Raising the Inflation Target to Manoeuvre the Zero Lower Bound: The Role of Fiscal Policy

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Abstract

With policy rates in many advanced economies now at or near the zero lower bound, a recent monetary policy proposal is that central banks in these economies should pursue a higher inflation target that would give them more "room-to-manoeuvre" during deep recessions. This paper evaluates the efficacy of such a proposal with a particular emphasis on the role of fiscal policy. For this, I use a New Keynesian DSGE model that features Ricardian and non-Ricardian households and where the government sector comprises of a monetary and a fiscal authority. I provide a global solution for the model in a fully stochastic setting and where agents are aware of the occasionally binding constraint associated with the zero lower bound. I find that the scope for a countercyclical fiscal policy weakens the case for raising the inflation target as a means to mitigate the effects of the zero lower bound. The efficacy of countercyclical fiscal policy during zero lower bound episodes, however, depends on the initial level of government debt - a high initial level of government debt limits that efficacy.

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1 Introduction

Most advanced economies saw a deep and prolonged slump in economic activity during the Great Recession of 2007-2009. Central banks in these economies responded by easing monetary policy to the extent that the policy rates or short term nominal interest rates are now at or near zero. Figure 1 presents these stylized facts by taking a representative example of the U.K. Generally speaking, the nominal interest rate cannot be negative so that this scenario presents a constraint on further monetary easing, through the nominal rate, to stabilize the economy: the zero lower bound (ZLB henceforth) constraint.[1] Given this experience, a view has emerged whether the the nominal rate should have been higher prior to the crisis that would have allowed central banks to cut rates more. To that end, one policy proposal is that central banks should pursue a higher inflation target which would then raise the long run nominal rate through the Fisher relation (Blanchard et al. (2010)).

The ZLB is primarily a constraint on monetary policy and that too only when the monetary policy instrument is the short term nominal interest rate. Even when ZLB is a binding constraint, there are other macroeconomic stabilization tools available. For instance, the central bank can resort to unconventional monetary policy like quantitative easing and the fiscal authority can pursue countercyclical fiscal policy. Given this, it is therefore important to evaluate the efficacy of these alternative tools vis-a-vis raising the inflation target as a means to mitigate the effects of the ZLB constraint. This paper focuses on the role of countercylical fiscal policy. Given that government debt levels have shot up in recent years (Figure 1), another objective of this paper is to understand if and how high government debt limits the scope of countercyclical fiscal policy in stabilizing the economy especially during ZLB episodes.

I address these questions in the context of a New Keynesian DSGE model. The model features a monetary authority choosing the inflation target and setting the nominal rate using a Taylor rule truncated at ZLB and a fiscal authority that conducts fiscal policy according to a fiscal surplus rule. To have a better understanding of how the level of government debt matters, the model also features Ricardian and non-Ricardian households (rule-of-thumb consumers). This results in a framework where the Ricardian Equivalence does not hold. The model is solved using global methods in a fully stochastic set-up and where agents are

[1] On rare occasions, policy rates have taken negative numbers, the most recent example being in the Euro Area when the ECB cut rates below zero in the summer of 2014. However, these are exceptions rather than the norm so that the ZLB constraint is still discussed in the literature as a binding constraint on monetary policy.

aware of the occasionally binding constraint associated with ZLB. This solution method allows me to capture nonlinear global dynamics and expectational effects at or near the bound. Using this *structural* framework, I then perform *policy counterfactuals* with respect to monetary and fiscal policy to answer the questions set out in the paper.

Even though the context and the issues in this paper are quite general in nature and apply to most advanced economies, I focus on the U.K. economy for the purpose of calibrating the model. The main reason for this is that the U.K. is an inflation targeting economy (starting 1992), with a publicly announced annual target of 2%. This allows me to conveniently abstract away from modeling how agents learn the inflation target.[2] A second reason is that the U.K. has a formal national fiscal rule which takes the form of a cyclically adjusted budget balance rule or a debt rule (IMF's Fiscal Monitor, Oct 2012). While such rules have been deployed rather flexibly to respond to the slump in economic activity during the crisis years, the fiscal mandate now, as per the Fiscal Responsibility Act of 2010, is to meet specific statutory targets on fiscal deficits and government debt in the medium term. The fiscal surplus rule deployed in the model aligns well with such a fiscal institutional framework.

The main findings are as follows: a higher inflation target, by providing more "room to manoeuvre", indeed helps to stabilize business cycle fluctuations (second moments) in the presence of the ZLB constraint thereby corroborating the point in Blanchard et al. (2010). However, the results from the model in this paper also suggest that a carefully calibrated countercyclical fiscal policy presents an alternative policy choice to meet the same objective. From a welfare perspective, a countercyclical fiscal policy is even better. This is because a higher inflation target, by increasing long run price dispersion, reduces long run output and consumption which then reduces welfare, outweighing the gains from stabilizing business cycle fluctuations. Countercyclical fiscal policy, on the other hand, is neutral in the long run. In an equilibrium where the monetary authority stabilizes inflation and the fiscal authority stabilizes government debt (monetary-led equilibrium), a countercyclical fiscal policy also does not pose significant fiscal challenges for the government. The efficacy of countercyclical fiscal policy in mitigating the effects of the ZLB constraint, however, depends on the initial level of government debt - an initial high level of government debt reduces that efficacy.

The rest of the paper is organized as follows. In Section 2, I briefly review the related

[2] See Nunes (2009) for a model that features agents learning about the inflation target in the case of the U.S. The Federal Reserve made the inflation target explicit in 2012. However, insofar as inflation has been low and stable in most advanced economies since the beginning of the Great Moderation, the distinction between an explicit and an implicit target seems to be a minor point.

literature. Section 3 describes the model. In Section 4, I discuss model calibration. Here, I also explain the nature of the equilibrium (i.e. monetary-led equilibrium) used in the paper and relate that to the choice of parameter values in the monetary and fiscal rules. I discuss the global solution method in Section 5. Section 6 presents the results and Section 7 concludes.

2 Related Literature

This paper is related to the literature on optimal inflation targets. Closely related is Coibion et al. (2011) who compute the optimal inflation target in New Keynesian DSGE models while taking into account the ZLB constraint. Calibrated for U.S., they show that the optimal inflation target is positive but less than 2%.[3] They therefore argue that raising the inflation target above 2% is "too blunt an instrument to efficiently reduce the severe costs of zero-bound episodes". Unlike their work, this paper focuses on the role of countercyclical fiscal policy and in some sense complements their conclusion in that the results from this paper also suggest that an inflation target higher than 2% may not be warranted as long as countercyclical fiscal tools are available. An important difference from Coibion et al. (2011) is the model solution method: while they use a linearized solution under perfect foresight, this paper deploys a global solution in a fully stochastic setting which has the advantages of being able to capture nonlinear global dynamics and expectational effects associated with ZLB.

Another strand of related literature is fiscal-monetary interactions. This begins with the seminal work of Leeper (1991) who introduces different equilibrium concepts (monetary-led and fiscally-led) in DSGE models. Following this, a lot of studies have looked at jointly optimal monetary and fiscal policies in DSGE models (e.g. Schmitt-Grohe and Uribe (2006)). Particularly relevant to this paper are those that study jointly optimal policies in the context of the ZLB constraint. For instance, Nakata (2013) shows that the optimal policy, in the context of a small New Keynesian DSGE model, is characterized by increased government expenditure at ZLB. This paper explores the role of additional state variables like price dispersion and government debt and highlight how these additional features drive the key results in the paper. In terms of modeling strategy, this paper is more similar to Bi and Kumhof

[3]The literature on the optimal inflation target is quite big. Friedman's rule implies an optimal inflation level which is negative so as to target a zero nominal interest rate. Subsequent monetary models that feature money still point to an optimal inflation target which is negative (e.g. Khan et al. (2002), Schmitt-Groh and Uribe (2007)). Positive optimal inflation targets are obtained in models that feature downward nominal wage rigidity and the ZLB constraint. But in most of these studies, the optimal targets are small and below 2%.

(2011) who, instead of analyzing optimal policies, evaluate optimal fiscal and monetary rules.

The ZLB is an occasionally binding constraint which ideally requires global solution techniques.[4] This paper extends the relatively few but growing literature that deploys global solution techniques to handle the occasionally binding ZLB constraint. Most of these studies consider a small monetary model on lines of Clarida et al. (1999). For instance, Billi and Kahn (2008) and Nakov (2008) use such models to study optimal monetary policy in the presence of the ZLB constraint. Fernandez-Villaverde et al. (2012) add more structural shocks and include additional model features like price dispersion. This paper builds on and extends the model in Fernandez-Villaverde et al. (2012) in two dimensions. First, the model in this paper features Ricardian and non-Ricardian households. Second, the model features a more elaborate fiscal sector with an endogenous fiscal rule that seeks to stabilize output and debt fluctuations. I use these additional model features to answer the questions set out in this paper: the significance of countercyclical fiscal policy and the role of government debt level.

Finally, this paper is related to the literature on trend inflation in DSGE models. Ascari (2004) and Ascari and Ropele (2007) show that positive trend inflation under less than full indexation can have non-trivial implications for monetary models. In particular, these papers highlight that firm pricing behavior becomes more forward looking as the trend inflation increases which then requires stronger monetary responses to inflation for ensuring determinacy. A key model feature that drives the results in this paper is partial indexation in the Calvo pricing scheme. In this regard, Cogley and Sbordone (2008) point out that once positive trend inflation is taken into account, full indexation which is often hardwired in DSGE models to match inflation persistence in the data, is no longer required. Along with their result, estimates of indexation from several studies are key elements of this paper.

3 Model

The model economy is populated by Ricardian and non-Ricardian households. The number of households in the economy is normalized to unity with the fraction of Ricardian households given by $(1-\nu)$. The government comprises of a monetary authority and a fiscal authority. The monetary authority chooses the inflation target and sets the nominal interest rate according to a Taylor rule truncated at ZLB. The fiscal authority sets government

[4]For a discussion on alternative model solution techniques used in the literature to handle the ZLB constraint and the shortcomings associated with them, see Nakov (2008).

expenditure according to a fiscal surplus rule. Price setting follows a Calvo (1983) scheme with partial indexation to the steady state inflation.

3.1 Households

3.1.1 Ricardian

The period utility function for the representative Ricardian household is $U(c_{R,t}, l_{R,t})$, where $c_{R,t}$ denotes real consumption and $l_{R,t}$ labor.[5] The representative household enters period t with B_{t-1} units of nominal bonds which pay the gross nominal interest rate, R_t, between t and $t+1$. During period t, the Ricardian household supplies labor to the intermediate good producers for which it receives wage income $w_t l_{R,t}$, where w_t is the economy-wide real wage. Her labor income is taxed at a proportional constant rate τ.[6] In addition, the Ricardian household receives a lump-sum real transfer, T_t, from the fiscal authority and real dividend payments, Ω_t, from the firms in the economy. The household allocates these funds to consumption and nominal bond holdings. The household's budget constraint in real terms is:

$$c_{R,t} + \frac{B_t}{p_t} = (1-\tau) w_t l_{R,t} + R_{t-1}\frac{B_{t-1}}{p_t} + T_t + \Omega_t \tag{1}$$

The period utility function of the representative household is of type considered in Greenwood et al. (1988) (GHH henceforth). The representative household maximizes expected utility by choice of $c_{R,t}$, $l_{R,t}$, and B_t subject to the budget constraint. The household's optimization problem is:

$$\max_{\{c_{R,t}, l_{R,t}, B_t\}} E_0 \sum_{t=0}^{\infty} \beta^t d_t \left\{ \frac{1}{1-\gamma} \left(c_{R,t} - \psi \frac{l_{R,t}^{1+\vartheta}}{1+\vartheta} \right)^{1-\gamma} \right\}$$

subject to (1). The parameter β denotes the discount rate, γ the risk aversion, and ϑ inverse of Frisch elasticity. The weight on leisure in the household's utility function is denoted by ψ. The preference shock d_t follows an AR(1) process as follows:

$$\log(d_t) = \rho_d \log(d_{t-1}) + \epsilon_{d,t}; \quad \epsilon_{d,t} \sim N(0, \sigma_d) \tag{2}$$

The preference shock is the only shock that drives model dynamics in this paper. This is to

[5]I consider a cashless economy on the lines of Woodford (2003).

[6]A constant tax rate means that I am not specifying it as a fiscal instrument. I can also switch to the tax rate as the fiscal instrument instead of government expenditure. In that case, the former is variable and the latter constant.

minimize on the number of state variables since the model is solved using global methods. Among the many business cycle shocks, I focus on preferences shock since they move output, inflation, and the nominal rate in the same direction.[7] This allows me to simulate recession episodes with a binding ZLB constraint.

The first order conditions for the Ricardian household's problem are:

$$\lambda_t = d_t \left(c_{R,t} - \psi \frac{l_{R,t}^{1+\vartheta}}{1+\vartheta} \right)^{-\gamma} \tag{3}$$

$$\psi l_{R,t}^{\vartheta} = (1-\tau) w_t \tag{4}$$

$$\lambda_t = \beta E_t \left[R_t \frac{\lambda_{t+1}}{\pi_{t+1}} \right] \tag{5}$$

where λ_t is the Lagrange multiplier associated with the budget constraint of the Ricardian household. The gross inflation rate is defined as $\pi_t \equiv \frac{p_t}{p_{t-1}}$. With GHH preferences, Equation 4 shows that labor supply decisions depend only on the real wage rate.

The long run Fisher relationship between the level of inflation and the nominal rate can be derived by evaluating the bond pricing Euler equation (5) in the steady state. This results in $R = \frac{\pi}{\beta}$, which shows that steady state inflation determines steady state nominal rate.[8] Thus, by controlling the inflation target (steady state inflation), the monetary authority can control the long run (steady state) nominal interest rate. This is the "room to manoeuvre" argument of Blanchard et al. (2010): raising the inflation target raises the long run nominal rate which then gives central banks more margin to cut rates when hit by adverse shocks.

3.1.2 Non-Ricardian

The period utility function of the representative non-Ricardian household is the same as that of the Ricardian household. The non-Ricardian household, however, does not have access to nominal bonds and hence, cannot save and borrow.[9] Thus, her consumption, $c_{N,t}$, must be financed only by her net labor income, $(1-\tau)w_t l_{N,t}$. Note that the non-Ricardian household receives the economy wide wage, w_t, from her labor supply, $l_{N,t}$, and is subject to the same

[7] In a standard New Keynesian DSGE model, productivity shocks, for instance, move output and nominal interest rate in opposite direction and hence, is less suitable for the purpose of the paper. That said, the results from this paper are quite general and will carry over to any shocks whose effects are qualitatively similar to those of preference shocks.

[8] This of course assumes that the discount factor β is a fixed structural parameter.

[9] Non-Ricardian households are modeled in different ways in the literature. In this paper, these are the rule-of-thumb consumers.

tax rate as the that of the Ricardian household. The budget constraint of the non-Ricardian household is:

$$c_{N,t} = (1-\tau)w_t l_{N,t} \tag{6}$$

The first order condition for the non-Ricardian household's problem, after substituting out for the Lagrange multiplier, can be written as:

$$\psi l_{N,t}^{\vartheta} = (1-\tau)w_t \tag{7}$$

3.2 Final Good Producer

A perfectly competitive final good producer aggregates the intermediate goods to produce the final good as:

$$y_t = \left(\int_0^1 y_{jt}^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}} \tag{8}$$

where θ is the elasticity of substitution across goods. The final good producer maximizes profit, taking as given the intermediate goods prices $p_{j,t}$ and the final good price p_t which results in the following input demand function:

$$y_{j,t} = \left(\frac{p_{j,t}}{p_t}\right)^{-\theta} y_t \tag{9}$$

The aggregate price level is

$$p_t = \left(\int_0^1 p_{j,t}^{1-\theta} dj\right)^{\frac{1}{1-\theta}} \tag{10}$$

3.3 Intermediate Good Producers

3.3.1 Production

There is a continuum of intermediate good producers, indexed by j, each of which produces a differentiated good $y_{j,t}$ using labor supplied by households:

$$y_{j,t} = l_{j,t} \tag{11}$$

The real marginal cost is the cost associated with producing one unit of output. In the case of the production function in this paper that depends only on labor, it equals the real wage rate. Thus,

$$\xi_t = w_t \tag{12}$$

3.3.2 Price Setting

Each intermediate good producer sets the price of its differentiated good according to a Calvo (1983) scheme that allows for partial indexation to steady state inflation which is also the inflation target. The price setting mechanism is as follows: each firm cannot re-optimize its selling price unless it receives a random signal. The constant probability of receiving such a signal is $(1-\phi)$. Thus, firm j sets its price, $p^*_{j,t}$, that maximizes the expected profit for l periods. However, with probability ϕ, the firm j must charge the price that was in effect in the preceding period partially indexed to the steady state gross rate of inflation, π. Thus, with probability ϕ, the price charged by firm j is given by:

$$p_{j,t} = \pi^{\omega} p_{j,t-1} \tag{13}$$

where $\omega \in [0,1]$ is the degree of indexation.[10] At time t, if firm j receives the signal to re-optimize, it chooses price $p^*_{j,t}$ that maximizes its discounted expected real total profit over the interval during which its price remains fixed. The optimization problem for firm j is:

$$\max_{p^*_{j,t}} E_t \sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} \Omega_{j,t+l}/p_{t+l} \tag{14}$$

subject to the demand function

$$y_{j,t} = \left(\frac{p_{j,t}}{p_t}\right)^{-\theta} y_t \tag{15}$$

and where firm j's nominal profit is given by

$$\Omega_{j,t+l} = \left[\pi^{\omega l} p^*_{j,t} - p_{t+l}\xi_{t+l}\right] y_{j,t+l} \tag{16}$$

The first order condition is:

[10] The Calvo indexation scheme used in this paper follows Yun (1996) and Christensen and Dib (2008) in that indexation is with respect to the steady state inflation. The literature has also considered indexation to lagged inflation (e.g. Christiano et al. (2005), Smets and Wouters (2007)). Indexation to lagged inflation adds an additional state variable in the model and is computationally very expensive for a global solution. The main results of the paper are, however, not dependent on the particular choice of the indexation scheme as long as it is partial and not full.

$$\frac{p_{j,t}^*}{p_t} = \frac{\theta}{\theta - 1} \frac{E_t \sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} \xi_{t+l} (\pi^{\omega l})^{-\theta} \pi_{t,t+l}^{\theta} y_{t+l}}{E_t \sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} (\pi^{\omega l})^{1-\theta} \pi_{t,t+l}^{-(1-\theta)} y_{t+l}} \tag{17}$$

where,

$$\pi_{t,t+l} \equiv \begin{cases} \prod_{i=1}^{l} \pi_{t+i} & l > 0 \\ 1 & l = 0 \end{cases}$$

In a symmetric equilibrium, all intermediate good producers set the same price. Dropping the subscript j from the optimal re-set price and defining $\pi_t^* \equiv \frac{p_t^*}{p_t}$, I can re-write the first order condition compactly as:

$$\theta g_{1,t} = (\theta - 1) g_{2,t} \tag{18}$$

where $g_{1,t}$ and $g_{2,t}$ are auxiliary variables defined recursively as:

$$g_{1,t} = \lambda_t \xi_t y_t + \beta\phi E_t \left[\left(\frac{\pi^{\omega}}{\pi_{t+1}} \right)^{-\theta} g_{t+1}^1 \right] \tag{19}$$

$$g_{2,t} = \lambda_t \pi_t^* y_t + \beta\phi E_t \left[\left(\frac{\pi^{\omega}}{\pi_{t+1}} \right)^{1-\theta} \frac{\pi_t^*}{\pi_{t+1}^*} g_{t+1}^2 \right] \tag{20}$$

The equation that governs the evolution of aggregate price can be written as:

$$1 = \phi \left(\frac{\pi^{\omega}}{\pi_t} \right)^{1-\theta} + (1 - \phi) \pi_t^{*1-\theta} \tag{21}$$

3.4 Government

3.4.1 Monetary Authority

The monetary authority sets the nominal interest rate according to a Taylor rule truncated at ZLB as:

$$R_t = \max\{Z_t, 1\} \tag{22}$$

where,

$$\frac{Z_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\rho_\pi} \left(\frac{y_t}{y} \right)^{\rho_y} \right]^{1-\rho_r} \tag{23}$$

where, the variables without a time index, t, denote the respective steady states. The variable Z_t is the unconstrained nominal interest. The parameter ρ_r determines interest rate smoothing, while ρ_π and ρ_y are the weights on inflation and output stabilization respectively.

While solving the model, following Garcia and Zangwill (1981), the truncated Taylor rule in (22) is re-specified as:

$$R_t = Z_t + \max\{\mu_t, 0\}^2 \tag{24}$$
$$R_t = 1 + \max\{-\mu_t, 0\}^2 \tag{25}$$

where, μ_t is an auxiliary variable. Specifying the truncated Taylor rule in this manner allows the use of gradient-based nonlinear solvers and facilitates computation. To see how this formulation works, consider the case where the unconstrained Taylor rule in (23) prescribes a gross interest rate $Z_t > 1$. Then, Equations (24) and (25) result in the following:

$$R_t = Z_t \;\; and \;\; \mu_t = -\sqrt{R_t - 1} < 0$$

If, on the other hand, $Z_t \leq 1$, the zero lower bound constraint is enforced as follows:

$$R_t = 1 \;\; and \;\; \mu_t = \sqrt{R_t - Z_t} > 0$$

3.4.2 Fiscal Authority

The fiscal authority enters time t with an amount of nominal debt denoted by $B_{g,t-1}$ for which it pays the nominal interest rate R_{t-1}. The fiscal authority also spends a real amount g_t. Part of the financing of these two government expenditure items is through the aggregate tax revenue, $\tau w_t l_t$, collected from the Ricardian and the non-Ricardian households. The fiscal authority can also borrow from the Ricardian households by issuing nominal bonds, $B_{g,t}$. The budget constraint of the fiscal authority in real terms is then given by:

$$g_t + b_{g,t-1}\frac{R_{t-1}}{\pi_t} = \tau w_t l_t + b_{g,t} \tag{26}$$

where $b_{g,t} \equiv \frac{B_{g,t}}{P_t}$.

The fiscal surplus, f_t, is defined as the negative of the change in real government debt as:[11]

[11] Following Bi and Kumhof (2011), the surplus defined in this way includes interest payments. An alternative approach is to define in terms of the primary surplus which excludes interest payments. In the

$$f_t \equiv -\left(b_{g,t} - \frac{b_{g,t-1}}{\pi_t}\right) \tag{27}$$

The fiscal surplus rule is given by:

$$f_t - f = \rho_\tau \left(y_t - y\right) + \rho_b \left(b_t - b\right) \tag{28}$$

where, the variables without time index, t, represent the respective steady states. The parameters ρ_τ and ρ_b control the extent to which the fiscal surplus endogenously responds to deviations of output and real debt from their respective steady states.[12] In the remainder of this paper, I will refer to these two deviations as "output deviation" and "debt deviation" respectively. Specifying the fiscal rule in this manner delivers a mechanism in the model where the fiscal authority can stabilize the business cycle (output fluctuations) while ensuring fiscal sustainability (non-exploding debt).

While the fiscal surplus serves as the operational target, the fiscal instrument is taken to be government expenditure. That is, the fiscal authority endogenously adjusts the level of government expenditure that is necessary to achieve a given value of the fiscal surplus as pinned down by output and debt deviations from the fiscal surplus rule. To illustrate, suppose $\rho_\tau = 1$ and $\rho_b = 0$. When the output deviation is negative (due to adverse preference shocks), the fiscal surplus rule prescribes a reduction in fiscal surplus or, stated differently, an increase in fiscal deficits which is operationalized by increasing government expenditure. The increase in government expenditure, in turn, increases aggregate demand and helps stabilize the economy especially when the nominal interest rate is constrained at ZLB. Thus, in this paper, the primary channel through which fiscal policy affects the economy is via the demand side of the economy.[13]

3.5 Aggregation and Market Clearing Conditions

In equilibrium, aggregate demand of labor by intermediate good producers must equal their aggregate supply by Ricardian and non-Ricardian households. Thus,

context of the paper, this distinction is however trivial.

[12]The specification of the fiscal surplus rule is similar to the one in Bi and Kumhof (2011). Unlike their rule which is specified in terms of ratios, the fiscal rule in this paper is specified in terms of levels. This makes the model more stable with GHH preferences. For a discussion on how GHH preferences fail to generate output and inflation persistence, see Dey (2014).

[13]This need not be always the case. For instance, if the fiscal instrument is taken to be the tax rate on labor income, then fiscal policy affects the economy via the supply side.

$$\int l_{j,t}dj = l_t = (1-\nu)l_{R,t} + \nu l_{N,t} \tag{29}$$

Using the production function (11) and the demand (9) for each intermediate good, I can write:

$$l_{jt} = \left(\frac{p_{jt}}{p_t}\right)^{-\theta} y_t \tag{30}$$

This can be aggregated to yield an aggregate supply equation as follows:

$$l_t = s_t y_t \Leftrightarrow y_t = \frac{l_t}{s_t} \tag{31}$$

where, $s_t \equiv \int_0^1 \left(\frac{p_{jt}}{p_t}\right)^{-\theta} dj$ captures the degree of price dispersion. Price dispersion evolves as:

$$s_t = \phi\left(\frac{\pi^\omega}{\pi_t}\right)^{-\theta} s_{t-1} + (1-\phi)\pi_t^{*-\theta} \tag{32}$$

Equations (31) and (32) highlight the effects of trend inflation (π) on aggregate output through its effects on price dispersion. More precisely, Equation (31) shows that the effect of higher price dispersion, ceteris paribus, is to reduce aggregate supply of output and hence, aggregate output in equilibrium. And from Equation (32), one can see that the dynamics of price dispersion is dependent on trend inflation. More precisely, with less than full indexation ($\omega < 1$), an increase in trend inflation increases price dispersion. This is the welfare cost of inflation that the model primarily captures and is the cost against which the benefit of reduced incidences of ZLB episodes associated with a higher inflation target is compared.[14]

Aggregate demand in the economy comprises of consumption and government expenditure and is given by:

$$y_t = c_t + g_t \tag{33}$$

where c_t denotes aggregate consumption and is given by:

$$c_t = (1-\nu)c_{R,t} + \nu c_{N,t} \tag{34}$$

[14]The literature has discussed other costs of inflation which are not captured in the model. These include distortions in cash holdings, distortions of the tax system, difficulties in financial planning etc. See Mishkin (2011) for an elaborate discussion.

Finally, the market for nominal bonds clears as follows:

$$B_{g,t} = (1-\nu)B_t \tag{35}$$

4 Calibration

4.1 Parameter Values

The model is calibrated for quarterly frequency. The discount factor, β, is set as 0.99 to match the average real interest rate during the sample period. The share of non-Ricardian households is taken to be 11.84% which is the value estimated for the U.K. in Bhattarai and Trzeciakiewicz (2013). The risk aversion parameter γ in the utility function is taken to be 1.[15] The inverse Frisch elasticity of labor supply is 0.5. The coefficient before leisure, ψ, is calibrated as 1.22 to ensure that one-third of the aggregate household's time is spent working in the steady state.

The parameter θ that measures the degree of monopoly power of intermediate good producers is set equal to 8, implying a steady-state price markup of around 14%. Regarding the Calvo pricing parameters, I pick values close to the estimates provided in Benati (2008) and Cogley et al. (2011) for the U.K. during the inflation targeting period. The Calvo probability parameter, ϕ, is taken to be 0.7. For the indexation parameter, ω, I pick a value of 0.1. Such a choice which implies an almost lack of indexation is a key aspect of the inflation targeting regime in the U.K. as emphasized in Benati (2008).

Coming to the parameters in the Taylor rule, the gross steady state quarterly inflation is 1.005 thereby implying a net annual inflation target of 2% which is the current target adopted in the U.K. Interest smoothing parameter ρ_r is chosen as 0.7 and the coefficient before output ρ_y is 0.4. I choose the coefficient before inflation ρ_π as 3. The parameter values in the Taylor rule are broadly in line with the estimates in Cogley et al. (2011). I choose a slightly larger value for ρ_π because that is necessary to ensure determinacy for higher inflation targets.[16]

[15]This is the same parameter value used in Fernandez-Villaverde et al. (2012). For a given choice of parameters in the fiscal and monetary rules, the policy function iteration routines are a bit sensitive to the choice of γ. For instance, when I choose $\gamma < 1$ and given the baseline fiscal and monetary parameters, those routines would not converge. This is because smaller values of γ make Ricardian households more sensitive to real interest movements. This makes their consumption demand to drop even more sharply at or near ZLB which, in the absence of a stronger fiscal stabilization, makes the policy function iteration routines to explode.

[16]This is consistent with the result in Ascari and Ropele (2009) who show that a stronger coefficient on inflation is required to ensure determinacy with higher trend inflation. By choosing $\rho_\pi = 3$, I can then

Also, I choose the coefficient before output to be a bit larger than Cogley et al. (2011) to generate a more reasonable probability of zero lower bound episodes without having to rely on really big shocks for the same.

To calibrate the fiscal parameters I proceed as follows: I choose the steady state government debt-to-GDP ratio and government expenditure-to-GDP ratio as 52.77% and 16.54% respectively. These are the average values during the sample period 2000-2013 for which quarterly government debt-to-GDP ratio data is available at Eurostat. By evaluating the government budget constraint in the steady state, these choices result in an average tax rate τ which equals 19.5%. To the best of my knowledge, there is no study to guide the choice of parameter values for the coefficients in the fiscal surplus rule. In the baseline specification, the coefficient before output ρ_τ is set as 0.3 and that before debt ρ_b as 0.5. In the model, the coefficient ρ_τ controls the strength of fiscal response to stabilize output fluctuations. As highlighted later in Section 6, this response is weak when $\rho_\tau = 0.3$. I, therefore, take this choice as the baseline against which the implications of much stronger fiscal responses are evaluated by choosing larger values of ρ_τ. Choosing a positive value for the coefficient before debt gap, ρ_b, stabilizes government debt and ensures that the government is solvent.

The AR(1) coefficient in the law of motion of preference shocks is set as 0.8. The standard deviation of the shocks is calibrated as 0.023. With this, the model when simulated under a 2% inflation target results in a 2.87% probability of hitting the zero lower bound, or once every about 9 years.[17] The complete set of parameter values used in the baseline specification is provided in Table 1. The parameter values in alternative specifications of the model are in Table 2.

4.2 Discussion on Equilibrium

As with all models that feature both a monetary authority and a fiscal authority, it is important to characterize the nature of equilibrium, whether it is monetary-led or fiscally-led

use the same parameter value for different inflation targets thereby yielding a consistent scheme for model comparison.

[17]The shock size calibrated is much larger than the ones estimated in the literature. Two comments are in order here. First, it is plausible that such big shock sizes, which will not be picked up by studies that report "average" estimates during the Great Moderation period, are relevant in the context of the recent crisis episodes. Second, this paper focuses on the role of monetary and fiscal policies during ZLB episodes. Therefore, it is more important to generate ZLB spells that are quantitatively significant by appropriately calibrating the shock size rather than to focus on which shocks and with sizes that are empirically reasonable can result in those spells. The latter is a slightly different research question. See, for instance Amano and Shukayev (2009).

(Leeper (1991)). In a monetary-led equilibrium, (a) the Taylor principle is satisfied so that the nominal rate responds more than one-to-one to movements in inflation, and (b) fiscal policy stabilizes government debt. This is also referred to as an active monetary and passive fiscal regime. In a fiscally-led equilibrium, on the other hand, monetary policy is passive while fiscal policy is active. As pointed out in Leeper (1991), for this class of models to be determinate, both monetary and fiscal policies cannot be active at the same time.

Against the backdrop of the theoretical underpinnings above, the analysis in this paper is confined to a monetary-led equilibrium. Accordingly, the parameters in the monetary and the fiscal rules are chosen so as to be consistent with a monetary-led equilibrium. Thus, the choice of the coefficient before inflation in the Taylor rule $\rho_\pi = 3 > 1$ implies that monetary policy is active. Fiscal policy is set to be passive by choosing the coefficient before debt in the fiscal surplus rule $\rho_b = 0.5 > 0$. Given these parameter values, the coefficient before output in the fiscal rule, ρ_τ, is restricted to yield a determinate solution.[18]

The choice of the equilibrium, whether monetary-led or fiscally-led, should ideally reflect the actual experience of the U.K. economy during the inflation targeting period. While estimates of Taylor rule coefficients from previous studies (e.g. Cogley et al. (2011)) and the current fiscal mandate that stresses on meeting statutory targets for fiscal deficits and government debt suggest a monetary-led equilibrium, fiscal policy has been arguably much more "active" during the crisis years (Aizenman and Pasricha (2013)). In other words, it is not very clear from existing work whether a monetary-led equilibrium best describes the entire 1992-2013 period, even though it seems be the case for majority of the times. Given this ambiguity, an ideal modeling choice for this paper would have been a regime switching model that switches between monetary-led and fiscally-led equilibria (Bianchi and Melosi (2013)). With this caveat in mind, this paper, nonetheless, makes an attempt to answer the questions set out in the paper in the specific case of a monetary-led equilibrium.

5 Solution Method

The complete set of equations that describe the equilibrium conditions among the model's endogenous variables is given in Appendix A.1. This is a system of 21 equations in 21 endogenous variables. The model features three endogenous states: government debt ($b_{g,t-1}$),

[18] Since the model is solved globally, the relevant determinacy criterion is global determinacy and not local determinacy. Local criteria like Blanchard and Kahn conditions are not sufficient to establish global determinacy. While global determinacy conditions have been developed for small stylized models (for instance, Benhabib et al. (2002)), extending those to the model used in this paper is not straightforward.

nominal interest rate (R_{t-1}), and price dispersion (s_{t-1}). The exogenous state in the model is the preference shock (d_t).

The zero lower bound constraint poses a nonlinearity which, under standard calibration of the model parameters, also happens to be far away from the steady states. This implies that standard perturbation methods, irrespective of the order of approximation, do not provide a satisfactory model solution. The goal in this paper is to solve the model in a fully stochastic setting and where agents are aware of the occasionally binding constraint associated with ZLB. For this, I deploy a global solution method, in particular the policy function iteration algorithm of Coleman (1990).[19] Solving the model globally in this manner allows me to explore nonlinear global dynamics and expectational effects associated with the ZLB constraint.[20]

The policy function iteration algorithm is implemented as follows:

1. **Discretize States**: The states are discretized around their steady states. Since price dispersion and the nominal interest rate cannot take values less than one, I choose a lower bound of 1 for these. The rest of the bounds are chosen iteratively such that they cover the state spaces when the model is simulated. The state space for the preference shock is discretized following Tauchen's method with lower and upper bounds taken to be 3.5 times the standard deviation of the shocks.

2. **Initial Guess**: For each node, start with an initial guess for these 3 policy rules: π_t, $g_{1,t}$, and λ_t. For the initial guess, I solve the model with an unconstrained Taylor rule using the first order perturbation solution in Dynare and use the policy rule as the initial guess.

3. **Recursive Solution**: Given these 3 policy rules, solve for the rest of the policy rules using the model's nonlinear equations except the ones that feature expectational terms.

4. **Compute Expectations**: Using current policy rules, compute variables in the next period interpolating wherever necessary. Then, compute the expectational terms that enter Equations 1.1.2, 1.1.8, and 1.1.9 using the conditional transition probabilities from Tauchen's method.

5. **Update Policy Rule**: Evaluate the complete set of nonlinear equations and update the policy guesses for π_t, $g_{1,t}$, and λ_t via a root finding algorithm.

[19]I use the routines in Richter et al. (2013) for the policy function iteration.

[20]I illustrate in Appendix A.2 that such effects are significant.

6. **Iterate**: Goto Step 3 and iterate until convergence.[21]

6 Results

This section presents three sets of results. First, I present the global solution with the occasionally binding ZLB constraint. Second, I compare and contrast two different policy interventions that help mitigate the effects of ZLB: (a) higher inflation target and (b) countercyclical fiscal policy. Third, I discuss how the initial level of government debt matters for countercyclical fiscal policy during ZLB episodes.

6.1 Global Dynamics and Expectational Effects

In this section, I discuss how the occasionally binding ZLB constraint results in nonlinearities in the dynamics of model variables. I begin with a general analysis of the transmission mechanism of preference shocks in the model. Thereafter, I extend the analysis to understand how the ZLB constraint affects the transmission mechanism giving rise to expectational effects and nonlinear global dynamics.

In the model, preference shocks have the effect of changing the effective discount rate for both Ricardian and non-Ricardian households. When hit by adverse preference shocks, Ricardian households reduce current consumption and save more. This has the effect of reducing aggregate consumption which, in turn, reduces aggregate demand. With sticky prices, the decline in aggregate demand works to reduce output in equilibrium. Furthermore, the decline in labor demand due to a decline in output results in lower wages, marginal costs, and hence inflation. In the case of non-Ricardian households, their labor supply and consumption decisions are not directly affected by preference shocks due the assumption of GHH utility in the model.[22] Nonetheless, non-Ricardian labor and consumption decline in response to the general equilibrium effects of a decline in economy-wide output and wages which contributes to the already declining aggregate demand. The monetary authority responds to the decline in output and inflation by cutting the nominal interest rate. If the adverse preference shocks are big enough, the drop in the nominal rate can hit the ZLB constraint. Once the constraint binds, further monetary stimulus via nominal rate cuts is ruled out to stabilize output and

[21] For Step 3, wherever possible, I solve for the rest of the equations analytically given the 3 policy guesses. An analytical solution is, however, not available for all equations in which case I use a numerical nonlinear solver. In particular, I use the solver in Morini and Porcelli (2012). In Step 4, I use a linear interpolation scheme. The convergence tolerance is taken to be 10^{-5}.

[22] With GHH utility functions, labor supply decision of households depends only on wage rate. And for a non-Ricardian household, consumption is only a function of her labor income.

inflation. This is the basic reason why the ZLB constraint is destabilizing in the model.

Under rational expectations and in a fully stochastic environment, agents take into account expectations of the future evolution of model variables while making their decisions. The ZLB constraint, by shaping these expectations, affects current decisions of agents and introduces an additional dimension of nonlinearity in the dynamics of model variables. In particular, expectations of future real interest rates are crucial in the model. When the nominal rate is at or near ZLB due to big adverse preference shocks, agents expect the real interest rate to increase because they are aware that inflation will decline. In this environment, Ricardian households further postpone current consumption in favor of savings, thereby reinforcing the collapse in aggregate demand. Such expectational effects, therefore, make the ZLB constraint even more destabilizing. Furthermore, they imply that these effects of the ZLB constraint should show up even before the nominal rate hits zero.

Of course, a nonlinear solution method is required to capture these global dynamics and expectational effects.[23] The global solution method deployed in this paper is exactly designed for that. Figure 2 plots the policy rules of key model variables across the grids of preference shocks used in the global solution.[24] These are from the baseline specification of the model. Shaded highlights regions where the ZLB constraint is binding. As the figure shows, the ZLB constraint is binding for big adverse preference shocks. The kink in the policy rule of the nominal interest rate at ZLB translates into kinks in the policy rules of the rest of the variables. Output, aggregate consumption, and inflation decline sharply in the shaded region where ZLB binds. This is consistent with destabilizing nature of the ZLB constraint as discussed above. Furthermore, the curvature in these policy rules begins to show up even before ZLB binds. This corroborates the earlier point on the expectational effects associated with the ZLB constraint.

The ZLB constraint has fiscal implications as well. The policy rule of government borrowing shows that the government borrows more (less) with adverse (favorable) preference shocks. When hit by adverse preference shocks, Ricardian households forgo current consumption and save. In general equilibrium, these household savings equal government borrowing. Also, the policy rule of government borrowing exhibits a sharp upward kink in and around the shaded region where ZLB binds. This partly reflects the sharp increase in savings by Ricardian

[23] A linearized solution does not capture any of these effects and hence, understates the destabilizing effects of the ZLB constraint. This is established more concretely in Figure 10 where I compare the linearized solution method of Coibion et al. (2011) with the global solution used in this paper.

[24] All other state variables are fixed at grid points at or closest to steady states.

households around this region. The sharp rise in government borrowing is also due to the fact that the government's real interest payments on its past debt increase sharply thereby requiring the government to borrow even more to finance those payments. In the baseline specification, the fiscal response to stabilize output fluctuations is weak. The policy rule of government expenditure, that closely mirrors that of output, is consistent with the weak fiscal response.

In sum, the policy rules from the baseline specification, with a 2% inflation target and a weak fiscal response to output fluctuations, highlight that the ZLB constraint binds for big adverse preference shocks with destabilizing effects on macroeconomic variables. As discussed earlier in the calibration section, the ZLB constraint binds once in about every 9 years under the baseline specification subjecting the economy to those destabilizing effects. In the next section, I discuss two alternative policy interventions to maneuver the ZLB constraint and how they help stabilize the economy.

6.2 Maneuvering the Zero Lower Bound

Policy Experiments: I discuss two policy interventions to maneuver the ZLB constraint. First, the monetary authority raises the inflation target to 4%.[25] Second, the fiscal authority pursues a countercyclical fiscal policy. I label these as Model A and Model B respectively. To illustrate how these policy interventions maneuver the ZLB constraint and help stabilize the economy, I compare the dynamics of model variables across these policy counterfactuals and the baseline specification during a ZLB episode.[26] The ZLB episode is simulated by hitting the economy, which is initially at its steady state, with adverse preference shocks of size 2 s.d. in the first 4 periods.[27]

Figure 3 presents the results. The solid blue line in the figure shows the model dynamics under the baseline specification. During the simulated episode, the ZLB constraint binds at 2 quarters after the impact of the initial shock and continues so for the next 8 quarters. Output, aggregate consumption, and inflation decline sharply consistent with the policy rules

[25] A 4% inflation target is the one emphasized in Blanchard et al. (2010) and I use that to illustrate the effects of a higher inflation target.

[26] Because these policy counterfactuals are conducted using a structural model, they are consistent with the Lucas Critique. Of course, this assumes that the structural parameters in the DSGE model are truly structural. There are many papers in the literature that rigorously evaluate such an assumption, for instance Fernndez-Villaverde and Rubio-Ramrez (2007). The literature has, in particular, focused on the Calvo probability parameter. However, this is more of a serious issue for really high levels of inflation.

[27] Simulating the ZLB episode in this manner via a sequence of adverse shocks rather than one huge shock ensures that the simulation stays within the state grids used in the global solution.

described earlier. Given the weak fiscal response in the baseline specification, government expenditure declines. On the other hand, government borrowing increases sharply which in part reflects the increase in savings by Ricardian households at ZLB. The sharp increase in government borrowing is also due to the increase in real interest payments on its past obligations and the decline in tax revenues at ZLB (Figure 4).[28] I now discuss these model dynamics under the baseline specification with those under the two policy counterfactuals.

Higher Inflation Target: The dotted black lines in Figure 3 show the results when the inflation target is raised to 4%. With the higher inflation target, the Fisher relationship implies that the steady state (long run) nominal interest rate is also higher. Since the initial states in the simulated ZLB episode are taken to be the steady states, the monetary authority starts off with a higher nominal rate at the beginning of the ZLB episode. More specifically, this gives the monetary authority an additional "room to maneuver" of about 2% (8% minus 6%) in net annual terms.[29] And as the dotted black lines show, the monetary authority indeed uses this extra room to further ease monetary policy in response to the adverse shocks. The additional monetary stimulus then ensures that the drops in output, aggregate consumption, and inflation are all smaller with respect to the baseline specification (thick blue lines).[30] The improved macroeconomic stabilization, in turn, steers the nominal rate away from ZLB reducing the duration of the ZLB spell. With regard to the fiscal variables, tax revenues improve which help to reduce government borrowing compared with the baseline specification (Figure 4). All in all, these findings lend support to the point in Blanchard et al. (2010) who advocate a higher inflation target to maneuver the ZLB constraint during a deep recession.

Countercyclical Fiscal Policy: I now turn to countercyclical fiscal policy. Fiscal policy is specified to be countercyclical by choosing a higher coefficient on output deviations, ρ_τ, in the fiscal surplus rule. For the purpose of comparability, this parameter value is chosen to be 1.4 such that the drop in the nominal rate during the simulated episode is roughly the same as was in the previous exercise with the higher inflation target of 4%. In this manner, the extent to which ZLB presents a constraint during the simulated episode is roughly the

[28] The former is due to the fact that real rates increase at ZLB and the latter is attributed to the decline in wages and labor.

[29] Given that most rate cuts are in terms of basis points, such a margin of 2% or 200 basis points is quite significant.

[30] These improvements are quantitatively significant. For instance, while output decline bottoms out at about -13% in the baseline specification, it is only about -8% with the higher inflation target. In addition, there is some improvement on the recovery horizon as well. However, that is minor and is most likely due to the fact that the model in this paper abstracts away from endogenous propagation mechanisms like habit formation and investment adjustment costs that are considered in medium scale DSGE models.

same across Model A and Model B.

The dotted red lines in Figure 3 show the results. The most obvious difference with the countercyclical fiscal policy is that government expenditure now increases in response to adverse shocks while it decreases in the other two specifications. The increase in government expenditure works to increase aggregate demand which, under sticky prices, works to increase equilibrium output, labor, wages, and inflation. The expansionary fiscal response, thus, wrests the drops in output and inflation and results in a much improved macroeconomic scenario with respect to the baseline specification. This, in turn, steers the nominal rate away from ZLB in the same manner as was with the higher inflation target. In the monetary-led equilibrium that is the focus in this paper, the fiscal surplus rule also stabilizes government debt. This, along with the fact that tax revenues improve with macroeconomic stabilization (Figure 4), explains why government borrowing is much smaller than the baseline specification despite having to finance the expansionary government expenditure.

The upshot of the foregoing analysis is that as much as a higher inflation target helps to stabilize business cycle fluctuations in the presence of the ZLB constraint, a carefully calibrated fiscal response presents as an alternative policy choice to achieve the same objective. Furthermore, in a monetary-led equilibrium, a countercyclical fiscal policy does not pose significant fiscal challenges for the government.

Higher Inflation Target vs. Countercyclical Fiscal Policy: I now compare the two policy interventions from the perspective of business cycle stabilization, welfare, and government financing.

Business Cycle Stabilization: Table 3(b) shows the standard deviation of key macroeconomic variables from model simulations across different specifications.[31] The table shows a clear decline in the volatility of macroeconomic variables when either the inflation target is raised or when fiscal policy is countercyclical. These two policy interventions also result in a much smaller probability and duration of ZLB episodes (Table 4). This corroborates the stabilizing role of these policy interventions in the presence of the ZLB constraint. Between the two policies, the countercyclical fiscal policy fares better than the higher inflation target as evident from the smaller volatilities in the former vis-a-vis the latter. Because the strength of the countercyclical fiscal response is picked in a rather adhoc fashion, these results should not be construed as establishing a universal superiority of countercyclical fiscal policy over

[31] These are based on model simulations with a simulation length of 50,000.

higher inflation targets in stabilizing business cycle fluctuations (second moments) when confronted with the ZLB constraint. Nonetheless, they do highlight the point that a carefully calibrated fiscal response presents an alternative policy choice to higher inflation targets in this regard.

The analysis above suggests that fiscal policy has strong stabilizing effects on the model economy. Part of the reason lies in the calibration of the fiscal surplus rule which generates strong countercyclical movements in government expenditure. Part of the reason also lies in model features. The real effects of an increase in government expenditure depend on two opposite forces. The increase in aggregate demand works to increase equilibrium output. On the other hand, crowding-out effects on consumption pull output in the opposite direction.[32] Crowding-out effects operate via two mechanisms in the model. First, monetary tightening in response to the expansionary fiscal policy crowds out Ricardian consumption. Second, the fiscal surplus rule implies that the government will adjust by reducing government borrowing.[33] Since Ricardian households hold government debt, this imposes a negative wealth effect which then reduces their current consumption demand. Because of the assumption of GHH utility functions, such wealth effects do not apply to labor supply decisions of Ricardian households. If their labor supply were to depend on wealth effects, an expansionary fiscal policy would have resulted in an increase in labor supply thereby dampening the positive effects on wages. Thus, with GHH preferences, an expansionary fiscal policy has a much more pronounced positive effect on wages. This undoes some of the crowding out effects on Ricardian consumption. The presence of non-Ricardian households in the model also contributes to strong fiscal effects. Unlike Ricardian households, non-Ricardian consumption demand is not subject to negative wealth effects. And their consumption demand simply responds positively to the increase in economy-wide wages and labor brought about by expansionary fiscal policy.

Welfare: The preceding analysis only looks at stabilizing business cycle fluctuations or second moments. I now compare welfare across the two policy interventions - an exercise that takes into account both first and second moment effects. The distinction is not trivial because a higher inflation target increases steady state price dispersion in the model. This, in turn, reduces steady state output and consumption which then works to reduce welfare.[34] Such

[32]Note that the model in this paper does not feature investment so that crowding-out effects only apply to consumption.

[33]Note that the tax rate is taken to be constant in this paper so that fiscal adjustment is via a reduction in government borrowing.

[34]By the same token, steady state labor also declines which then implies an increase in in steady state

first moment effects are absent under the countercyclical fiscal policy. Figure (5) shows the distribution of price dispersion in relation to different inflation targets and Table 3(a) shows the means of the macroeconomic variables from model simulations. These results confirm the observations. The key model feature that drives these results is partial indexation in the Calvo pricing scheme. As the figure and the table further confirm, such effects disappear with full indexation (Model C).

Formally, I compute the unconditional welfare (i.e. present value of lifetime utility) of Ricardian and non-Ricardian households.[35] For this, I simulate a long time series of the state variables of length 50,000 and then take the average of the value functions corresponding to these states for each type of household. Table 5 and Figure 6 present the results which show that the unconditional welfare under the higher inflation target (Model A) is lower than that under the countercyclical fiscal policy (Model B) for both Ricardian and non-Ricardian households. However, with full indexation (Model C), the unconditional welfare under the higher inflation target improves. This illustrates the first moment effects of higher inflation target under partial indexation as discussed above. From a welfare perspective, the main result here is that countercyclical fiscal policy is better than higher inflation target.

With respect to the baseline specification, the unconditional welfare under the countercyclical fiscal policy is, however, smaller for both Ricardian and non-Ricardian households thereby implying a welfare loss in an unconditional sense. While the earlier results from the specific ZLB episode suggest that countercyclical fiscal policy should be welfare improving (vis-a-vis the baseline), Table 5 shows that this need not be the case in an unconditional sense. To investigate further, I compare conditional welfare - welfare conditional on a given state. Figure 7 shows the difference in the conditional welfare of the Ricardian and non-Ricardian households under the countercyclical fiscal policy (Model B) and the baseline model across different grid points of the preference shock.[36] A positive (negative) value indicates a welfare gain (loss). As the figure shows, with respect to the baseline specification, Ricardian households are worse off under the countercyclical fiscal policy across all states of the preference shock.[37] This is not surprising given that Ricardians are subject to crowding out

leisure. This works to increase welfare. But the effects on consumption dominate for overall welfare.

[35] Alternatively, one could also address welfare in terms of consumption equivalents. This is particularly relevant for comparing the magnitude of welfare gain or loss. Since the focus of this section is more on the sign of the welfare change rather than the magnitude, I analyze welfare in terms of lifetime utility.

[36] All other state variables are fixed at grid points at or closest to steady states.

[37] Figure 7 also shows the conditional welfare difference between the higher inflation target and the baseline specification. The welfare difference is all negative thereby implying a welfare loss with respect to the baseline. The welfare difference is also below that under the countercyclical fiscal policy which is in agreement with

effects as discussed earlier. For the non-Ricardian households, the result, however, is mixed. For adverse shocks, where the ZLB is likely to bind, countercyclical fiscal policy is welfare improving with respect to the baseline specification. However, this is not the case for favorable shocks. The result here, therefore, suggests that countercyclical fiscal policy, as a macroeconomic stabilization tool, is particularly valuable to Ricardians during periods of a deep recession associated with a binding ZLB constraint.

As mentioned above, the key model feature that discriminates the two policy interventions from a welfare standpoint is partial indexation in the Calvo pricing scheme. Because partial indexation has been established as a robust empirical feature not only for the U.K. and but also other advanced economies like the U.S., the difference in welfare consequences across the two policy interventions is a robust result.[38] In other words, while a higher inflation target has to contend with the adverse welfare consequences coming from first moment effects, it is not the case with countercyclical fiscal policy. This weakens the case for raising the inflation target to mitigate the effects of ZLB when countercyclical fiscal tools are available.

Government Financing: The final metric I use to compare the two policy interventions is from the perspective of government financing. In particular, I evaluate whether the countercyclical fiscal policy results in significant fiscal challenges for the government. For that, I compute the maximum government debt and fiscal deficit as a percentage of GDP from model simulations. As Table 6 shows, these fiscal numbers are admittedly higher under the countercyclical policy than the higher inflation target. However, the differences are minor. For instance, the maximum debt-to-GDP ratio is 59.6% under the countercyclical fiscal policy while it is 57.9% under the higher inflation target.

One reason why countercyclical fiscal policy does not result in high government debt and fiscal deficit numbers in the model is because by stabilizing the economy, countercyclical fiscal policy also results in improved tax revenues thereby easing the government budget constraint (Figure 4).[39] Another reason is that the equilibrium considered in this paper is monetary-led, so that government debt is stabilized in the model. How much of these results change in a fiscally-led equilibrium is an important question which I leave for future research.

the result from the unconditional welfare exercise.

[38]For the estimates of indexation in the U.K., see for instance Benati (2008) and for the U.S., see for instance Smets and Wouters (2007). In the case of the U.S., full indexation is also in conflict with the micro level evidence on price setting (Bils and Klenow (2004)).

[39]If for instance, the proportional tax is replaced by lump sum taxes, this will require the government to borrow more during ZLB episodes raising government debt and fiscal deficit numbers.

In conclusion, this section underscores the point that as much as a higher inflation target stabilizes business cycle fluctuations in the presence of the ZLB constraint, a carefully calibrated countercyclical fiscal policy is an alternative policy choice to meet the same objective. From a welfare perspective, a countercyclical fiscal policy is better than a higher inflation target, because the latter reduces the long run output and consumption while the former is neutral in the long run. Furthermore, in a monetary-led equilibrium, countercyclical fiscal policy does not pose significant fiscal challenges for the government.

6.3 Does the Initial Level of Government Debt Matter?

So far, the upshot is that a countercyclical fiscal policy helps in mitigating the effects of the ZLB constraint thereby resulting in improved macroeconomic performance. This section evaluates how the initial level of government debt matters for the efficacy of countercyclical fiscal policy, particularly in the context of the ZLB constraint. For that, I deploy a similar event study as done earlier. In particular, I simulate ZLB episodes from different levels of initial government debt: low, steady state, and high.[40] And then, I evaluate the dynamics of model variables in the simulated episodes under the countercyclical fiscal rule. Because the countercyclical fiscal rule steers the nominal rate away from ZLB in the earlier exercise (Figure 3), I choose a bigger shock size of 3 s.d. in this exercise. Figure 8 presents the results.

The stabilizing role of countercyclical fiscal policy stems from an increase in government expenditure during the ZLB episode. Therefore, key to analyzing the role of initial government debt lies in how it affects the expansionary response of government expenditure. In general, because the fiscal authority can always borrow more to finance its expenses, a higher level of initial government debt does not necessarily mean that the government expenditure is lesser vis-a-vis the case where the initial government debt is low. However, in a monetary-led equilibrium that must stabilize government debt, it is the case. The response of government expenditure in Figure 8 confirms this: government expenditure, even though expansionary, is lower when the initial government debt is higher. This then implies that the boost in aggregate demand due to the countercyclical fiscal rule is smaller when the initial government debt is higher. Accordingly, the drop in equilibrium output is more when the initial government debt is higher, as the figure confirms. This result suggests that a higher level of initial government debt limits the scope and the efficacy of countercyclical

[40]The low, steady state, and high levels of government debt roughly correspond to 50%, 53%, and 57% of GDP respectively. While I can choose a really high debt level (which infact helps in drawing a sharper inference), I restrict myself to a high debt level that is actually realized in model simulations.

fiscal policy during ZLB episodes. The theoretical result in this paper is also consistent with the empirical findings in Ilzetzki et al. (2013) who report lower fiscal multipliers for those countries with high government debt.

The initial level of government debt also matters for inflation. And here, the assumption of GHH utility function is crucial. As discussed in detail earlier, households' labor supply decisions are independent of wealth effects under GHH utility function. In particular, a decrease in labor supply that would have arisen due to a higher government debt induced bigger (positive) wealth effects has no bearing in determining wages in the model. Therefore, a lower aggregate demand with the higher initial government debt, for reasons outlined above, means that wages and hence, marginal costs also decline much more.[41] This results in inflation declining more when the initial government debt is higher. The bigger drops in inflation and output (as discussed above) then mean that the nominal rate also declines much more when the initial level of government debt is higher. As a result, a higher level of government debt also increases the duration of the ZLB spell in the model (Figure 8).

With regard to consumption, the effects of a higher initial government debt are somewhat nuanced in the model. Ricardian consumption is subject to bigger (positive) wealth effects when the initial government debt is high. Thus, as Figure 9 shows, Ricardian consumption initially declines much less with the higher initial government debt. However, the general equilibrium effects of a bigger drop in wages and labor, due to the limited fiscal expansion on count of the higher government debt, offset some of these. Because such wealth effects do not apply to non-Ricardian households, the corresponding effects on their consumption are via wages and labor movements in the model. Accordingly, a higher government debt unambiguously implies that non-Ricardian consumption drops more in the simulated ZLB episode. Due to the larger share of Ricardians in the model, Ricardian consumption response weighs more for the dynamics of aggregate consumption (Figure 8). But the important takeaway point in this exercise is that a higher level of initial government debt, by limiting the scope of expansionary fiscal response, adversely affects the non-Ricardians during ZLB episodes.

[41] In terms of wealth effects, the polar opposite case is the type of utility function considered in King et al. (1988). Under this utility function, labor supply effects dominate labor demand effects so that wages decline much less with a higher level of government debt. Accordingly, the effects of a higher level of initial government debt on inflation are the opposite to the ones shown in Figure 8.

7 Conclusion

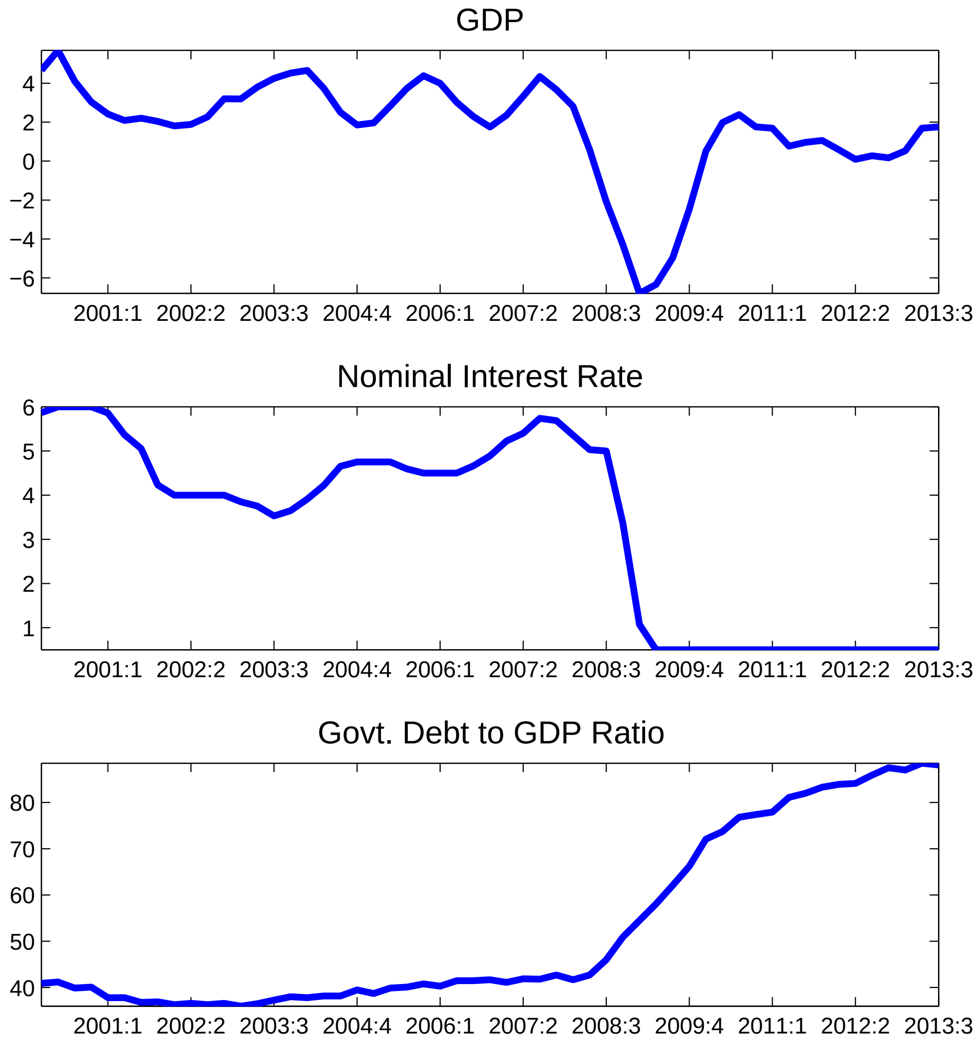
In the light of policy rates in most advanced economies now at or near ZLB, a recent monetary policy proposal is that central banks should pursue a higher inflation target that would give them more "room-to-manoeuvre" during deep recessions (Blanchard et al. (2010)). This paper evaluates the efficacy of such a proposal with an emphasis on the role of countercyclical fiscal policy. I use a New Keynesian DSGE model that features Ricardian and non-Ricardian households and where the government sector comprises of a monetary and a fiscal authority. I provide a global solution for the model in a fully stochastic setting and where agents are aware of the occasionally binding constraint associated with the zero lower bound.

The results from the model suggest that as much as a higher inflation target stabilizes business cycle fluctuations in the presence of the ZLB constraint, a carefully calibrated countercyclical fiscal policy is an alternative policy choice to meet the same objective. From a welfare perspective, a countercyclical fiscal policy is better than a higher inflation target, because the latter reduces the long run output and consumption while the former is neutral in the long run. Furthermore, in a monetary-led equilibrium, countercyclical fiscal policy does not pose significant fiscal challenges for the government. Thus, the scope for a countercyclical fiscal policy weakens the case for raising the inflation target as a means to mitigate the effects of the zero lower bound. The results from the paper also suggest that the efficacy of countercyclical fiscal policy during zero lower bound episodes depends on the initial level of government debt. In particular, a high initial level of government debt limits that efficacy.

While the model used in this paper is rather stylized so that some caution is warranted, this paper highlights the important point that one needs to rigorously evaluate all available policy options as far as mitigating the effects of ZLB is concerned. In this regard, important extensions to the model will be useful. One important extension is to introduce fiscal implementation lags in the model. Another extension is to consider a regime switching model where the economy switches between monetary-led and fiscally-led equilibria on the lines of (Bianchi and Melosi (2013)). Using that framework, one can re-evaluate the results in this paper, particularly those related to government debt dynamics. To further explore the significance of government debt, one can also extend the model to include endogenous sovereign risk premiums (Corsetti et al. (2013)) and debt limits. I leave these extensions for future work.

8 Tables and Figures

Figure 1: U.K. Macroeconomic Variables



Note: The graph shows GDP (annual growth rates), the nominal interest rate (net annual), and government debt to GDP ratio for the U.K. All numbers shown are in percentages.

Table 1: Baseline Parameter Values

Definition	**Parameter**	**Value**
Discount factor	β	0.99
Share of non-Ricardians	ν	0.1184
Utility risk aversion	γ	1
Frisch labor supply	ϑ	0.5
Labor preference	ψ	1.22
Mark-up	θ	8
Calvo probability	ϕ	0.7
Indexation	ω	0.1
Gross inflation target	π	1.005
Interest smoothing	ρ_r	0.7
Taylor coefficient on inflation	ρ_π	3
Taylor coefficient on output	ρ_y	0.4
Govt. expenditure-to-GDP ratio	$\frac{g}{y}$	0.1654
Govt. debt-to-GDP ratio	$\frac{b}{y}$	0.5277
Tax rate	τ	0.195
Fiscal coefficient on output	ρ_τ	0.3
Fiscal coefficient on debt	ρ_b	0.5
AR(1) of preference shock	ρ_d	0.8
S.D of preference shock	σ_d	0.023

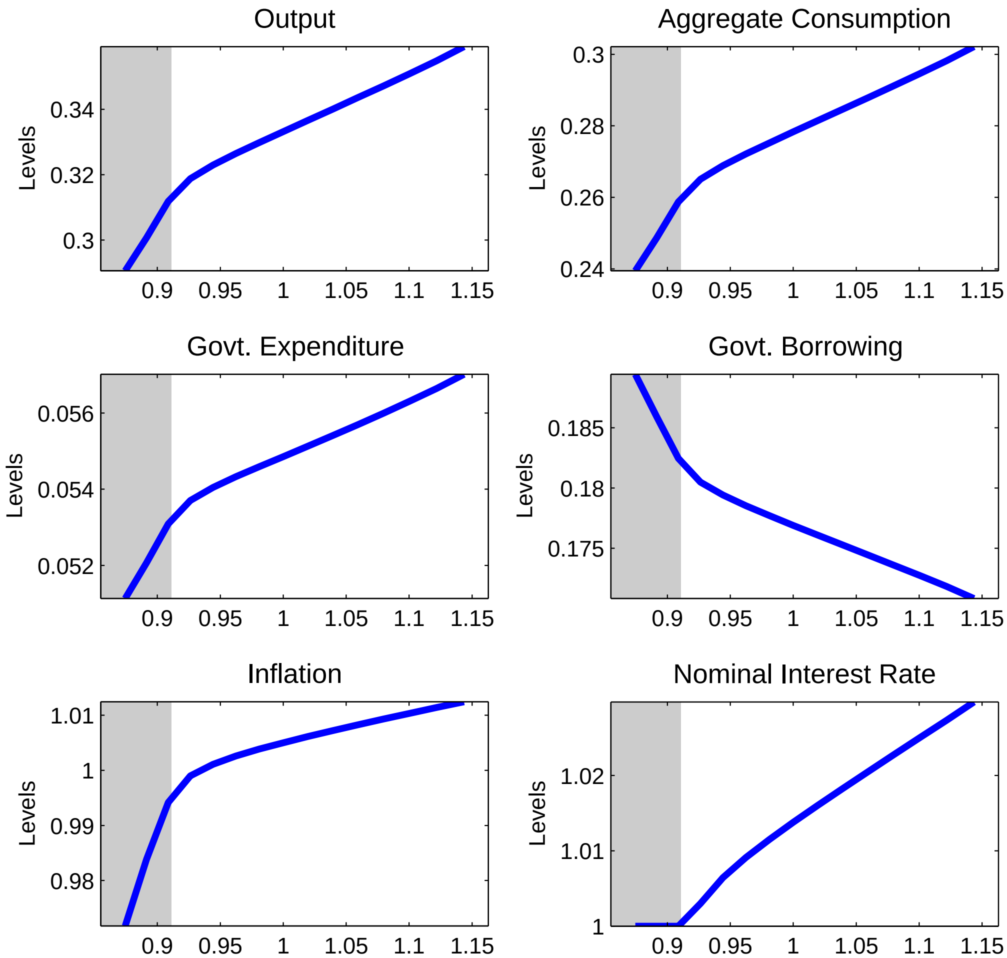
Note: The table shows the parameter values chosen in the baseline specification of the model.

Table 2: Alternative Model Specifications

Parameter	**Baseline**	**Model A**	**Model B**	**Model C**
Inflation target	1.005	1.01	1.005	1.01
Fiscal coefficient on output	0.3	0.3	1.4	0.3
Indexation	0.1	0.1	0.1	1

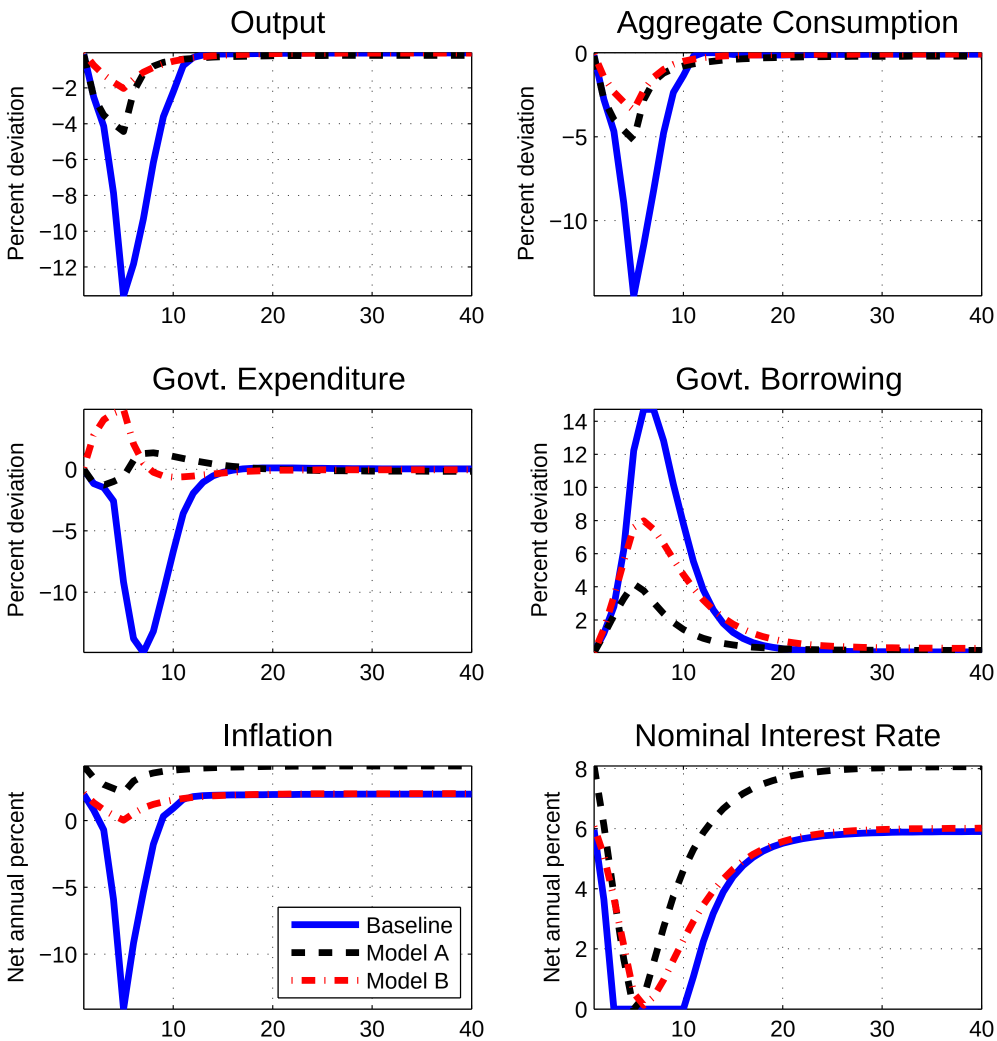
Note: The table shows the parameter values chosen in alternative specifications of the model. **Model A**: higher inflation target of 4% with partial indexation. **Model B**: countercyclical fiscal policy. **Model C**: higher inflation target of 4% with full indexation.

Figure 2: Policy Rules in the Baseline Specification



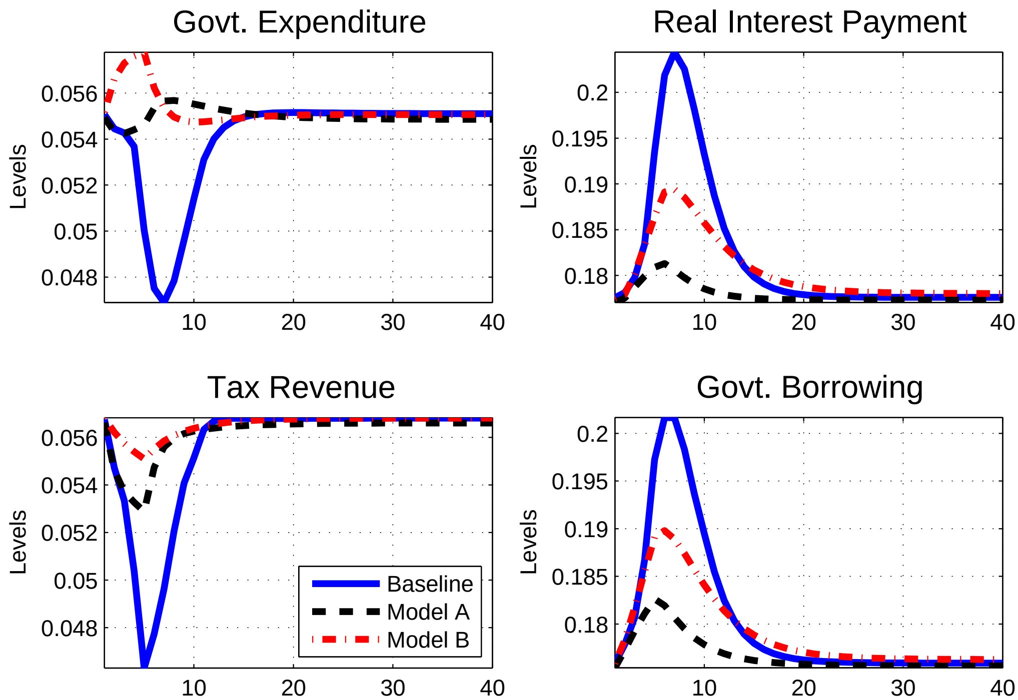
Note: The graph shows the policy rules at different grid points of the preference shock. These are from the baseline specification. All other state variables are fixed at grid points at or closest to steady states. Shaded highlight regions where the ZLB binds.

Figure 3: Higher Inflation Target vs. Countercyclical Fiscal



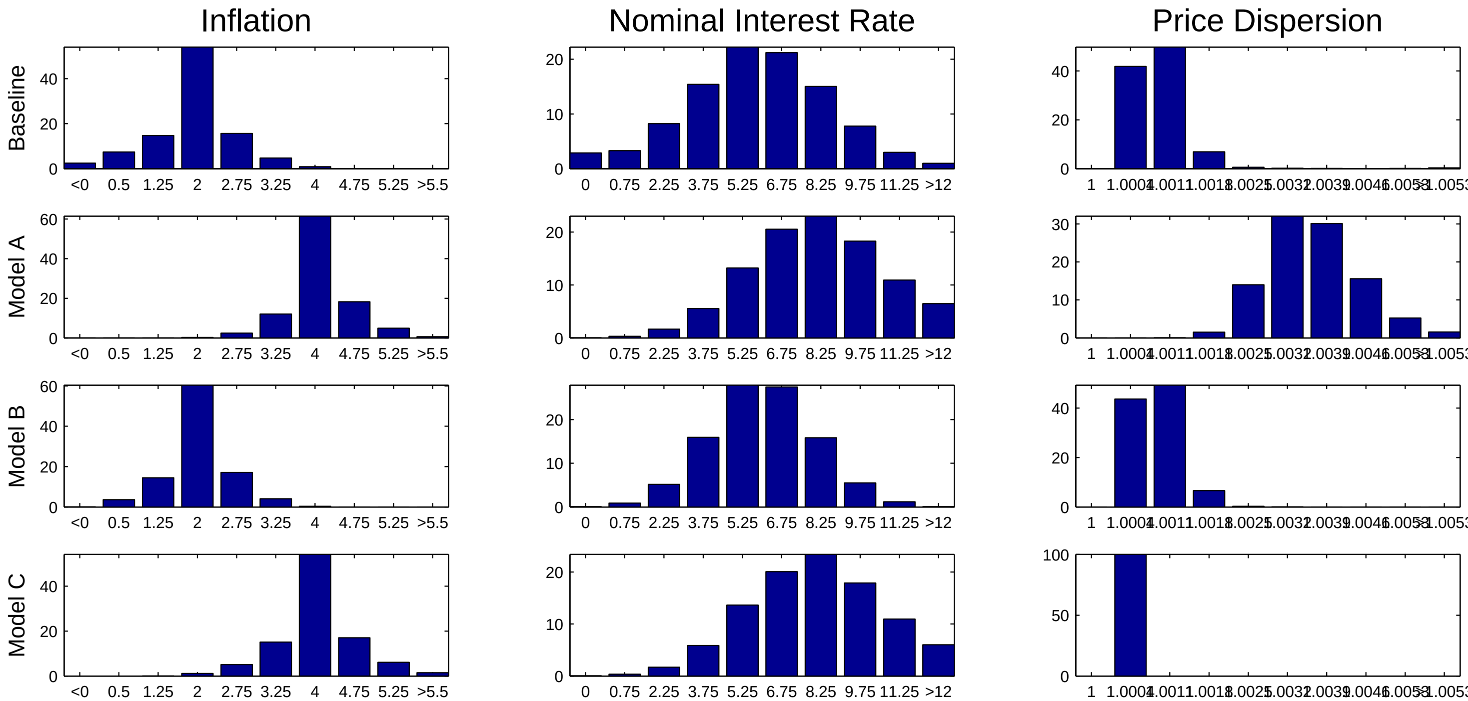
Note: The graph compares the dynamics of macro variables during a ZLB episode across these specifications: Baseline, Model A (higher inflation target of with partial indexation) and Model B (countercyclical fiscal policy). The ZLB episode is generated by hitting the economy, initially at its steady state, with adverse preference shocks of size 2 s.d. during the first 4 periods.

Figure 4: Components of Govt. Budget Constraint



Note: The graph shows the dynamics of the components of the government budget constraint during a ZLB episode. The ZLB episode is generated by hitting the economy, initially at its steady state, with adverse preference shocks of size 2 s.d. during the first 4 periods. The top two figures are government expenditure items and the bottom two are the means by which those are financed. Model A: higher inflation target with partial indexation. Model B: countercyclical fiscal policy.

Figure 5: Unconditional Distributions



Note: The graph shows the frequency distributions (in percentage on Y-axis) of inflation, nominal interest rate, and price dispersion from model simulations across these specifications: Baseline, Model A (higher inflation target with partial indexation), Model B (countercyclical fiscal policy), and Model C (higher inflation target with full indexation). Inflation and nominal interest rate are in net annual rates while price dispersion is in gross quarterly levels. The results are based on simulations of length 50,000 with steady states of the baseline model as the starting point.

Table 3: Unconditional Moments from Model Simulations

(a) Mean

Model	Baseline	Model A	Model B	Model C
Output	0.3327	0.3317	0.3329	0.3331
Aggregate Consumption	0.2777	0.2768	0.2778	0.278
Ricardian Consumption	0.2835	0.2826	0.2836	0.2838
Non-Ricardian Consumption	0.2344	0.2339	0.2346	0.2345
Aggregate Labor	0.333	0.3329	0.3332	0.3331
Inflation	1.0046	1.0102	1.005	1.0101
Nominal Interest Rate	1.0146	1.0202	1.0151	1.0201

(b) Standard Deviation

Model	Baseline	Model A	Model B	Model C
Output	1.68	1.38	0.57	1.32
Aggregate Consumption	1.83	1.59	0.94	1.51
Ricardian Consumption	1.76	1.52	0.95	1.44
Non-Ricardian Consumption	2.51	2.18	0.89	2
Aggregate Labor	1.68	1.44	0.6	1.32
Inflation	0.29	0.14	0.14	0.17
Nominal Interest Rate	0.66	0.62	0.48	0.62

Note: Table (a) shows the unconditional mean of macroeconomic variables from model simulations. Table (b) reports the standard deviation of these variables as a percentage of the respective steady states. Model A: higher inflation target with partial indexation. Model B: countercyclical fiscal policy. Model C: higher inflation target with full indexation. The results are based on simulations of length 50,000 with steady states of the baseline model as the starting point.

Table 4: Zero Lower Bound Episodes

Model	**Baseline**	**Model A**	**Model B**	**Model C**
Frequency	2.87	0.03	0.06	0.04
Duration	2.43	2.41	2.39	2.36

Note: The table shows the frequency (in percentages) and average duration (in quarters) of zero lower bound episodes from model simulations.

Table 5: Unconditional Welfare

Model	**Baseline**	**Model A**	**Model B**	**Model C**
Ricardian	-653.01	-654.50	-653.15	-652.41
Non-Ricardian	-807.16	-807.86	-807.18	-807.17

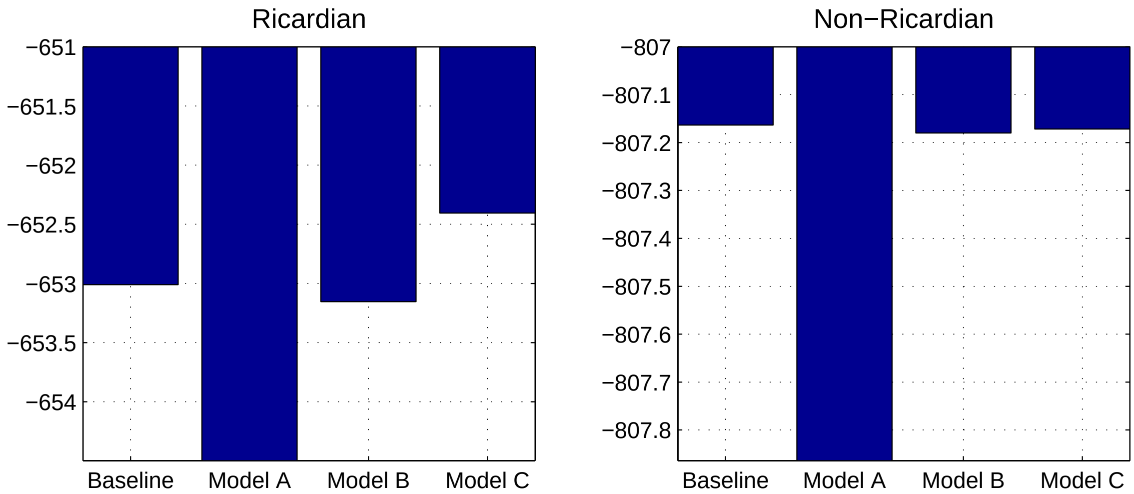
Note: The table shows the unconditional welfare of Ricardian and non-Ricardian households across model specifications. The unconditional welfare is obtained by simulating the value function of each type of household 50,000 times and then taking the average.

Table 6: Fiscal Variables

Model	**Baseline**	**Model A**	**Model B**	**Model C**
Govt. Debt	79.4	57.9	59.6	57.6
Fiscal Deficit	1.8	1.7	1.9	1.7

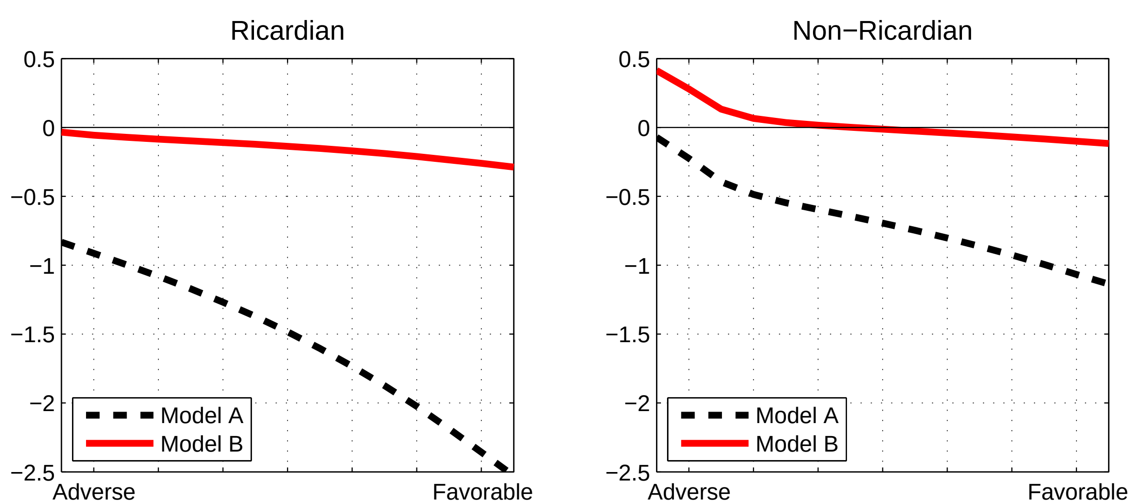
Note: The table shows the maximum government debt and fiscal deficit as a percentage of GDP from model simulations. All of the above results are based on simulations of length 50,000 with steady states of the baseline model as the starting point. Model A: higher inflation target with partial indexation. Model B: countercyclical fiscal policy. Model C: higher inflation target with full indexation.

Figure 6: Unconditional Welfare



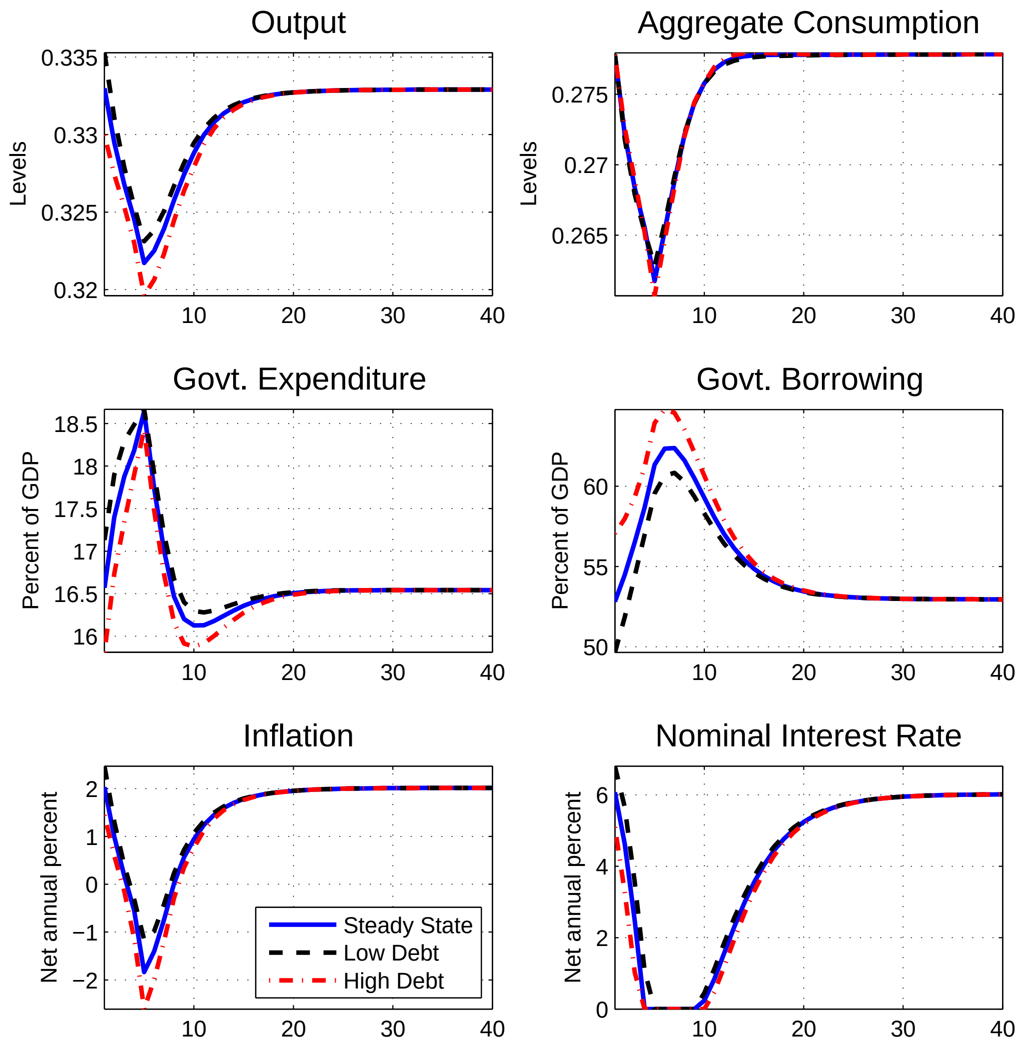
Note: The graph shows the unconditional welfare (Y-axis) of Ricardian and non-Ricardian households across model specifications. The unconditional welfare is obtained by simulating the value function of each type of household 50,000 times and then taking the average.

Figure 7: Conditional Welfare over Baseline Model



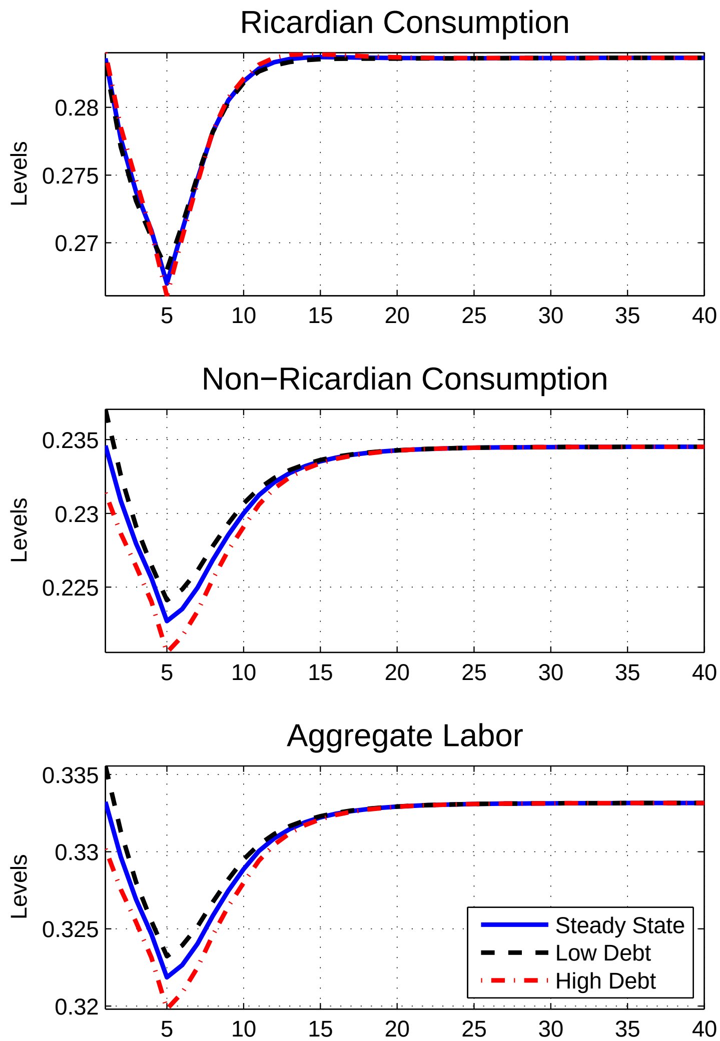
Note: The graph shows the difference in the conditional welfare (Y-axis) between each alternative model specification and the baseline model. A positive (negative) number indicates a welfare gain (loss). The conditional welfare shown is for different grids of preference shocks (X-axis), going from adverse (left) to favorable (right). All other state variables are fixed at grid points at or closest to steady states.

Figure 8: Countercyclical Fiscal Policy for Different Levels of Initial Govt. Debt



Note: The graph compares the dynamics of macro variables during ZLB episodes generated with different levels of initial government debt. These are from the specification with countercyclical fiscal policy (Model B). The initial levels of government debt considered are the steady state and debt levels lower and higher than the steady state. From these initial conditions, the ZLB episodes are generated by hitting the economy with adverse preference shocks of size 3 s.d. during the first 4 periods.

Figure 9: Countercyclical Fiscal Policy for Different Levels of Initial Govt. Debt



Note: The graph compares the dynamics of macro variables during ZLB episodes generated with different levels of initial government debt. These are from the specification with countercyclical fiscal policy. The initial levels of government debt considered are the steady state and debt levels lower and higher than the steady state. From these initial conditions, the ZLB episodes are generated by hitting the economy with adverse preference shocks of size 3 s.d. during the first 4 periods.

A Appendix

A.1 Nonlinear Equations

$$\lambda_t = d_t \left(c_{R,t} - \psi \frac{l_{R,t}^{(1+\vartheta)}}{(1+\vartheta)} \right)^{-\gamma} \tag{A.1.1}$$

$$\lambda_t = \beta E_t \left[R_t \frac{\lambda_{t+1}}{\pi_{t+1}} \right] \tag{A.1.2}$$

$$\psi l_{R,t}^{\vartheta} = (1-\tau) w_t \tag{A.1.3}$$

$$c_{N,t} = (1-\tau) w_t l_{N,t} \tag{A.1.4}$$

$$\psi l_{N,t}^{\vartheta} = (1-\tau) w_t \tag{A.1.5}$$

$$\xi_t = w_t \tag{A.1.6}$$

$$\theta g_{1,t} = (\theta - 1) g_{2,t} \tag{A.1.7}$$

$$g_{1,t} = \lambda_t \xi_t y_t + \beta \phi E_t \left[\left(\frac{\pi^{\omega}}{\pi_{t+1}} \right)^{-\theta} g_{t+1}^1 \right] \tag{A.1.8}$$

$$g_{2,t} = \lambda_t \pi_t^* y_t + \beta \phi E_t \left[\left(\frac{\pi^{\omega}}{\pi_{t+1}} \right)^{1-\theta} \frac{\pi_t^*}{\pi_{t+1}^*} g_{t+1}^2 \right] \tag{A.1.9}$$

$$1 = \phi \left(\frac{\pi^{\omega}}{\pi_t} \right)^{1-\theta} + (1-\phi) \pi_t^{*1-\theta} \tag{A.1.10}$$

$$s_t = \phi \left(\frac{\pi^{\omega}}{\pi_t} \right)^{-\theta} s_{t-1} + (1-\phi) \pi_t^{*-\theta} \tag{A.1.11}$$

$$\frac{Z_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\rho_\pi} \left(\frac{y_t}{y} \right)^{\rho_y} \right]^{1-\rho_r} \tag{A.1.12}$$

$$R_t = Z_t + \max\{\mu_t, 0\}^2 \tag{A.1.13}$$

$$R_t = 1 + \max\{-\mu_t, 0\}^2 \tag{A.1.14}$$

$$g_t + b_{g,t-1} \frac{R_{t-1}}{\pi_t} = \tau w_t l_t + b_{g,t} \tag{A.1.15}$$

$$f_t = -\left(b_{g,t} - \frac{b_{g,t-1}}{\pi_t} \right) \tag{A.1.16}$$

$$f_t - f = \rho_\tau (y_t - y) + \rho_b (b_t - b) \tag{A.1.17}$$

$$y_t = c_t + g_t \tag{A.1.18}$$

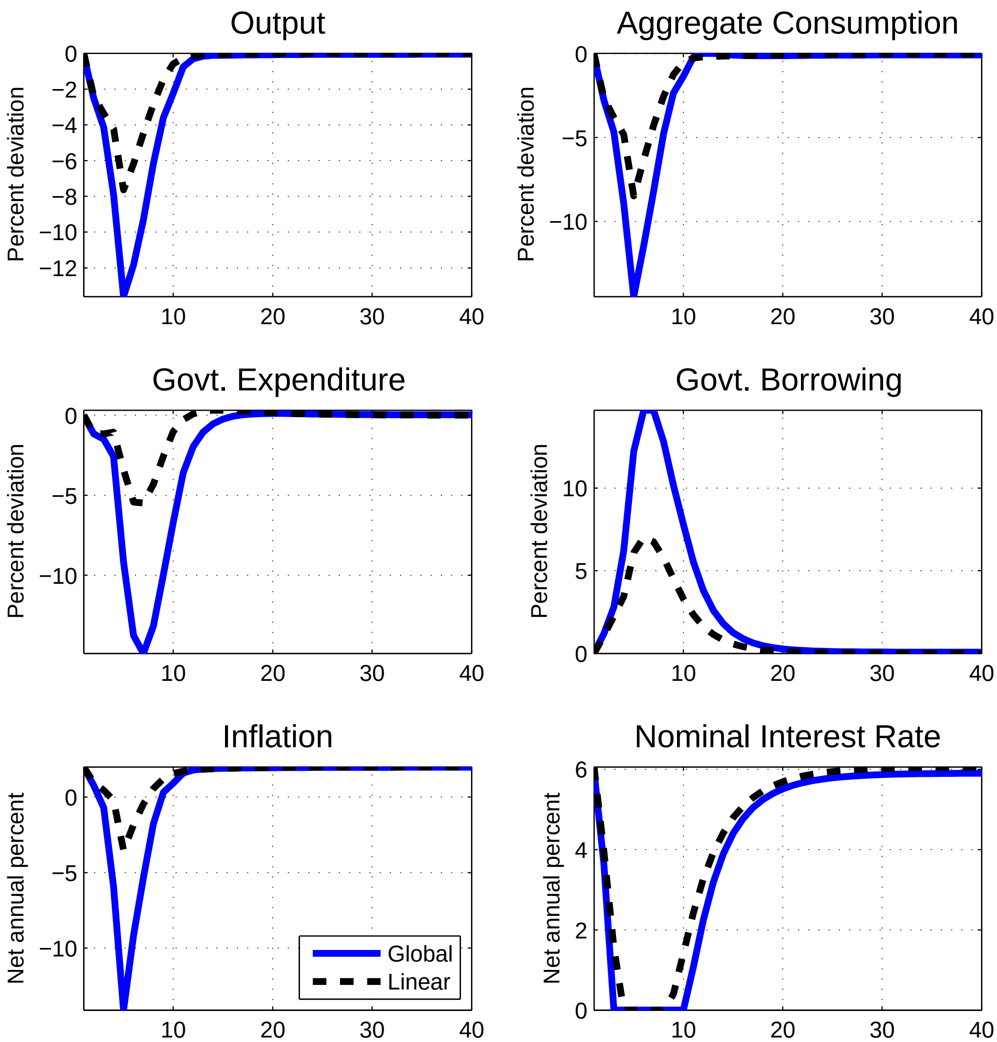
$$y_t = \frac{l_t}{s_t} \tag{A.1.19}$$

$$l_t = (1-\nu) l_{R,t} + \nu l_{N,t} \tag{A.1.20}$$

$$c_t = (1-\nu) c_{R,t} + \nu c_{N,t} \tag{A.1.21}$$

A.2 Additional Graphs and Tables

Figure 10: Global vs. Linear Solution



Note: The graph compares the dynamics of macro variables during a ZLB episode across the global and linear solution methods. These are from the baseline specification. The ZLB episode is generated by hitting the economy, initially at its steady state, with adverse preference shocks of size 2 s.d. during the first 4 periods.

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