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# Modern Monetary Theory: the post-Crisis economy misunderstood?

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# Modern Monetary Theory: the post-Crisis economy misunderstood?

Chunping Liu* Patrick Minford† Zhirong Ou‡

**Abstract**

We set out Modern Monetary Theory (MMT) as a full DSGE model, and test it by indirect inference on post Financial Crisis US data, alongside a standard New Keynesian, NK, model. The MMT model is rejected, while the NK model has a high probability. We then evaluate replacing the fiscal and monetary policies within the NK model by MMT policies, and find that they imply a material loss of welfare.

*Keywords: Modern Monetary Theory; DSGE model; fiscal activism; Wald test; indirect inference*

## 1 Introduction

The past decade since the global Financial Crisis has seen conventional monetary policy losing traction and fiscal policy stimulus frustrated by fears about long-run solvency, which gave rise to policies of 'austerity', generally supported by mainstream economists. However, during the Covid crisis, such fears were set on one side as developed country governments pursued policies of massive fiscal support, accompanied by very large expansions of the monetary base and also the wider money supply. A rising group of political activists and 'heterodox' economists has strongly supported such policies not merely for the Covid emergency but also for normal times – their views are known as Modern Monetary Theory (MMT), a school of thought largely ignored by the mainstream since its creation in the 1990s, but which has recently spread much more widely (especially via blogs and social media) and attracted many followers. As Colander (2019) has pointed out, the marketing success of MMT has made it part of the mainstream conversation to which mainstream economists have felt compelled to respond. The fact that MMT is quoted (whether more explicitly or less so) in many recent discussions of policy proposals, such as the Green New Deal and Job Guarantee, and even the latest ones related to post-Covid recovery, speaks for itself and underlines the need to give the theory a careful evaluation.

The fundamental distinction of MMT from the New Keynesian theory which has been the standard workhorse for macro policy analysis for nearly three decades lies in its view of the nature of money and what this means for the government's capacity to pursue fiscal policy. Thus, instead of seeing money as a 'medium of exchange', MMT economists argue that money derives its fundamental value from being a

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'unit of account' imposed by the government requiring taxes to be paid in a designated currency[1]. Thus, a monetarily sovereign government – being the monopoly issuer of that currency – would never be confronted by a 'budget constraint'. As long as the government does not attempt to consume more than what is available in the economy (i.e., its consumption does not breach the real resource constraint), it would always be able to finance its own spending by 'printing' as much money as needed.

MMT portrays a world in which fiscal activism is possible because the fiscal authority enjoys much more space than mainstream models would predict. If the fiscal authority could never run out of money, this would be a welcome addition to the set of policy instruments available to manage the economy, since fiscal instruments – which generally have strong direct impacts – could be used whenever needed; and fiscal policy is easier to implement in low-interest environments (as in the US and EU today), and in economies where monetary transmission remains inefficient (as in most developing economies). The problem of concern to macro-economists, however, is: 'how can inflation be stabilised if money can be printed freely to finance public deficits?'

According to MMT inflation is stabilised by taxes. Thus, another key distinction of MMT from New Keynesian theory lies in the role of taxes. The MMT school argues that since the government can print as much money as it needs, taxes are no longer needed for financing its spending; yet they are levied by the government, and must be paid in the currency it has issued. This acts as a means of draining money from circulation, whereby excess money can be withdrawn and 'burnt', as an 'inflation-avoidance maneuver' (Wray, 2019). Thus taxes, which control the supply of money in the MMT world, are an inflation management tool (Armstrong, 2019; Mitchell et al. 2019; Murphy, 2019; Wray, 2019).

The policy regime in the MMT world can therefore be described in the following way. Government spending stabilises output (or employment); money is created to finance such spending at interest rates held down by limiting government borrowing. Money thus enters circulation; taxes, which stabilise inflation, are then levied to drain it from the economy so that the quantity in circulation delivers the inflation target in the steady state. MMT claims that this description is in line with what was observed in the post-crisis era of the US during which public debt continued to swell and QE injected a huge amount of money, while inflation remained moderate (Davies, 2019). Wray (2019, p.10) further claims that: '*This is the way it has worked for the past 4000 years... in spite of the modern procedures adopted*'.

However, no MMT contribution has so far spelt out this narrative as a model in a testable form. This not only prevents MMT from taking its theory beyond the heated blogs and social media posts to convince the profession at large, but also makes the rosy picture it describes for fiscal activism both vague and unconvincing. On the other hand, other economists have so far also not been able to assess MMT formally, using standard statistical methods. Without this analysis, we lack formal evidence on whether the policies advocated by MMT would achieve what it claims.

This is the gap in the literature we aim to fill in this work. Thus, in this paper we construct an MMT model side by side with a standard New Keynesian model inclusive of an explicit demand for money for comparability with the MMT model: we treat this model here as the benchmark model for evaluation against the MMT model. The MMT model differs from this benchmark NK model by replacing the Taylor rule with an explicit money supply function implied by the MMT description of monetary policy, namely, a)

[1] MMT economists do not deny money's role as a medium of exchange. Nevertheless, they argue that this role only comes after a currency has been chosen by the government to be the legitimate unit of account for tax payments. See Wray (1998) for example.

New Keynesian models do not generally include money explicitly; nevertheless, it is assumed that in them there is an implicit demand for money, and that money supply is set by an interest rate-setting rule to equal money demnd at the market interest rate.

money is issued to finance government spending not covered by taxes or bond issues, where b) bond issues are made to keep nominal interest rates close to an interest rate target, and c) taxes are levied to meet an inflation target. Hence the money supply responds positively both to government deficits and to nominal interest rates which it aims to stabilise, and negatively to inflation above target. This creates a monetary regime quite distinct from the Taylor rule, enabling us to distinguish the behaviour of the two otherwise identical models.

We set up these rival models with a view to testing the key propositions, which appear to be two-fold, put forward by the MMT school: first, over the period since the Financial Crisis the operation of monetary policy in controlling interest rates and issuing currency via QE has been best described by the money policy functions of the MMT model rather than by the Taylor rule of the benchmark model; second, monetary policy would better stabilise the economy if it is carried out in the MMT manner – i.e., monetary policy coordinates with fiscal policy to create policy space for the latter, through deficit monetisation – than by pursuing monetary independence with a Taylor rule. We test both these propositions here, the first by indirect inference against the data since the Crisis where we ask if any model can pass a Wald test of the data's behaviour with a high-enough probability; the second by stochastic simulations of the economy under both regimes.

We find that, while the benchmark NK model passes the indirect inference Wald test comfortably, the MMT model is clearly rejected. Since the two models only differ in how monetary policy operates within them, effectively this is a rejection of the monetary behaviour described by MMT economists; by contrast, the Taylor rule remains a robust abstraction of the true behaviour of the Fed. Compared to the Taylor rule regime, monetary-fiscal policy coordination advocated by MMT economists would bring no gain in inflation and real interest rate stabilities; however, it would destabilise output substantially, jeopardising macro stability overall and diminishing household welfare.

To the best of our knowledge, this is the first time that MMT has been spelt out as a standard general equilibrium model, alongside a canonical New Keynesian model, so that its validity and recommended policies could be evaluated against the data with a formal statistical test. That we find that MMT neither explains how the transmission works nor points a viable way forward for future reform provides important implications for the current debate on how post-Covid recovery may be supported by fiscal policies. While fiscal activism may remain the theme until spaces for monetary policy are restored, any stimulus must not undermine fiscal disciplines – even if the economy is monetarily sovereign. What we establish in this paper therefore provides solid, empirical evidence against MMT, despite its recent popularity in some quarters.

In the remainder of this paper: we set out the benchmark NK model and its MMT variant in Section 2; in Section 3 we explain the indirect inference method for testing DSGE models and report the test results; Section 4 analyses the data using the 'true' model; Section 5 compares the implications on stability and welfare under the benchmark and MMT regimes; Section 6 concludes.

# 2 Model

## 2.1 The benchmark model

Our benchmark model is a standard New Keynesian model with money. There are three sectors: households, firms (including capital producers), and the public sector. Households consume and work; firms hire labour and capital, and produce goods which are sold at the retail level following Calvo pricing; capital producers build capital, and sell it to households who then rent it to firms; the public sector consists of a central bank managing nominal interest rates and a fiscal authority managing government spending and taxes; money is introduced by assuming money-in-utility. For convenience, we bypass the Zero Lower Bound problem by treating the corporate bond yield (which never hit the Bound) as the target of monetary policy via any instruments it chooses, whether the short-term interest rates or QE. The model structure is outlined below. The first order conditions are listed in the appendix.

#### 2.1.1 Households

Households are assumed to consume, work, hold money and save; and they buy capital from capital producers, rent it to firms, and resell in the end of each period the undepreciated portion back to capital producers. Households own all profits of the economy. They have life-time utility:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t j_t \left\{ \Gamma \ln \left(c_t - \vartheta c_{t-1}\right) + \chi \ln m_t - \psi \frac{n_t^{1+\eta}}{1+\eta} \right\} \tag{1}$$

where $c_t$ is the real consumption, $m_t$ is the real money holding, $n_t$ is the labour hour, $\eta$ is the inverse of the wage elasticity, $\chi$ and $\psi$ are the preferences for money and leisure relative to consumption, $\vartheta$ is the habit persistence in consumption, $\Gamma$ is a scaling factor[2], $\beta$ is the discount factor, and $j_t$ is the time preference shock. The household budget constraint is:

$$\begin{aligned} & c_t + s_t + m_t + q_t k_t \\ = \; & (1-\tau_t) w_t n_t + (1+r_{t-1}) s_{t-1} + \frac{m_{t-1}}{1+\pi_t} + h_t + r_{k,t} k_{t-1} + q_t \left(1-\delta\right) k_{t-1} + \Pi_{y,t} + \Pi_{k,t} \end{aligned} \tag{2}$$

where $s_t$ is the real savings, $\tau_t$ is the tax rate on wage income, $w_t$ is the real wage rate, $r_{t-1}$ is the lagged real interest rate, $\pi_t$ is the inflation rate, $h_t$ is the real money balance transferred from the public sector, $q_t$ and $r_{k,t}$ are the sales and rental prices of capital, $k_t$ is end-of-period capital stock, $\delta$ is the rate of capital depreciation, $\Pi_{y,t}$ and $\Pi_{k,t}$ are the real profits transferred from firms and capital producers, respectively.

The household problem is to maximise (1) subject to (2) by choosing $c_t$, $m_t$, $n_t$, $s_t$ and $k_t$. The first order conditions determine the demand for goods, money and capital, and the supply of labour; the budget constraint determines the demand for deposits.

#### 2.1.2 Firms

Firms produce with the following technology:

$$y_t = z_t n_t^{1-u} k_{t-1}^{u} \tag{3}$$

where $y_t$ is output, $z_t$ is productivity, $u$ is the capital share.

The intermediate goods market is perfectly competitive. The optimisation problem faced by firms in this market is to minimise the cost of production $TC_t = w_t n_t + r_{k,t} k_{t-1}$ by choosing $n_t$ and $k_{t-1}$. The first order conditions imply the optimal substitution between labour and capital (expressed here as the demand for labour):

$$n_t = \frac{1-u}{u} \frac{r_{k,t}}{w_t} k_{t-1} \tag{4}$$

[2] This is set to $\Gamma \equiv \frac{1-\vartheta}{1-\vartheta\beta}$, such that in the steady state $U_c' = 1/\bar{c}$, where $\bar{c}$ is the steady-state level of consumption.

and the real marginal cost of production:

$$mc_t = \frac{1}{z_t}(\frac{1}{u})^u(\frac{1}{1-u})^{1-u}w_t^{1-u}r_{k,t}^u \tag{5}$$

The intermediate goods are then differentiated by firms in the retail market, which is monopolistically competitive, at no extra cost. The standard Calvo (1983) pricing strategy allowing for partial inflation indexation (Christiano et al., 2005) in the profit maximisation problem implies the New Keynesian Phillips curve:

$$\hat{\pi}_t = \frac{\beta\Omega}{1+\beta\epsilon\Omega}E_t\hat{\pi}_{t+1} + \frac{\epsilon}{1+\beta\epsilon\Omega}\hat{\pi}_{t-1} + \frac{(1-\omega)(1-\omega\beta\Omega)}{\omega(1+\beta\epsilon\Omega)}\widehat{mc}_t + \hat{\varepsilon}_{\pi,t} \tag{6}$$

which relates inflation to the expected future inflation, past inflation, and the real marginal cost ('^' denotes the percentage deviation of a variable from its steady-state value). $1-\omega$ is the fraction of retailers who are able to reset an optimal price. $\epsilon$ is the degree of inflation indexation adopted by those who are unable to reoptimise. $\Omega \equiv (1+\bar{\pi})^{(\theta-1)(1-\epsilon)}$ where $\bar{\pi}$ is the steady-state level of inflation and $\theta$ is the price elasticity of demand. $\hat{\varepsilon}_{\pi,t}$ is the price mark-up shock.

The retail firm profit, which is transferred to households as a lump-sum, is:

$$\Pi_{y,t} = (1-mc_t)y_t \tag{7}$$

where the real price of goods is normalised to unity.

#### 2.1.3 Capital producers

Capital producers invest to build capital in the following law of motion:

$$k_t - k_{t-1} = \varepsilon_{i,t}\left[i_t - \frac{F}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2 i_t\right] - \delta k_{t-1} \tag{8}$$

where $i_t$ is the real investment, $\frac{F}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2 i_t$ is the capital adjustment cost, $\varepsilon_{i,t}$ is the shock to investment efficiency. The optimisation problem of capital producers is to maximise life-time profit $E_0\sum_{t=0}^{\infty}\beta^t V_{0,t}\Pi_{k,t}$ by choosing $i_t$, subject to (8)[3], which determines the supply of capital.

The lump-sum profit transferred to households in each period is:

$$\Pi_{k,t} = q_t k_t - q_t(1-\delta)k_{t-1} - i_t \tag{9}$$

#### 2.1.4 The public sector

**Central bank** The central bank stabilises output and inflation by adjusting the nominal interest rate following a Taylor rule:

$$1+R_t = (1+R_{t-1})^{\rho_R}(\frac{1+\pi_t}{1+\pi^*})^{(1-\rho_R)\varphi_\pi}\left(\frac{y_t}{\bar{y}}\right)^{(1-\rho_R)\varphi_x}(1+\bar{R})^{(1-\rho_R)}\varepsilon_{TR,t} \tag{10}$$

[3] $V_{0,t} \equiv \lambda_t/\lambda_0$ is the marginal rate of substitution between incomes received in periods $t$ and 0, where $\lambda_{i=0,t}$ is the Lagrangian multipliers in the household problem.

where $R_t$ is the policy rate, $\rho_R$ is the policy inertia, $\varphi_\pi$ and $\varphi_x$ are the interest rate responses to inflation and output, $\pi^*$ is the inflation target, $\bar{y}$ and $\bar{R}$ are the steady-state levels of output and the policy rate, $\varepsilon_{TR,t}$ is the shock to monetary policy.

**Fiscal authority** The fiscal authority stabilises output and public debt by adjusting government spending, $g_t$, following:

$$g_t = \varepsilon_{g,t}\bar{g}(\frac{y_t}{\bar{y}})^{\gamma_x}(\frac{b_{t-1}}{\bar{b}})^{\gamma_b} \tag{11}$$

where $b_{t-1}$ is the debt outstanding, $\gamma_x$ and $\gamma_b$ are the policy responses to output and debt, $\bar{g}$ is the steady-state-level government spending, $\varepsilon_{g,t}$ is the government spending shock. It also stabilises by taxing, by adjusting the marginal tax rate on wage income in a similar manner:

$$(1+\tau_t) = \varepsilon_{\tau,t}(1+\bar{\tau})(\frac{y_t}{\bar{y}})^{\phi_x}(\frac{b_{t-1}}{\bar{b}})^{\phi_b} \tag{12}$$

where $\phi_x$, $\phi_b$ and $\bar{\tau}$ have similar meanings, and $\varepsilon_{\tau,t}$ is the shock to the tax policy.

Tax revenue, $t_t$, is given by:

$$t_t = \tau_t w_t n_t \tag{13}$$

The government budget constraint is given by:

$$g_t - t_t = \Delta b_t - r_{t-1}b_{t-1} \tag{14}$$

which requires primary deficit to be met by the new issuing of debt, net of the interest payment on the previous debt outstanding.

### 2.1.5 Market clearing, identities and shock processes

The goods market clears with:

$$c_t + i_t + g_t = y_t \tag{15}$$

The bond market clears with:

$$s_t = b_t \tag{16}$$

The real interest rate is defined by the Fisher equation:

$$1 + r_t = \frac{1+R_t}{1+E_t\pi_{t+1}} \tag{17}$$

The real money stock in circulation is given by:

$$m_t = \frac{m_{t-1}}{1+\pi_t} + h_t \tag{18}$$

where $h_t$ is the seigniorage.

All the shocks are mean-reversing and the logs of them are AR(1) processes.

## 2.2 The MMT model variant

In the benchmark model above, government spending is financed by tax revenue and public debt; money is issued by the central bank 'independently' according to the bank's own targets. Central bank independence in such a setting requires that government spending must be 'Ricardian' – that is, the current primary deficit must be equal to the present value of the expected future primary surplus – such that the government budget is solvent intertemporally and that, the central bank is not forced to monetise any deficit (or debt) which would otherwise be inflationary according to the familiar 'unpleasant monetarist arithmetic' (Sargent and Wallace, 1981). As will be seen, given the various rules that impact on the issuing of money under MMT, the government is still constrained to follow a Ricardian policy. Nevertheless, with part of the deficit being monetised directly, long-run solvency will require an 'inflation tax' – implying an inflation equilibrium – though under reasonable inflation targets the discipline will be not much affected.

Thus under MMT government spending still aims at stabilising output (or 'full employment' as described in most MMT narratives). But monetary policy, instead of being bound by the central bank's benchmark interest rate rule, is essentially accommodative in the short run: the supply of cash is determined as whatever is needed to finance the government's budget. Furthermore, interest rates are held down to a target value by issuing debt, which correspondingly reduces the cash issue. Finally, taxes, that must be paid with money, are manipulated to hit an inflation target by absorbing any excess money creation threatening excess long run inflation[4]. Our MMT variant of the benchmark model therefore features the following modifications: a) fiscal deficits drive the supply of money – hence monetary policy loses its direct role in stabilising inflation; b) inflation is stabilised by the marginal tax rate on wages; c) debt is no longer determined by the government budget constraint (which is now effectively a money supply equation); instead, it is adjusted for delivering a desired level of the nominal rate of interest. Effectively, this means that monetary policy under MMT takes the form of a complex money supply process resulting from a)-c) in place of the New Keynesian Taylor rule for interest rates; interest rates in turn are set by money market equilibrium.

The first modification involves rewriting the government budget constraint to be:

$$h_t = g_t - t_t - \Delta b_t + r_{t-1} b_{t-1} \tag{19}$$

such that the net increase in the monetary base, $h_t$, is determined by the shortfall of the government budget given the tax revenue and debt outstanding; since the central bank is now consolidated with the fiscal authority into a single entity, this equation also replaces the Taylor rule in the benchmark model.

The second modification involves rewriting the tax policy rule to be:

$$1 + \tau_t = \varepsilon_{\tau,t}(1 + \bar{\tau})(\frac{1 + \pi_t}{1 + \pi^*})^{\phi_\pi} \tag{20}$$

such that the tax rate is now adjusted against inflation, instead of output and debt.

The third modification involves adding a debt supply equation:

$$b_t = \varepsilon_{b,t}\bar{b}(\frac{1 + R_t}{1 + \bar{R}})^{\varsigma} \tag{21}$$

[4] One implicit assumption (which is barely mentioned by MMT economists, however) is that this must be before the tax rate has reached an upper limit defined by the Laffer curve. Going beyond such a limit higher tax rates would undermine tax revenue, such that excess money has to generate a sufficient inflation tax – which can skyrocket – for the long-run government budget to be solvent. In our modelling here we respect this assumption by ensuring that the steady-state tax rate is below the Laffer curve limit such that the MMT model does not deliver the 'unpleasant' outcome.

where debt stabilises the nominal interest rate (with $\varsigma < 0$), and $\varepsilon_{b,t}$ is the debt supply shock. As the MMT school argues, debts in the MMT world are only needed for preventing excess reserves in the banking system from pushing the nominal interest to zero – i.e., it is an interest rate management tool (Ehnts and Höfgen, 2019). Accordingly the government spending rule is modified to be:

$$g_t = \varepsilon_{g,t}\bar{g}(\frac{y_t}{\bar{y}})^{\gamma_x} \tag{22}$$

such that it no longer stabilises debt outstanding.

It is not difficult to see that under this setting long-run solvency is guaranteed by $\bar{b} \approx \frac{1}{\bar{r}}(\bar{t} - \bar{g} + \bar{m}\bar{\pi})$, i.e., the steady-state outstanding debt is approximately equal to the present value of the 'permanent' primary surplus embracing an inflation tax, as in any standard model where government spending is partly money financed[5]. Nevertheless, since (20) requires the tax rate to keep adjusting until the inflation target is hit, given a reasonable target, say 2%, and the fact that $\bar{m}$ has a similar size as $\bar{g}$, the steady-state inflation tax, $\bar{m}\bar{\pi}$, would be so small that it would hardly affect the discipline. Hence from a long-term viewpoint MMT can still be quite disciplinarian on deficits in spite of the ongoing monetisation. What the regime has essentially changed is the short-run dynamics of monetary policy, by linking it to fiscal policy, interest rates and inflation.

## 2.3 How do the two models differ in their behaviour?

Before moving forward to evaluate the models' fit, it would be worth disentangling how the behaviour of the two models differs under the different policy settings. As noted earlier, the fundamental difference between MMT and the benchmark NK model lies in the former's replacement of the Taylor rule with a money supply function driven by public deficits – thus, the replacement of (10) with (19) in our modelling above. Since primary deficit equals $g_t - t_t$, it would be the most convenient to illustrate how the transmission differs with a shock to government spending or the tax rate on wages.

Figure 1 compares the key impulse responses of the two models caused by a one-standard-deviation shock to government spending[6]. As the figure shows, a rise in government spending under the benchmark model drives up output and inflation, leading to a rise in the nominal interest rate – made to happen via a reduced money supply – enforced by the Taylor rule; public debt rises to finance the budget deficit due to the insufficient rise in tax revenue. These 'orthodox' responses are in sharp contrast to those under MMT, where although the rise in government spending still drives up output and inflation and causes tax revenue to rise[7], money – instead of debt – has to rise to finance the deficit as it emerges, as under MMT, debt, which is merely an interest rate management tool, does not respond to the deficit directly. Such a rise in money does not lead to a fall in the nominal interest rate, as it shows; rather, as the initial rise in output and inflation triggers a strong rise in money demand, the nominal interest rate rises to clear the market, which mimics the Taylor rule's behaviour. Hence under MMT monetary policy enforces through the money supply some indirect raising of interest rates as the Taylor rule does; but this 'indirect monetary tightening' is much weaker and more gradual and as a result, the output boost lasts much longer.

[5] To derive this condition, note that in the steady state where the net change in real debt outstanding is zero (19) reduces to $\bar{h} = \bar{g} - \bar{t} + \bar{r}\bar{b}$. Solving for $\bar{b}$ by rearranging this steady-state equation and substituting out $h$ using (18) therefore yields $\bar{b} = \frac{1}{\bar{r}}\left[\bar{t} - \bar{g} + \bar{m}\left(\frac{\bar{\pi}}{1+\bar{\pi}}\right)\right] \approx \frac{1}{\bar{r}}(\bar{t} - \bar{g} + \bar{m}\bar{\pi})$.

[6] In this comparison, as well as in Figures 2 and 3 that follow, we parameterise the models with an identical set of 'true' parameter values which we estimate and report in Table 1, Section 3.3 below.

[7] In this case, tax revenue rises both because the higher output raises employment – as under the benchmark model, and because the tax rate on wages rises in response to inflation under MMT.

Figure 1: Effect of a rise in government spending

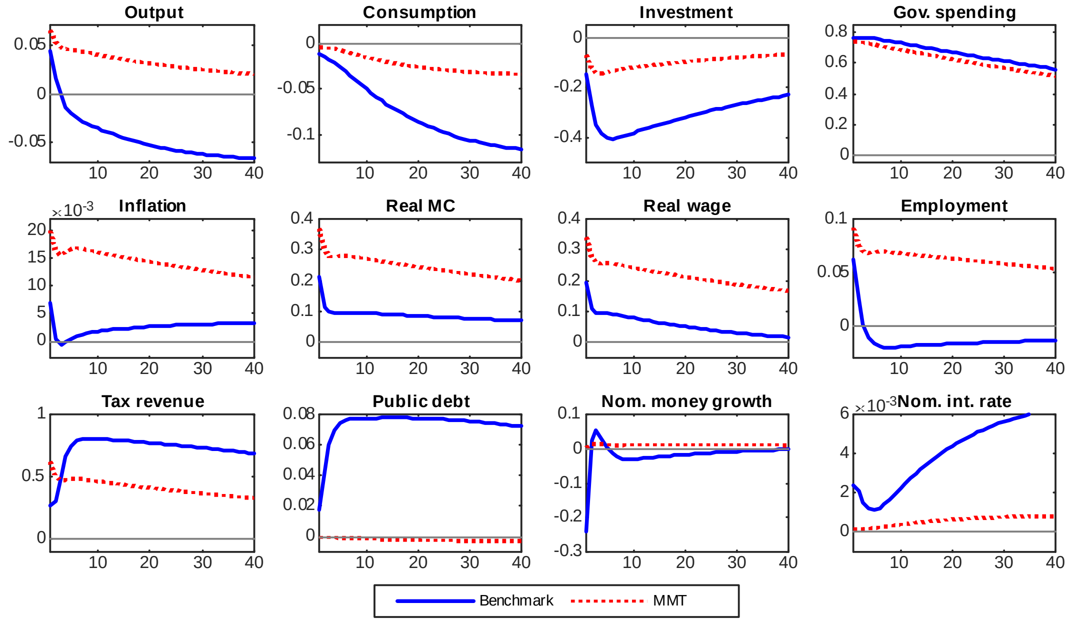



Figure 2: Effect of a tax cut on wages

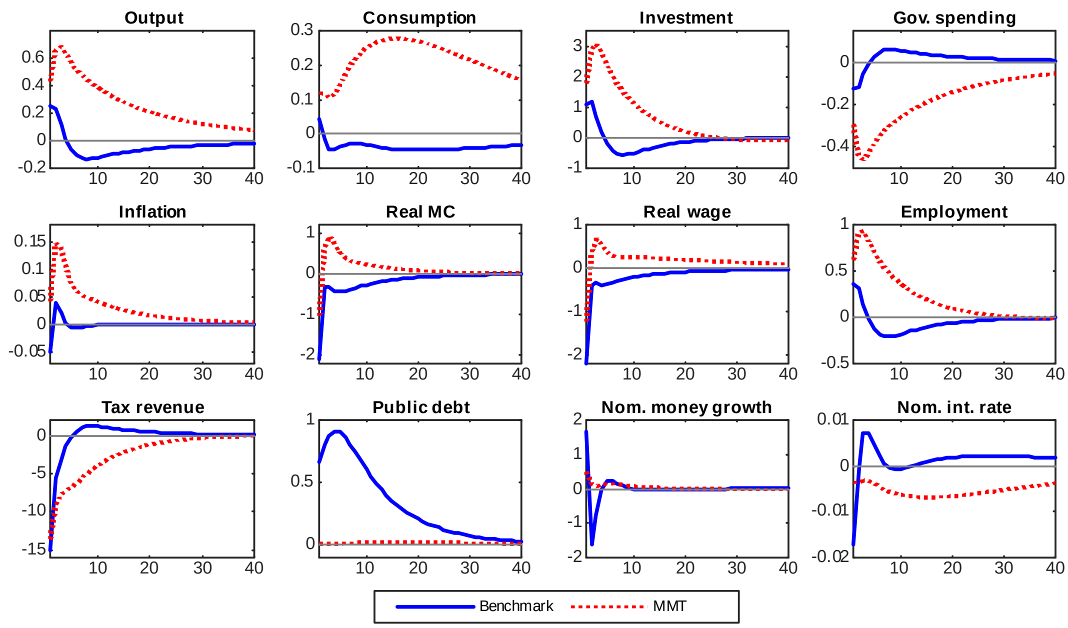


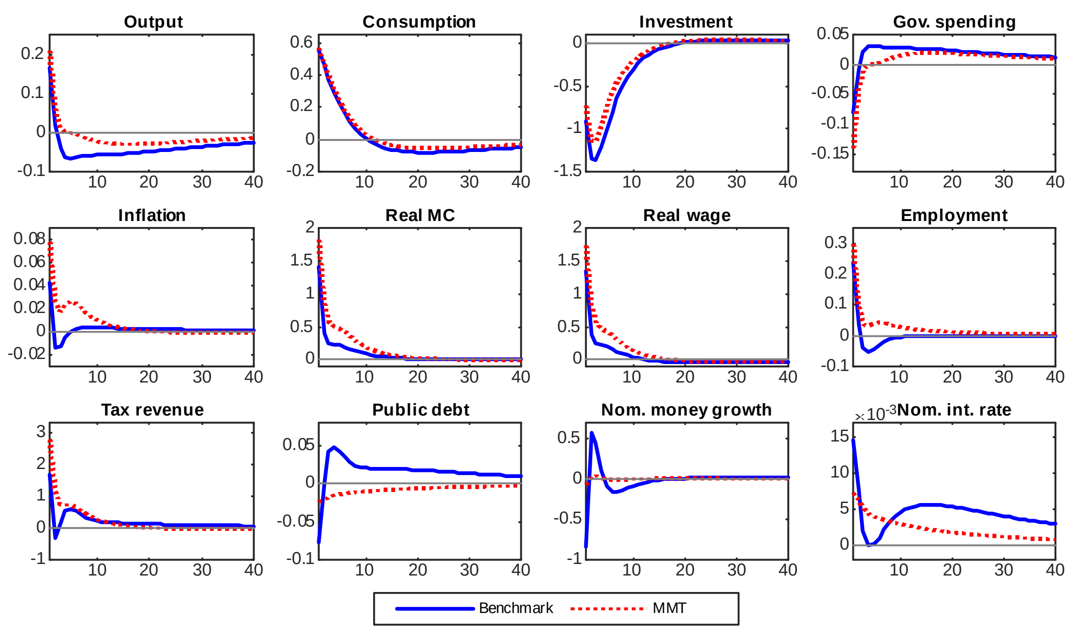

Figure 2 compares the impulse responses to a tax cut on wages. This encourages work participation in both models, causing the real wage (hence also the real marginal cost) to fall; and supply (output) rises. Under the benchmark model, the nominal interest rate falls initially in response to lower prices due to the Taylor rule; but rebounds quickly, as inflation emerges as demand is stimulated. The ultimate rise in the interest rate, implying a fall in money supply, crowds out sufficient consumption and investment finally, which ends the output boost. Under MMT, by contrast, the nominal interest rate can fall only, as money supply has to rise in response to the tax cut since the reduction in fiscal revenue cannot be filled by the issuing of public debt. Hence, output is boosted further with a surge in both consumption and investment.

On this occasion, the demand side always dominates the supply side, such that the inflation response is always positive and the surge in it is much more substantial in contrast to the benchmark case.

In sum, fiscal expansion, whether via a rise in government spending or a general tax cut on wages, results in much larger output multipliers at the expense of more inflation under MMT which, by forcing money to finance such expansion, implies a much more permissive money supply process – as might be expected from the thrust of MMT policy advice.

Figure 3 shows the effect of a straight demand shock (due to a rise in consumption preference) to illustrate how the policy instruments under the two regimes would respond. The shock increases consumption and output directly, which elicits three policy responses: two are fiscal, where government spending falls under both models to reduce the output gap, and the tax rate rises under the benchmark model to reduce the gap and under MMT to reduce inflation; one is monetary, where under the benchmark model the Taylor rule raises rates, while under MMT the rise in money demand raises rates less, with the money supply changing little with limited deficit changes. What we see here is that government spending and tax revenues differ little between the two models, suggesting that fiscal responses are similar. However, the interest rate responses differ sharply, being considerably larger under the benchmark model. This fits in with the picture of an MMT world in which money is largely accommodative to fiscal needs and to money demands triggered by output rises. It is only intolerant of demands triggered by inflation, because of the MMT inflation target in the tax function.

Figure 3: Effect of a rise in consumption




# 3 Confronting the models with the data: can either model fit the facts?

We have seen that the different monetary policies asserted by the benchmark and MMT models imply quite different model behaviour and so a differing capacity to match the data behaviour. In this section we evaluate this capacity. We do so by testing the models formally with a statistical test – the indirect inference Wald test, which compares the models' behaviour to the data's as characterised by an auxiliary, empirical, model which can be viewed as a reduced form of the 'true' model. Indirect inference (II), which is a simulation-based method, was originally designed for estimating models whose likelihood functions were too complex for them to be estimated directly (Smith, 1993; Gregory and Smith, 1991, 1993; Gourieroux et al., 1993; Gourieroux and Monfort, 1996). The method has been developed more recently by Minford et al. (2008), Meenagh et al. (2009), Le et al. (2011, 2016) and Minford et al. (2019) to be a formal statistical test for DSGE models, which evaluates whether a candidate model – estimated or calibrated – can pass a Wald test on the distance between the model and the data with a high-enough probability such that the model may be considered 'true'. The p-value of the test may also be used for ranking competing models.

While the Bayesian method has been the workhorse for empirical DSGE analyses since Smets and Wouters (2007), we deviate from this convention by using indirect inference here since it is our aim to test, rather than just estimate, the models, which would enable us to determine if any of them is rejected by the data when their best-fitting version is evaluated. The Bayesian method, which estimates a model with set priors, does not generally test whether the model fits the data or not. The DSGE-VAR method of Del Negro and Schorfheide (2006), which is also a Bayesian method, does evaluate model fit; however it only does so informally, by estimating a hyper-parameter interpreted as a goodness-of-fit index, which is not a statistical test and therefore, provides no indication as to when a model should be rejected. The Maximum Likelihood method does test as well as estimating a model formally – like indirect inference; but ML estimates in small samples (which are common in macro-models including ours below) are highly biased – as is well-known – and, as the Monte Carlo experiments of Le et al. (2016) show, likelihood tests generally suffer from insufficient power to reject a false model when it can be rejected by indirect inference tests with good power.

We explain the method in detail next.

## 3.1 Estimating and testing a DSGE model with indirect inference

The basic idea is to use an unrestricted, empirical model, which is used as an auxiliary model, for features of the data (the 'facts') to be established; the DSGE model is then estimated/tested against such features based on the distance between the two models' implications. In model estimation where the DSGE parameters are unknown, the task is to find parameter values that minimise this distance. In model testing where the DSGE parameters are known in advance, the task is to judge whether such distance is sufficiently large (small), such that the DSGE model can (cannot) be rejected at a chosen significance level. The whole procedure may be described with three steps:

**Step 1: Construct descriptors of the data behaviour using the auxiliary model.**

Here we use an unrestricted VAR with a deterministic trend:

$$Y_t = C + A(L)Y_{t-1} + Bt + e_t \tag{23}$$

where $Y_t$ is a vector of endogenous variables whose behaviour is what we want the DSGE model to fit, $C$ is a vector of constants, $t$ is the deterministic trend, $e_t$ is a vector of the VAR residuals; $A$ and $B$ are matrices of the VAR coefficients. It is worth pointing that by fitting the data to (23), our purpose is *not* to find an empirical model that 'fits the data the best'. Instead, the empirical model, which is used as an auxiliary model here, is estimated for providing a benchmark description of the data, against which the DSGE model can be evaluated. Any unrestricted model may in principle be used. Here we use a VAR, as the linear solution of any DSGE model can be written as a VAR with restrictions. Using an unrestricted VAR to describe the data therefore provides a natural benchmark which the DSGE model – if it was 'true' – has to match.

Since the debate on MMT revolves around the interaction between government spending, monetary policy, and output and inflation, we set $Y_t \equiv (g_t, R_t, y_t, \pi_t)'$. We use a VAR(1), instead of higher-order VARs, in order to limit the degrees of freedom used in describing the data. Meenagh et al. (2019) show that raising the VAR order tends to raise the power of the test excessively, preventing tractable models close to the truth from passing the test. A VAR(1) has considerable but not such excessive power.

Descriptors of the data behaviour may be simply the VAR estimates or functions of them. Here, we let them be the autoregressive parameters and the variances of the VAR residuals, such that the data behaviour we require the DSGE model to fit is their dynamic behaviour (including cross-variable interactions) and volatility. These data descriptors are denoted as $\Phi^{Act}$.

**Step 2: Simulate the DSGE model to create parallel simulations; and with each of these, re-estimate the auxiliary model to generate a distribution of the same data descriptors.**

Since the true distribution of the DSGE shocks is unknown, for simulating the model, we first calculate the historical shocks using the data and the solution of the DSGE model. We then generate parallel simulations by bootstrapping these sample shocks. Effectively, the simulations are based on an estimate of the small-sample distribution of the DSGE shocks, which Le et al. (2011) find to be generally more accurate than the asymptotic distribution for small samples.

The distribution of the data descriptors estimated with the parallel simulations, which represents the implication of the DSGE model, is denoted as $\Phi^{Sim} = (\Phi^{Sim1}, \Phi^{Sim2}, ..., \Phi^{SimN})$. In model estimation, we search for DSGE parameters which minimise the distance between $\Phi^{Act}$ and $\overline{\Phi}$, where $\overline{\Phi} = E(\Phi^{Sim})$. In model testing, we ask whether $\Phi^{Act}$ came from this distribution with a high-enough probability, i.e., the distance between $\Phi^{Act}$ and $\overline{\Phi}$ is sufficiently close, such that the DSGE model is not rejected by the data.

**Step 3: Evaluate the distance between the data and the DSGE model.**

The distance between the data and the DSGE model, which is both the objective function in estimation and the test statistic in testing, is given by the Wald statistic:

$$Wald = (\Phi^{Act} - \overline{\Phi})' \sum\nolimits_{\Phi\Phi}^{-1} (\Phi^{Act} - \overline{\Phi}) \tag{24}$$

where $\sum_{\Phi\Phi}$ is the variance-covariance matrix of the vector of the data descriptors generated with the parallel simulations.

To estimate the model, the II estimator conducts a grid search for the DSGE parameters until (24) is minimised[8]. The optimal set of parameters may be denoted as $\theta^{DSGE}$.

To test whether the model is rejected with a given set of DSGE parameters (be it the optimal set or any other set), we set the null hypothesis that 'the DSGE model is true' (i.e., $H_0$: $\Phi = \overline{\Phi}$, where $\Phi$ is a vector of the hypothetical true values of the data descriptors), and we calculate the p-value of the null hypothesis using:

$$P = (100 - WP)/100 \tag{25}$$

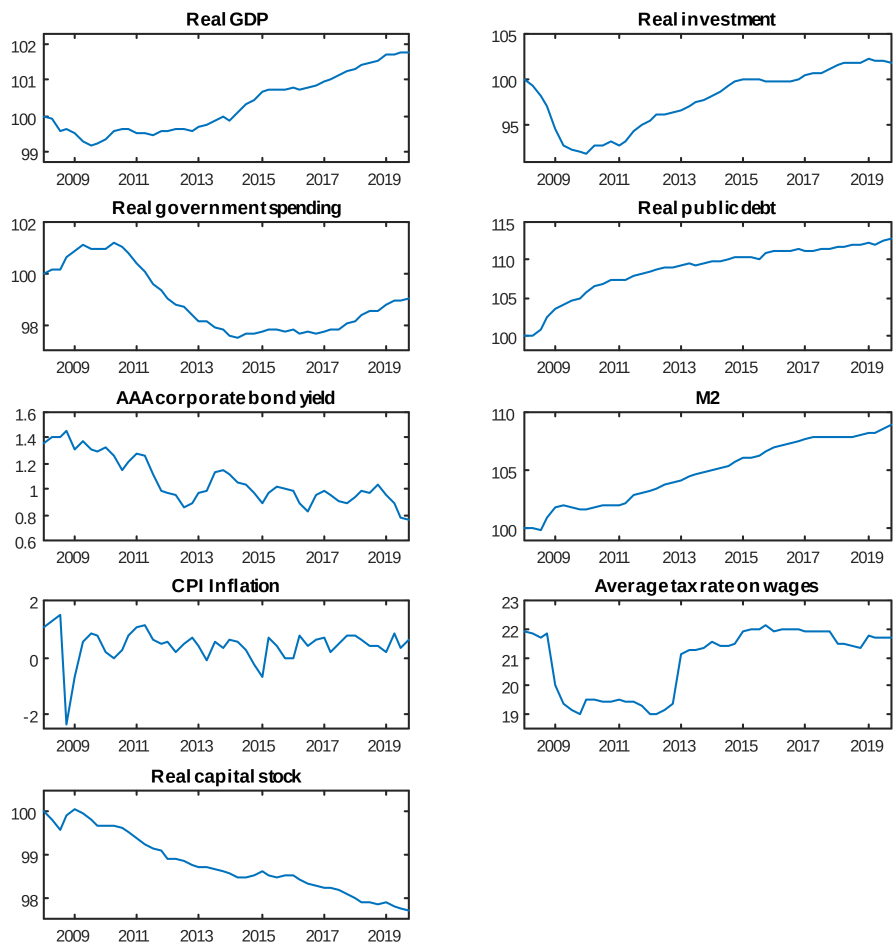
where $WP$ is the percentile of $\Phi^{Act}$ in the distribution of $\Phi^{Sim}$. The DSGE model would pass (fail) the Wald test if the p-value is above (below) the 1%, 5% or 10% threshold.

[8] In our practice below we implement this search by using the Simulated Annealing algorithm.

## 3.2 Data and calibrated parameters

The variables involved in calculating the historical shocks are: output, investment, government spending, public debt outstanding, nominal interest rate, money supply, inflation, tax rate on wages, and capital stock. These embrace the four variables fitted to (23) for generating the chosen data descriptors; and other 'state variables' used by the solution of the DSGE models. The data are observed between 2008Q1 and 2019Q4. Both nominal interest rate (which we measure with the corporate bond rate), inflation and tax rate on wages are measured as quarterly rates. The other variables, defined in real and per-capita terms, are measured in natural logarithm. The processed data are plotted in Figure 4. The data sources, the time series collected, and the adjustments to the raw data are detailed in the appendix.

Figure 4: The data




Of the model parameters we fix those that are known to be hard to identify or on which consensus has been made in the literature at their calibrated values, where we set $\beta = 0.995$, $u = 0.3$, $\delta = 0.025$, $\pi^* = 0.02$, $\bar{g} = 0.22$ and $\bar{\tau} = 0.21$[9]. These values resemble those used by Smets and Wouters (2007) and Leeper et al. (2010), to which we also refer in setting the starting values of the estimated parameters reported in the following section.

[9]These parameters are calibrated for the models to imply key steady-state ratios that are broadly in line with the data according to a 'full' sample between 1966 and 2019. $\bar{g}$ is set to 0.22 such that both models imply a government-spending-to-output ratio of about 12%. $\bar{\tau}$ is set to equal the sample mean of the tax rate on wage income.

## 3.3 Model estimates and fit

The estimated parameters and the models' p-values are reported in Table 1[10].

Table 1: Model parameters and p-values

| Parameter | Definition | Starting value | II estimate | |
|---|---|---|---|---|
| | | | Benchmark | MMT |
| $\beta$ | Time discount factor | 0.995 | Fixed at starting value | |
| $u$ | Labour share | 0.3 | Fixed at starting value | |
| $\delta$ | Capital depreciation rate | 0.025 | Fixed at starting value | |
| $\pi^*$ | Annual inflation target | 0.02 | Fixed at starting value | |
| $\bar{g}$ | Steady-state government spending | 0.218 | Fixed at starting value | |
| $\bar{\tau}$ | Steady-state tax rate on wage income | 0.205 | Fixed at starting value | |
| $\vartheta$ | Consumption habit persistence | 0.5 | 0.01 | 0.53 |
| $\eta$ | Inverse of wage elasticity of labour | 2 | 3.23 | 2.04 |
| $\chi$ | Preference to money | 0.003 | 0.05 | 0.01 |
| $\psi$ | Preference to leisure | 1.5 | 2.05 | 0.94 |
| $\epsilon$ | Inflation indexation | 0.5 | 0.07 | 0.38 |
| $\theta$ | Price elasticity of demand | 7.5 | 14.9 | 13.8 |
| $\omega$ | Calvo non-adjusting probability | 0.83 | 0.75 | 0.92 |
| $F$ | Cost to capital adjustment | 10 | 14.6 | 18.3 |
| $\rho_R$ | Interest rate smoothness | 0.75 | 0.83 | – |
| $\varphi_\pi$ | Interest rate response to inflation | 1.5 | 2.00 | – |
| $\varphi_x$ | Interest rate response to output | 0.12 | 0.00 | – |
| $\gamma_x$ | Gov. spending response to output | -0.07 | -0.49 | -0.67 |
| $\gamma_b$ | Gov. spending response to debt | -0.4 | 0.00 | – |
| $\phi_x$ | Tax rate response to output | 0.5 | 0.07 | – |
| $\phi_b$ | Tax rate response to debt | 0.4 | 1.67 | – |
| $\phi_\pi$ | Tax rate response to inflation | 0.5 | – | 1.64 |
| $\varsigma$ | Debt response to interest rate | -0.5 | – | -1.39 |
| $\rho_j$ | Persistence of the time preference shock | 0.5 | 0.82 | 0.89 |
| $\rho_z$ | Persistence of the productivity shock | 0.5 | 0.35 | 0.21 |
| $\rho_\pi$ | Persistence of the mark-up shock | 0.5 | 0.35 | 0.17 |
| $\rho_i$ | Persistence of the investment shock | 0.5 | 0.77 | 0.84 |
| $\rho_g$ | Persistence of the gov. spending shock | 0.5 | 0.99 | 0.99 |
| $\rho_\tau$ | Persistence of the tax policy shock | 0.5 | 0.90 | 0.45 |
| $\rho_{TR}$ | Persistence of the Taylor rule shock | 0.5 | 0.15 | – |
| $\rho_b$ | Persistence of the debt supply shock | 0.5 | – | 0.83 |
| Model p-value ($H_0$: the DSGE model is true) | | Benchmark: 58.3% | MMT: 2.70% | |

Sample: 2008Q1-2019Q4.

Variables accounted by the auxiliary VAR model: $g_t, R_t, y_t, \pi_t$.

We can see that the II estimator finds quite different values of the structural, 'deep', parameters for the two models. Most notably, the benchmark model suggests literally no consumption habit ($\vartheta$), but a high relative preference to leisure ($\psi$), while the opposite is found under MMT. The benchmark model also suggests little price indexation ($\epsilon$), though both models agree on a high Calvo non-adjusting probability

[10]We also report the starting parameter values for reference, though the choice of them do not generally affect the estimation since the II estimator conducts a grid search for values permitted by the model theory assuming a uniform distribution.

($\omega$). The difference in the other structural parameters, which is less striking, is also obvious. In terms of the policy parameters, the benchmark model suggests a high degree of interest rate smoothing ($\rho_R$) and an active interest rate response to inflation ($\varphi_\pi$), while the MMT model suggests an active tax rate response ($\phi_\pi$). Government spending responds modestly, in both models, to output ($\gamma_x$). Debt is stabilised actively by the tax rate under the benchmark model ($\phi_b$), but is adjusted actively under MMT to stabilise the nominal interest rate ($\varsigma$). The shock processes suggested by the two models are, however, similar; in particular, they both agree on the high persistence of the time preference shock and government spending shock ($\rho_j$ and $\rho_g$).

How do the models fit the data? As the p-values show, the benchmark model (whose reported p-value is 58%) passes the Wald test comfortably at the usual 5% significance level, whereas the MMT model (whose p-value is only 2.7%) is clearly rejected. Hence the joint behaviour of $g_t, R_t, y_t, \pi_t$ (around which the 'MMT debate' revolves) is overwhelmingly in favour of the benchmark model whose mean prediction is statistically in line with what is observed with the auxiliary model – the unrestricted VAR(1). Hence the benchmark model is not only significant but, in fact, also quite 'probable'. The MMT model, which does pass the Wald test at the looser 1% level, does also explain the data to some extent. Nevertheless, it only does so by literally mimicking the benchmark model apart from its monetary setting, as pointed out earlier. Indeed, as the sharp contrast in the models' p-values has testified, it is precisely such (spurious) characterisation of monetary policy that makes MMT a much worse candidate than the benchmark Taylor-rule model in fitting the empirical fact.

What we have established here therefore provides strong evidence against MMT as a better – or even just a valid – explanation of the working of the US monetary system since the Financial Crisis, let alone '*the past 4000 years*' as Wray (2019) claims. In the following sections, we use the benchmark model as informed by the above test as the 'true' model to analyse how shocks affect output and inflation since the Crisis – an episode less studied in the literature, especially with a model surviving a formal statistical test like ours; and then go on to evaluate the policy implications of a potential MMT reform.

# 4 How do shocks affect output and inflation post-Crisis?

The benchmark model has seven shocks: the time preference shock, the productivity shock, the mark-up shock (which includes exogenous cost shocks), the investment shock, the government spending shock, the tax policy shock, and the monetary policy (interest rate) shock. We start by establishing how these shocks contribute to output and inflation volatilities according to a forecast error variance decomposition. We then analyse the model's working with the impulse responses to the key shocks. We then consider how output and inflation were driven by these shocks in the post-Crisis history.

## 4.1 Variance decomposition

Table 2 decomposes the variances of output and inflation on different forecast horizons.

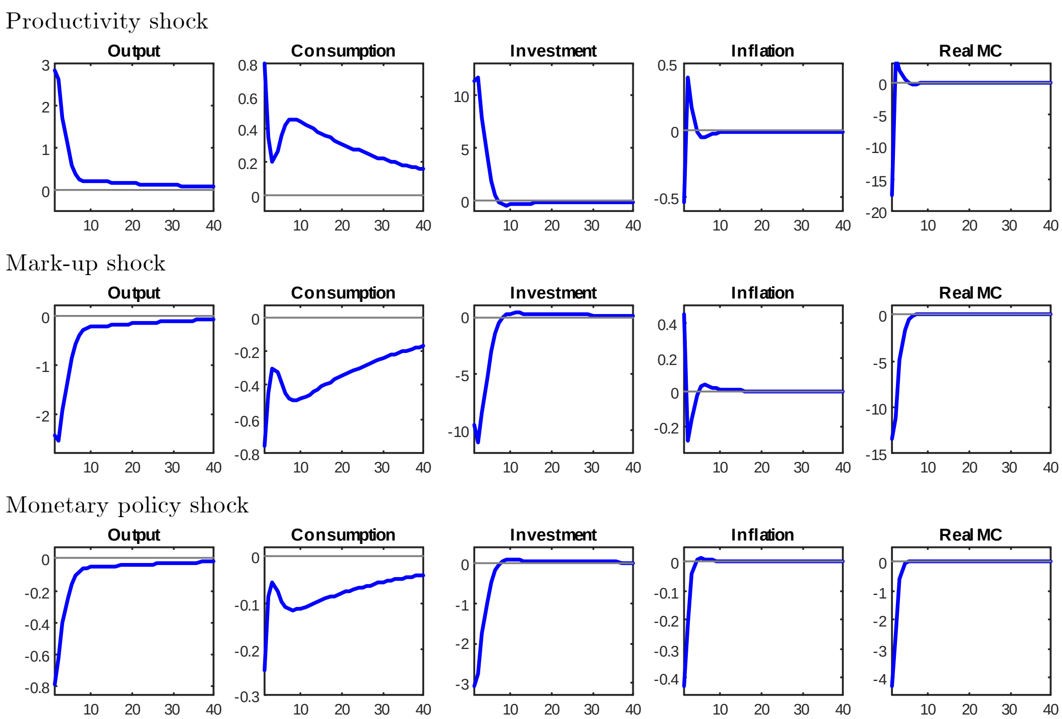
The shocks' impact on the two variables is found to be similar across time, indicating the relatively fast convergence of the dominating shocks. Output is governed by the productivity shock, which accounts for 48-54% of its variance; and the mark-up shock, which accounts for 40-47%. The other shocks, including the policy shocks, fail to exhibit a real impact. As for inflation, the productivity shock continues to dominate, accounting for 41-46%. But in this case the mark-up shock (which remains the second most impactful) is less dominating, with a weight reducing to 30%, while the interest rate shock, which weighs 22-27%, is the third most impactful factor.

These findings are broadly in line with what has been established in the literature for the pre-Crisis episode – e.g., Smets and Wouters (2007) and Iacoviello and Neri (2010) – in that, supply-side factors generally dominate the determination of output and inflation. What is new, as we discover here for the post-Crisis episode, is that, the demand side hardly plays any role. For a comparison, the government spending shock and investment shock are found to contribute by up to 35% and 23%, respectively, of the short-run output variation in SW, while IN, who focus on the long run, find a smaller, yet still non-negligible, contribution of the investment shock by 8%. Another key feature of this episode is characterised by the substantial role played by monetary policy in determining inflation – in both SW and IN, the reported contribution of the interest rate shock is only some 5%.

Table 2: Variance decomposition

| Qtrs. Ahead | Pref. | Prod. | Mark | Invest | G.Spn. | W.Tax | Interest |
|---|---|---|---|---|---|---|---|
| 4 | | | | | | | |
| Output | 0.2 | 54.0 | 40.2 | 1.0 | 0.0 | 0.4 | 4.1 |
| Inflation | 0.3 | 41.2 | 30.0 | 1.5 | 0.0 | 0.4 | 26.7 |
| 12 | | | | | | | |
| Output | 0.1 | 48.9 | 46.4 | 1.2 | 0.0 | 0.3 | 3.2 |
| Inflation | 0.2 | 45.5 | 29.9 | 1.4 | 0.0 | 0.4 | 22.5 |
| 20 | | | | | | | |
| Output | 0.2 | 47.7 | 47.2 | 1.2 | 0.0 | 0.6 | 3.1 |
| Inflation | 0.2 | 45.6 | 30.1 | 1.4 | 0.0 | 0.4 | 22.2 |
| 40 | | | | | | | |
| Output | 0.2 | 47.5 | 47.2 | 1.3 | 0.1 | 0.7 | 3.1 |
| Inflation | 0.2 | 45.6 | 30.1 | 1.4 | 0.0 | 0.4 | 22.2 |

Figure 5: The key impulse responses



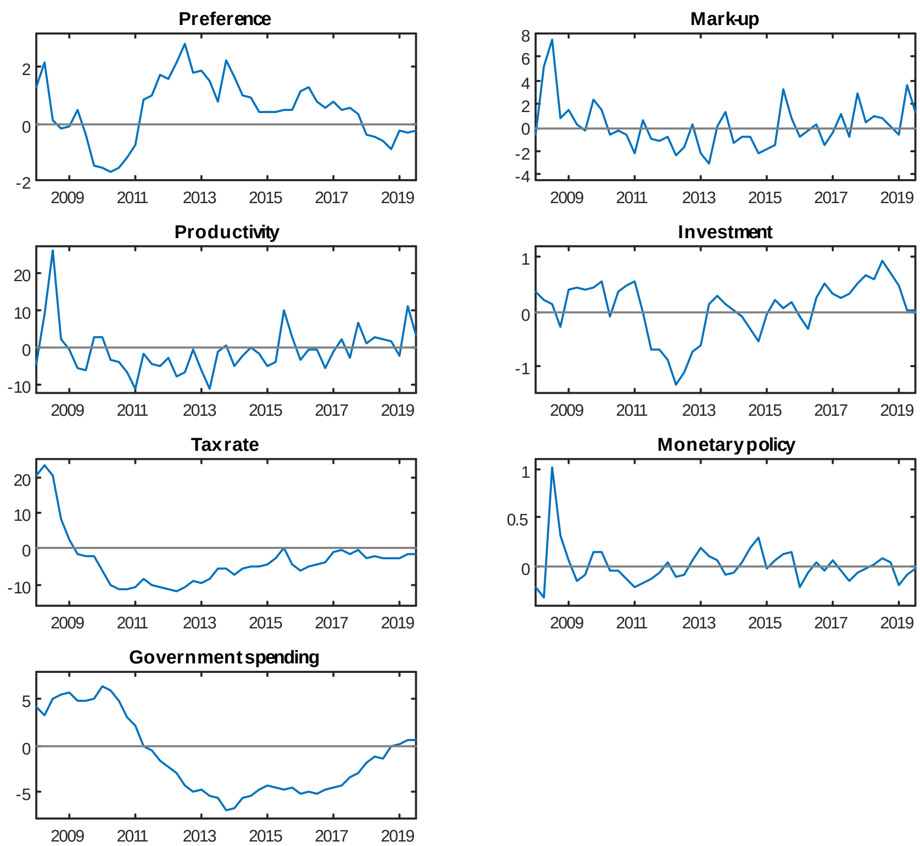
## 4.2 The key impulse responses

Figure 5 shows how output and inflation are affected by the key shocks identified above. The IRFs are completely standard: a rise in productivity raises output, causing inflation to fall as a result of excess supply; a rise in the price mark-up raises inflation, reducing demand and hence, leads to a fall in the equilibrium output; a rise in the nominal interest rate crowds out private demand, which reduces output and inflation in the usual manner.

## 4.3 Historical decomposition

The shocks realised over the sample according to the estimated model are reproduced in Figure 6. In Figure 7, we evaluate the impact of these shocks on the timelines of output and inflation over the sample history, which runs from the Financial crisis to today pre-Covid.

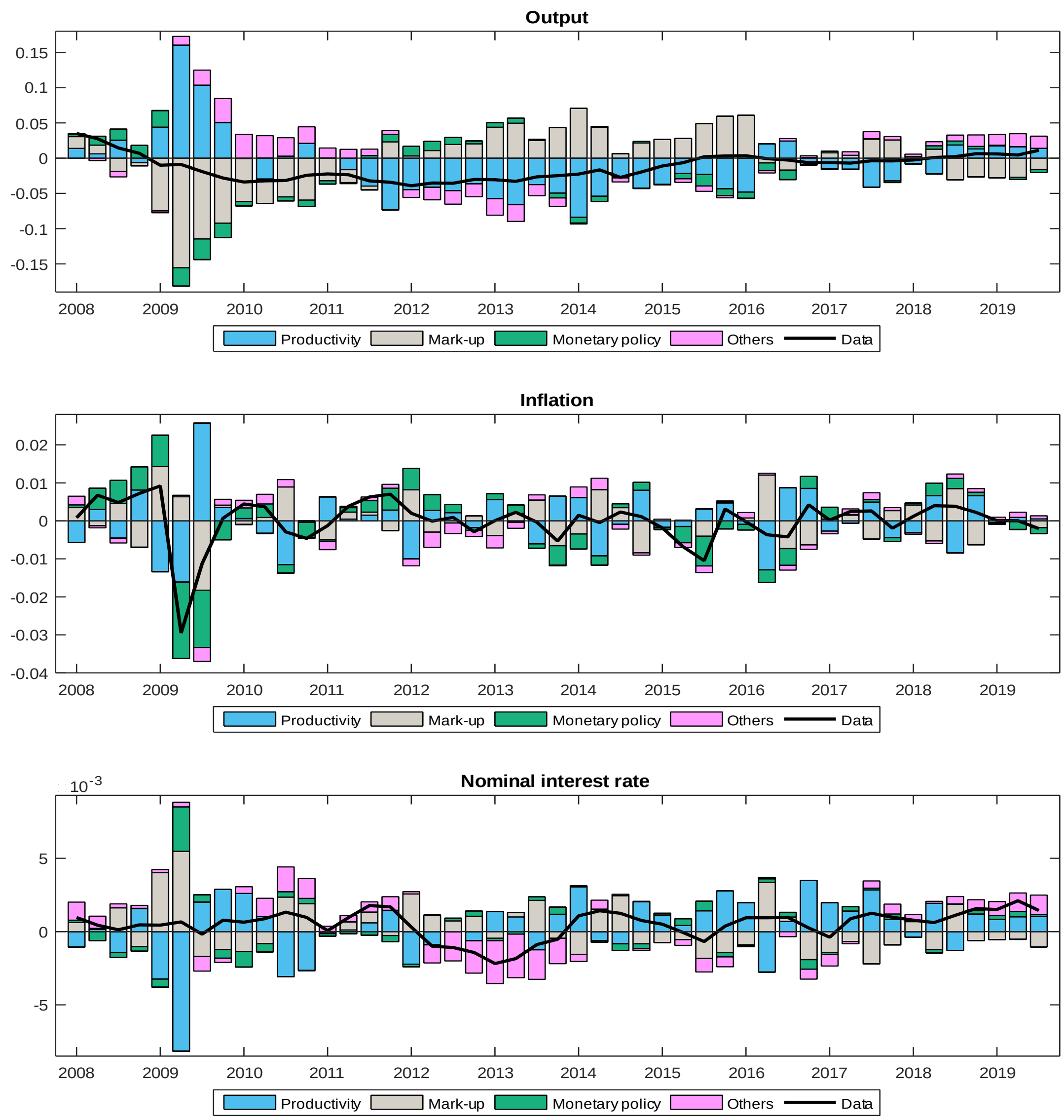
Figure 6: Historical shocks




As Figure 7 shows, the extended output recession since the Crisis up until 2015 was first induced by a surge in the price mark-up, deepened by tighter monetary conditions, and then maintained as productivity slumped albeit the improvement of the former factors (See also Figure 6 for the shocks' evolution). The productivity shock became more stabilised in the mid-2014, which established a weak momentum of recovery; and as it continued to improve, output recovered to the steady-state level in the mid-2015 and levelled out until Covid hit. Over the whole sample, there was no real role of the fiscal shocks (which are embraced by the 'Others' factor in the Figure). The monetary policy shock only played a limited role.

Inflation, which was clearly less volatile and persistent than output, was driven by the same shocks whose impacts were, however, quite balanced and generally off-setting. It was more destabilised in the late 2000s, so to speak, due to a slump in 2009 caused by a drastic, but short-lived, surge in productivity and the nominal interest rate. Otherwise, it was quite well managed by the monetary authority.

Figure 7: Historical decomposition




# 5 Evaluating the welfare effects of MMT as a policy regime

So far, we have established that MMT fails to provide a valid explanation of the working of the US monetary policy since the Financial Crisis. But looking forward – especially, given that conventional monetary expansion via interest rate cuts and quantitative easing seems to have lost its space and effectiveness substantially, could a shift of monetary policy to an MMT basis, which embeds automatic deficit monetisation, and taxing as a means to stabilise inflation, be a promising way forward?

In this section we evaluate the potential gains/losses in terms of stability and welfare implied by MMT by comparing them to the implications of the benchmark model. We do so by simulating the models, by bootstrapping the historical shocks treated as a sample from the shocks' true distribution[11]. For each model we generate 20,000 independent bootstraps having the same length as the sample; and calculate from them the average variances of the key variables, social welfare losses, and losses in household utility converted to equivalent permanent consumption.

For a better contrast we list the policy equations under each of the two regimes in Table 3. Under the benchmark Taylor-rule regime, monetary and fiscal policies are independent; nominal interest rate and money supply (implicitly) are governed by the Taylor rule targeting output and inflation, while government spending and the tax rate are governed by the fiscal rules targeting output and debt. Under MMT the money supply is adjusted as required by its various fiscal rules: money supply is created to finance government spending directly, while this in turn reacts to the output gap; the tax rate reduces the money supply, in response to an inflation target; sales of debt, reducing money supply, are made in response to a nominal interest rate target. Notice that fiscal policy is active under both monetary regimes, in the sense that it responds to the output gap.

Table 3: Policy equations under the benchmark Taylor and MMT regimes

| | Benchmark | MMT |
|---|---|---|
| Monetary policy | $1+R_t=(1+R_{t-1})^{\rho_R}\left(\frac{1+\pi_t}{1+\pi^*}\right)^{(1-\rho_R)\varphi_\pi} \cdot \left(\frac{y_t}{\bar{y}}\right)^{(1-\rho_R)\varphi_x}\left(1+\bar{R}\right)^{(1-\rho_R)}\varepsilon_{TR,t}$ | $h_t=g_t-t_t-\Delta b_t+r_{t-1}b_{t-1}$ |
| Gov. Spending | $g_t=\varepsilon_{g,t}\bar{g}(\frac{y_t}{\bar{y}})^{\gamma_x}(\frac{b_{t-1}}{\bar{b}})^{\gamma_b}$ | $g_t=\varepsilon_{g,t}\bar{g}(\frac{y_t}{\bar{y}})^{\gamma_x}$ |
| Tax policy | $(1+\tau_t)=\varepsilon_{\tau,t}(1+\bar{\tau})(\frac{y_t}{\bar{y}})^{\phi_x}(\frac{b_{t-1}}{\bar{b}})^{\phi_b}$ | $1+\tau_t=\varepsilon_{\tau,t}(1+\bar{\tau})(\frac{1+\pi_t}{1+\pi^*})^{\phi_\pi}$ |
| Issuing of debts | $g_t-t_t=\Delta b_t-r_{t-1}b_{t-1}$ | $b_t=\varepsilon_{b,t}\bar{b}(\frac{1+R_t}{1+\bar{R}})^{\varsigma}$ |

## 5.1 Implications for stability and welfare

Table 4 reports the average variances of the simulated output, inflation and real interest rate under the two differing regimes just described.

What do these alterations in the monetary and fiscal regime due to MMT achieve? We find that the output variance rises to about 2.5 times that under the current benchmark regime, while the inflation and real interest rate variances are literally unaffected. Table 5 translates these changes into household welfare in the spirit of Lucas (1987), revealing that MMT lowers it by a material 0.8% consumption equivalent per capita, which, with reference to the mean consumption level over the sample and CPI in 2021, is worth $1,795 per annum[12]. And this lowering is confirmed by ad hoc loss measures weighting the variances in

[11] In order that the simulations will have fully, but not overly, reflected the regimes' differences, we impose that the two models share the same 'deep' parameter values as found with the benchmark, 'true', model; for the small set of parameters that are MMT-specific, we use their sample estimates as reported in Table 1. The same principle applies to the choice of the 'historical sample shocks' bootstrapped for generating the simulations.

[12] The Lucas (1987)'s $\lambda$, which measures the percentage in permanent consumption one has to be compensated for him/her to be equally satisfied under an alternative regime, is calculated by $\lambda=\exp\left[(1-\beta)\left(U^{MMT}-U^{Bench}\right)\right]-1$, where $U^{Bench}$ and $U^{MMT}$ are the household life-time utilities under the benchmark and MMT regimes, respectively.

different ways, which show that the overall stability loss under MMT is some 50-110% higher.

Table 4: Variances of output, inflation and the real interest rate

| | $Var(\hat{y})$ | $Var(\tilde{\pi})$ | $Var(\tilde{r})$ |
|---|---|---|---|
| Benchmark | 2.08 | 0.35 | 0.11 |
| MMT | 5.17 | 0.34 | 0.13 |

Table 5: Welfare losses

| Panel A: in consumption (Shift from Benchmark to MMT) | | | | | |
|---|---|---|---|---|---|
| Lucas (1987)'s $\lambda$ | | 0.83% | | | |
| Cons. Equiv. | | $1,795 pcpa | | | |
| Panel B: in overall stability (SWL=$\frac{1}{2}\tilde{\pi}_t^2+\varpi_y\hat{y}_t^2+\varpi_r\tilde{r}_t^2$) | | | | | |
| | $\varpi_y \backslash \varpi_r$ | 0 | 0.1 | 0.3 | 0.5 |
| Benchmark | 0.1 | 0.28 | 0.29 | 0.30 | 0.31 |
| MMT | | 0.43 | 0.44 | 0.45 | 0.46 |
| Benchmark | 0.3 | 0.48 | 0.49 | 0.50 | 0.52 |
| MMT | | 0.95 | 0.95 | 0.97 | 0.98 |
| Benchmark | 0.5 | 0.70 | 0.70 | 0.71 | 0.72 |
| MMT | | 1.46 | 1.47 | 1.48 | 1.50 |

The MMT regime is therefore plainly inferior to the current Taylor rule regime in stabilising output and so consumption. The current regime embodies a fiscal response to output from both spending and tax, only moderated by a Ricardian debt response. However, as we saw above when considering the IRFs to a pure demand shock to output, fiscal responses were very similar across the two models. Meanwhile the monetary policy response to output via the interest rate channel is much weaker under MMT, as can also be seen from the model IRFs; MMT is generally accommodative of money demands from output and fiscal changes, but is not accommodative of money demands due to inflation. Hence, it would seem that the greater output volatility under MMT comes from its accommodative response to output shocks, while the similar inflation variance comes from its similar inflation response, which is non-accommodative, much like the Taylor rule.

# 6 Conclusion

Modern monetary theory (MMT), which portrays a world in which fiscal activism need not be constrained by the government budget, has received much more attention since the Financial Crisis while the space for monetary policy has largely contracted. In this paper, we have spelt out MMT as a full DSGE model in a testable form, and tested its empirical validity and implications on stability and welfare side by side with a canonical New Keynesian model, which has never been done in the literature.

The fact that – while the NK model is not – the MMT model is rejected by the data is strong evidence against the MMT narrative of how fiscal and monetary policies have interacted and affected the US economy post-Crisis. What we have shown here, is that the MMT alternative description of monetary policy does not match the data behaviour as well as the benchmark Taylor rule; and furthermore that if it and its version of fiscal policy had replaced the Taylor rule, it would have resulted in a material loss of welfare.

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# Appendix

## A Model and the optimisation problems

### A.1 The benchmark Model

#### A.1.1 The household problem

Households maximise lifetime utility:

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t j_t \left\{ \Gamma \ln \left( c_t - \vartheta c_{t-1} \right) + \chi \ln m_t - \psi \frac{n_t^{1+\eta}}{1+\eta} \right\} \tag{A.1}$$

by choosing $c_t$, $n_t$, $m_t$, $k_t$ and $s_t$, subject to budget constraint:

$$\begin{aligned} & c_t + s_t + m_t + q_t k_t \\ = \; & (1-\tau_t) w_t n_t + (1+r_{t-1}) s_{t-1} + \frac{m_{t-1}}{1+\pi_t} + h_t + r_{k,t} k_{t-1} + q_t (1-\delta) k_{t-1} + \Pi_{y,t} + \Pi_{k,t} \end{aligned} \tag{A.2}$$

The first order conditions are:

$$\frac{\partial U_0}{\partial c_t} : \Gamma \frac{1}{c_t - \vartheta c_{t-1}} - \beta E_t \left( \frac{j_{t+1}}{j_t} \right) \Gamma \vartheta \frac{1}{E_t c_{t+1} - \vartheta c_t} = \lambda_t \tag{A.3}$$

$$\frac{\partial U_0}{\partial n_t} : \; \psi n_t^{\eta} = \lambda_t (1-\tau_t) w_t \tag{A.4}$$

$$\frac{\partial U_0}{\partial m_t} : \; \left( \frac{\chi}{m_t} - \lambda_t \right) = -\beta E_t \left( \frac{j_{t+1}}{j_t} \right) E_t \lambda_{t+1} \frac{1}{(1 + E_t \pi_{t+1})} \tag{A.5}$$

$$\frac{\partial U_0}{\partial k_t} : \; q_t = \beta E_t \left( \frac{j_{t+1}}{j_t} \right) E_t \left( \frac{\lambda_{t+1}}{\lambda_t} \right) \left[ E_t r_{k,t+1} + E_t q_{t+1} (1-\delta) \right] \tag{A.6}$$

$$\frac{\partial U_0}{\partial s_t} : \; \lambda_t = \beta E_t \left( \frac{j_{t+1}}{j_t} \right) E_t \lambda_{t+1} (1 + r_t) \tag{A.7}$$

#### A.1.2 The firms' problem

Individual firm $j$ in a monopolistically competitive market maximises:

$$\Pi_{y,0} = E_t \sum_{i=0}^{\infty} \omega^i \beta^i V_{i,t+i} \left( \frac{p_{jt}}{E_t P_{t+i}} - \varphi_{t+i} \right) y_{j,t+i} \tag{A.8}$$

by choosing $p_{jt}$, subject to the demand function $y_{j,t+i} = \left( \frac{p_{jt}}{P_t} \right)^{-\theta} y_t$. The first order condition is:

$$\hat{p}_{jt} = (1-\omega\beta) \sum_{i=0}^{\infty} \omega^i \beta^i (E_t \hat{\varphi}_{t+i} + E_t \hat{P}_{t+i}) \tag{A.9}$$

which, under Calvo (1983) pricing allowing for past inflation indexation, implies the hybrid Phillips curve:

$$\pi_t = \frac{1-\beta\Omega(1-\epsilon)-\epsilon}{1+\beta\epsilon\Omega}\bar{\pi} + \frac{\beta\Omega}{1+\beta\epsilon\Omega}E_t\pi_{t+1} + \frac{\epsilon}{1+\beta\epsilon\Omega}\pi_{t-1} + \frac{(1-\omega)(1-\omega\beta\Omega)}{\omega(1+\beta\epsilon\Omega)}\widehat{mc}_t + \hat{\varepsilon}_{\pi,t} \tag{A.10}$$

Let the production function be:

$$y_t = z_t n_t^{1-u}(k_{t-1})^u \tag{A.11}$$

The optimal substitution between labour and capital is:

$$n_t = \frac{1-u}{u}\frac{r_{k,t}k_{t-1}}{w_t} \tag{A.12}$$

The real marginal cost of production is:

$$mc_t = \frac{1}{z_t}(\frac{1}{u})^u(\frac{1}{1-u})^{1-u}w_t^{1-u}r_{k,t}^u \tag{A.13}$$

Firm profit transferred to households in each period is:

$$\Pi_{y,t} = (1-mc_t)y_t \tag{A.14}$$

### A.1.3 The capital producer problem

Capital accumulates with the following rule:

$$k_t - k_{t-1} = \varepsilon_{i,t}(i_t - adj_t) - \delta k_{t-1} \tag{A.15}$$

subject to adjustment costs:

$$adj_t = \frac{F}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t \tag{A.16}$$

Capital producers maximise lifetime profit:

$$\Pi_{k,0} = E_0\sum_{t=0}^{\infty}\beta^t V_{0,t}\left[q_t k_t - q_t(1-\delta)k_{t-1} - i_t\right] \tag{A.17}$$

by choosing $i_t$. The first order condition is:

$$\begin{aligned}\frac{\partial\Pi_{k,0}}{\partial i_t} &: \quad q_t\varepsilon_{i,t}\left[1 - F\left(\frac{i_t}{i_{t-1}}-1\right)\frac{i_t}{i_{t-1}} - \frac{F}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2\right] \\ &= \quad 1 - \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left\{q_t E_t\varepsilon_{i,t+1}\left[F\left(\frac{i_{t+1}}{i_t}-1\right)\left(\frac{i_{t+1}}{i_t}\right)^2\right]\right\}\end{aligned} \tag{A.18}$$

Capital producer profit transferred to households in each period is:

$$\Pi_{k,t} = q_t k_t - q_t(1-\delta)k_{t-1} - i_t \tag{A.19}$$

### A.1.4 Monetary policy

Taylor rule:

$$1 + R_t = (1 + R_{t-1})^{\rho_R}(\frac{1 + \pi_t}{1 + \pi^*})^{(1-\rho_R)\varphi_\pi} \left(\frac{y_t}{\bar{y}}\right)^{(1-\rho_R)\varphi_x} (1 + \bar{R})^{(1-\rho_R)}\varepsilon_{TR,t} \tag{A.20}$$

Central bank balance sheet constraint:

$$m_t = \frac{m_{t-1}}{1 + \pi_t} + h_t \tag{A.21}$$

### A.1.5 Fiscal policy

Government spending:

$$g_t = \varepsilon_{g,t}\bar{g}(\frac{y_t}{\bar{y}})^{\gamma_x}(\frac{b_{t-1}}{\bar{b}})^{\gamma_b} \tag{A.22}$$

where $\gamma_x$, $\gamma_b < 0$.

Tax policy:

$$1 + \tau_t = \varepsilon_{\tau,t}\,(1 + \bar{\tau})\,(\frac{y_t}{\bar{y}})^{\phi_x}(\frac{b_{t-1}}{\bar{b}})^{\phi_b} \tag{A.21}$$

where $\phi_x$, $\phi_b > 0$.

Tax revenue:

$$t_t = \tau_t w_t n \tag{A.22}$$

Government budget constraint:

$$g_t - t_t = \Delta b_t - r_{t-1}b_{t-1}$$

### A.1.6 Marking clearing and identities

Goods market clearing:

$$c_t + i_t + g_t = y_t \tag{A.23}$$

Fisher equation:

$$1 + R_t = (1 + r_t)(1 + E_t\pi_{t+1}) \tag{A.24}$$

### A.1.7 Shock processes

The natural logarithm of all model shocks follow an AR(1) process.

## A.2 The MMT model variant

The MMT model is otherwise identical to the benchmark model except for the following modifications:

a. The change in real money supply is determined by the fiscal deficit (A new government budget constraint):

$$h_t = g_t - t_t - \Delta b_t + r_{t-1}b_{t-1} \tag{A.25}$$

b. The tax rate is adjusted to stabilise inflation (A new tax rule):

$$1 + \tau_t = \varepsilon_{\tau,t}(1 + \bar{\tau})(\frac{1 + \pi_t}{1 + \pi^*})^{\phi_\pi} \tag{A.26}$$

c. Public debt is adjusted to target the nominal interest rate (There is no longer a Taylor rule):

$$b_t = \varepsilon_{b,t}\bar{b}(\frac{1 + R_t}{1 + \bar{R}})^{\varsigma} \tag{A.27}$$

d. Government spending targets output only (Public debt is no longer stabilised by the spending):

$$g_t = \varepsilon_{g,t}\bar{g}(\frac{y_t}{\bar{y}})^{\gamma_x} \tag{A.28}$$

# B Data sources, time series collected, and adjustments to the raw data

The observable variables are: output, investment, government spending, public debt outstanding, nominal interest rate, money supply, inflation, tax rate on wages, and capital stock. The real variables are normalised by $CPI$ and population; inflation is defined as the quarter-on-quarter growth of $CPI$; nominal interest rate is quoted as quarterly rate. All variables, except inflation, nominal interest rate and tax rate on wages, are in natural logarithm.

The sample spans from 2008Q1 to 2019Q4. Capital stock, which is only available as annual data at source, is collected from Feenstra et al. (2015) via the FRED database; the original time series is converted to quarterly data using the 'quadratic-match average' algorithm with *Eviews*®. The other time series are collected from FRED and the US Bureau of Economic Analysis. Seasonal adjustment is applied to all time series except nominal interest rate. Table B.1 details the time series collected, their sources, and the relevant adjustments.

Table B.1: Data sources, time series collected & adjustments to the raw data

| Obs. Variables | Time series collected | Source[a] | Divided by CPI? | Divided by pop? | Seasonally adjusted? |
|---|---|---|---|---|---|
| Output | 'Nominal GDP' | BEA | √ | √ | √ |
| Investment | 'Fixed Private Investment' | BEA | √ | √ | √ |
| Gov. Spending | 'Gov. Cons. Expenditures & Gross Investment' | BEA | √ | √ | √ |
| Debt outstanding | 'Total Public Debt' | FRED | √ | √ | √ |
| Nom. Interest rate | 'AAA corporate bond yield' | FRED | N.A. | N.A. | N.A. |
| Money supply | 'M2' | FRED | √ | √ | √ |
| Inflation | 'CPI' (Quarter-on-quarter growth) | FRED | N.A. | N.A. | √ |
| Tax rate on wages[b] | 'Personal current taxes' (IT) | BEA | N.A. | N.A. | N.A. |
| | 'Wages and salaries' (W) | BEA | N.A. | N.A. | N.A. |
| | 'Proprietors' income with IVA and CCAdj' (PRI) | BEA | N.A. | N.A. | N.A. |
| | 'Rental income of persons with CCAdj' (RI) | BEA | N.A. | N.A. | N.A. |
| | 'Corporate profits with IVA and CCAdj' (CP) | BEA | N.A. | N.A. | N.A. |
| | 'Net interest and miscellaneous payments' (NIP) | BEA | N.A. | N.A. | N.A. |
| | 'Contributions for gov. social insurance' (CSI) | BEA | N.A. | N.A. | N.A. |
| | 'Compensation of employees' (EC) | BEA | N.A. | N.A. | N.A. |
| Capital stock | 'Capital stock at current PPPs' (Feenstra et al., 2015) | FRED | √ | √ | √ |
| Population index | 'CNP16OV' | FRED | N.A. | N.A. | √ |

a: BEA – US Bureau of Economic Analysis); FRED – Federal Reserve Economic Data.

b: The rate is calculated following Leeper et al. (2010). $\tau = \frac{\tau^p(W+PRI/2)+CSI}{EC+PRI/2}$, where $\tau^p = \frac{IT}{W+PRI/2+CI}$, CI =RI+CP+CSI.