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Is There a Fiscal Free Lunch in a Liquidity Trap?*

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First version: April 2009
This version: June 2009

Abstract

This paper uses a DSGE model to examine the effects of an expansion in government spending in a liquidity trap. The spending multiplier can be much larger than in the normal situation if the liquidity trap is very persistent, and fiscal stimulus can be rapidly implemented. Moreover, the budgetary costs may be minimal as the large response of output boosts tax revenues, allowing for something close to a "fiscal free lunch." However, we caution that the multiplier may be much smaller under plausible implementation lags for many types of public spending,and/or if the liquidity trap lasts less than two years. In addition, because the marginal impact of fiscal expansion decreases in the scale of the outlay, it is crucial to distinguish between average and marginal multipliers.

JEL Classification: E52, E58
Keywords: Monetary policy, Liquidity trap, Fiscal policy, zero lower bound constraint, New Keynesian model

*We thank Mark Clements for excellent research assistance, and Martin Bodenstein and Luca Guerrieri for helpful discussions. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System. ** Corresponding Author: Telephone: 202-452-2575. Fax: 202-263-4850 E-mail addresses: christopher.erceg@frb.gov and jesper.l.linde@frb.gov

1. Introduction

During the past two decades, a voluminous empirical literature has attempted to gauge the effects of fiscal policy shocks. This literature has been instrumental in identifying the channels through which fiscal policy affects the economy, and, in principle, would seem a natural guidepost for policymakers seeking to assess how alternative fiscal policy actions could mitigate the current global recession.

However, it is unclear whether estimates of the effects of fiscal policy from this empirical literature – which focuses almost exclusively on the postwar period – should be regarded as applicable under conditions of a recession-induced liquidity trap. Keynes (1933, 1936) argued in support of aggressive fiscal expansion during the Great Depression exactly on the grounds that the fiscal multiplier was likely to be much larger during a severe economic downturn than in normal times, and the burden of financing it correspondingly lighter. His logic underlying a larger multiplier in a liquidity trap was formalized in subsequent IS-LM analysis, with a liquidity trap corresponding to a flat LM curve.

In this paper, we use a New-Keynesian DSGE modeling framework to examine the implications of an increase in government spending for output and the government budget when monetary policy faces a liquidity trap. A key advantage of the DSGE framework is that it allows explicit consideration of how the conduct of monetary policy – and, in particular, the zero bound constraint on nominal interest rates – affects the multiplier.

We begin by showing in a stylized New Keynesian model that the government spending multiplier can be greatly amplified in the presence of a persistent liquidity trap; for example, the multiplier roughly triples if monetary policy refrains from adjusting interest rates for 12 quarters compared with its value under "normal situation conditions" in which policy followed a standard linear Taylor rule. Both the structure of the model and implication of an outsized multiplier corroborate previous work by Eggertson (2006). We also reach broadly similar conclusions in a variant of the Smets-Wouters (2007) model – which incorporates both endogenous capital accumulation and habit persistence in consumption – as the multiplier roughly doubles relative to usual conditions. The amplification in the presence of a liquidity trap is even larger in other variants we examine that embed financial frictions (following Christiano, Motto, and Rostagno 2004), and hand-to-mouth agents (as in Gali, Lopez-Salido, and Valles 2007).

The large and persistent effects of higher government spending on output in a liquidity trap also has important implications for the government budget. In particular, a given-sized rise in government spending induces much less of increase in public debt than in the normal situation, mainly because the higher output response in the liquidity trap case substantially boosts tax revenues.

Overall, these results seem highly supportive of Keynes' argument for fiscal expansion in the case of a recession-induced liquidity trap – the benefits are extremely high, and the budgetary expense to achieve it very low. So why would policymakers want to pass up on a free lunch, or at least a very cheap lunch? And is there any reason to limit the size of fiscal spending packages?

To answer these questions, we proceed to identify the factors that play a key role in accounting for an outsized multiplier in the benchmark "severe recession scenario" described above. One pivotal factor is that private agents expect that the liquidity trap would last for a long time in the absence of fiscal stimulus. Consistent with the analysis of Cogan et al 2009, the fiscal multiplier isn't much different from the normal situation (in which the zero bound constraint never binds) if the liquidity trap is only expected to last roughly 4-6 quarters. However, because the impact of weak aggregate demand in a liquidity trap increases exponentially as the period lengthens in which monetary policy is constrained, fiscal policy can become extremely potent if the liquidity trap lasts more than a couple of years.

A second factor that helps generate a large multiplier in the benchmark severe recession scenario is that the higher government spending is highly front-loaded, consistent with standard practice in modeling the effects of fiscal policy. However, many types of government spending have implementation lags more in the range of 2-3 years (especially infrastructure projects). We find that taking account of such implementation lags can have pronounced effects on the implied government spending multiplier. Even if the liquidity trap lasts 12 quarters – as in the "severe recession scenario," an implementation lag of 2 years can cut the multiplier in half relative to the case in which government spending occurs immediately; with a shorter liquidity trap in the range of 6-8 quarters, the multiplier can be depressed to zero. Thus, echoing Friedman (1953), the efficacy of fiscal policy in macroeconomic stabilization – even in a liquidity trap – can be seriously hampered by "long and variable lags."

Another important factor in accounting for a large multiplier is a substantial response of expected inflation. Because monetary policy does not raise nominal interest rates for an extended period, the increase in expected inflation due to fiscal stimulus depresses real interest rates, which can "crowd in" rather than crowding out private demand. This crowding in effect varies directly with the magnitude of the inflation response, which in turn depends importantly on the slope of the Phillips Curve, and on the rule that monetary policy is expected to follow after the economy exits the liquidity trap.

Finally, our analysis also highlights the importance of factors that influence the expected tax burden of fiscal stimulus, including its persistence and how it is financed. A large government spending multiplier – as in our benchmark – depends on a slow response of labor taxes to higher public debt levels, as long has been recognized by Keynesian economists (e.g., the early discussion of the multiplier effect in Kahn 1931). But provided that private agents are forward-looking and internalize the government's budget constraint – as in our DSGE framework – it is also quite crucial that the spending die away fairly quickly, which serves to minimize the drag on permanent income.

Overall, our results suggest a somewhat nuanced view of the role of fiscal policy in a liquidity trap. For an economy facing a protracted recession and for which monetary policy seems likely to be constrained by the zero bound for a sustained period, there is a strong argument for increasing government spending on a temporary basis. Consistent with the views originally espoused by Keynes, this temporary boost can have much larger effects than under usual conditions, and comes at relatively low cost to the Treasury. However, all forms of higher government spending are not equally desirable; the multiplier on those components of government spending with long implementation lags may be quite low and even negative. From a practical perspective, this means it is important to focus on types of spending that can be increased fairly quickly, e.g., front-loading purchases of military equipment. In addition, insofar as local governments are often forced to cut spending sharply due to financing constraints, policies that temporarily ease such constraints may achieve a similar outcome as a short-lived spending boost.

Our analysis is also conducted in a framework that is helpful in gauging the appropriate scale of the fiscal response by distinguishing between the *marginal* and *average* effects of higher government spending. In particular, our framework allows the economy's exit from a liquidity trap – and return to conventional monetary policy – to depend on the scale of the fiscal response. Quite intuitively, a large fiscal response pushes the economy out of a recession-induced liquidity trap more quickly. Because the multiplier is much smaller under usual conditions than in the trap, the marginal impact of fiscal spending decreases with the magnitude of the spending hike. Accordingly, even if conditions warrant a substantial increase in fiscal spending, it is essential to have a good sense of the marginal multiplier associated with a given-sized spending plan: the fiscal spending may have high payoff on average, but little at the margin.

The paper is organized as follows: Section 2 discusses our characterization of a liquidity trap in the context of the simple New Keynesian model. Section 3 contrasts the effects of government spending expansion in a liquidity trap with a normal situation. In Section 4, we study the robustness of the results in a more empirically oriented model with capital similar to those successfully estimated by Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003, 2007). Section 5 adds the Bernanke, Gertler and Gilchrist (1999) financial accelerator mechanism and "hand-to-mouth" households (as in Erceg, Guerrieri and Gust (2006)), and again examines robustness. Some conclusions are provided in Section 6.

2. A stylized New Keynesian model

In this Section, we present the workhorse New Keynesian model that we use on the first part of the paper.[1]

2.1. The Model

As in Eggertsson and Woodford (2003), we begin by analyzing the effects of fiscal shocks in a standard log-linearized version of the New Keynesian model that imposes a zero bound constraint on interest rates. The key equations of the model are:

$$x_t = x_{t+1|t} - \sigma(1 - g_y)(i_t - \pi_{t+1|t} - r_t^{pot}), \tag{1}$$

$$\pi_t = \beta\pi_{t+1|t} + \kappa_p x_t, \tag{2}$$

$$i_t = \max\left[-i, (1-\gamma_i)\left(\gamma_\pi \pi_t + \gamma_x x_t\right) + \gamma_i i_{t-1}\right], \tag{3}$$

$$r_t^{pot} = \psi_g(g_t - g_{t+1}) + \psi_\nu(\nu_t - \nu_{t+1}), \tag{4}$$

where

$$\psi_g = \frac{1}{\sigma}\frac{g_y}{1-g_y}(1 - \frac{1-\alpha}{\phi_{mc}}) \tag{5}$$

$$\psi_\nu = \frac{1}{\sigma}\nu(1 - \frac{1-\alpha}{\phi_{mc}}) \tag{6}$$

and where x_t is the output gap, π_t is the inflation rate, and i_t is the short-term nominal interest rate.[2]

[1] Appendix A provides some details on the New Keynesian model used in the analysis.
[2] See Appendix A for details on the derivation of the model.

Equation (1) parsimoniously expresses the IS curve in terms of output and real interest rate gaps. Thus, the output gap depends inversely on the deviation of the real interest rate ($i_t - \pi_{t+1|t}$) from its potential rate r_t^{pot}. The sensitivity of the output gap to the real interest rate depends on the household's intertemporal elasticity of substitution in consumption σ, and the steady state government spending share of output g_y. The price-setting equation (2) specifies current inflation to depend expected inflation and the output gap, where the sensitivity to the latter is determined by the composite parameter κ_p. This parameter can be expressed: $\kappa_p = \frac{(1-\xi_p)(1-\beta\xi_p)}{\xi_p}\phi_{mc}$ where $1 - \xi_p$ is the probability that a firm is allowed to re-optimize its price, and ϕ_{mc} is the sensitivity of real marginal cost to the output gap. The interest rate reaction function is simply a Taylor rule, aside from the constraint that policy rates – represented as a deviation from baseline – cannot fall below the steady state interest rate of i. The potential real interest rate r_t^{pot} is determined by equation (4). For reasonable calibrations, the marginal cost elasticity ϕ_{mc} is well above unity, implying that the potential real rate varies inversely with the growth rate of government spending $g_{y,t}$, and with the taste shock ν_t.

We assume that $g_{y,t}$ and ν_t are given by the following exogenous stochastic processes

$$\Delta g_{y,t} = \rho_{g,1}\Delta g_{y,t-1} - \rho_{g,2}\left(g_{y,t-1} - g_y\right) + \varepsilon_{g,t}, \tag{7}$$

$$\Delta \nu_t = \rho_{c,1}\Delta \nu_{t-1} - \rho_{c,2}\left(\nu_{t-1} - \nu\right) + \varepsilon_{\nu,t}, \tag{8}$$

where $g_{y,t}$ is the government spending as share of nominal trend output, i.e. $g_{y,t} \equiv \frac{G_t}{\bar{Y}_t}$ where $\bar{Y}_t$ is trend real output (assumed to be constant in our model). Notice also that eq. (8) implies that $\nu_t = 1$ in steady state.

In the variant of the model where we assume the fiscal expansion needs to be financed by distortionary labor income taxes, the evolution for public debt is given by

$$B_{G,t} = (1 + i_t)B_{G,t-1} + P_t G_t - T_t - \tau_{N,t} W_t L_t,$$

and we work with the following specification of the endogenous labor tax income adjustment rule

$$\tau_{N,t} - \tau_N = \phi_\tau\left(\tau_{N,t} - \tau_N\right) + \phi_b\left(b_{G,t} - b_G\right) + \phi_d\left(b_{G,t} - b_{G,t-1}\right) \tag{9}$$

where we have defined $b_{G,t} \equiv \frac{B_{G,t}}{P_t\bar{Y}_t}$ and τ_N is labor income tax rate in the steady state.

2.2. Solution and Calibration

We compute the reduced-form solution of the model for a given set of parameters using the numerical algorithm of Anderson and Moore (1985), which provides an efficient implementation of the solution method proposed by Blanchard and Kahn (1980). When solving the model subject to the zero lower bound constraint, we use the techniques described in Lindé and Svensson (2009).

The parameterization of the model is summarized in Table 1. These parameter values are standard in most cases, and inspired by empirical estimates in the literature. One key parameter is the degree of price stickiness ξ_p, and as can be seen from the table, we use a fairly high value in order for inflation and inflation expectations not to be too sensitive to movements in the output gap. Notice also that we use a fairly high value of the inverse Frisch labor supply ($\chi = 1$) in order to compensate for the fact that this model does not embody any nominal wage frictions, which will make the labor supply less response to shocks in comparison to models with both nominal price and wage frictions.

3. Dynamic Effects of Fiscal Expansions in the Stylized Model

In this section, we present the dynamic effects of fiscal policy interventions. We will contrast the effects under normal situations, i.e. when the central bank has the ability and desire to raise or lower interest rates in response to the fiscal impetus, with a situation when the nominal short term interest rate is subject to the zero lower bound. When the zero lower bound (henceforth ZLB) binds, the central bank may chooose not change the short-term nominal interest rate for some time following the fiscal intervention. We will contrast the responses under two different parametrizations of the policy rule. One specification we will consider is a very aggressive policy rule, and another specification will use coefficients that are in line with the estimates in the literature. By comparing the results under the two different policy rules, we will get an understanding of the role monetary policy plays in shaping the outcomes in the economy during the liquidity trap and after the exit from the liquidity trap.

3.1. Case 1: Aggressive policy rule

In this case, we assume that the central bank responds very hawkishly to movements in inflation from the target and the output gap. In terms of the policy rule (3), we set $\gamma_\pi = 300$, $\gamma_x = 500$ and $\gamma_i = 0$. This formulation of policy essentially implies that only shocks that create a tension between stabilizing inflation and the output gap will affect the economy.

3.1.1. Creating a baseline

In this Subsection, we present the dynamic effects of the underlying shock that forms the basis for the fiscal policy interventions analysed in the subsequent sections of the paper. In our analysis below, we assume for simplicity that the underlying shock is a strong fall in demand for consumption goods, which will cause the activity in the economy to drop considerable due to our formulation of the policy rule. We set the coefficients in the persistence of the consumption demand shock ν_t to 0.90 (i.e. we set $\rho_{\nu,1} = 0$ and $\rho_{\nu,2} = 0.1$) in eq. (8), and the size of the shock is calibrated so that the potential real interest rate initially drops to about -14 percent. This fall is completely natural as the consumers wants to consume less and the only storage facility available to them in this economy is nominal bonds. The dynamic effects of this fall in consumption demand is depicted in Figure 1. In the figure, we show the effects under the zero lower bound constraint and when policy is hypothetically unconstrained. Notice that the assumed steady state value for the annualized nominal interest rate is 4 percent, and the annualized real interest rate and inflation rates are assumed to be 2 percent in steady state. In this version of the model, we assume that government deficits are entirely financed by lump-sum taxes, and that government expenditures are exogenously given, so the evolution of public debt and the conduct of fiscal policy is irrelevant for the paths shown in Figure 1.

As is clear from the figure, the central bank is able to perfectly insolate the economy from the negative demand shock when policy is unconstrained by appropriately adjusting the nominal interest rate to offset the movements in the potential real interest rate induced by the fall in consumption demand. However, monetary policy cannot, and does not intend to, counteract the fall in actual output of slightly more than 10 percent because this is an efficient fall in production.

As is evident in Figure 1, the effects on actual output of the drop in consumption demand is magnified by the zero lower bound constraint, because the actual real interest rate does not fall to the same extent as when policy is unconstrained. When monetary policy is constrained by the ZLB constraint for the nominal interest rate, the central bank cannot induce a sufficiently large decrease in the actual real interest rate to keep the real interest rate gap, i.e. the difference between the actual and the potential real interest rate, unaffected. Therefore, the output gap falls and causes a decline in inflation which in turn causes the actual real interest rate to actually rise even more initially and this magnifies the negative effects on output and inflation even further. Due to the contraction in the output gap and the fall in inflation, the ZLB will in this case bind immediately with a **duration of** 13 **periods**. Given the high response coefficients on the output gap and inflation in the policy rule, the ZLB constraint will bind as long as the output gap is negative and inflation is below the target. First when the output gap is essentially nil and inflation is back on the target at 2 percent the economy will exit out of the Liquidity trap and the interest rate will not be bounded by the ZLB constraint. This feature of the results in Figure 1 are thus in line with analysis in Eggertsson (2008), who assume that the economy will return to steady state as soon as the economy exits from the liquidity trap.

3.1.2. Effects of a front-loaded fiscal expansion financed by lump-sum taxes

We now consider an expansion in government spending intended to counteract the fall in economic activity depicted in Figure 1. In the benign case, we assume that the government expenditures expands the same period as the negative demand shock hits the economy, and that the fiscal expansion has the same persistence as the underlying consumption demand shocks, i.e. we set $\rho_{g,1} = \rho_{\nu,1} = 0$ and $\rho_{g,2} = \rho_{\nu,2} = 0.1$ in eq. (7). The increase in government spending is set to 1 percent of the initial level (i.e. the trend level) of output. The government is assumed to be able to finance the increase in government expenditures with lump-sum taxes.[3],[4]

The results of the fiscal expansion is depicted in Figure 2 along with the effects of the consumption demand only. In both cases, we assume that monetary policy is subject to the ZLB constraint. We see that the fiscal expansion moderates the initial contractions in inflation and the nominal interest rates by raising the actual and potential real interest rate.

Also, although the fiscal expansion considered in Figure 2 does not cause the central bank to exit the liquidity trap earlier (but it raises the interest rate somewhat from period 13 and onwards until the economy return to steady state), it could potentially do so by increasing the size of the fiscal stimulus package in this benign case with a well timed expansion financed by lump-sum taxes. Thus, the analysis in Cogan et al. (2009), where they impose that the nominal interest rate is pegged at zero for a fixed horizon no matter the size of the fiscal expansion is misleading, and is not an appropriate assumption when monetary policy responds to the state of the economy according to a policy rule.

In Figure 3, we report the fiscal multipliers to the government expansion, which for the ZLB case implies that we compute the difference between the lines in Figure 2. As a benchmark, we

[3] **Relate this to the expansion in G in Obama's stimulus package?**
[4] **An interesting extension of our work would be to figure out optimal coordination between fiscal and monetary policy under the ZLB constraint.**

also include the fiscal multipliers in a normal situation where the ZLB constraint does not bind. A normal situation, is here defined to be an initial state where output is close to potential and inflation is close to target, so that the nominal interest rate is free to adjust.

As can be seen from Figure 3, the fiscal multipliers are magnified substantially by the ZLB constraint. In a normal situation, the aggressive policy rule would completely offset the expansionary effects on the output gap of the fiscal stimulus by raising nominal/real interest rates to the same extent as the increase in the potential real interest rate. By doing so, the central bank offsets the effects on the real interest rate gap and therefore the effects on the output gap and inflation. It can do so because there is only one nominal friction in this economy and due to the fact that the expansion in government expenditures works as a demand shock and therefore does not create any tensions between stabilizing the output gap and inflation. However, actual output will expand, reflecting that households will have to work more in order to produce the goods consumed by the public sector. However, in the case when the ZLB binds, the fiscal intervention has much more stimulative effects on the economy, causing the output gap to expand with over 1.5 percent initially and the multiplier for actual output to be almost three times higher than normal. This stimulative effect stems from the fact that the rise in government expenditures drive up the potential real interest rate and when the nominal interest rate is bounded at zero then the real interest rate gap will fall by the same amount, and this will trigger an expansion in the output gap and an increased inflation rate, which drives down the actual real interest rate as well because the nominal interest rate is fixed and thus further contributes to the decline in the real interest rate gap. Thus, Figure 3 contains the standard arguments in favor of very large fiscal multipliers in a liquidity trap. Below, we will examine the robustness of the results in Figure 3 along a number of dimensions.

3.1.3. Effects of a fiscal expansion plagued by implementation lags

We now change the assumption about the fiscal stimulus somewhat. In particular, we abandon the assumption that the increase in government expenditures can peak directly. Instead we study a case where the fiscal stimulus is subject to implementation lags, i.e. we assume that $\rho_{g,1} = 0.90$ and that $\rho_{g,2}$ is small (0.01), so that the peak effect of the expansion in government expenditures occurs with a delay of slightly more than 2 years. We adjust the size of the initial shock in period 0 so that the maximum increase in government expenditures is the same as the impact response in the previous experiment (i.e. one percent of steady state GDP). In practice, this is a very plausible specification of fiscal interventions, both from historical experience and the projected effects of the current fiscal stimulus package according to Cogan et al. (2009).[5] We still maintain the assumption that the fiscal expansion can be financed by lump sum taxes.

The effects of a delayed increase in government expenditures are depicted in Figure 4. In contrast to Figure 3, the peak response of $g_{y,t}$ occurs after about 10 quarters. From the figure, we see that the impulse response functions in Figure 4 are strikingly different to the ones reported in Figure 3. Actual output now contracts initially and do not expand until after about 4 quarters. The output gap essentially newer expands with the exception of a tiny expansion during the third year. The reason why the results are so different in Figures 3 and 4 is that the delayed expansion in fiscal policy causes the potential real interest rate to fall which is evident from eq. (4) above. [**Write more about the intuition for this fall!**] This fall in the potential real interest rate then causes the output gap and inflation to fall when the nominal interest rate is constrained by the ZLB. The subsequent slight expansion in the output gap is due to the subsequent slight drop in the real interest rate relative to the normal path.

Figures 3 and 4 highlights that the timing of the government expansion is crucial in order to achieve expansionary effects on output. With plausible implementation lags, it is not clear that the fiscal stimulus package will be very stimulative to begin with, although we assume that the expansion of government expenditures can be financed by lump-sum taxes.

3.1.4. Effects of a fiscal expansion plagued by implementation lags financed by distortionary taxes

We now drop the assumption of lump-sum taxes and assume that the fiscal stimulus needs to get financed by increases in labor income taxes.More specifically, we assume that labor taxes react endogenously to the increase in government debt caused by the expansion in $g_{y,t}$ according to the tax rule in eq. (9). In the tax rule, we set $\phi_\tau = 1$ (tax-smoothing), $\phi_b = 0.05$ and $\phi_d = 0.10$. This is not a very aggressive tax rule, and the coefficients are in line with the historical correlations of total taxes and government debt and deficit.[6] In this specification of the model, the evolution of government debt is of relevance for the equilibrium allocations as it affects the labor income tax rate, and we therefore report the evolution of these two extra variables in Figure 5.

From Figure 5, we see that the need to finance the expansion in government expenditures with

[5] See Figure 2 in Cogan et al. Using US data 1960Q1-2008Q4, we estimate (7) and find that imposing $\rho_{g,1} = 0.90$ and$\rho_{g,2} = 0.01$ only results in a minor loss of adjusted R^2 relative to the best fitting estimates (from 0.98 to 0.97).

[6] We collected data on total nominal tax revenues as share of trend nominal GDP, and estimated (9) with OLS. Imposing the coefficients we are using only results in a fall in R^2 from 0.97 to 0.95 relative to the best fitting OLS estimates.

distortionary labor income taxes depresses the output gap and actual output even further relative to the effects in Figure 4. Given that it is reasonable to believe that fiscal expansions to a large extent must be financed by distortionary taxes, these results cast even more doubts about the notion of very large fiscal multipliers in a Liquidity trap. At most, the multiplier w.r.t. actual output increases to about 0.4 for actual output after about 10 quarters, but the multiplier during the first year is actually negative and as low as -4 for actual output and -9 for the output gap.

3.2. Case 2: Standard Policy Rule

We now turn to the case where we assume that the coefficients in the policy rule are in line with those estimated in the literature on estimated policy rules, instead of the high ones used so far ($\gamma_i = 0, \gamma_\pi = 300$ and $\gamma_y = 500$). Estimates policy rules are typically not so aggressive, and often include a role for the lagged interest rate, see e.g. Clarida, Galí and Gertler (2000), Orphanides (2001), Smets and Wouters (2007). Based on earlier studies and our own estimations, we set $\gamma_i = 0.7$, $\gamma_x = 0.25$ and $\gamma_\pi = 3$ in the policy rule used here. The coefficients for inflation and the output gap are somewhat larger than normally used, but Taylor (2007) argues that these coefficients have doubled during the recent years, so they might be a better approximation going forward.

We will repeat the experiments in Figures 3-5 for this alternative specification of the policy rule.

3.2.1. Effects of a front-loaded fiscal expansion financed by lump-sum taxes

We first consider the same experiment as in Subsection 3.1.2. The only difference is the specification of the policy rule. The results are depicted in Figure 6. Comparing Figures 3 and 6, we find that the stimulative effects of a fiscal expansion are enhanced by a less aggressive policy rule. This is so because policy will not be as aggressive in bringing inflation and output gap back to their targets once the economy have exited the liquidity trap. So expectations about the conduct of policy after exiting from the liquidity trap is crucial in forming the effects of the fiscal expansion even during the time the economy is in fact in the liquidity trap. Thus, the analysis in Eggertsson (2008), who assumes that expectations of the conduct of policy once the economy has left the liquidity trap is irrelevant, can be highly misleading. According to our analysis in Figures 3 and 6, expectations about future conduct of policy once the economy have exited from the liquidity trap have quantitatively important implications for the transmission of the fiscal stimulus packages.

3.2.2. Effects of a fiscal expansion plagued by implementation lags

We now consider the same experiment as in Subsection 3.1.3. By comparing Figures 4 and 7, we see that the fiscal multipliers are slightly higher but still negative initially for the output gap. The reason why the output gap and actual output tend to respond more is that inflation expectations and inflation will be allowed to rise more, thereby reducing the real interest relative to the aggressive policy path for the real interest rate in Figure 4. It is still the case though that the multiplier is not particularly high, at most it peaks at 0.6 after about 10 quarters for actual output, and is not higher than 0.3 for the output gap after about 8 quarters. A key result is still that the formulation of the policy rule is a key ingredient to shape the fiscal multipliers, and it should be kept in mind that an even less aggressive policy rule will be associated with even higher fiscal multipliers.

3.2.3. Effects of a fiscal expansion plagued by implementation lags financed by distortionary taxes

Finally, we consider the variant of the model where the fiscal expansion is financed by distortionary labor income taxes. The results of this experiment is reported in Figure 8. By comparing Figures 5 and 8, we notice that the fiscal multipliers are almost as negative as when policy is aggressive, in particular during the first two years. One interesting difference is that while Figure 7 suggests that the ZLB constraint can exacerbate the fiscal multipliers under a less aggressive policy rule (compare with Figure 4), the results in Figure 8 suggests that these results too a large extent hinges on the ability of the government to finance the expansion with lump sum taxes. If not financing with lump sum taxes are available, our model in Figure 8 suggests that the ZLB constraint will exacerbate the negative effects of expansionary fiscal policy shocks even under a standard monetary policy rule if it takes time to fully implement the increase in government expenditures.

4. An Empirical New Keynesian Model with Capital

In this section, we present a fully-fledged model economy with capital. The model can be regarded as a slightly simplified version of the model utilized by Christiano, Eichenbaum and Evans (2005), and Smets and Wouters (2003, 2007). Thus, our model incorporates nominal rigidities by assuming that labor and product markets each exhibit monopolistic competition, and that wages and prices are determined by staggered nominal contracts of random duration (following Calvo (1983) and Yun (1996)). We also include various real rigidities emphasized in the recent literature, including habit persistence in consumption, and costs of changing the rate of investment. The idea is to examine to what extent our results in the simple stylized New Keynesian model analyzed above carries over to a more empirically realistic model. Christiano, Eichenbaum and Evans (2005) documents that their model can account well for the dynamic effects of monetary policy during the post-war period and the papers by Smets and Wouters (2003, 2007) have shown that their model augmented with a certain set of shocks is able to fit certain features of Euro and US business cycles well.

4.1. The Model

Below, we will outline the key features of the model and describe our assumptions about the conduct of fiscal and monetary policy.

4.1.1. Firms and Price Setting

Final Goods Production As in Chari, Kehoe, and McGrattan (2000), we assume that there is a single final output good Y_t that is produced using a continuum of differentiated intermediate goods $Y_t(f)$. The technology for transforming these intermediate goods into the final output good is constant returns to scale, and is of the Dixit-Stiglitz form:

$$Y_t = \left[\int_0^1 Y_t\left(f\right)^{\frac{1}{1+\theta_p}} df \right]^{1+\theta_p} \tag{10}$$

where $\theta_p > 0$.

Firms that produce the final output good are perfectly competitive in both product and factor markets. Thus, final goods producers minimize the cost of producing a given quantity of the output index Y_t, taking as given the price $P_t\left(f\right)$ of each intermediate good $Y_t(f)$. Moreover, final goods producers sell units of the final output good at a price P_t that is equal to the marginal cost of production:

$$P_t = \left[\int_0^1 P_t\left(f\right)^{\frac{-1}{\theta_p}} df \right]^{-\theta_p} \tag{11}$$

It is natural to interpret P_t as the aggregate price index.

Intermediate Goods Production A continuum of intermediate goods $Y_t(f)$ for $f \in [0,1]$ is produced by monopolistically competitive firms, each of which produces a single differentiated good. Each intermediate goods producer faces a demand function for its output good that varies inversely with its output price $P_t\left(f\right)$, and directly with aggregate demand Y_t :

$$Y_t\left(f\right) = \left[\frac{P_t\left(f\right)}{P_t} \right]^{\frac{-(1+\theta_p)}{\theta_p}} Y_t \tag{12}$$

Each intermediate goods producer utilizes capital services $K_t(f)$ and a labor index $L_t(f)$ (defined below) to produce its respective output good. The form of the production function is Cobb-Douglas:

$$Y_t(f) = K_t(f)^{\alpha} L_t(f)^{1-\alpha} \tag{13}$$

Firms face perfectly competitive factor markets for hiring capital and the labor index. Thus, each firm chooses $K_t(f)$ and $L_t(f)$, taking as given both the rental price of capital R_{Kt} and the aggregate wage index W_t (defined below). Firms can costlessly adjust either factor of production. Thus, the standard static first-order conditions for cost minimization imply that all firms have identical marginal cost per unit of output. By implication, aggregate marginal cost MC_t can be expressed as a function of the wage index W_t, the aggregate labor index L_t, and the aggregate capital stock K_t, or equivalently, as the ratio of the wage index to the marginal product of labor MPL_t:

$$MC_t = \frac{W_t L_t^{\alpha}}{(1-\alpha) K_t^{\alpha}} = \frac{W_t}{MPL_t} \tag{14}$$

We assume that the prices of the intermediate goods are determined by Calvo-Yun style staggered nominal contracts. In each period, each firm f faces a constant probability, $1 - \xi_p$, of being able to reoptimize its price $P_t(f)$. The probability that any firm receives a signal to reset its price is assumed to be independent of the time that it last reset its price. If a firm is not allowed to optimize its price in a given period, we follow Christiano, Eichenbaum and Evans (2005) and assume that it simply adjusts its price by a weighted combination of the lagged and steady state rate of inflation (i.e., $P_t(f) = \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} P_{t-1}(f)$ for the non-optimizing firms). When ι_p is set close to unity, this formulation introduces structural inertia into the inflation process.

4.1.2. Households and Wage Setting

We assume a continuum of monopolistically competitive households (indexed on the unit interval), each of which supplies a differentiated labor service to the production sector; that is, goods-producing firms regard each household's labor services $N_t(h)$, $h \in [0,1]$, as an imperfect substitute for the labor services of other households. It is convenient to assume that a representative labor aggregator (or "employment agency") combines households' labor hours in the same proportions as firms would choose. Thus, the aggregator's demand for each household's labor is equal to the sum of firms' demands. The labor index L_t has the Dixit-Stiglitz form:

$$L_t = \left[\int_0^1 N_t(h)^{\frac{1}{1+\theta_w}} \, dh \right]^{1+\theta_w} \tag{15}$$

where $\theta_w > 0$. The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking each household's wage rate $W_t(h)$ as given, and then sells units of the labor index to the production sector at their unit cost W_t:

$$W_t = \left[\int_0^1 W_t(h)^{\frac{-1}{\theta_w}}\,dh\right]^{-\theta_w} \tag{16}$$

It is natural to interpret W_t as the aggregate wage index. The aggregator's demand for the labor hours of household h – or equivalently, the total demand for this household's labor by all goods-producing firms – is given by

$$N_t(h) = \left[\frac{W_t(h)}{W_t}\right]^{-\frac{1+\theta_w}{\theta_w}} L_t \tag{17}$$

The utility functional of a typical member of household h is

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \{ \frac{1}{1-\sigma}\left(C_{t+j}(h) - \varkappa C_{t+j-1}(h)\right)^{1-\sigma} + \frac{\chi_0}{1-\chi}(1 - N_{t+j}(h))^{1-\chi}\} \tag{18}$$

where the discount factor β satisfies $0 < \beta < 1$. The dependence of the period utility function on consumption in both the current and previous period allows for the possibility of external habit persistence in consumption spending (e.g., Smets and Wouters, 2003). In addition, the period utility function depends on current leisure $1 - N_t(h)$, and current real money balances. $\frac{M_t(h)}{P_t}$.

Household h's budget constraint in period t states that its expenditure on goods and net purchases of financial assets must equal its disposable income:

$$\begin{aligned}
& P_t C_t(h) + P_t I_t(h) + \frac{1}{2}\psi_I P_t \frac{(I_t(h) - I_{t-1}(h))^2}{I_{t-1}(h)} + \\
& P_{Bt} B_{Gt+1} - B_{Gt} + \int_s \xi_{t,t+1} B_{D,t+1}(h) - B_{D,t}(h) \\
= \; & (1-\tau_{Nt}) W_t(h) N_t(h) + (1-\tau_{Kt}) R_{Kt} K_t(h) + \tau_{Kt} P_t \delta K_t(h) + \Gamma_t(h) - T_t(h)
\end{aligned} \tag{19}$$

Thus, the household purchases the final output good (at a price of P_t), which it chooses either to consume $C_t(h)$ or invest $I_t(h)$ in physical capital. The total cost of investment to each household h is assumed to depend on how rapidly the household changes its rate of investment (as well as on the purchase price). Our specification of such investment adjustment costs as depending on the square of the change in the household's gross investment rate follows Christiano, Eichenbaum, and Evans (2005). Investment in physical capital augments the household's (end-of-period) capital stock $K_{t+1}(h)$ according to a linear transition law of the form:

$$K_{t+1}(h) = (1-\delta) K_t(h) + I_t(h) \tag{20}$$

In addition to accumulating physical capital, households may augment their financial assets through increasing their government bond holdings ($P_{Bt}B_{Gt+1} - B_{Gt}$), and through the net acquisition of state-contingent bonds. We assume that agents can engage in frictionless trading of a complete set of contingent claims. The term $\int_s \xi_{t,t+1}B_{D,t+1}(h) - B_{D,t}(h)$ represents net purchases of state-contingent domestic bonds, with $\xi_{t,t+1}$ denoting the state price, and $B_{D,t+1}(h)$ the quantity of such claims purchased at time t. Each member of household h earns after tax labor income $(1 - \tau_{Nt}) W_t(h) N_t(h)$, and receives gross after tax rental income of $(1 - \tau_{Kt})R_{Kt}K_t(h)$ from renting its capital stock to firms. Each member also receives an aliquot share $\Gamma_t(h)$ of the profits of all firms, and pays a lump-sum tax of $T_t(h)$ (this may be regarded as taxes net of any transfers).

In every period t, each member of household h maximizes the utility functional (18) with respect to its consumption, investment, (end-of-period) capital stock, money balances, and holdings of contingent claims, subject to its labor demand function (17), budget constraint (19), and transition equation for capital (20). Households also set nominal wages in Calvo-style staggered contracts that are generally similar to the price contracts described above. Thus, the probability that a household receives a signal to reoptimize its wage contract in a given period is denoted by $1 - \xi_w$, and as in the case of price contracts this probability is independent of the date at which the household last reset its wage. In addition, we specify a dynamic indexation scheme for the adjustment of the wages of those households that do not get a signal to reoptimize, i.e., $W_t(h) = \omega_{t-1}^{\iota_w}\omega^{1-\iota_w}W_{t-1}(h)$, where ω_{t-1} is the gross nominal wage inflation in period $t-1$ and $\omega = \pi g_z$ is the steady state rate of change in the nominal wage (gross price inflation times steady state gross productivity growth). As discussed by Christiano, Eichenbaum, and Evans (2005), dynamic indexation of this form introduces some element of structural persistence into the wage-setting process.

4.1.3. Fiscal and Monetary Policy and the Aggregate Resource Constraint

The government purchase some of the aggregate output, but these government purchases, denoted G_t, are neither assumed to have direct effects on the utility of the household nor be beneficiary in the production process of either intermediate or the final good. Government expenditures are assumed to be set as a share of trend output, so that $g_{y,t} = \frac{G_t}{Y}$ follows an exogenous stochastic process given by eq. (7). The government expenditures are assumed to be financed by a combination of labor and capital income, and lump sum taxes. However, the government does not need to balance its budget each period and is hence assumed to be able to issue government nominal debt to finance a budget deficit according to

$$P_{B,t}B_{G,t+1} - B_{G,t} = P_tG_t - T_t - \tau_{N,t}W_tL_t - \tau_{K,t}\left(R_{Kt} - \delta P_t\right)K_t. \tag{21}$$

In eq. (21), we have aggregated the capital stock, money and bond holdings and transfers over households so that e.g. $T_t = \int_0^1 T_t\left(h\right)dh$ are aggregate lump-sum taxes. Throughout the analysis, we will assume that capital taxes τ_{Kt} are given by an exogenous stochastic process with mean τ_K, but as in Section 2, we study the effects of expansions in $g_{y,t}$ when either tabor income taxes τ_{Nt} or lump-sum taxes T_t adjust endogenously to stabilize the government debt to trend nominal output ratio, i.e. $b_{Gt} = \frac{B_{Gt}}{P_tY}$, around a constant steady state in the long run. The labor tax income and/or lump sum tax functions are assumed to have the same form as eq. (9) in Section 2. Some simple econometric analysis suggest that this specification fits the US post-1980 evidence quite well if ϕ_b and ϕ_d are set to the values we consider (0.05 and 0.10, respectively).

Monetary policy is still assumed to be given by the policy rule in eq. (3), and we assume the same coefficients as in Subsection 3.2, i.e. we set $\gamma_i = 0.7$, $\gamma_\pi = 3$ and $\gamma_x = 0.25$. From a positive perspective, these coefficients enables the rule to fit the US post-1980 period quite well given that the output gap of interest for the policy maker can be well approximated with the deviation of actual output from the level of output that would prevail if prices and wages would be completely flexible.

Finally, total nominal output of the service sector is subject to the following resource constraint:

$$Y_t = C_t + I_t + G_t + \psi_{I,t} \tag{22}$$

where $\psi_{I,t}$ is the adjustment cost on investment aggregated across all households (from eq, 19, we have that $\psi_{I,t} \equiv \frac{1}{2}\psi_I\frac{(I_t(h)-I_{t-1}(h))^2}{I_{t-1}(h)}$).

4.1.4. Solution and Calibration

To analyze the behavior of the model, we log-linearize the model's equations around the non-stochastic steady state. Nominal variables, such as the contract price and wage, are rendered stationary by suitable transformations. We then compute the reduced-form solution of the model for a given set of parameters using the numerical algorithm of Anderson and Moore (1985), which provides an efficient implementation of the solution method proposed by Blanchard and Kahn (1980).

The model is calibrated at a quarterly frequency. Thus, we assume that the discount factor $\beta = .995$, consistent with a steady-state annualized real interest rate $\overline{r}$ of about 2 percent. We assume that the subutility function over consumption is logarithmic, so that $\sigma = 1$, while we set the parameter determining the degree of habit persistence in consumption $\varkappa = 0.6$ (similar to the empirical estimate of Smets and Wouters 2003). The parameter χ, which determines the curvature of the subutility function over leisure, is set equal to 2.5, implying a Frisch elasticity of labor supply of 0.4. This value is higher relative to what we used in the stylized New Keynesian model analysed in Section 2, but motivated by two considerations. First, the introduction of sticky wages will make the labor supply more sensitive to variations in consumer demand if χ was unchanged. Thus, increasing χ will increase the comparability between the two models. Second, and perhaps more importantly, this value is well within the range of most estimates from the empirical labor supply literature, especially when considering potential biases in empirical estimates (see e.g. Domeij and Flodén, 2006). The scaling parameter χ_0 is set so that employment comprises one-third of the household's time endowment.

The capital share parameter α is set to 0.35, consistent with the observed labor share in the US. The quarterly depreciation rate of the capital stock $\delta = 0.025$, implying an annual depreciation rate of about 10 percent. The price and wage markup parameters θ_P and θ_W are set to 0.1 and 1/3, respectively. For the standard value of δ, θ_p is pinned down by the steady state investment to output ratio. The value θ_W is set to a higher value in order to avoid implausible variations in hours between different cohorts of labor according to eq. (17) and to get a plausible curvature in the nominal wage equation for a given degree of nominal wage stickiness. We set the cost of adjusting investment parameter $\psi_I = 3$, which is somewhat smaller than the value estimated by Christiano, Eichenbaum, and Evans (2005) using a limited information approach; however, the analysis of Erceg, Guerrieri, and Gust (2005) suggests that a lower value in the range of unity may be better able to capture the unconditional volatility of investment within a similar modeling framework. We maintain the assumption of a relatively flat Phillips curve by assuming that $\xi_p = 0.9$. As in Christiano, Eichenbaum and Evans (2005), we also allow for a fair amount of intrinsic persistence by setting $\iota_p = 0.9$. For nominal wages we set $\xi_w = 0.85$ and $\iota_w = 0.9$. The calibration of these parameters is in the range typically estimated in the literature.

The parameters pertaining to fiscal policy are set as follows. The share of government spending of total expenditure is set equal to 20 percent. The steady state capital income tax rate, τ_K, is set to 0.2 while the lump sum tax revenue to GDP ratio is set to 0.02. For simplicity, we consider a steady state where the government debt to GDP ratio is 0. Eq. (21) then implies that we need to set the labor income tax rate τ_N equal to 0.27 to get a balanced gross budget deficit. It should be emphasized that the results are not much affected if we consider a steady state where the government debt to output ratio equals 0.4, as the log-linearized version of eq. (21) implies that the real interest rate has relatively modest direct effects on the evolution of government debt.

Finally, when we solve the model subject to the zero lower bound constraint on the nominal interest rate, we use the techniques described in Lindé and Svensson (2009).

4.2. Dynamic Effects of Fiscal policy Expansions

We now study the effects of increases in government expenditures in this model. The policy rule we consider is identical to the one used in Subsection 3.2, and the intention is thus to compute the effects of fiscal policy expansions under an empirically plausible characterization of the conduct of monetary policy. We report results for the same simulations as for the stylized model. Thus, the fiscal expansion occurs in the same period as the consumption demand shock hits the economy. The size of the underlying consumption shock is set so that the ZLB binds for 2 years (periods $1-9$ without the fiscal expansion), and induces a fall in output of about 10 percent and a decline in annualized inflation from 2 to -0.5 percent in the ZLB case.

In Figure 9, we report results to a front-loaded increase to government expenditures with the same persistence as the underlying negative consumption demand shock. The fiscal expansion is assumed to be financed by lump-sum taxes that responds endogenously following the same rule as eq. (9) with the same parameters as in Subsection 3.2. As in the stylized model analyzed in Subsection 3.2, the fiscal policy expansion has exacerbated multipliers for output and the output gap relative to a normal situation as the fiscal expansion is associated with a net present lower real interest rate path compared to a normal situation. The multipliers are slightly above unity in the short-run for actual output, but somewhat below unity for the output gap. The initial increase in the nominal interest rate path reflects the fact that the fiscal expansion will make the economy enter into a the liquidity trap first in period 2, i.e. one period later than without the fiscal expansion. An additionally interesting feature is that government debt and lump-sum taxes do not increase to the same extent in the ZLB case as in a normal situation due to the enhanced fiscal multipliers.

In Figure 10, we report the effects of a more gradual rise in government expenditures under the maintained assumption that the time profile is fully incorporated into the information set of the households and firms in period 0 (i.e. the first period). The same assumption was done in 3.1.3 and 3.2.2 when generating Figures 4 and 7. Figure 10 confirms the findings in Figures 4 and 7, and we see that the multipliers are strongly reduced when the fiscal stimulus packages are plagued by implementation lags. The multipliers are negative for the output gap, but still positive for actual output initally due to the negative wealth effects which force the households to increase their labor supply. The reduction of the multipliers again has to do with the reversed effects on the potential real interest rates, which now falls substantially initially instead rising as in Figure 9.

Finally, we consider the case where the fiscal expansion is financed by distortionary labor income taxes as in Subsections 3.1.4 and 3.2.3. The effects of the corresponding experiment in this model is reported in Figure 11, which confirms the results in Figure 8. The fiscal policy multiplier is again found to be considerably lower when that the fiscal expansion needs to be financed by distortionary labor income taxes. The multiplier for the output gap is negative and exacerbated by the ZLB constraint, and even the multiplier for actual output is mostly negative and only slightly positive for a couple of periods in a Liquidity trap. Thus, there are little reasons according to this model to believe that fiscal stimulus packages will be particularly stimulative. Moreover, we would like to stress that we have selected parameters in the policy function for the labor tax income rate to make the tax rate path fairly unresponsive to the increase in government debt. The higher the responsiveness to debt, the more negative the fiscal multipliers will be. Although not reported, we have also studied a case where the fiscal stimulus package is financed by capital income taxes, and this financing alternative is associated with considerable more negative multipliers for actual output in comparison to the ones reported in Figure 11.

To sum up, while the quantitative results differ somewhat w.r.t. to the stylized model studied in Section 2, the qualitative aspects are very similar. Thus, the analysis in this more empirically realistic model supports our beliefs that the more favorable multipliers of fiscal policy stimulus packages in a liquidity trap hinges crucially on it's financing, implementation and the monetary policy response.

5. Robustness analysis: The Empirical Model Augmented with Financial Frictions and Keynesian Households

In this section, we check the robustness of our results in the Christiano, Eichenbaum and Evans (2005) style of model studied in Section 4 augmented with financial frictions and Keynesian households. In modelling the financial frictions, we adopt the framework in Bernanke, Gertler and Gilchrist (1999), henceforth BGG, but we follow Christiano, Motto and Rostagno (2007) and assume that the loan contract between the entrepreneurs and the bank is in nominal terms as opposed to BGG where the loan contract is specified in real terms. Following Galí, López-Salido and Vallés (2007) and Erceg, Guerrieri and Gust (2005), we also allow for the possibility that a fraction of the households in the economy simply consume their current after-tax income as opposed to the standard model where all households decide their consumption path based on intertemporal optimality conditions.

5.1. Key Model Equations and Calibration

This model is identical to the model described in Section 4, with the following exceptions.

First, a fraction s_{kh} of the population of the households are assumed to determine their level of consumption as a fraction of current after-tax income, i.e.

$$P_t C_t(h) = (1 - \tau_{Nt}) W_t(h) N_t(h) - T_t.$$

The Keynesian households are assumed to set their wage to be the average wage of the forward-looking households. Since Keynesian households face the same labor demand schedule as the optimizing households, each Keynesian household works the same number of hours as the average optimizing household. We set the share of the Keynesian households to optimizing households, s_{kh}, to 0.47, which implies that the Keynesian households share of total consumption is about 1/3.

In addition, this version of the model embodies a Bernanke, Gertler and Gilchrist (1999) type of financial accelerator mechanism. In particular, the optimizing households are assumed to supply labor to the homogenous market for labor, and so called entrepreneurs supply capital to homogeneous factor markets. The optimizing households produce new capital by combining investment goods with used capital purchased from the entrepreneurs to produce new capital. Entrepreneurs then purchase this new capital, using a combination of their own net worth and loans from banks. Idiosyncratic productivity shocks hitting the entrepreneurs and asymmetric information (costly state verification) introduces financial frictions between the borrowers (i.e. the entrepreneurs) and the banks (i.e. the households). The only difference w.r.t. BGG, is that we follow Christiano, Motto and Rostagno (2007) and assume that the debt contract between the entrepreneurs and the bank is written in nominal terms, so that the return received by households from the banks is nominally non-state contingent. We adopt the calibration of the parameters pertaining to the financial accelerator mechanism to the values chosen by BGG. In particular, we set the monitoring cost, μ, expressed as a proportion of the entrepreneurs total gross revenues to 0.12. The variance of the idiosyncratic productivity shocks hitting the entrepreneurs is set 0.28. The annualized steady state default rate of the entrepreneurs is set to 0.03/4, which corresponds to a quarterly default rate of about 0.75 percent.

In all other respects, this model and parameterization is identical to the CEE/Smets-Wouters model analysed in the previous Section.

5.2. Dynamic Effects of Fiscal policy Expansions

We now study the effects of expansions in government expenditures in this environment with financial frictions and Keynesian households. The experiments and parameterization of the fiscal expansion and response of tax rules are identical to the setup in Subsection 4.2. The only difference is that the size of the underlying consumption shock is set to a slightly lower value and that the ZLB constraint in this model binds for periods $1-8$ instead of periods $2-9$ as in Subsection 4.2. Thus, the consumption demand shock propagates somewhat faster in this environment compared to the model without the financial accelerator and the Keynesian households. The results of the three corresponding experiments are reported in Figures 12-14.

In Figure 12, we report the results of the front-loaded increase in government expenditures of 1 percent to trend GDP corresponding to the experiment in Figure 9. We see by comparing the effects in Figure 12 with the ones in Figure 9 that the introduction of the financial accelerator and Keynesian households roughly doubles the multipliers for the output gap and actual output. Although not reported, we have analyzed the contribution of the financial accelerator and the introduction of Keynesian households to the amplified multipliers. It turns out that the financial accelerator is clearly the most important mechanism behind the amplified multiplier for the output gap; without the financial accelerator the impulse response for the output gap is very similar to the one reported in Figure 9. For actual output, the introduction of Keynesian households matter somewhat more, and the impact multiplier is increased from 1.1 in Figure 9 to about 1.4 in the model with Keynesian households. But the introduction of the financial accelerator amplifies the impact multiplier from 1.4 to about 1.75 in Figure 12 and also makes the multipliers persistently higher relative to the multipliers implied by the paths in Figure 9 and the model augmented with Keynesian households only. Another noticeable feature is that the multipliers in a normal situation are not much affected by the introduction of the financial accelerator, outside a liquidity trap it is the introduction of Keynesian households that causes the impact multiplier to rise above unity as opposed to the less than unity impact multiplier reported in Figure 9 for the normal situation. So the role of the financial accelerator mechanism is clearly enhanced by the presence of the ZLB constraint. Finally we notice that due to the fiscal expansion, the economy will enter into the liquidity trap one quarter later than in the no fiscal policy expansion case.

In Figure 13, we report the impulse response functions when the fiscal policy intervention is plagued by implementation lags and financed by lump sum taxes. First, comparison of Figures 12 and 13 reveals that the fiscal multipliers are clearly moderated, both in a Liquidity trap and under normal circumstances. Second, we see that in contrast to the results in Figure 10, the multipliers are above and close to one for actual output and the output gap, respectively. Thus, even a fiscal expansion that are plagued with implementation lags can have expansionary effects on the economy when financed by lump sum taxes if policy is not too aggressive. Again, it should be emphasized that it is the financial accelerator and not the Keynesian households that accounts for the differences between the results in Figures 10 and 13 in the ZLB case. Only in a normal situation when the ZLB constraint does not bind the financial accelerator does not affect the fiscal multipliers much.

Finally, Figure 14 plots the effects of the fiscal intervention plagued by implementation lags where the financing is assumed to be via increased labor income taxes. By comparing Figures 13 and 14, we see that the financing of the fiscal expansion is still of key importance when assessing the size of the multipliers. The multipliers in the labor income financing case are reduced by roughly half as opposed to the case when the financing of the government expansion can be accomplished with increased lump sum taxes only. However, the multipliers are still positive for about 2 years initially, before they turn negative, so the fiscal expansion in this case do have stimulative effects on the economy as opposed to the results in Figure 11. Again, it can be shown that these stimulative effects are mainly driven by the financial accelerator mechanism in the model and not the inclusion of Keynesian households. And an important prerequisite for the stimulative effects to occur is that policy is not aggressive once the economy exits from the liquidity trap.

By and large, Figure 14 suggests that the fiscal multipliers are rather moderate even in a Liquidity trap.

6. Conclusions

There is no evident fiscal free lunch in a liquidity trap. [**Remains to be written.**]

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Appendix A. Analytics of the Stylized New Keynesian Model

[Here we might want to write up some details on derivation and analytical solution to the stylized New Keynesian model. **Remains to be written.**]

Table 1: Calibrated parameters in stylized model

Parameter	Description	Calibrated value
β	Households' discount factor	0.995
α	Labor share in production	0.30
ξ_p	Calvo sticky price parameter	0.90
σ	Intertemporal cons subst elast	0.50
θ_p	Net Price Markup	0.10
π	Inflation target	1.005
ν	Taste shock weight	0.01
χ	Inverse Frisch labor supply	1.00
γ_π	Coefficient on inflation in policy rule	1.50
γ_y	Coefficient on output gap in policy rule	0.50
$\rho_{v,1}$	Coefficient in cons dem process	0.00
$\rho_{v,2}$	Coefficient in cons dem process	0.10
ϕ_τ	Coefficient on τ_{-1} in labor tax rule	1.00
ϕ_b	Coefficient on gov debt in tax rule	0.05
ϕ_d	Coefficient on gov deficit in tax rule	0.10
b_G	Government debt to output ratio	0.00
g_y	Government expenditure to output ratio	0.20

Figure 1: Unconstrained Responses and Responses under the Zero Lower Bound Constraint to a Negative Consumption Taste Shock
Stylized New Keynesian Model: Aggressive Policy Rule

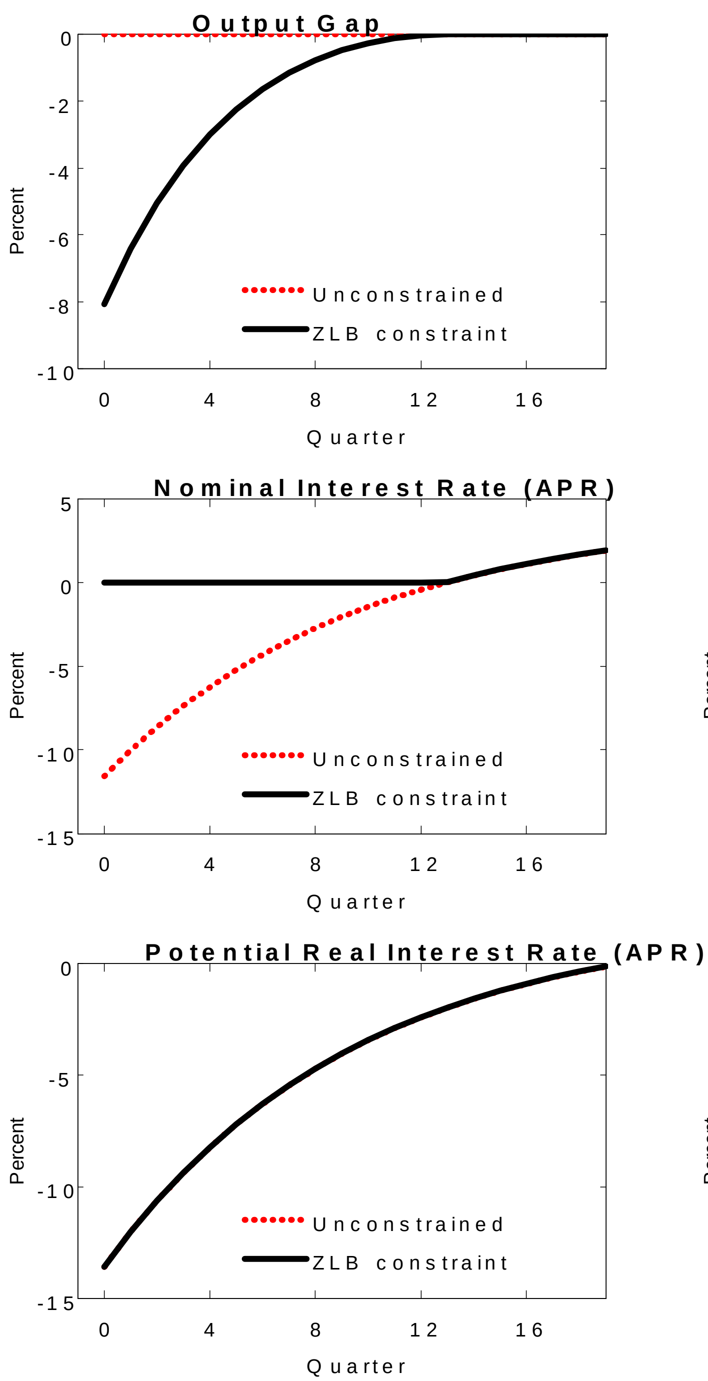

Figure 2: Dynamic Effects of a Front-loaded Increase in Government Spending Under the ZLB Constraint on the Nominal Interest Rate Stylized New Keynesian Model: Aggressive Policy Rule

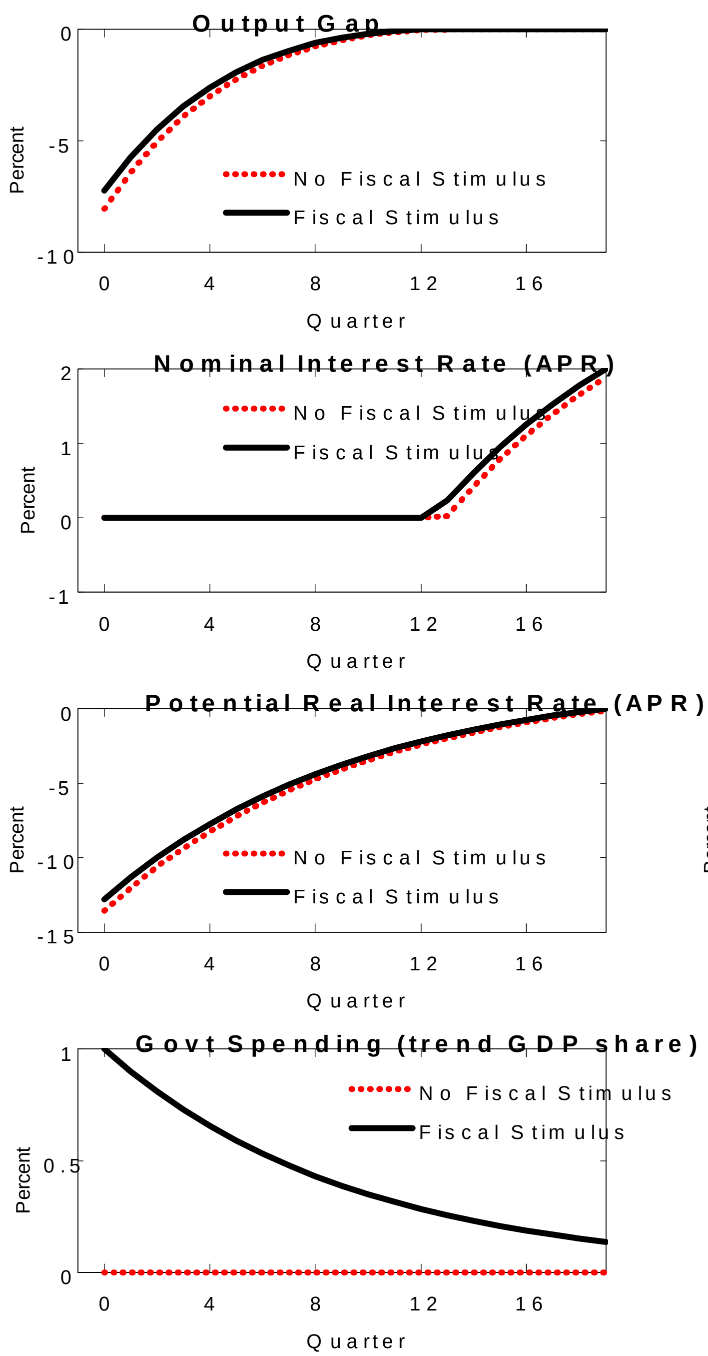

Figure 3: Responses to a Front-loaded Increase in Government Spending Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Stylized New Keynesian Model: Aggressive Policy Rule

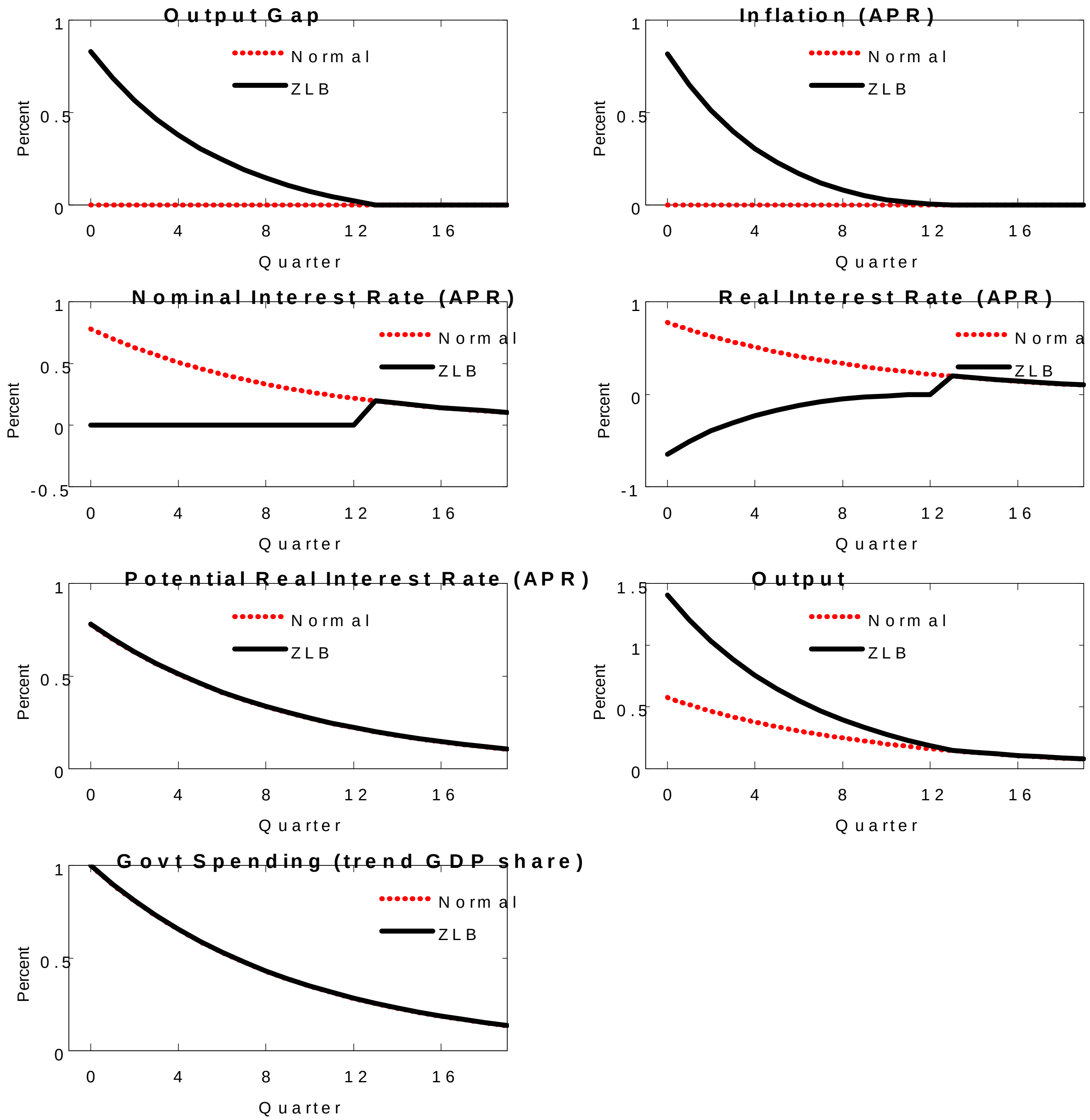

Figure 4: Responses to an Increase in Government Spending with Implementation Lags in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Stylized New Keynesian Model: Aggressive Policy Rule

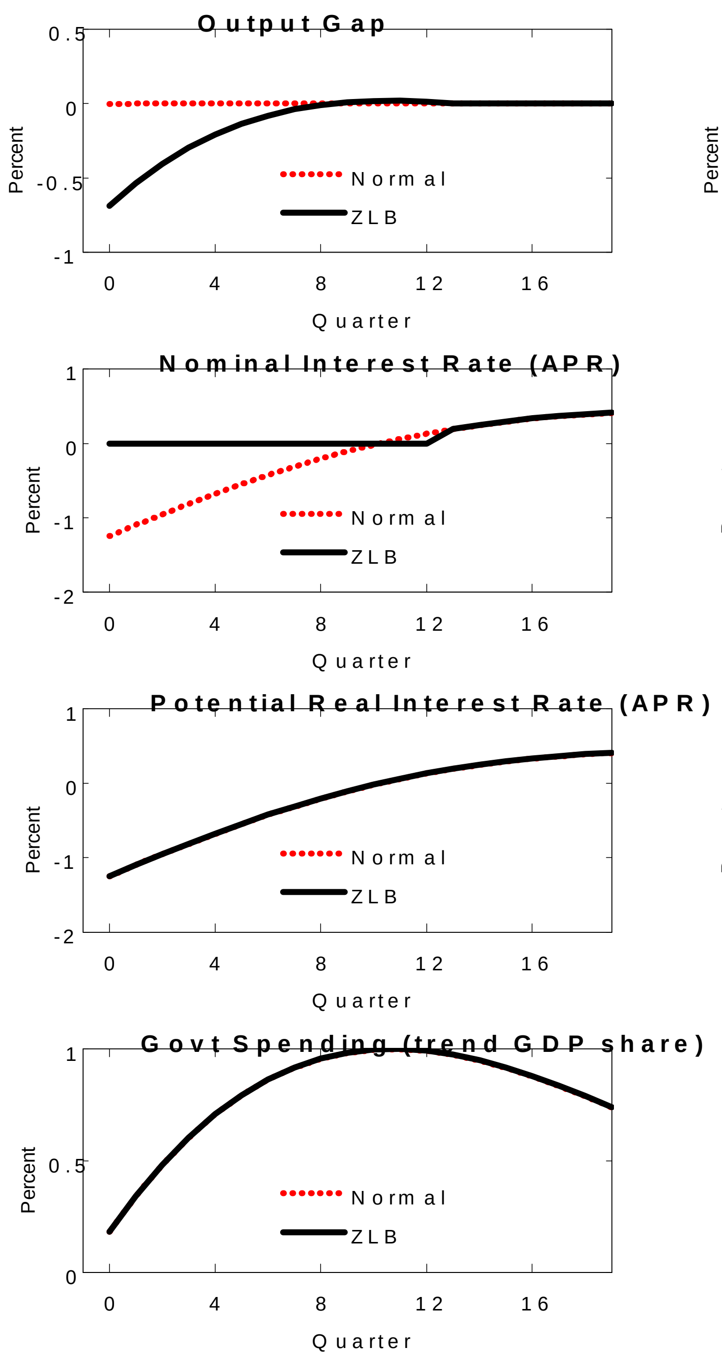

Figure 5: Responses to a Gradual Increase in Government Spending Financed with Labor Income Taxes in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Stylized New Keynesian Model: Aggressive Policy Rule

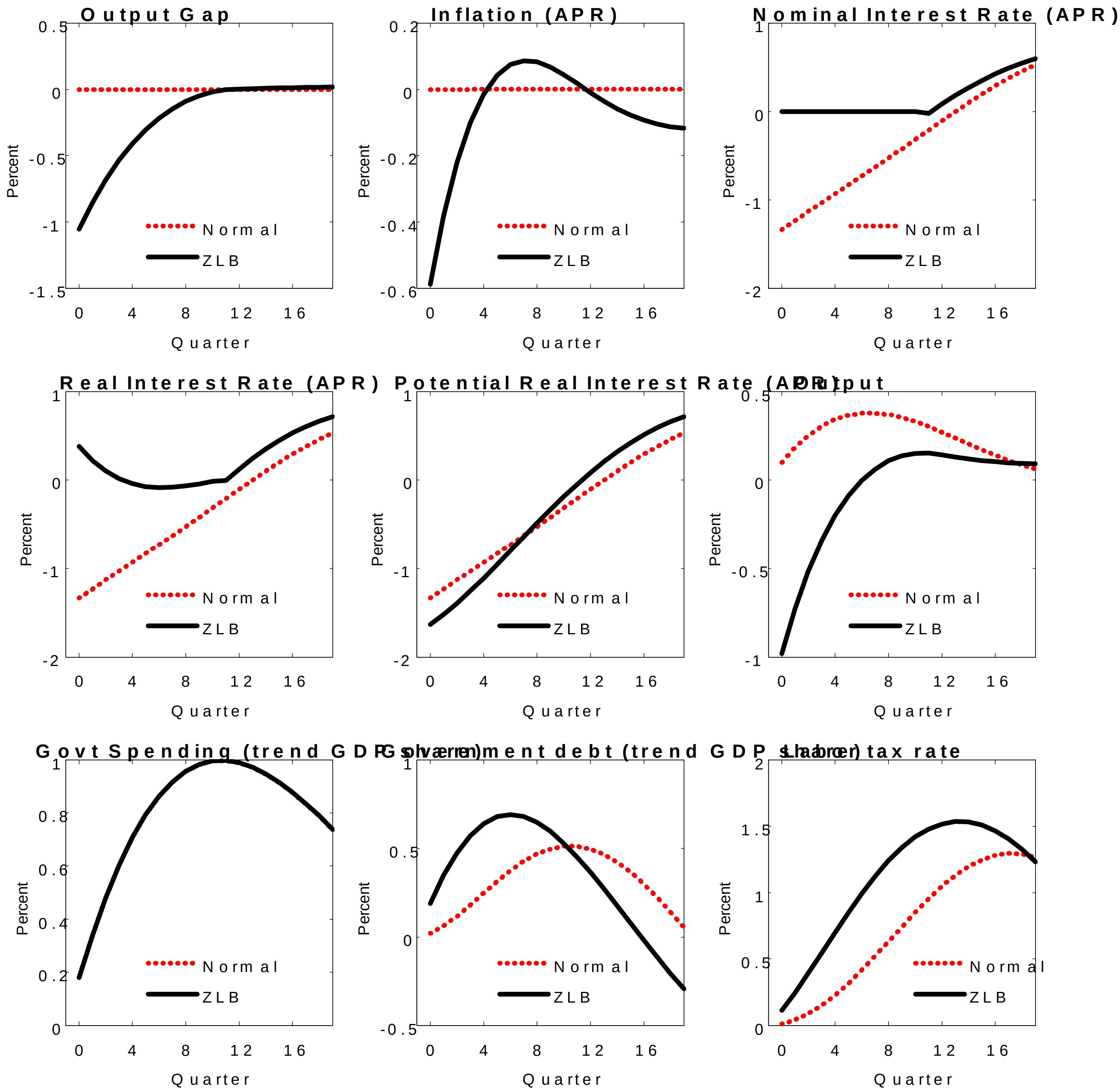

Figure 6: Responses to a Front-loaded Increase in Government Spending in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate
Stylized New Keynesian Model: Standard Policy Rule

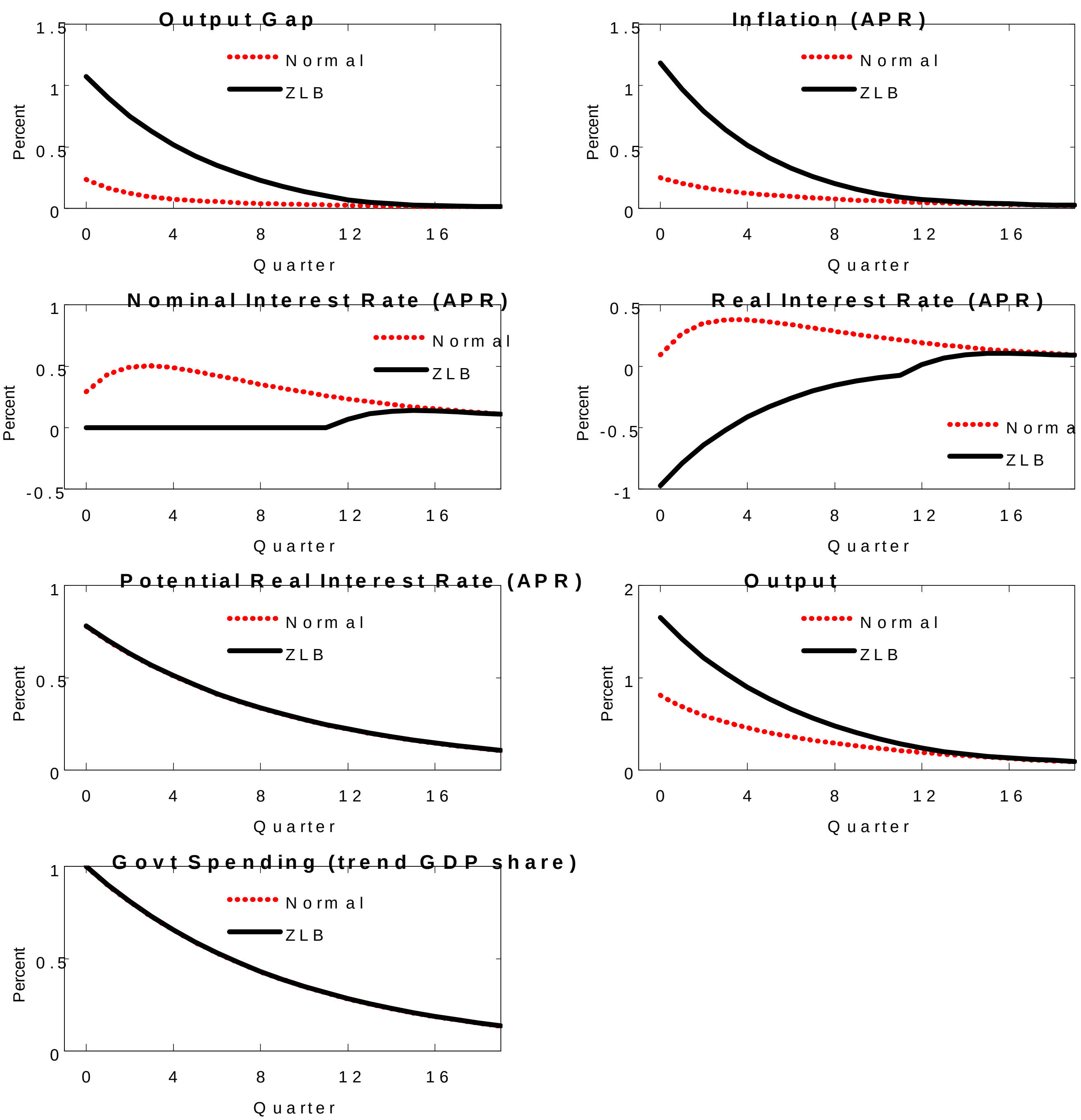

Figure 7: Responses to a Gradual Increase in Government Spending in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Stylized New Keynesian Model: Standard Policy Rule

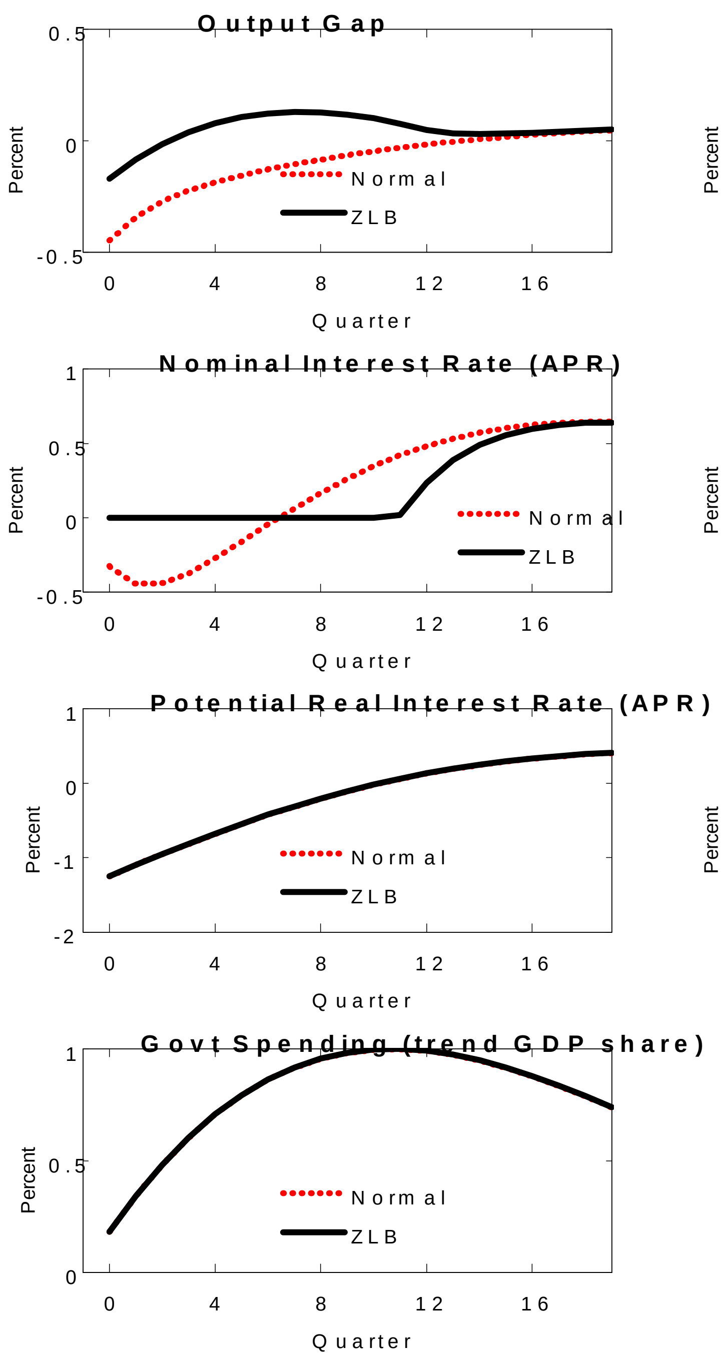

Figure 8: Responses to a Gradual Increase in Government Spending Financed by Labor Income Taxes in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate
Stylized New Keynesian Model: Standard Policy Rule

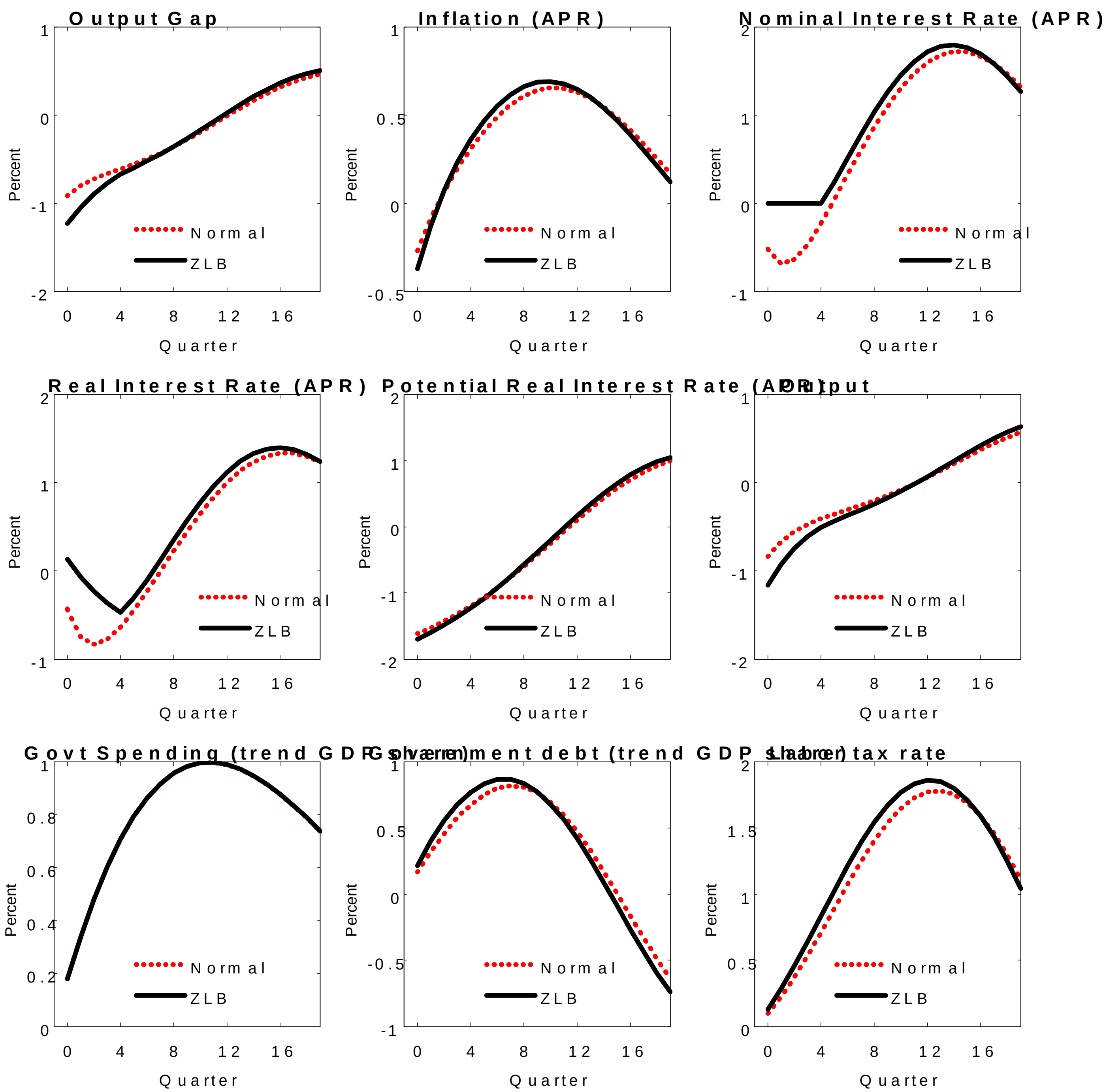

Figure 9: Responses to a Front-Loaded Increase in Government Spending in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate CEE-SW Model with Capital: Standard Policy Rule

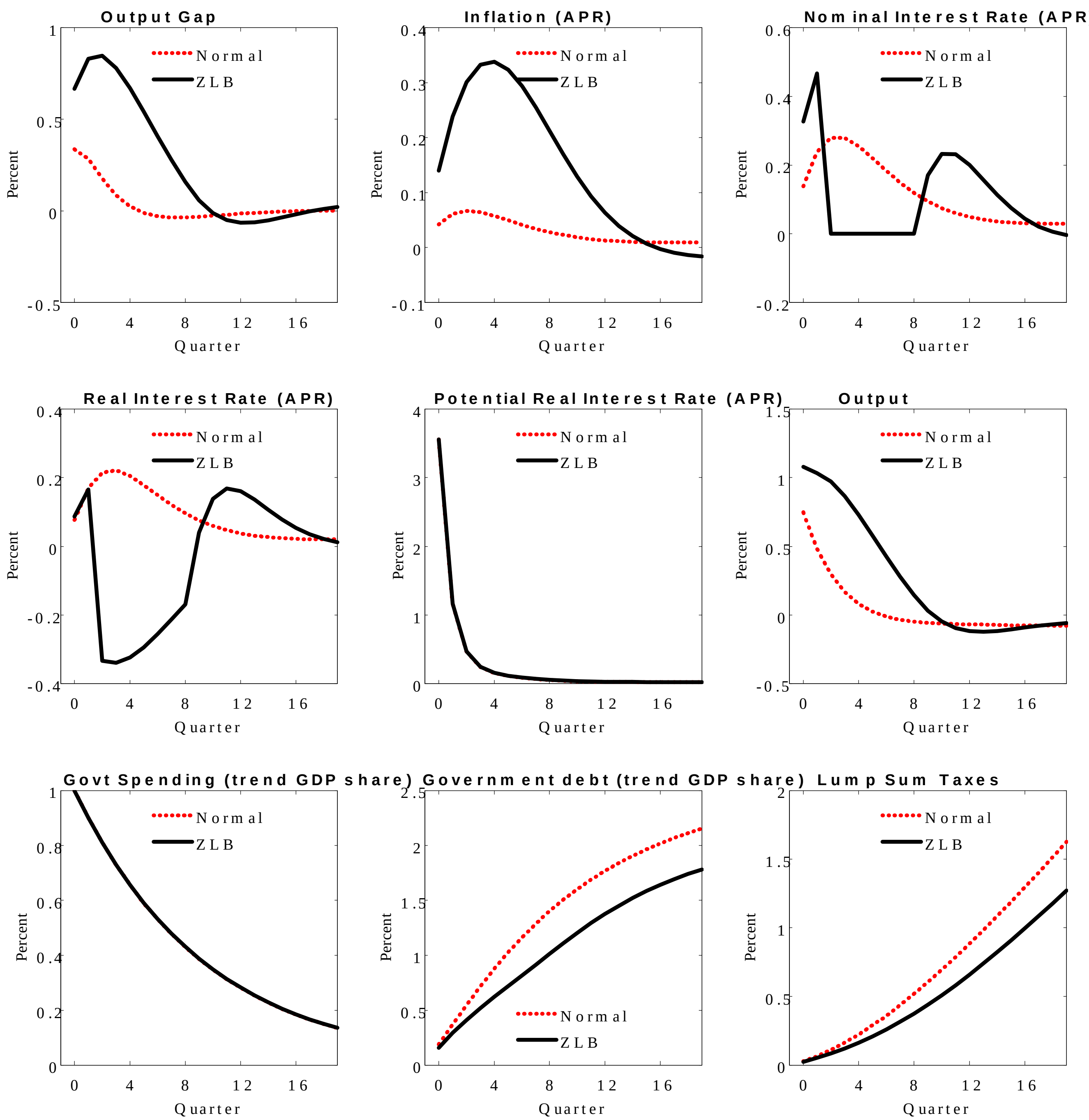

Figure 10: Responses to a Gradual Increase in Government Spending in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate CEE-SW Model with Capital: Standard Policy Rule

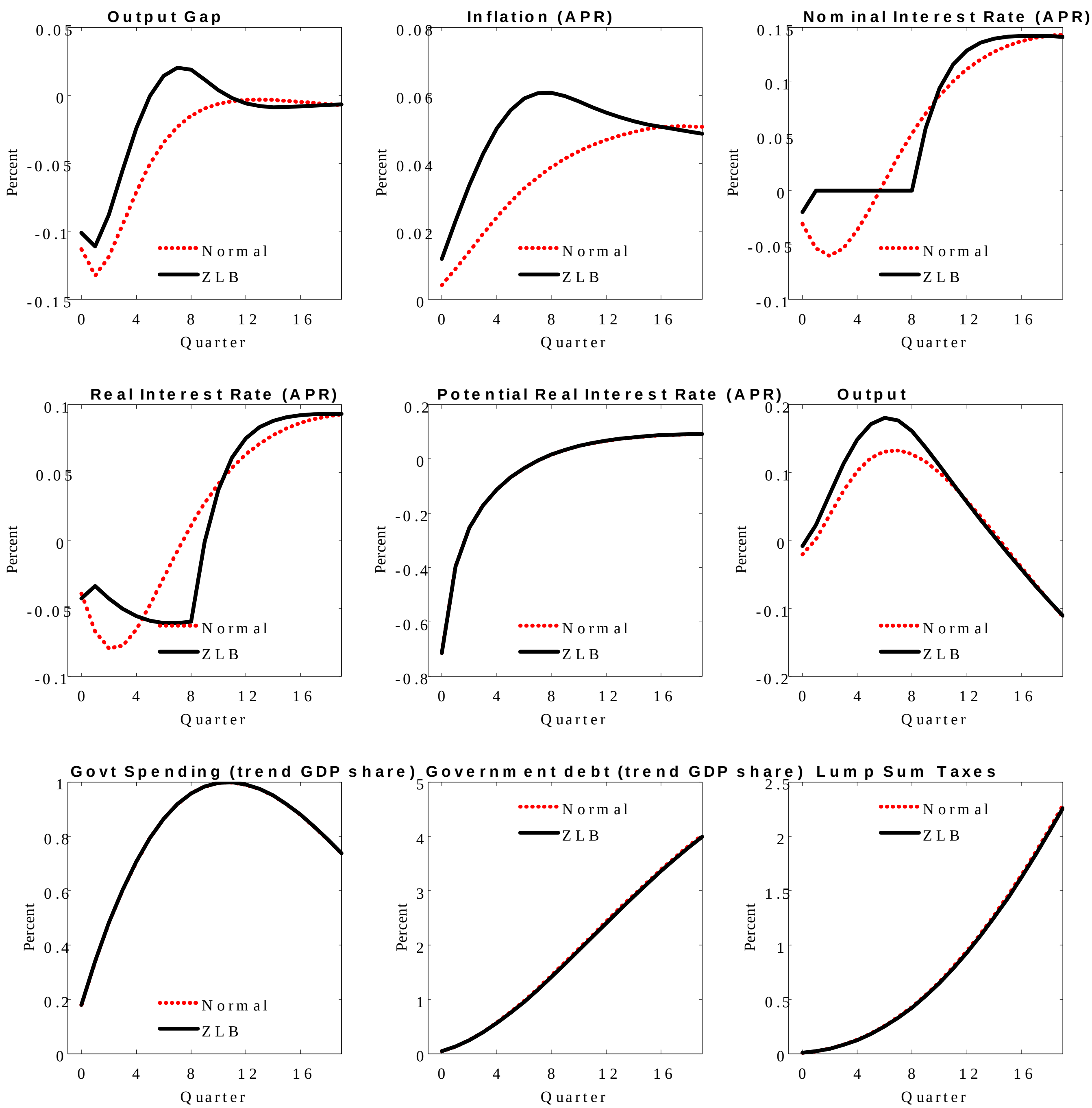

Figure 11: Responses to a Gradual Increase in Government Spending Financed by Labor Income Taxes in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate CEE-SW Model with Capital: Standard Policy Rule

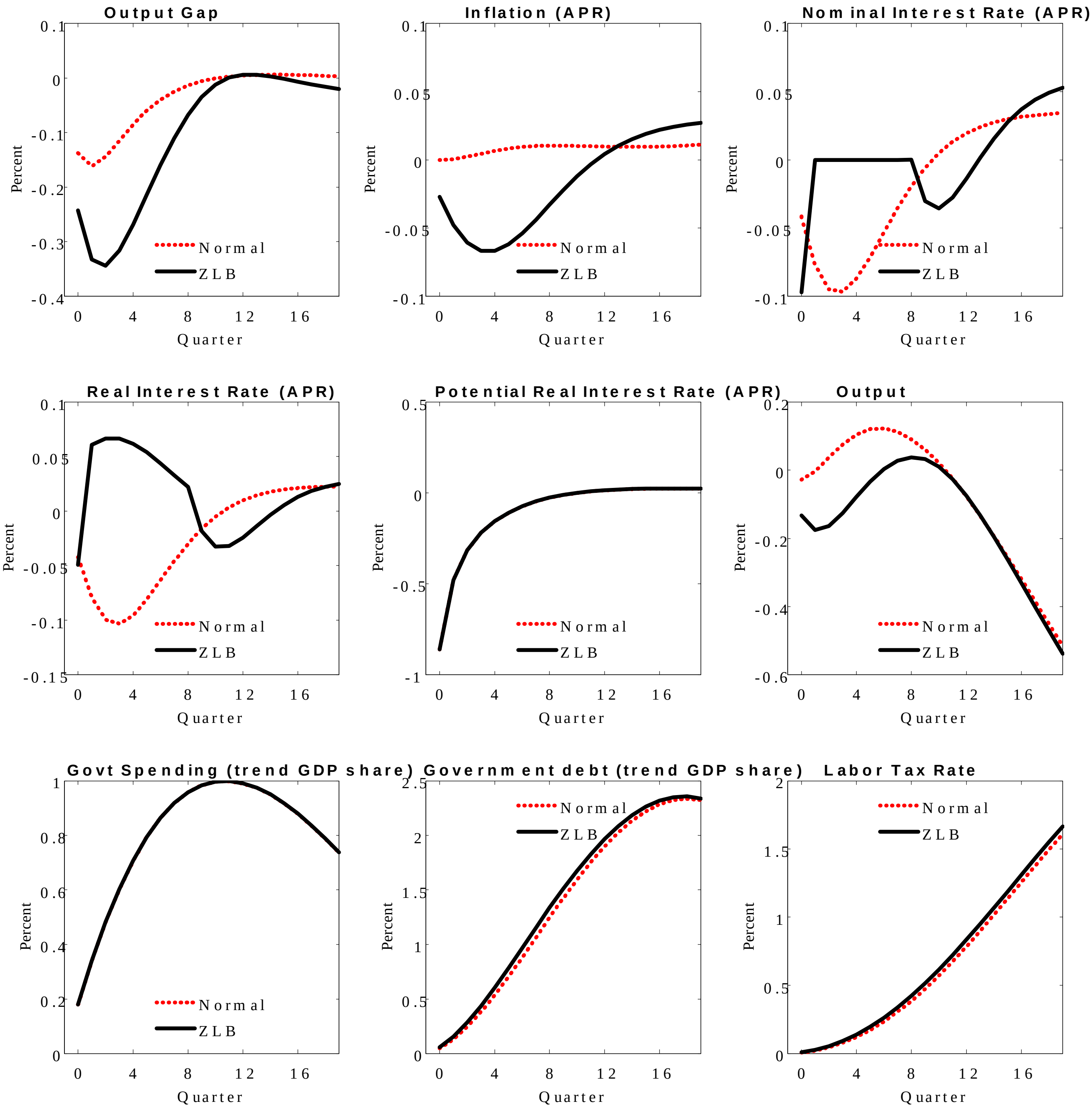

Figure 12: Responses to a Front-Loaded Increase in Government Spending in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Model with Capital, Financial Frictions and Keynesian Agents: Standard Policy Rule

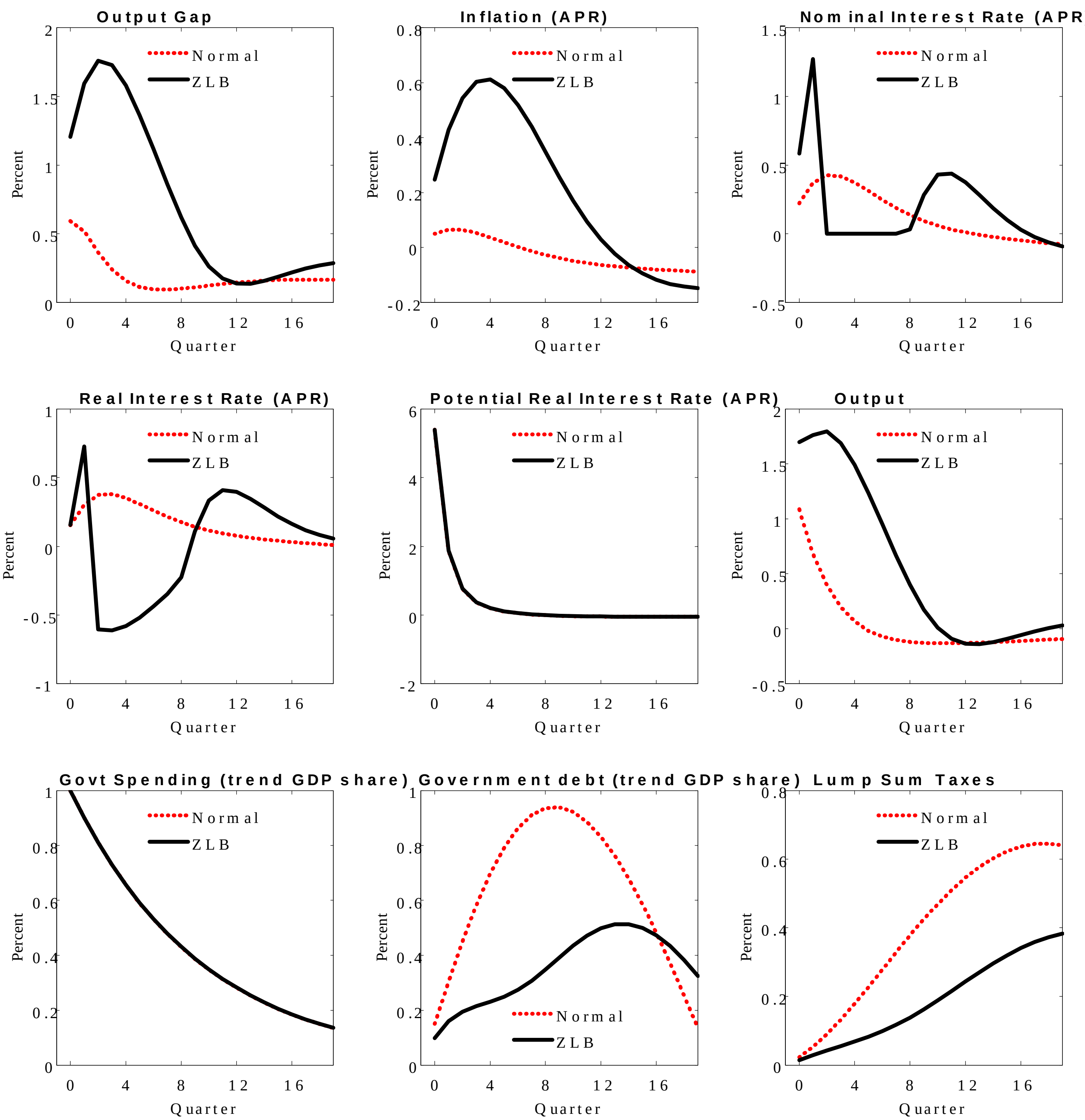

Figure 13: Responses to a Gradual Increase in Government Spending in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Model with Capital, Financial Frictions and Keynesian Agents: Standard Policy Rule

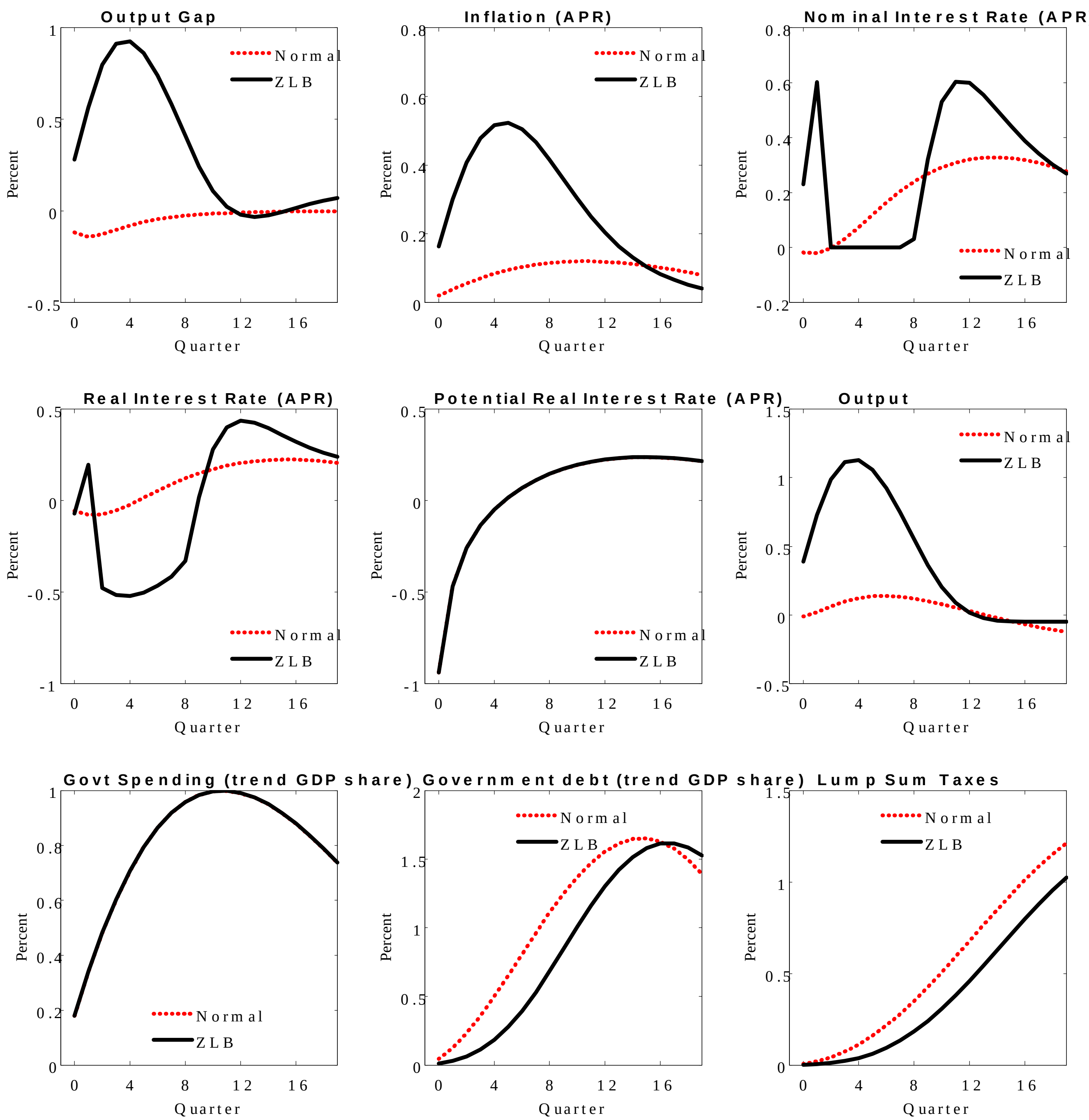

Figure 14: Responses to a Gradual Increase in Government Spending Financed by Labor Income Taxes in Normal Times and Under the ZLB Constraint on the Nominal Interest Rate Model with Capital, Financial Frictions and Keynesian Agents: Standard Policy Rule