the best-fitting explanation of the whole period. This gives a key role to the FTPL in explaining postwar US behaviour through its continuous debt-related effect on the credibility of the fiscal Ricardian commitment.

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1 Introduction

The Fiscal Theory of the Price Level (FTPL) posits that inflation is determined by fiscal policy rather than monetary policy. When the government follows a non-Ricardian fiscal regime — setting primary surpluses exogenously without committing to service debt — the price level must adjust to ensure intertemporal solvency. This contrasts sharply with orthodox New Keynesian models where monetary policy controls inflation via the Taylor Rule (Taylor, 1993) and fiscal policy adjusts endogenously to satisfy the government budget constraint.

Despite three decades of debate (Leeper, 1991; Woodford, 2001; Cochrane, 2023), empirical tests have failed to discriminate between these theories. The fundamental problem is observational equivalence in particular respects: both theories satisfy the intertemporal government budget constraint, differing only in whether fiscal policy adjusts to inflation or inflation adjusts to fiscal policy. Tests based on long-run budget balance, cointegration between revenues and spending, or impulse responses of debt to surpluses cannot identify the direction of causation (Cochrane, 1999, 2001; Bajo-Rubio et al., 2014).

This paper implements the first quantitative test capable of distinguishing these theories using a structural model and US postwar data. We exploit differences in the policy commitments implied by each regime to achieve identification. Under Ricardian policy, the Taylor Rule determines inflation and fiscal policy is committed to generate future surpluses sufficient to service any debt path without default; thus at any time T in the future, outstanding debt is backed by these future surpluses. This model is the well-known Ricardian New Keynesian model, which we estimate and test across the whole postwar sample. We also propose an alternative model of an 'FTPL episode' under which during some sample period 'episode' exogenous fiscal policy determines nominal debt by the date T periods ahead and the price level adjusts to ensure that this debt is devalued sufficiently for the government to remain solvent, with sufficient future surpluses after T to back this devalued debt; monetary policy, as represented by an interest rate rule, is 'passive' — that is, it responds weakly to inflation, i.e. with a coefficient less than unity. This passivity ensures that the monetary authority does not try to overturn the inflation implied by fiscal policy, since if it did there would be no feasible equilibrium. These distinct policy conditions generate different reduced-form dynamics over the sample period for which they prevail; we investigate both models over the whole period as well as for different sample periods. We test whether each model can replicate observed data behaviour in these periods using indirect inference, a simulation-based method shown to have high power in small samples such as we encounter here (Le et al., 2016a).

Our findings reconcile competing claims in the literature. The orthodox NK model with Ricardian fiscal policy provides the best structural account of the whole postwar US sample. The FTPL model by contrast is rejected over the whole period. We also split the sample at the date of the Global Financial Crisis (GFC), after which point fiscal policy became crucial in preventing bank collapse and monetary policy supported it with largescale asset purchases under 'Quantitative Easing', financed by creating bank reserves. We argue that in the post-GFC period, this active fiscal policy could well imply an FTPL episode. We find indeed that a combination of FTPL pre-GFC and orthodox post-GFC is strongly rejected; but that a combination of the orthodox model pre-GFC with FTPL post-GFC is not rejected by our test and is also about as likely as the orthodox model throughout. Thus for continuous-regime models, one which switches to FTPL at the GFC is as probable as one where the orthodox continues throughout, which supports the idea of FTPL post-GFC. Finally, we test a model of orthodox policy throughout but within which FTPL plays a crucial role through credibility effects: rising debt increases the perceived probability of future fiscal dominance, raising inflation expectations and current inflation. We find that this credibility-augmented model throughout is the most likely model of the whole period by a factor of two, compared with the orthodox model throughout or the equally probable combined model above. The credibility mechanism was particularly important post-GFC when debt-GDP ratios rose sharply. FTPL's importance, we find, thus lies not in being the operating regime but in threatening orthodox policy credibility — analogous to "fiscal backing" in Bianchi, Faccini and Melosi (2023) and Smets and Wouters (2024).

Our contribution is threefold. First, we provide model identification of the orthodox regime and a proposed FTPL regime and a test with sufficient power to discriminate between these models of macroeconomic policy previously thought observationally equivalent in respect of available tests. Second, we systematically explore possible combinations of the two regimes across the key structural break caused by the GFC — finding support for the idea of FTPL emerging after the GFC. Third, we uncover FTPL's most likely role

in US inflation dynamics as coming through regime uncertainty rather than regime switches.

The paper proceeds as follows. Section 2 reviews related literature on FTPL testing and regime switching models. Section 3 specifies the orthodox New Keynesian model under Ricardian fiscal policy and also sets out our proposed FTPL model and its non-Ricardian fiscal regime. The solvency conditions and characterizes fiscal processes under both models are dervied, and our model with regime uncertainty is introduced. Section 4 describes our indirect inference methodology. Section 5 presents our empirical results. Section 6 concludes.

2 Literature Review

2.1 Testing FTPL

Cochrane's suggestion of a continuous FTPL regime (Cochrane 2023) comes after a long and heated debate in which a variety of tests have been put forward, though with little success. The FTPL has been set out and developed in Leeper (1991), Sims (1994), Woodford (1998a, 2001) and Cochrane (2001, 2005) — see also comments by McCallum (2001, 2003) and Buiter (1999, 2002), and surveys by Kocherlakota and Phelan (1999), Carlstrom and Fuerst (2000) and Christiano and Fitzgerald (2000). Empirical tests have been proposed by Bohn (1998), Canzoneri et al. (2001) and Bajo-Rubio et al. (2014). 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. In addition, there has been extensive work on FTPL in monetary unions[1] and specifically on European economies[2].

Nonetheless, a number of problems beset empirical tests of the FTPL. Cochrane (1999, 2001, 2005, 2022 and 2023) has noted that there is a basic identification problem affecting tests of present value relations such as the intertemporal budget constraint (IGBC). This is a point also noted by Bajo-Rubio et al. (2014). The IGBC is a logical implication of (and is derived from) the government budget constraint which is an identity. Whether policy is non-Ricardian, as in the FTPL, or Ricardian as in orthodox theory, the IGBC must be satisfied. As a result, conventional tests of the long-run implications of the IGBC cannot distinguish between Ricardian and non-Ricardian policies. In the FTPL fiscal policy is exogenous which forces inflation to deliver fiscal solvency and hence satisfy the IGBC. The IGBC can also be consistent with an exogenous monetary policy that determines inflation in the 'orthodox' way, with Ricardian fiscal policy endogenously responding to the government budget constraint to ensure solvency given that inflation path — the orthodox model. A further identification problem is that equations that appear to reflect the FTPL and are used to 'test' it, could also be implied by the orthodox set-up.

Bohn (1998) has proposed a 'backward-looking' feedback rule where the government is Ricardian with the government primary surplus reacting positively to lagged debt; this can be tested by checking the cointegration of revenue and spending (both non-stationary series) with a unit coefficient. In the 'forward-looking' version due to Canzoneri et al. (2001), the future level of debt should react negatively to the current primary surplus. Here the test is of the impulse response function of debt to the surplus. This version too requires cointegration to hold.

The cointegration test needs in principle to include inflation-tax revenues. But these revenues include the reduction in the value of debt due to inflation. This inflation is precisely what is generated by FTPL to ensure solvency. As solvency is always assured in equilibrium by either Ricardian or non-Ricardian FTPL conditions, cointegration must hold for either condition; and so, while interpretation is possible, there is, strictly speaking, no way of distinguishing which condition is causing this to happen.

As a result of this critique, some authors — for example Bianchi (2012), Bianchi and Melosi (2013) — have abandoned the idea of testing whether the FTPL was, or was not, prevailing in an episode. Instead they have assumed that various possible combinations of fiscal and monetary policy were operating at different times, with switches between them occurring according to some Markov process. They then estimated, usually by Bayesian methods, which combinations were operating and when. In the context of the US, to

[1] See for example Sims (1997), Woodford (1998b), Bergin (2000), Canzoneri et al. (2001), and Bajo-Rubio et al. (2009).

[2] See Mèlitz (2000), Afonso (2000) and Ballabriga and Martínez-Mongay (2003) and Bajo-Rubio et al. (2014).

which most of this work is devoted and where the constitution divides power between three branches of government, this idea, that at any one time there is not necessarily a definite 'regime' operating, but rather a constant process of flux between transitory regimes, may well seem plausible.

After a long period in which the FTPL has been given little credence Cochrane (2022 and 2023) has returned to its defence. On p500 of Cochrane (2023) he says:

"Observational equivalence goes both ways. Any rejection of fiscal theory from equilibrium time series also rejects other theories of equilibrium formation. Observational equivalence opens the door to understanding any sample equally via fiscal theory as via new-Keynesian models. It guides us to find and examine the identifying assumptions of any proposed test. It guides us to look to institutions, regimes, commitments, and statements by fiscal and monetary authorities about how they operate, commentary on how people expect them to operate, narrative approaches to historical events, and times of regime change or construction."

Hence Cochrane (2022) argues that the models can best be tested by whether they give plausible accounts of historical episodes. He does this from the FTPL perspective, where the government is fiscally dominant, and accounts for inflation in each episode in terms of its policies towards primary surpluses. This 'narrative approach' seems attractive but has the drawback that 'plausibility' is difficult to achieve in an objective way. As an illustration, consider his account of why the introduction of low inflation targets introduced in the early 1980s for independent central banks led to the sharp fall in inflation. According to Cochrane, this was due to governments agreeing to back these new targets with higher primary surpluses, so that expected inflation melted away without the need for any monetary tightening via higher interest rates or induced recession. However, the orthodox model can also provide a narrative rationale of these events, namely that the new monetary targets gave a credible commitment to prevent above-target inflation by raising interest rates as necessary; by implication the government would have to produce primary surpluses to meet solvency in a Ricardian way. Inflation fell in response to the new rules, and fiscal policy had to adapt too.

A second episode, the recent aftermath of the 2008 banking crisis, provides a further example. According to the FTPL, the collapse of interest rates to the zero lower bound, ZLB, effectively made primary surpluses unnecessary as the solvency constraint was non-binding and hence no inflation was needed even though there was massive printing of base money via 'QE'. An orthodox account dwells on the role of a new regulatory assault on the banks that made it expensive to lend, with the result that broad money and credit hardly rose, demand weakened and there was no support from fiscal policy.

These rival accounts illustrate the limitations of the narrative approach. In the absence of quantitative support from models that specify the exact connection between surpluses and expected future surpluses, it is difficult to see any objective means of judging between them. We therefore propose an alternative approach, namely, to formulate the rival accounts of these and other episodes into quantitative model predictions whose accuracy can be properly measured against actual data behaviour. We aim to do this via tests based on Indirect Inference in which estimates of an auxiliary model using actual data are compared with estimates using data simulated from each model, where the auxiliary model is chosen to capture observed quarterly U.S. data 1959-2017. This requires simulated data of the whole economy from each model which should, in principle, permit the full identification of the two rival models, thereby enabling a clear and powerful test of each theory. We distinguish between the two models through their implied restrictions on fiscal and monetary policy in any given sample period 'episode'; these are the identifying restrictions for each model. To carry out the test we need to specify a full dynamic model for each theory. We base this on the full model of Le et al. (2021) which has been estimated on US data across the whole postwar period from 1959. This model embodies orthodox theory and fits the data behaviour well. Our task in this paper is to repurpose it as an FTPL model and test whether this too can pass our Indirect Inference test. In order to respond to Cochrane's charge that this is a futile task since the rival theories are in general observationally equivalent and so both will match the data equally well, we need to specify alternative identifying restrictions which clearly distinguish between the rival models. These restrictions are provided through the contrasting and distinct conditions on policy behaviour imposed by each theory; it is these that create identification and different reduced forms. This is because orthodox theory forces inflation and interest rates to be consistent with the Taylor Rule, whereas FTPL forces them to be consistent with debt at the future date T and the associated primary surplus from then.

An earlier effort by Fan et al. (2016) to apply these methods to the UK for the 1970s and 1980s tended to support Cochrane's assertion. They found evidence that the FTPL model did have influence during both periods in a weighted joint model of both while the FTPL model on its own could not be rejected, and nor

could the orthodox model. The weight on FTPL in the best-fitting joint model fell from about a half in the 1970s to around 15% in the 1980s, as fiscal policy was sharply tightened. These UK results suggest that it is hard to tell the models apart, even using the full powers of Indirect Inference on complete models; the need to use a weighted combination of them suggests that each regime may have been operating during different parts of each decade. We wish to discover whether using US data covering the majority of the postwar period can provide a clearer distinction between the two models. In effect, we are using each framework, with its identifying restrictions, to create a quantitative, model-based, account of the historical episodes encountered in the postwar period in place of the qualitative accounts illustrated above, and thereby move the debate forward.

2.2 Regime-switching models

Research on fiscal and monetary policy has also examined models where there are switches of regime between the two models either randomly or non-randomly rather than being fixed as assumed so far. We review the research on this approach before describing how we modify our models to include switching effects.

Many researchers estimate Markov-switching policy rules and embed them into standard DSGE models to analyse transitions between active and passive monetary and fiscal regimes. Davig and Leeper (2007) allow the reaction coefficients of monetary policy to change randomly, so that the monetary policy rule can satisfy the Taylor principle in the long run, even while deviating from it intermittently — whether briefly or for a substantial period — according to a Markov process. They first estimate a Markov-switching process that produces determinacy, and then use it in a DSGE model to find a solution for the rational expectations model equilibrium. The expectation of possible future regime changes leads agents to alter their expectations functions. The impact of this depends on the probability of transitioning from the possible future regime back to the current one, on the policy behaviour responses, and on the persistence of the new regime. They note that due to expectations of active fiscal policies in the future, the fiscal-led regime, or FTPL, is always operative in the model, even when the current regime is the conventional monetary-led one. They find that the possibility of regime switching amplifies macroeconomic responses to exogenous shocks.

Bianchi and Melosi (2017) examine how economies can transition between fiscal and monetary policy regimes under fiscal stress. They first estimate a Markov-switching VAR model using post-war data to highlight distinct regimes in the relationship between the deficit-to-debt ratio and inflation. They then develop a structural model incorporating these features to study the Great Recession. The model assumes that policymakers' behaviour is characterised by a mixture of both monetary-led and fiscal-led policy. Due to large demand shocks, the economy occasionally hits the ZLB. When this occurs, the central bank sets the nominal interest rate to zero, and the fiscal authority disregards the debt level. A parameter controls agents' beliefs about policymakers' future policies. They find that during the recent crisis, the probability of a switch to the fiscal-led regime increased, even though agents still regarded a return to the monetary-led regime as more likely. They argue that although the probability of switching to a fiscal-led regime is relatively low, the inflationary pressure arising from the large stock of debt in that regime is sufficient to prevent deflation in the aftermath of the Great Recession and the post-pandemic inflation. In this literature, fiscal policy does not respond to increasing levels of debt, which is taken as an indication that fiscal policy has entered a new regime.

While it was accepted that researchers could estimate stand-alone Markov switching rules and then plug them into a calibrated DSGE model, Bianchi and Ilut (2017) estimate the policy rules and the other parameters of the DSGE model jointly for the US sample period 1954-2009. The model assumes three policy regimes — monetary-led, fiscal-led and a conflict regime with both policies being active. They find that the fiscal authority was the leading authority from the late 50s until Volcker's appointment, and the monetary authority was the leading authority from then to the end of the sample. The monetary-led regime is the most recurrent regime, but when a conflict between two authorities arises the fiscal authority is more likely to prevail. They also use impulse responses to interpret the role of agents' beliefs and how fiscal shocks propagate through the economy across different regimes. They find that if the monetary-led regime had been in place for the entire sample, or if agents had been confident about the switch to the monetary-led regime, there would have been no Great Inflation, and the debt-to-GDP would have been higher. This is because the rise in trend inflation and the decline in debt in the 70s were caused by a series of fiscal shocks that were inflationary when monetary policy was passive. Likewise, as the active fiscal regime caused the

Great Inflation and decline in the debt-to-GDP ratio, the change in the mix to monetary-led policy at the end of 1981 reversed these dynamics and caused recession. Had the switch not occurred, they find that inflation would have been higher for another 15 years and the reversal in the debt-to-GDP dynamics would not have occurred.

Bassetto and Miller (2025) theorise that non-random regime switches between monetary and fiscal policy explain sudden episodes of inflation. They assume that agents are not endowed with knowledge of the prevailing regime but can spend resources to learn about it. Consumers, who save via nominal government bonds, must decide whether it is worth incurring the cost of acquiring information about future government surpluses compared with the benefit of making more informed saving decisions. For example, safe assets, such as government bonds, have a very high cost associated with researching their backing. In normal times, all households hold uniformly positive beliefs about the repayment of a safe asset. However, during a crisis, when the backing of these assets is in doubt, they are willing to pay the price to research it. When buying government bonds, consumers anticipate that the economy may be in either a monetary-led or fiscal-led regime and form their expectations accordingly. As long as they perceive a high probability of a monetary-led regime, government debt is considered an informationally insensitive asset, and there is no incentive to acquire information about future deficits. In this case, a small amount of bad fiscal news does not trigger inflation. However, when signals of fiscal imbalances suggest a greater likelihood of a fiscal-led regime, a threshold may be reached at which agents begin to acquire more information about future deficits. At this point, bad news about current and future deficits has an immediate impact on prices, as concerns over higher future inflation begin to influence current inflation.

In another approach that avoids random switches, Bianchi, Faccini and Melosi (2023) develop a New Keynesian model that incorporates interactions between monetary and fiscal policy, allowing for intermediate regimes with partial fiscal banking. In this model, in response to business cycle shocks and funded fiscal shocks, the monetary authority controls inflation and fiscal policy stabilises debt by running future surpluses. However, the model also includes unfunded fiscal shocks, i.e. transfers not backed by future fiscal surpluses. In such cases, the fiscal authority does not carry the full burden of adjustment due to the monetary authority adopting a more accommodating stance. This results in higher inflation, which is necessary to stabilise the unfunded amount of debt. The paper highlights the dynamic interplay between monetary and fiscal policy, showing that the monetary authority accommodation of unfunded fiscal expansion can drive long-term inflation trends. The estimated version of the model provides a framework for understanding US inflation surges after the pandemic and has implications for policy coordination to manage inflation and debt sustainability. Building on this work, Smets and Wouters (2024) offer a broader framework that parameterises fiscal backing and examines its impact on inflation as well as US business cycles. They analyse how fiscal and monetary policies jointly respond to various shocks, not just fiscal ones.

Here, we make use of these ideas by assuming that there is a probability that in the future the fiscal regime will prove not to be Ricardian (i.e. with a commitment to pay interest on future debts via primary surpluses) but to be non-Ricardian (i.e. abandoning this commitment in favour of the FTPL). We assume that the monetary regime is fixed by the presence of an independent Fed, pursuing a Taylor Rule, and that the fiscal regime is Ricardian (that is, it will pay interest on the debt via future surpluses with a probability depending on the current debt/GDP ratio), and otherwise is non-Ricardian (FTPL). The fiscal regime is therefore continuously evolving: as debt accumulates relative to GDP, and so raises the cost of debt interest, the degree of Ricardian commitment declines, similarly to the idea of reduced 'fiscal backing'. As the FTPL probability rises, expected inflation rises. This in turn affects the model's behaviour via inflation and interest rates. We find that this model fits the data best of all the alternatives considered, and gives an important role to the FTPL as a factor in the extent of Ricardian commitment.

3 The economic models

3.1 An overview of their Ricardian and non-Ricardian representations in the New Keynesian model

The benchmark model we use in which we embed both the FTPL and the orthodox theories is the New Keynesian model. The choice of New Keynesian model reflects its success in numerous studies in representing

the U.S. economy. Its key features as far as FTPL is concerned are its price setting via a Phillips curve and its monetary policy framework via a Taylor Rule. Given the demand from households, firms and government, prices and wages adjust to any excess demand over equilibrium supply at equilibrium marginal costs, causing inflation via the Phillips Curve. Necessary control of demand is carried out by the Fed setting interest rates through a Taylor Rule in order to push the economy to an inflation target and to equilibrium supply. With a coefficient on inflation in the Taylor Rule greater than unity, demand and hence inflation is controlled by raising interest rates until inflation returns to target and demand falls back to equilibrium.

In the episodes where the zero lower bound (ZLB) on risk-free interest rates is triggered, we assume that the Taylor Rule is abandoned and an alternative rule for QE is followed that targets the banks' lending rate; we used this assumption in our benchmark NK model from Le et al. (2021)

As Cochrane has noted, behind this framework there is an implicit fiscal solvency issue that must prevent rising inflation and hence rising interest rates from causing government debt to also rise. This is provided by a Ricardian fiscal policy in which the government commits to raising future taxes to pay for its spending, including paying interest on its debt, such that at the terminal date the present value of future taxes equals the real value of the debt. This then leads households to practice Ricardian equivalence. For example, as lump-sum taxes rise, households know their permanent income is unchanged as future taxes will be lowered to give the same present value of taxation. Hence they consume the same and their savings fall by the amount of the tax rise, and vice versa when taxes fall. Alternatively, solvency can be achieved under FTPL via inflation, i.e. in a non-Ricardian manner. For example, instead of assuming that lump-sum taxes are set to reduce government debt, pay for spending and ensure that any terminal real debt is paid for by the present value of future taxes, it is assumed that taxes are set independently of debt and spending, with terminal T prices intended to devalue terminal debt to a sustainable real value — i.e one that is from then on backed by primary surpluses. Notice that there must still be a terminal surplus as otherwise the price level (and implied inflation up to then) would have to go to infinity, which is impossible, and not therefore a valid solution. Effectively, therefore, FTPL trades off terminal prices against terminal future surpluses in order to enjoy unconstrained borrowing up to that point.

3.2 The specification of the benchmark New Keynesian Model

The orthodox model that forms the basis for testing the FTPL for the US is a standard New Keynesian model. It is taken from Le et al. (2021) which was designed to match the full US postwar data. Earlier versions, such as Le et al. (2011, 2016b), successfully captured behaviour of specific sub-periods but failed to match behaviour over the entire sample. The Le et al. (2021) model extends these earlier works by incorporating state-dependent price and wage setting in the general equilibrium framework proposed by Le et al. (2016b) which was developed from Le et al. (2011) to deal with the zero-bound-interest rate era. This in turn had extended Smets and Wouters (2007) by allowing for 'hybrid' pricing in which a fixed fraction of goods/labour markets are flexprice while the rest set prices/wages for longer durations. In addition to these frictions in labour and goods markets, the model incorporates financial frictions as proposed by Bernanke et al. (1999) and allows for cheap money collateral as in Le et al. (2016b) in order to make monetary policy effective via unconventional monetary measures (base money printing via Quantitative Easing, QE) at the ZLB. The way that QE works at the ZLB is by providing more cheap collateral in the form of money, which lowers the cost of credit, so expanding the supply of money and credit used by entrepreneurs.

As found in Le et al. (2021), a state-dependent formulation of this model is vital for the model to fit the full sample. The focus in obtaining this formulation is the Calvo structure of price/wage determination. In the previous studies by Le et al. (2011, 2016b) it was assumed that imperfectly competitive firms and labour unions decide on changing their prices/wages based on Calvo fixed probabilities, but there were fixed weights on the fractions of goods and labour markets where there is 'long' duration of more than one quarter, and those in a 'short duration'/flexprice sector where prices and wages change continuously each quarter. That is, we assumed the structure of price/wage durations is fixed. Le et al. (2021) relax this assumption and assume this structure changes with the state of the economy, specifically with the recent rate of inflation, denoted by Π and measured by the squared moving average of inflation. Thus, if prices in general, i.e. other prices, have moved substantially then demand and supply for the particular product must also be affected; hence, as recent inflation rises, so does the variance of the idiosyncratic distributions being used by price setters. This implies that the critical shock size for changing prices is at a lower percentile of this more

volatile distribution. This percentile is then the Calvo percentage of firms not changing their price. This Calvo parameter is therefore a reduced-form function of the idiosyncratic distribution, which in turn depends on Π. We do not derive this parameter but rather we estimate a general form from the macro data. Hence the probability of not changing price is reduced by Π and so too is the Calvo parameter. As a result more sectors will become flexprice (i.e. have an overall duration of 1 quarter) and in the remaining sectors the Calvo parameter may fall.

Thus, to summarise the orthodox NK model used here (a full listing of it is in the Model Appendix, together with listings of the FTPL versions of the model), it has the following features:

1. A Taylor rule, Ricardian fiscal policy, and Calvo price-setting by both a flexprice sector and a sticky price sector, whose weights vary with past inflation, with rigidities in consumption and capital.

2. The Taylor rule operates within a banking sector developed from Bernanke et al. (1999) which sets a lending rate designed to pay off in the event of default, given also a fixed collateral requirement. When the ZLB hits, the Taylor rule is suspended in favour of a QE rule that injects liquidity, reducing the cost of collateral and targeting the lending rate.

This model was estimated and tested in Le et al. (2021). It passed the test comfortably; it also passes when we re-estimate it on the current data sample, with a p-value of 0.10. As explained more fully below, we obtain a FTPL version of the model by altering the orthodox model to reflect the non-Ricardian assumptions about fiscal policy. Effectively, government spending and taxation decisions are chosen by exogenous political processes without regard for solvency and accumulate through the government budget constraint to create nominal public debt at a future date T when the FTPL regime is expected to end. This has to be rendered sustainable by a price level at T that produces solvency. This requires that the debt's real value at T must equal the present value then of the future primary surpluses that the government has committed to. The price level at T, P_T, translates into an average inflation rate from the pre-regime period price level, P_{-1}, to this date T; this acts as the expected inflation rate over the entire period of the FTPL, determining actual inflation via the Phillips curve. Thus the identifying conditions on policy are an exogenous primary surplus process, together with a commitment to inflate sufficiently to devalue the debt at T to a sustainable real value. When this regime begins at $t = 0$, it is fully understood by the economy's agents, who then update their expectations as the primary surplus shocks evolve. The regime is expected to continue to period T when it will end. When we test this model over any given sample, within this sample period it will always be expected to continue to a future date, T periods ahead, when it is assumed to end.

3.3 Solvency conditions under Ricardian and FTPL assumptions

3.3.1 Solvency under Ricardian assumptions

We now explain in full detail how the Ricardian and the non-Ricardian FTPL models differ in their treatment of the government budget solvency conditions. The nominal government budget constraint (GBC) may be written as

$$B_t = -P_t s_t + (1 + R_t)B_{t-1}$$

where B_t is nominal debt, s_t is the real primary surplus, P_t is the price level and R_t is a nominal interest rate. The real GBC is then

$$b_t = -s_t + (1 + r_t)b_{t-1}$$

where b_t is real debt and $r_t = \frac{1+R_t}{1+\pi_t} - 1$ is the real interest rate (π_t is inflation which, for simplicity, we treat here as expected to remain constant). This can be rewritten for constant r as

$$b_t = E_t \sum_{i=1}^{N} \frac{s_{t+i}}{(1+r)^i} + \frac{b_{t+N}}{(1+r)^N}$$

The crucial condition for solvency to hold is that the transversality condition for the inter-temporal GBC is satisfied, namely $\lim_{N\to\infty} E_t \frac{b_{t+N}}{(1+r)^N} \to 0$. This implies solvency with debt growing by less than the real interest rate. It also implies that $b_t = E_t \sum_{i=1}^{\infty} \frac{s_{t+i}}{(1+r)^i}$ equals the present value of (expected) future primary surpluses.

If $g_{b,t}$ is the growth rate of b_t, then

$$g_{b,t} = \frac{\Delta b_t}{b_{t-1}} = -\frac{s_t}{b_{t-1}} + r_t$$

As the solvency condition implies that $E_t \frac{b_t}{(1+r)^t} \to 0$ as $t \to \infty$, we have $\frac{b_t}{(1+r)^t} = \frac{b_0(1+g_b)^t}{(1+r)^t} \to 0$ as $t \to \infty$. This requires that $\frac{\Delta b_t}{b_{t-1}} = g_{b,t} = -\frac{s_t}{b_{t-1}} + R_t - \pi_t < r$. Hence the solvency condition is equivalent to enforcing that in the long run expected real debt growth is less than the real rate, i.e. $E_t g_b < r$.

The solvency condition must be met for a government that is expected to be solvent, but a government may, of course, fail to be solvent, in which case the market will lower its debt price until its value equals the present value of future primary surpluses, whatever they are expected to be. For a developed economy that has never defaulted, we assume that it will not default and will remain solvent. Hence we treat the solvency condition as binding on policy.

In what follows, our discussion assumes the model is solved in Dynare (Juilliard, 1996) in which the model is linearised around its steady state. We assume each regime reaches its steady state at T which we refer to as its terminal date.

With Ricardian fiscal policy, the Treasury sets s to satisfy the solvency condition at the terminal date, $t = T$, which implies that $-s_T/b_T + R_T - \pi_T < r_T$; and since $R_T - \pi_T = r_T$ at T, this implies that $-s_T/b_T < 0$; in other words $s_T/b_T > 0$ and there must be a primary surplus at T which is expected to prevail indefinitely thereafter. In the orthodox model, we set a terminal condition in which tax revenue exceeds government spending excluding debt interest, by an amount sufficient to pay the debt interest. In this model fiscal policy is constrained by the situation created by the monetary policy rule and households are indifferent between buying real debt and tax-financing government spending (we assume lump-sum tax to abstract from distortionary tax and supply-side issues) as they know the debt will be backed by future surpluses, with taxes paying for the spending stream.

We solve for debt by using the equation for the government budget constraint that is set out in detail below. We complement this with a Ricardian setting of the lump-sum tax, τ, in which it responds negatively to the ratio of debt to GDP and, at the terminal date, reaches $\tau_T = g_T + r b_T$ and determines each period's government budget deficit.

Because in the model both the goods and labour markets clear, by Walras's Law the bond market also clears. Given that in the goods market $y_t = c_t + i_t + g_t$ it follows that $y_t - \tau_t + RDI_t - c_t = g_t - \tau_t - RDI_t + i_t$ (where RDI_t is real debt interest paid to households) or, in other words there is bond market equilibrium with $Private\ Savings = Government\ deficit + Investment$. It follows that whatever lump-sum tax and debt interest occurs, raising the deficit and debt, creates an equal upward adjustment in private saving, leaving consumption and the rest of the solution the same. This is Ricardian equivalence. Thus the solutions for interest rates, inflation and output are unaffected by the evolution of taxes and debt which can be chosen freely by the government, provided it obeys the terminal solvency condition.

3.3.2 Solvency under FTPL assumptions

We now set out how we implement solvency in order to be able to test FTPL. We note that $b_T = \frac{B_T}{P_T}$ where B_T results from the accumulated fiscal deficits up to T. It follows that

$$E_t b_T = E_t \sum_{i=1}^{\infty} \frac{s_{T+i}}{(1+r_T)^i}$$

Let $s_{T+i} = \sigma_T b_0$ where σ has the dimension of a fraction and b_0 is the baseline reference value of real debt that is used to convert this fraction into a real value term, then

$$b_T = \sum_{i=1}^{\infty} \frac{\sigma_T}{(1+r_T)^i} b_0 = \frac{\sigma_T}{r_T} b_0,$$

We allow σ_t $(t = 0, 1, ..., T-1)$ to be projected by exogenous government spending and tax processes that must be constrained to terminate in a real surplus, σ_T. At this point FTPL does not differ from the

Ricardian regime. Where the difference occurs is that these exogenous fiscal trends determine nominal debt, $B_T = P_T b_T$ and under FTPL, P_T reconciles B_T with the present value of the terminal surplus. In effect, these exogenous choices of fiscal outcomes before T are paid for by inflation tax revenue, determined at T. As $P_T = e^{\pi T} P_{-1}$, for given P_{-1} (which is the price level prevailing before the latest FTPL regime process was in operation) this determines long-run inflation, π, and the price level P_T as

$$P_T = e^{\pi T} P_{-1} = \frac{B_T r_T}{\sigma_T b_0}.$$

σ_T can be chosen as required to maximise the model's fit; it will typically be positive because in the present value condition debt will typically be positive owing to past primary deficits. In practice we look for a σ_T that lies in a range close to zero, from 0.001 to 0.02. Then B_T, as well as σ_T, is found from the time series for g and tax, τ, which are assumed to reflect the exogenous fiscal choices of the government, ignoring Ricardian principles.

Notice that in the FTPL model $t = T$ is the date at which the FTPL regime finishes and is expected to be succeeded by an NK equilibrium steady state. At this point the debt is devalued by the price level to an amount whose real interest will from then on be paid for by the ongoing primary surplus, so that the real debt is equal to the present value of future primary surpluses.

In this FTPL set-up, inflation emerges as the rate that will reduce the value of debt at T to equate to the present value of future surpluses at T, which we refer to as the terminal date. A country can fail to be solvent if no inflation rate is high enough to achieve this. In effect such a situation represents a failure to find a solution to the model. In this case the conditions for the FTPL to hold are not satisfied. It should be noted that under the FTPL the government can in principle freely choose its terminal primary surplus; however, to be credible, given the lack of any Ricardian constraint before the terminal condition, some limit to this must be set. Thus, in principle, the inflationary consequences of terminal debt can be largely avoided simply by promising a large terminal surplus; this would reduce inflationary behaviour generated by the FTPL model. In practice, however, in the US context, it would not be believable as there has only been a federal surplus in a few years around the late 1940s and 1990s — see Figure 1 which shows the primary surplus/deficit that we have calculated (sources: OMB; St. Louis Fed) as the gross federal surplus with debt interest added back, both as a percentage of GDP. This reveals a general absence of primary surpluses over the postwar period.

3.3.3 Modelling the government debt process under the FTPL

In order to implement the FTPL we need to add to the benchmark model the specification of the exogenous processes that determine government debt. The price level is calculated from this debt. We combine nominal government expenditures G_t and nominal tax revenues T_t into the surplus S_t that is represented by a nonstationary process:

$$\Delta S_t = c_0 + c_1 \Delta S_{t-1} + \eta_t$$

We then take the following steps:

1. From the US data we estimate the S_t process. The value of c_1 estimated on the data was 0.707. In later robustness checks, shown below, we re-estimated this equation in stationary form; and we also estimated it from the debt/GDP ratio process, converting it to nominal value using baseline GDP. As can be seen below, our findings were unaltered.

2. Using the GBC we accumulate the resulting nominal debt, assuming nominal debt of 5-year maturity is issued (the average maturity of US public debt). We approximate the GBC in the following way. Each period all debt is assumed to be re-issued at the new market value, allowing for the revaluation of debt. (We assume that the debt maturity share is constant and equal across the previous five years, i.e. 20 quarters.) In principle this is the most accurate approximation as each period we recalculate the market value of the debt as rates change; this revaluation then means that the interest rate on the revalued debt is the current 5-year market rate. The interest payments are then recalculated using current rates and revalued debt. We also allow for the effect of inflation via indexed debt which is about 7.5% of the total. There is also a proportion of the debt which is non-marketable, held by various statutory bodies such as state pension funds on behalf

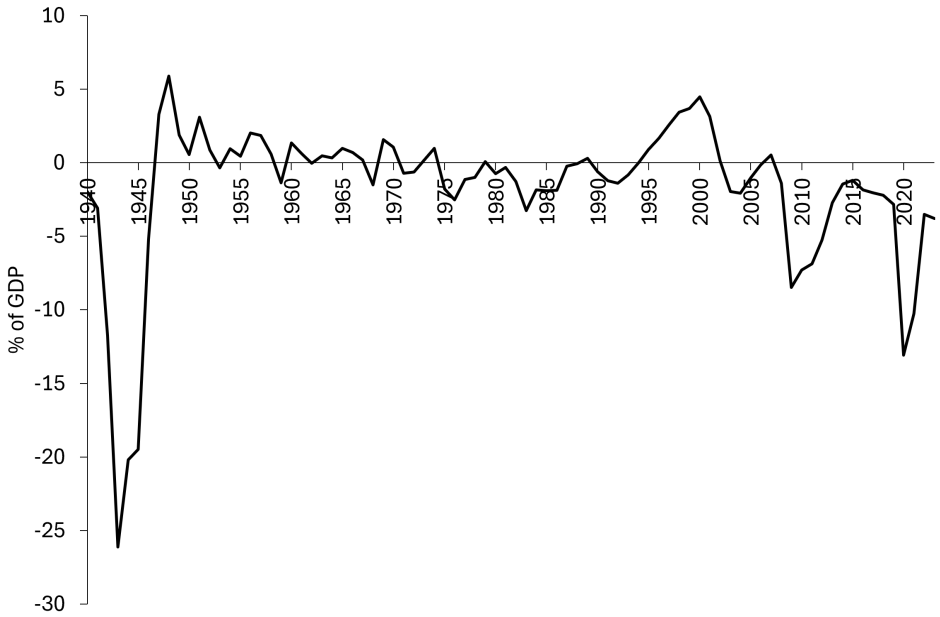


Figure 1: Primary Surplus/Deficit as a Percent of GDP

of private households. We assume this debt behaves like marketable debt. It turns out that this formula for debt evolution gives a close approximation to actual debt over the sample, with an R^2 of 0.99.

$$\Delta B_t = S_t + R_{5,t-1}(B_{t-1} + REVAL_t) - 0.075\pi_{t-1}B_{t-1}$$

where $REVAL_t = -(20 \times \Delta R_{5,t})B_{t-1}$, $R_{5,t}$ is the 5-year interest rate in period t derived from the model's solution — the rational expectation of the future expected interest rates at t.

3. The terminal value of the debt at T is calculated from these processes as B_T.

4. The terminal price level is calculated as: $P_T = e^{\pi T}P_{-1} = \frac{r^* B_T}{\sigma_T b_0}$. From this we take π as the implied long run inflation rate enforced by FTPL.

5. This inflation rate is calculated by the model solution at each period t, using the t-based projections made above. This π enters the Phillips Curve as the expectation of future inflation, $E_t\pi_{t+1}$. Using all the model equations, including determining monetary policy from the Taylor Rule, the model solves for all time t variables, including inflation. As in the original New Keynesian model, a determinate solution for real interest rates, and hence demand, is obtained from the monetary rule for interest rates, which is assumed to be 'passive', i.e. to respond to inflation with a coefficient of less than one. This passivity is necessary to guarantee a stable solution for inflation, which would be prevented by monetary policy pushing up rates to contain inflation, as noted by Leeper (1991).

3.4 Incorporating regime uncertainty in the model — the FTPL as a threat to inflation and interest rates

The FTPL literature reviewed above emphasises that regimes are temporary and that there can be uncertainty about what will succeed them. This suggests a candidate model in which households know the current monetary regime and the current evolution of fiscal surpluses, but they are uncertain about the future fiscal regime. Throughout the postwar period the Fed has been independent, with a constitutional duty to stabilise output and control inflation, so we assume that throughout the period it follows a Taylor Rule, and that fiscal policy is supposedly Ricardian, in the sense that the government announces a commitment to pay interest on the debt ultimately via primary surpluses. There is, however, the possibility that this Ricardian fiscal policy will be abandoned in the future in favour of an FTPL fiscal regime. We assume

that this outcome has a probability weight which depends on the debt/GDP ratio — a natural assumption as this raises the real debt interest cost, so increasing the fiscal cost of Ricardian policy. Thus expected inflation up to the terminal date is this probability times the FTPL rate plus one minus this weight times the Ricardian rate. This expectation then feeds into the model via the Phillips Curve. In this way the FTPL regime continuously affects the model's behaviour through the debt fiscal policy is creating. We will call this the Mixed Uncertainty Regime, or MUR. It is similar to the idea of the partial absence of 'fiscal backing', as defined by Smets and Wouters (2024); in effect the FTPL probability undermines the credibility of the Ricardian commitment. Our aim here is to test a model that reflects the evolution of the prospects that inflation will be needed to ensure solvency but yet is realistic in assuming a constant Fed monetary policy and a constant announced Ricardian fiscal policy. Thus it differs from models in which both the monetary and fiscal regimes are constantly changing, such as Bianchi and Ilut (2017) and Bianchi and Melosi (2017). What changes is the probability of the ultimate fiscal financing mechanism.

4 The method of Indirect Inference

The method of Indirect Inference is used to evaluate whether the model can fit the data. This method was proposed in Minford et al. (2009) and refined by Le et al. (2011) who used Monte Carlo experiments to evaluate the method. Indirect Inference uses an auxiliary model to describe the observed data. The auxiliary model is also estimated using data simulated from the model to be tested. A test of the model is obtained by comparing the two sets of estimates. The test statistic can be constructed in several ways, for example, using the scores from two sets estimates, from a measure of their respective fits such as a Likelihood Ratio test, and by testing for differences in the coefficient estimates of the auxiliary model using a Wald test. Our previous investigations favour the latter.

The auxiliary model is chosen to account for US business cycle dynamics over the sample period 1959-2017. We use as the auxiliary model a VARX of the three macro variables, output, inflation and interest rates:

$$Y_t = AY_{t-1} + BX_{t-1} + e_t \tag{1}$$

where $Y_t \equiv (y_t, \pi_t, R_t)'$, $X_t \equiv (ea_t, t)'$ where ea_t is productivity, t is the deterministic trend, e_t is the error vector, and A and B are the coefficient matrices. The Wald test statistic is:

$$Wald = (\Phi_T - \overline{\Phi})' \sum\nolimits_{(\Phi\Phi)}^{-1} (\Phi_T - \overline{\Phi}) \tag{2}$$

where Φ_T is the vector of VARX estimates of the autoregressive coefficients, $\overline{\Phi}$ are the corresponding mean estimates using the simulated data and $\sum_{(\Phi\Phi)}$ is their variance-covariance matrix. Our null hypothesis H_0 is that the model being tested is "true". The p-value of the test is calculated by:

$$p = (100 - WP)/100 \tag{3}$$

where WP is the percentile of the Wald statistic found with the actual data in the distribution of it generated by the simulated samples. The models are deemed to pass/fail the Wald test if their p-value is above/below a 5% threshold.

In order to estimate the model and then find its minimum-value Wald statistic we use a search algorithm. This gives us a set of parameters that produces simulations that are closest to the data. These estimates have been shown to be consistent and asymptotically Normally distributed (see Smith, 1993; Gregory and Smith, 1991, 1993; Gourieroux et al., 1993; Gourieroux and Monfort, 1995; Canova, 2005).

We use estimates based on Indirect Inference rather than the now widely-used Bayesian approach to estimating our model because we wish to test the model as a whole against the data and avoid assuming prior distributions of the structural parameters which may unduly influence the posterior estimates. Evidence of the dangers of using Bayesian estimation was found by Le et al. (2011) Even a major model, such as the Smets-Wouters (2007) model of the US, was rejected by our Indirect Inference test. Our aim is to find a model that is not rejected by the data in order that we can rely on it for discussions of policy.

As noted, we could also use a Likelihood Ratio (LR) test instead of the Wald test. However, Le et al. (2016a) find that the two test statistics have quite different properties when used to check for model

misspecification: the LR test is based on a model's in-sample current forecasting ability whereas the Wald is based on the ability of the model, including its implied errors, to replicate the behaviour of the data, as represented by the VAR coefficients. In effect, the Wald test asks in a parsimonious way whether the model can replicate the impulse response functions found in the data.

It transpires that, in the context of a macro model like that used here, the Wald test has far greater power than the LR test. This property is demonstrated for the original Smets-Wouters model over the sample period $1947Q1 - 2004Q4$ by Le et al. (2016b) whose comparative table we reproduce next. Table 1 shows a Monte Carlo experiment in which the Smets-Wouters model is treated as true and in which the alternative hypothesis is formulated generated by mis-specifying the parameters alternately by $+/-x\%$. The rejection rate for the Wald statistic rises sharply with x. The table shows these results using both stationary and non-stationary data generated from the model. The power of the Wald test remains much the same for both whereas the LR test loses power on non-stationary data for reasons Le et al. (2016a) discuss.

Percent Mis-specified	Wald	LR	Wald	LR
	Stationary data		Non-stationary data	
True	5.0	5.0	5.0	5.0
1	19.8	6.3	7.9	5.2
3	52.1	8.8	49.2	5.8
5	87.3	13.1	97.8	6.2
7	99.4	21.6	100.0	7.4
10	100.0	53.4	100.0	9.6
15	100.0	99.3	100.0	15.6
20	100.0	99.7	100.0	26.5

Table 1: Rejection Rates for Wald and Likelihood Ratio for 3 Variable VAR(1)

5 The empirical results for the NK and FTPL model versions

Table 2 shows the estimated coefficients and the test results for each of the models. For the NK model we assume it is operant throughout the postwar sample, and test it for this. For the FTPL model we assume that is operant as a temporary episode, with the NK model expected to replace it eventually as the permanent operant model. We test whether this FTPL regime was operating either for the whole period, or for either of two subperiods, pre-GFC and post-GFC. Finally, we test the MUR model in which there is continuously an orthodox NK model with a Taylor Rule and an announced Ricardian fiscal policy but there is a possibility that fiscal policy will switch in the future into an FTPL regime, abandoning the Ricardian commitment which is thus effectively limited.

We begin by testing the orthodox NK model for the whole period. In line with our earlier work we find that it fits the data comfortably. We use the test using the VAR coefficients only which Le et al. (2016a) find has substantial power. The p-value was 0.10.

We then consider the FTPL model. We begin with its match over the full period. The model is strongly rejected. It can be seen that it fails to fit the data, with a p-value of only 0.003, well below our 0.05 threshold.

We turn next to finding whether combinations of the two regimes can explain the whole postwar period. One is the orthodox NK model pre-GFC, followed by FTPL post-GFC. This attains a p-value of 0.11, much the same as the orthodox model throughout. The possible combination of FTPL pre-GFC and NK post-GFC is strongly rejected, with a zero p-value.

Finally, we report the results for the whole period Mixed Uncertainty Regime (MUR). This comes closest to matching the data, with a high p-value of 0.194, indicating that allowing for fiscal regime uncertainty massively improves the fit of the model to the data. It suggests that concern about a possible shift into FTPL that is fed by rising debt, tends to raise inflation and interest rates, which resembles the experience of the postwar perod.

We also note that the parameter estimates of the rejected FTPL model, especially those associated with wage/price adjustment and indexation, are the principal differences between the model estimates. The best-performing MUR model has parameter estimates similar to those for the NK models.

Coefficients	NK	FTPL	Model NK/FTPL*	FTPL/NK+	MUR
Elasticity of capital adjustment	8.6689	6.8410	5.0120	6.2112	8.8046
Elasticity of consumption	1.4348	1.6585	2.6806	2.2345	1.9807
External habit formation	0.0267	0.1936	0.0245	0.0255	0.0249
Probability of not changing wages	0.7598	0.7430	0.7631	0.8131	0.8960
Elasticity of labour supply	3.9516	4.7381	3.5992	3.6847	4.2963
Probability of not changing prices	0.0852	0.0788	0.0770	0.0677	0.0749
Wage indexation	0.4316	0.2973	0.5494	0.5166	0.2591
Price indexation	0.5837	0.7484	0.4567	0.5279	0.7869
Elasticity of capital utilisation	0.7799	0.6122	0.4580	0.5267	0.5771
Share of fixed costs in production (+1)	1.0180	1.2985	1.7388	1.8040	1.4059
Taylor Rule response to inflation (NK)	1.7665		2.5057	2.8051	1.7980
Taylor Rule response to inflation (FTPL)		0.6504	0.5486	0.5171	
Interest rate smoothing	0.6404	0.6952	0.8319	0.7966	0.9225
Taylor Rule response to output	0.0745	0.0178	0.0469	0.0463	0.0646
Taylor Rule response to change in output	0.0177	0.0444	0.0184	0.0157	0.0166
Share of capital in production	0.2939	0.1710	0.2987	0.3454	0.3293
Elasticity of the premium with respect to leverage	0.0172	0.0464	0.0281	0.5835	0.0207
Money response to premium	0.0623	0.0861	0.0883	0.0792	0.0559
Money response to credit growth	0.0639	0.0165	0.0680	0.0708	0.0512
Elasticity of the premium to M0	0.0269	0.0584	0.0233	0.0220	0.0379
Parameter response of NK weight — prices	0.0222	0.0306	0.0278	0.0275	0.0207
Parameter response of NK weight — wages	0.0688	0.0182	0.0845	0.0965	0.0444
Coefficient on NBbase in P(T)		0.0121	0.0100	0.0115	0.0154
Wald Statistic	15.6702	38.2667	17.0292	128.8394	12.4123
P-value	0.1020	0.0033	0.1140	0.0000	0.1940

*NK model for the pre-GFC period, FTPL model for the post GFC period.

+FTPL model for the pre-GFC period, NK model for the post GFC period.

Table 2: Estimated Coefficients and P-values for Various Models Using the Banks' Lending Rate- the Corprate Credit model versiom Over the Full Sample

Figure 2 shows how the probability of FTPL being the ultimate outcome varies over the sample period according to our estimated model and the actual evolution of the public debt/GDP ratio. Plainly after the GFC the chances of FTPL rose sharply reaching close to 100% by the mid-2010s. Thus the evidence of our tests supports the idea that the FTPL dominated the fiscal regime after the GFC.

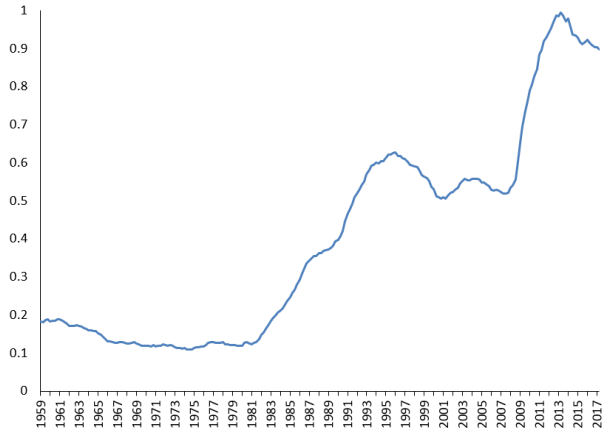


Figure 2: FTPL weight in the MUR model using the actual data

5.1 Robustness check on different specifications of the primary surplus process

A robustness check examines whether our modelling of the surplus process affects our assessment of the FTPL regime. Previously we used the nominal surplus process that best fitted the data — the non-stationary AR process reported above. We recalculated the tests of the FTPL throughout the whole data period, using different surplus processes. These were a) a stationary nominal AR process fitted to the data, and b) a process for the surplus/GDP fitted to the data — this was bootstrapped and converted to a nominal value by baseline GDP. The FTPL regime was strongly rejected, whatever the process, as shown in Table 3.

	Surplus Process*		
	Nonstationary	Stationary	Percent of GDP
Wald Statistic	38.2667	38.5861	35.2318
P-value	0.0033	0.0033	0.0046

*FTPL model through whole period

Table 3: Wald Statistics and P-values for FTPL Model operating temporarily throughout the sample period with Different Surplus Equations

Our conclusion from these results is that the FTPL was highly relevant to the postwar period, helping to create the best-fitting model. But its role was not as an actual policy regime in the period but, rather, as a possible future regime change fanning fears that inflation would be used to devalue rising debt. We cannot reject the hypothesis that the FTPL with weak monetary policy occurred after the GFC. But it is more probable that the New Keynesian model with orthodox monetary policy prevailed throughout the postwar period, with a fiscal regime that had a Ricardian commitment limited by the debt-related probability of a future switch to the FTPL.

5.2 Robustness of different terminal date T

Another source of empirical sensitivity in our results is the length of time ahead that we place T, the period at which the FTPL effects the devaluation of the accumulated debt from its primary surplus process via a rising price level, $P(T)$, to a sustainable real level, $b(T)$. Our chosen T is 50 quarters ahead of when the

FTPL regime is assumed to start at t. We compare the test of our FTPL regime simulations when this is varied to 20 or 40 quarters ahead. It can be seen that the p-values on our FTPL results vary little.

	Terminal date T^*			
	20	30	40	50
Wald Statistic	36.6535	37.8049	38.2268	38.2667
P-value	0.0033	0.0033	0.0033	0.0033

*FTPL model through whole period

Table 4: Robustness to different terminal dates

6 Conclusions

In this paper we have implemented a quantitative empirical test of FTPL defined as a non-Ricardian model of fiscal policy (the 'FTPL model'). We used Indirect Inference to compare its match to postwar US data with that of a standard New Keynesian model with Ricardian fiscal policy. The distinguishing feature of this FTPL version of the orthodox New Keynesian model is that government spending and taxation are allowed to evolve according to data-based exogenous processes. Nominal debt accumulates according to the government's budget constraint and at a future date, T, this accumulated nominal debt must be devalued to a sustainable real level by a terminal price level, which in turn defines an average inflation rate to that point from the pre-regime price level. This rate determines expected inflation which then enters the model up to the terminal date. Thus inflation is caused by expected fiscal policy. During this FTPL regime monetary policy has a weak (less than unity) interest rate response to inflation. The FTPL regime is expected to end at T and be replaced then by a Ricardian New Keynesian (orthodox) regime which will generate primary surpluses that back the resulting real debt at T. While this hypothesised FTPL regime was rejected over the whole postwar sample, it was accepted for the post-GFC period alone, with the orthodox regime prevailing otherwise; this regime combination was as probable an explanation of the whole period as the orthodox regime alone. Nevertheless, a more probable model was the New Keynesian model with an orthodox monetary regime throughout and a fiscal regime whose Ricardian commitment was limited by the debt-related probability of a future switch to the FTPL. This model provided the best-fitting explanation of the whole period. This gives a key role to the FTPL in explaining postwar US behaviour through its continuous debt-related effect on the credibility of the fiscal Ricardian commitment.

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A Appendix — The models listed

A.1 Solution method

The models are solved by Dynare (Juilliard, 1996) in which the model is solved by linearisation around a steady state. Our solutions assume that each regime reaches its steady state equlibrium at T, which we refer to as the terminal date.

A.2 The orthodox New Keynesian model

Consumption Euler equation

$$c_t = \frac{\frac{\lambda}{\gamma}}{1+\frac{\lambda}{\gamma}} c_{t-1} + \frac{1}{1+\frac{\lambda}{\gamma}} E_t c_{t+1} + \frac{(\sigma_c - 1)\frac{W_* L_*}{C_*}}{\left(1+\frac{\lambda}{\gamma}\right)\sigma_c}\left(l_t - E_t l_{t+1}\right) \tag{4}$$

$$- \left(\frac{1-\frac{\lambda}{\gamma}}{\left(1+\frac{\lambda}{\gamma}\right)\sigma_c}\right)\left(r_t - E_t \pi_{t+1}\right) + eb_t \tag{5}$$

Investment Euler equation

$$inn_t = \frac{1}{1+\beta\gamma^{(1-\sigma_c)}} inn_{t-1} + \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}} E_t inn_{t+1} \tag{6}$$

$$+ \frac{1}{\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\varphi} qq_t + einn_t \tag{7}$$

Tobin Q equation

$$qq_t = \frac{1-\delta}{1-\delta+R_*^K} E_t qq_{t+1} + \frac{R_*^K}{1-\delta+R_*^K} E_t rk_{t+1} - E_t cy_{t+1} \tag{8}$$

Capital Accumulation equation

$$k_t = \left(\frac{1-\delta}{\gamma}\right) k_{t-1} + \left(1 - \frac{1-\delta}{\gamma}\right) inn_t + \left(1 - \frac{1-\delta}{\gamma}\right)\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\varphi\left(einn_t\right) \tag{9}$$

Labour demand

$$l_t = -w_t + \left(1 + \frac{1-\psi}{\psi}\right) rk_t + k_{t-1} \tag{10}$$

NK Price Setting equation (π_t^{NK})

$$\pi_t = \begin{array}{c} \frac{\beta\gamma^{(1-\sigma_c)}\iota_P}{1+\beta\gamma^{(1-\sigma_c)}\iota_P} E_t \pi_{t+1} + \frac{\iota_P}{1+\beta\gamma^{(1-\sigma_c)}\iota_P}\pi_{t-1} - \left(\frac{1}{1+\beta\gamma^{(1-\sigma_c)}\iota_P}\right) \\ \left(\frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_p\right)\left(1-\xi_p\right)}{\xi_p\left(\left(\phi_p-1\right)\epsilon_p+1\right)}\right)\left(\alpha rk_t + (1-\alpha)\, w_t - ea_t\right) + ep_t \end{array} \tag{11}$$

NK Wage Setting equation (w_t^{NK})

$$w_t = \begin{array}{c} \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}} E_t w_{t+1} + \frac{1}{1+\beta\gamma^{(1-\sigma_c)}} w_{t-1} + \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}} E_t \pi_{t+1} - \frac{1+\beta\gamma^{(1-\sigma_c)}\iota_w}{1+\beta\gamma^{(1-\sigma_c)}}\pi_t \\ + \frac{\iota_w}{1+\beta\gamma^{(1-\sigma_c)}}\pi_{t-1} - \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}\left(\frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_w\right)\left(1-\xi_w\right)}{\left(1+\epsilon_w\left(\phi_w-1\right)\right)\xi_w}\right) \\ \left(w_t - \sigma_l l_t - \left(\frac{1}{1-\frac{\lambda}{\gamma}}\right)\left(c_t - \frac{\lambda}{\gamma} c_{t-1}\right)\right) + ew_t \end{array} \tag{12}$$

FP Marginal Product of Labour (w_t^{FP})

$$rk_t = \frac{1}{\alpha}\left[(1-\alpha)\, w_t + ea_t\right] \tag{13}$$

FP Labour Supply (π_t^{FP})

$$w_t = \sigma_l l_t + \left(\frac{1}{1-\frac{\lambda}{\gamma}}\right)\left(c_t - \frac{\lambda}{\gamma}c_{t-1}\right) - (\pi_t - E_{t-1}\pi_t) + ew_t^S$$

Weighted Inflation

$$\pi_t = \theta_\pi \pi_t^{NK} + (1-\theta_\pi)\pi_t^{FP} \tag{14}$$

Weighted Wage

$$w_t = \theta_w w_t^{NK} + (1-\theta_w) w_t^{FP} \tag{15}$$

Weights on sticky price (p) and wage (w) sectors depend on square of 4-year inflation MA (Π)

$$\theta_w = \exp(-\mu^w \Pi) \tag{16}$$

$$\theta_p = \exp(-\mu^p \Pi) \tag{17}$$

Market Clearing condition in goods market

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}inn_t + R_*^K k_y \frac{1-\psi}{\psi} rk_t + c_y^e c_t^e + eg_t \tag{18}$$

Aggregate Production equation

$$y_t = \phi\left[\alpha\frac{1-\psi}{\psi}rk_t + \alpha k_{t-1} + (1-\alpha)\, l_t + ea_t\right] \tag{19}$$

Taylor Rule- normal periods ($r_p \succ 1$)

$$r_t = \rho r_{t-1} + (1-\rho)\left(r_p\pi_t + r_y y_t\right) + r_{\Delta y}\left(y_t - y_{t-1}\right) + er_t \text{ for } r_t > 0.0625 \tag{20}$$

Premium of bank lending rate over real riskfree rate

$$E_t cy_{t+1} - (r_t - E_t\pi_{t+1}) = pm_t = \chi\left(qq_t + k_t - n_t\right) - \psi m_t + \xi_t + epr_t \tag{21}$$

Net worth

$$n_t = \frac{K}{N}\left(cy_t - E_{t-1}cy_t\right) + E_{t-1}cy_t + \theta n_{t-1} + enw_t \tag{22}$$

Entrepreneurial consumption

$$c_t^e = n_t \tag{23}$$

M0 (c*is target bank premium)

$$\text{Normal periods } (r_t > 0.0625)\ \Delta m_t = \psi_1 \Delta M_t + errm_{2t} \tag{24}$$

$$\text{ZLB periods } (r_t \leq 0.0625)\ \Delta m_t = \psi_2(pm_t - c^*) + errm_{2t} \tag{25}$$

M (total money−M0+bank deposits)

$$M_t = (1+\nu-\mu)k_t + \mu m_t - \nu n_t \tag{26}$$

Fiscal variables:

Evolution of nominal public debt

$$\Delta B_t = S_t + R_{5,t-1}(B_{t-1} + REVAL_t) - 0.075\pi_{t-1}B_{t-1}$$

Government spending (eg) follows an exogenous AR(1) process
The primary surplus responds positively to the debt/GDP ratio(B/Y)

$$\Delta\tau_t = \gamma(B_{t-1}/Y_{t-1})$$

and it must satisfy at the terminal date T

$$\tau_T = eg_T + rb_T$$

A.3 The FTPL model

The model is the same as above with the following changes:
In the Taylor Rule $r_p < 1$ (monetary policy is passive).
The tax and primary surplus process are exogenous:

$$\Delta\tau_T - \Delta eg_t = \Delta S_t = c_0 + c_1\Delta S_{t-1} + \eta_t$$

and at the terminal date T nominal debt from the accumulated fiscal deficits up to T must satisfy $b_T = \frac{B_T}{P_T}$ where

$$E_t b_T = E_t \sum_{i=1}^{\infty} \frac{s_{T+i}}{(1+r_T)^i}$$

and $s_{T+i} = \sigma_T b_0$ where σ has the dimension of a fraction and b_0 is the baseline reference value of real debt that is used to convert this fraction into a real value term, so that

$$b_T = \sum_{i=1}^{\infty} \frac{\sigma_T}{(1+r_T)^i} b_0 = \frac{\sigma_T}{r_T} b_0,$$

and

$$P_T = e^{\pi T} P_{-1} = \frac{B_T r_T}{\sigma_T b_0}.$$

with the resulting $\pi = E_t\pi_{t+1}$ in the model's price- and wage-setting equations above

A.4 The Mixed Uncertainty Regime

This model is the same as the Orthodox model but its terminal condition is a probability-weighted average, $(1-P(FTPL)_t)$ times the orthodox terminal conditions and $P(FTPL)_t$ times the FTPL terminal conditions, where $P(FTPL)_t = k(B_t/Y_t)$ and k is a parameter to be estimated. Effectively this implies that $E_t\pi_{t+1} = k\pi$ where π is set by projected B_T if the model defaults to FTPL from t.