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**FISCAL MULTIPLIERS AND MONETARY POLICY:
RECONCILING THEORY AND EVIDENCE**

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Fiscal Multipliers and Monetary Policy: Reconciling Theory and Evidence*

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This version: May 23, 2017

Abstract

Fiscal multipliers are typically observed to be moderate, which should, according to standard macroeconomic theory, be associated with real interest rates increasing with government spending. However, monetary policy rates have been found to decrease, which should – in theory – lead to large multipliers. In this paper, we rationalize these puzzling observations by accounting for responses of interest rates that are more relevant for private sector transactions than the monetary policy rate. We provide evidence that real interest rates on relatively illiquid assets and interest rate spreads which measure liquidity premia tend to increase after a government spending hike. We show that an otherwise standard macro model can explain diverging interest rate responses and moderate fiscal multipliers consistent with the data by accounting for an interest rate spread that decreases with the relative demand for less liquid assets. Our analysis indicates that neither a policy rate reduction nor a fixation at the zero lower bound are sufficient to induce large fiscal multipliers.

JEL classification: E32, E42, E63

Keywords: Fiscal multiplier, monetary policy, real interest rates, liquidity premium, zero lower bound

*The authors are grateful to Klaus Adam, Roel Beetsma, Jörg Breitung, Michael Krause, Gernot Müller, Massimo Giuliodori, Almuth Scholl, Roland Straub, Harald Uhlig, Sweder van Wijnbergen, and other seminar participants at the Ludwig-Maximilians-Universität München, University of Amsterdam, University of Konstanz, as well as the 46th Monetary Policy Committee Meeting of the German Economic Association, the annual conference of the German Economic Association 2015, CEF 2015, and EEA/ESEM 2016 for helpful comments and suggestions. A previous version of the paper circulated under the title “Fiscal policy, interest rate spreads, and the zero lower bound”. Financial support from the Deutsche Forschungsgemeinschaft (SPP 1578) is gratefully acknowledged.

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1 Introduction

The last decade has witnessed a resurgence of interest in the stimulative effects of government expenditures. A focal point of the debate is the role of the monetary policy stance during fiscal stimulus programs, exemplified by extraordinary large output multipliers at the zero lower bound (ZLB) found in theoretical studies. Surprisingly, the literature has largely overlooked a related clear-cut empirical evidence, which challenges the common view on the role of monetary policy for the fiscal multiplier.

When an increase in government spending crowds out private consumption and investment, standard macroeconomic theories predict these responses to be accompanied by higher real rates of return to clear markets for commodities (see Barro and King, 1984, Aiyagari et al., 1992, or Woodford, 2011). Yet, observed responses to government spending shocks constitute a clear puzzle according to the widespread view – particularly emphasized by the New Keynesian paradigm – that real rates of return essentially follow the real monetary policy rate: Empirical studies for the US typically find a moderate fiscal multiplier, i.e., an output multiplier around and mostly below one (see Hall, 2009, Barro and Redlick, 2011, and Ramey, 2011), and, accordingly, that private absorption hardly increases after a government spending hike. Simultaneously, the nominal and the real monetary policy rate however tend to *fall*, as documented by Mountford and Uhlig (2009) and Ramey (2016), which should in theory lead to an unambiguous increase in private absorption and a large output multiplier. Remarkably, this puzzling empirical pattern, which we document to be robust over different identification schemes and sample periods, has been almost unnoticed.¹ Instead, theoretical studies emphasize that, when the nominal policy rate is held constant, for example at the ZLB, private absorption increases and fiscal multipliers are large, i.e., output multipliers exceed two (see Christiano et al., 2011, Eggertsson, 2011), since the inflationary impact of government spending reduces the real monetary policy rate.²

In this paper, we reconcile macroeconomic theory and empirical evidence by accounting for real returns that are more relevant for private sector transactions than the real monetary policy rate and analyze how these rates react to fiscal policy shocks. First, we present evidence that real rates of return on relatively illiquid (i.e., less near-money) assets as well as interest rate spreads which are perceived as measures of liquidity premia tend to increase in response to positive government spending shocks, whereas the real monetary policy rate decreases. Second,

¹The only exceptions we were able to find are Ramey (2015) stating that "The fall in real interest rates is puzzling from the standpoint of any model" (p. 53) and Mountford and Uhlig (2009) who note that "deficit spending weakly stimulates the economy, that it crowds out private investment without causing interest rates to rise" (p. 962). Relatedly, Perotti (2005), Favero and Giavazzi (2007), and Corsetti et al. (2012) report ambiguous responses of longer-term interest rates, which are "regarded as difficult to reconcile with standard analyses of fiscal expansions" (Corsetti et al. 2012, p. 882).

²Large multipliers at the ZLB are questioned by recent empirical evidence on output effects of fiscal policy in times where the monetary policy rate is fixed. For example, Canova and Pappa (2011), Crafts and Mills (2013), Dupor and Li (2014), and Ramey and Zubairy (2016) have documented that output multipliers in such situations are not higher than on average.

we replicate observed interest rate responses and a moderate fiscal multiplier within a simple macroeconomic model where government spending crowds out private absorption and reduces the relative demand for less liquid assets, inducing an increase in (il-)liquidity premia. While the model rationalizes empirical observations on fiscal policy effects, it has striking implications regarding the role of monetary policy for the fiscal multiplier: Neither the empirically observed reductions in monetary policy rates nor the policy rate being fixed, for example, at the ZLB, are sufficient to generate a large fiscal multiplier.

The starting point of our empirical analysis is that, in estimated fiscal vector autoregressive models (VARs), the real and nominal monetary policy rate, i.e., the federal funds rate, decrease rather than increase in response to expansionary government spending shocks, as, for example, found by Mountford and Uhlig (2009) and Ramey (2016) for different identification schemes. While this feature can be understood as an accommodating monetary policy,³ the associated reactions of output, consumption, and investment are puzzling from a New Keynesian point of view. Specifically, private absorption is typically found to be crowded out or to rise only weakly and estimated output multipliers are around one (see Mountford and Uhlig, 2009, and Ramey, 2016). Since identification of fiscal shocks is subject to debate, we consider two widely applied identification approaches, for which we confirm these responses of output and the federal funds rate.⁴ Given that these simultaneous responses cannot be rationalized by theories based on a single interest rate set by the central bank, we consider measures of liquidity premia to account for possibly divergent responses of interest rates. Specifically, we follow Del Negro et al. (2016) and extract the common factor of a set of interest rate spreads which have been suggested to be primarily determined by liquidity premia and include it in our fiscal VARs.⁵ We find that the common liquidity factor as well as individual liquidity premia increase after a government spending hike. We further examine the responses of interest rates and yields, like on treasury debt, corporate bonds, or US-LIBOR rates, which are all more relevant for investment and saving decisions than the federal funds rate; the latter applying to overnight money market transactions. Consistent with the responses of the liquidity measures, we find that the responses of these real returns to fiscal policy shocks tend to deviate more from the response of the monetary policy rate the less the underlying asset (or liability) serves as a substitute for federal funds. For example, the response of the T-bill rate is similar to the federal funds rate response, whereas the real LIBOR rate and the real AAA corporate bond rate increase after a government spending hike.⁶ Overall, our empirical analysis provides evidence

³For example, a Taylor-type interest rate rule can include a direct government spending feedback (see Nakamura and Steinsson, 2014).

⁴We also consider different sample periods to make sure that our findings are not particularly affected by the Great Recession and its aftermath.

⁵The spreads that we apply for the common factor are, for example, suggested by Longstaff (2004), Krishnamurthy and Vissing-Jorgensen (2012), and Nagel (2016). A likelihood-ratio-based test for model selection further suggests that the common liquidity factor includes information that is relevant for the dynamics of the macroeconomic variables in the VARs.

⁶While we acknowledge that other factors might also contribute to the observed differential interest rate responses,

for differential interest rate responses to a government spending shock that are associated with changes in liquidity premia.

To understand these observations, recall that government spending in the first instance crowds out private absorption and leads to a negative wealth effect, according to the logic of basic dynamic general equilibrium models (see Barro and King, 1984). Given that aggregate demand tends to exceed supply due to the increase in government spending, real returns on savings have to rise to clear markets for commodities. Put differently, excess demand tends to increase the price of current relative to future consumption such that real interest rates on assets that private agents use as a store of wealth rise. Now suppose that assets are not equally used as a store of wealth, because they differ by their ability to provide liquidity services, i.e., to serve as a substitute for money, and, reflecting the additional convenience provided by relatively more liquid assets, by their pecuniary returns. An increase in government spending induces a fall in demand for less liquid assets, which are primarily used as a store of wealth, relative to the demand for near-money assets, which are primarily demanded for liquidity purposes and traded in money markets. As a consequence, relative to near-money assets, the prices for less liquid assets fall and their interest rates increase such that the spread between the interest rates on these asset types tends to widen when the monetary policy stance is not simultaneously tightened. Because interest rates are separated through (il-)liquidity premia, one can therefore observe moderate output increases in response to government spending hikes associated by higher real interest rates that are relevant for private agents' investment and intertemporal consumption choices, even when the real monetary policy rate falls.⁷

In contrast, when liquidity premia are neglected, as in a standard New Keynesian model, the central bank governs agents' intertemporal consumption choices (i.e., the marginal rate of intertemporal substitution) by controlling the real policy rate and thereby – up to first order – the rates of return on all assets in an arbitrage-free equilibrium. As a consequence, the joint responses of the nominal policy rate and expected inflation to government spending dictate private consumption growth and can even dominate the wealth effect in a situation where the real policy rate actually falls. As argued by Christiano et al. (2011) or Eggertsson (2011), the latter scenario would be relevant at the ZLB, where government spending crowds in private consumption and fiscal multipliers can be much larger than typically found in the data.

The model that we apply to explain the observed effects of fiscal policy shocks differs from a

our analysis indicates that expectations about future short-term interest rates or increases in government debt are not decisive. We neither observe an increase of cumulated federal funds rates nor professional forecasts of increasing future T-bill rates after government spending expansions. We further find that the AAA corporate bonds rate rises more strongly than the treasury bond rate, whereas the opposite should be observed – according to Krishnamurthy and Vissing-Jorgensen (2012) – if a debt-to-GDP increase were the dominant force behind differential interest rate changes.

⁷Notably, this line of argument is consistent with stimulative effects of an expansionary monetary policy, though, it is per se not sufficient to induce a consumption crowding-in and, correspondingly, lower real interest rates on less liquid assets.

standard New Keynesian model solely by differentiating between liquid and less liquid assets.⁸ We account for the fact that central banks typically supply reserves to commercial banks only against eligible assets, i.e., treasury bills, in open market operations. To explain observed interest rate spreads between eligible and non-eligible assets, we consider that the central bank sets the policy rate below the marginal rate of intertemporal substitution. The price of central bank money is then below the price that agents are willing to pay for liquidity, such that eligible assets are scarce and an endogenous liquidity premium arises.⁹ This premium reflects the valuation of near-money assets, which varies with the monetary policy stance as well as with agents' willingness to save and consume; the latter, for example, being altered by changes in government spending. In accordance with the data (see Simon, 1990), the T-bill rate then closely follows the policy rate, while rates of return on non-eligible assets, e.g., corporate debt, tend to be higher due to the liquidity premium. These less liquid assets serve as store of wealth for private agents, such that their real returns relate to the marginal rate of intertemporal substitution. The latter is – in contrast to the New Keynesian paradigm – separated from the policy rate by a liquidity premium and therefore not directly governed by the central bank in our model. While our model preserves monetary non-neutrality, its predictions regarding responses of real returns and output to fiscal policy shocks can substantially differ from the predictions of standard models. Precisely, if the real policy rate falls, whether due to monetary accommodation of fiscal policy or because the nominal rate is stuck at the ZLB, the standard New Keynesian model predicts a crowding-in of private absorption and a large fiscal multiplier, whereas our model with the liquidity premium generates rising real rates on less liquid assets and a moderate fiscal multiplier in line with empirical evidence. If, however, the real policy rate increases in response to fiscal policy shocks, the predictions of our liquidity premium model and of a standard New Keynesian model are aligned.

The main predictions of the model with the endogenous liquidity premium are presented analytically and are compared to a reference version without the liquidity premium, which accords with a standard New Keynesian model (with a cash-in-advance constraint). In particular, we show that our model with the liquidity premium can simultaneously generate a decline in the real policy rate, an increase in the marginal rate of intertemporal substitution, and a moderate fiscal multiplier, which is consistent with our VAR evidence and cannot be reproduced by a model version without the liquidity premium. Given that monetary policy is non-neutral in the model with the liquidity premium and therefore not irrelevant for the fiscal multiplier, the

⁸While exogenous interest rate premia on less liquid assets have been considered in related studies, as for example by Drautzburg and Uhlig (2015), the liquidity premium in our model responds endogenously to changes in government spending. We consider banks in order to motivate demand for reserves and demand deposits, but we neglect financial frictions for simplicity such that the Modigliani-Miller theorem applies.

⁹In an arbitrage-free equilibrium, there exists a spread between the policy rate and the price that agents are willing to pay for liquidity (i.e., the nominal marginal rate of intertemporal substitution), if eligible assets are not supplied abundantly. Note that such a policy regime which rations money supply can be welfare-enhancing compared to a regime where money demand is satiated (see Schabert, 2015).

results are conditional upon monetary policy not being too accommodating.¹⁰ To address this quantitative issue, we calibrate an extended version of the liquidity premium model and use it to study fiscal policy effects under three different monetary policy regimes. First, we account quantitatively for the observed fall in the monetary policy rate after a government spending hike. The calibrated model generates a moderate impact output multiplier of 0.84 and leads to an increase in the liquidity premium as well as in the real rates of return on less liquid assets, consistent with the data. Second, we study a scenario with nominal policy rate at the ZLB that has extensively been analyzed in the literature, where a decline in the real policy rate is due to the fixation of the nominal policy rate. Here, we confirm our previous results, while we find that the fiscal multiplier at the ZLB (0.54) is smaller than for the case of falling monetary policy rates. Intuitively, a fixation of the monetary policy rate at the ZLB tends to reduce the fiscal multiplier compared to situations where the policy rate falls in response to fiscal stimulus. Third, we consider a standard Taylor rule (without direct fiscal policy feedback), which induces a counterfactual increase in the real policy rate in response to spending hikes, and show that in this scenario the fiscal multiplier (0.51) is just slightly smaller than at the ZLB.

Thus, our model is able to reproduce – seemingly puzzling – observed responses of interest rates and output to government spending shocks, while implying that neither the empirically observed degree of monetary accommodation nor fixed monetary policy rates are sufficient to generate large fiscal multipliers. The response of the monetary policy rate to government spending shocks in fact alters the size of the fiscal multiplier, but it is far less influential than suggested by standard models that neglect liquidity premia. For example, when liquidity premia are considered, fiscal multipliers under a standard Taylor rule and under a binding ZLB are of similar magnitude. By contrast, in the model version without a liquidity premium, which corresponds to a standard New Keynesian model, the fiscal multiplier at the ZLB (3.29) is much larger than under a standard Taylor rule (0.57). These numbers reveal that accommodative monetary policy stances play a much smaller role for the size of fiscal multipliers when liquidity premium responses – as indicated by the data – are taken into account. While we fully acknowledge that the amount of slack in the economy or cyclical financial market conditions might lead to larger multipliers in recessions, as for example found by Auerbach and Gorodnichenko (2012),¹¹ our analysis shows that the relevance of the monetary policy stance for a potential cyclicity of the fiscal multiplier is overestimated when only monetary policy rate responses are taken into consideration and other rates of return are ignored.

The remainder of the paper is organized as follows. Section 2 relates our study to the literature. Section 3 provides empirical evidence. Section 4 presents the model. In Section 5,

¹⁰Put differently, the liquidity premium model is not per se incapable of generating a fiscal multiplier larger than one. This would actually be predicted for a sufficiently pronounced reduction of the monetary policy rate in response to a government spending hike.

¹¹For example, Canzoneri et al. (2016) provide a supportive theoretical analysis for the cyclicity of the fiscal multiplier, which relies on the severity of financial market frictions rather than on different monetary policy regimes.

we derive analytical results regarding fiscal policy effects. The section further presents impulse responses for an extended and calibrated version of the model for different stances of monetary policy. Section 6 concludes.

2 Related Literature

Our paper mainly relates to three strands of the literature. First, our VAR analysis of the effects of government spending shocks is based on the identification strategies suggested by Blanchard and Perotti (2002), who assume an implementation lag of fiscal policy, and Ramey (2011), who identifies fiscal shocks using professional forecast errors. Central for our analysis are the results in Ramey (2016), who provides an overview and a synthesis of the current understanding of the effects of government spending shocks. Specifically, the puzzling joint observation of a falling real policy rate in response to a government spending hike and a moderate fiscal multiplier, which she documents for two identification schemes, serves as the starting point of our empirical analysis. Likewise, Mountford and Uhlig (2009), who apply a sign restriction identification, report that government spending expansions are associated with a falling nominal policy rate and also a crowding-out of private absorption. Specifically, they find an impact output multiplier below one and a crowding-out of private investment, whereas private consumption rises only weakly in response to an increase in government spending. Further VAR analyses by Perotti (2005), Favero and Giavazzi (2007), and Corsetti et al. (2012) find that longer-term interest rates tend to fall after expansionary fiscal shocks, which relates to our findings regarding the responses of long-term treasury rates. Due to our identification of government spending shocks based on real-time forecast errors, our paper is further related to Auerbach and Gorodnichenko (2012), who find that fiscal multipliers are larger in recessions. Evidence on the fiscal multiplier at the ZLB is provided by Ramey and Zubairy (2016), who estimate state-dependent responses to fiscal policy using a local-projection approach. They identify two periods of pegged interest rates and "find no evidence that multipliers are greater than one at the ZLB in the full sample" (Ramey and Zubairy, 2016, p. 39).¹² Canova and Pappa (2011), Crafts and Mills (2013), and Dupor and Li (2015) provide evidence also suggesting that output multipliers at the ZLB are not substantially larger than on average.

Second, our analysis relates to theoretical studies on fiscal policy effects at the ZLB when the real monetary policy rate falls in response to a government spending hike due to a rise in future inflation. Most prominently, Christiano et al. (2011) and Eggertsson (2011) show that, when the central bank holds the short-run nominal interest rate at the ZLB, fiscal multipliers in a New Keynesian model become larger than typically observed in empirical studies, which has been confirmed by Woodford (2011) and Fahri and Werning (2013). Rendahl (2016) shows that

¹²They document mixed results for an analysis which excludes World War II from the sample. The model, which we apply below, is in principle able to explain differences in fiscal multipliers at the ZLB (based on multiple monetary policy instruments), which we will, however, not further examine in this paper, since we focus on the way the monetary policy rate is set.

under labor market frictions fiscal multipliers can be large at the ZLB even when government spending does not increase future inflation. Erceg and Linde (2014) show that the size of the fiscal multiplier relies on the duration of the ZLB episode, which is also pointed out by Fernandez-Villaverde et al. (2015) and Carlstrom et al. (2014). The latter studies as well as Boneva et al. (2016) further show that non-linearities of the model can crucially affect the fiscal multiplier at the ZLB. Besides the lack of empirical support, also a number of theoretical studies have raised doubts about large fiscal multipliers at the ZLB. Specifically, Drautzburg and Uhlig (2015) find a multiplier at the ZLB of roughly one half, for which mainly financing with distortionary taxation, changes in transfers to borrowing-constrained agents, and the anticipated duration of the ZLB are responsible. Mertens and Ravn (2014) show that, due to multiple equilibria at the ZLB, the fiscal multiplier might even be smaller than under normal circumstances, and Cochrane (2016) argues that, for a given path of interest rate expectations, alternative solutions of the New Keynesian model can even be associated with negative fiscal multipliers. Kiley (2016) further shows that fiscal multipliers at the ZLB are smaller than one when the assumption of price stickiness is replaced by sticky information. Our analysis suggests a novel mechanism that yields moderate fiscal multipliers at the ZLB building on endogenous liquidity premia and presents direct evidence that these premia indeed react to fiscal policy in the predicted way.

Third, our paper is related to several recent studies analyzing liquidity premia on treasury debt in a macroeconomic context. Krishnamurthy and Vissing-Jorgensen (2012) show that changes in the supply of treasuries alter yield spreads, indicating that short-term and long-term US treasury debt is characterized by liquidity and safety reflected by interest rate premia. Nagel (2016) provides evidence on a systematic relation between short-term interest rates and the liquidity premium on T-bills, implying that a central bank can mitigate effects of money demand shocks by targeting the interest rate. Del Negro et al. (2016) analyze the impact of central bank interventions during a recession induced by an adverse shock to the resaleability of assets (as specified in Kiyotaki and Moore, 2012), which is identified with a common factor of a broad set of liquidity premia. In our analysis, we also use a common factor as a measure of liquidity premia, similar to Del Negro et al. (2016). Our empirical analysis further implies short- and long-term treasury debt to provide liquidity services to a different extent, which relates to Greenwood et al. (2015), who analyze optimal government debt maturity when short-term debt is associated with liquidity services and roll-over risk. The theoretical foundation of the liquidity premium in our model is similar to Williamson (2016), who applies a model with differential pledgeability of assets for the analysis of unconventional monetary policy. While pledgeable assets are required for debt issuance of financial intermediaries in the latter study, we specify collateral requirements for central bank money as in Lacker (1997) or Schabert (2015); the former analyses the role of central bank deposits for private credit settlement and the latter examines welfare effects of collateralized central bank lending. Due to their eligibility

for central bank operations, short-term treasuries then serve as an imperfect substitute for money, which relates to Canzoneri et al.’s (2005) or Benigno and Nistico’s (2016) specification of agents’ liquidity constraints accounting for holdings of money and treasuries.

3 Fiscal policy effects in the data

In this section, we scrutinize the role of monetary policy for fiscal multipliers and document several novel empirical facts. The starting point of our empirical analysis is Mountford and Uhlig’s (2009) and Ramey’s (2016) finding that, in postwar US data, the nominal and the real monetary policy rate tend to *fall* in response to a positive government spending shock, while output effects are moderate, i.e., the fiscal multiplier is around 1. To corroborate this observation, which is clearly at odds with the New Keynesian paradigm, we apply two additional identification schemes and consider different sample periods. To address this puzzling finding, we extend standard fiscal VARs by considering interest rate spreads and real returns that are more relevant for private sector transactions than the federal funds rate. Specifically, we show that various measures of liquidity premia tend to increase after a government spending hike and, consequently, that real return responses of other assets differ from the response of the monetary policy rate. These differences tend to be the more pronounced the less the underlying asset serves as a substitute for central bank money.

3.1 Empirical specification and identification

To assess the responses of macroeconomic and financial variables to government spending shocks, we estimate fiscal VARs with quarterly data using two widely used strategies for the identification of fiscal shocks. First, we identify shocks to government spending recursively using short-run restrictions, following Blanchard and Perotti (2002), and assume that government spending has an implementation lag and is not affected by other variables within the quarter. We augment Blanchard and Perotti’s (2002) original approach by controlling for further determinants of government spending i.e., for public debt, tax receipts, and the monetary policy rate (following Perotti, 1999, Rossi and Zubairy, 2011, Ramey 2011).¹³ Second, we address Ramey’s (2011) anticipation critique of the simple recursive identification approach and use the forecast errors made by professional forecasters to identify fiscal shocks. To this end, we follow Auerbach and Gorodnichenko (2012), and construct forecast errors from the survey of professional forecasters (SPF) using real-time data.

For the Blanchard-Perotti identification, which we refer to as *BP*, the VARs include log real government spending per capita (g), log real GDP per capita (y), log real consumption of non-durables and services per capita or log real non-residential investment per capita (c, x), the effective federal funds (R^m), the ratio of public debt to GDP (d), log real net tax receipts

¹³Details on the set-up of our VAR together with data sources and variable definitions can be found in Appendix A.

per capita (tax), and the one-year inflation forecast from the SPF ($E\pi$). For the professional-forecast identification, which we refer to as AG , we follow Auerbach and Gorodnichenko (2012) by including the forecast error for government spending growth (real time data) ordered first and consider the shock to this variable, while omitting the debt-to-GDP ratio. Finally, we include a measure of liquidity premia, i.e., differences between returns on liquid and on less liquid assets or liabilities. To begin with, we follow Del Negro et al. (2016) and construct a common liquidity factor (clf) for a set of short-term and long-term spreads which the literature has identified as measures of liquidity premia (see Appendix A for details on liquidity spreads and the construction of the common factor). Including a measure of liquidity premia is motivated by theory and supported by the Vuong (1989) test, which is a likelihood-ratio-based test for model selection.¹⁴ The VAR models with the common liquidity factor outperforms the models without it in a statistically significant way with associated p-values in the magnitude of 10^{-9} , indicating that the common liquidity factor includes information that is relevant for the dynamics of the other variables in the VAR. Likewise, the Vuong test suggests the inclusion of inflation forecasts,¹⁵ which is – like the common liquidity factor – usually not considered in related studies.

Thus, our baseline VARs include variables needed for the proper identification of government spending shocks, i.e., g , tax , y , d , and R^m in the BP case and fe in the AG case together with g , tax , and y (as in Auerbach and Gorodnichenko, 2012), as well as macroeconomic variables which are of interest for our analysis (c , x , R^m and clf). Since we are interested in both the behavior of the nominal and the real federal funds rate, we separately include the nominal rate and the real-time inflation forecast. Below, we consider the combined time series for the real federal funds rate and further variables to those listed above. When doing so, we follow Burnside et al.’s (2004) strategy of using a fixed set of variables and rotating different variables of interest in (other interest rates and individual liquidity spreads) to keep the number of variables in the VARs limited.

Throughout, we use three lags and measure all variables as deviations from linear trends. The baseline sample period is 1979.IV to 2015.IV, where the starting date is determined by the availability of inflation forecast data needed to construct real-time real interest rates. Since several interest rates that we consider in the subsequent empirical analysis are available only from even later dates onward (see Appendix A), we include recent crisis years in our baseline

¹⁴Formally, it tests the null hypothesis that two models are equally close to the true data generating process. If this hypothesis is rejected, the test indicates which model is closer to the data but not whether this is the true model. The test statistic is the difference between the Bayesian information criteria (BIC, the log likelihood of the data given the model adjusted by the number of coefficients and observations) divided by the variance of observation-specific log-likelihood ratios (adjusted for the number of observations). If the Vuong (1989) test favors one model, the BIC criterion also does, but not vice versa, since the Vuong (1989) test also considers the statistical significance of the (parameter-adjusted) likelihood difference.

¹⁵Our full VAR models including the inflation forecast outperform their otherwise identical counterparts without the forecast with p-values of the Vuong tests in the magnitude of 10^{-4} . Both the inflation forecast and the common liquidity factor also lead to statistically significant improvements, individually and jointly, compared to a VAR that includes neither variable.

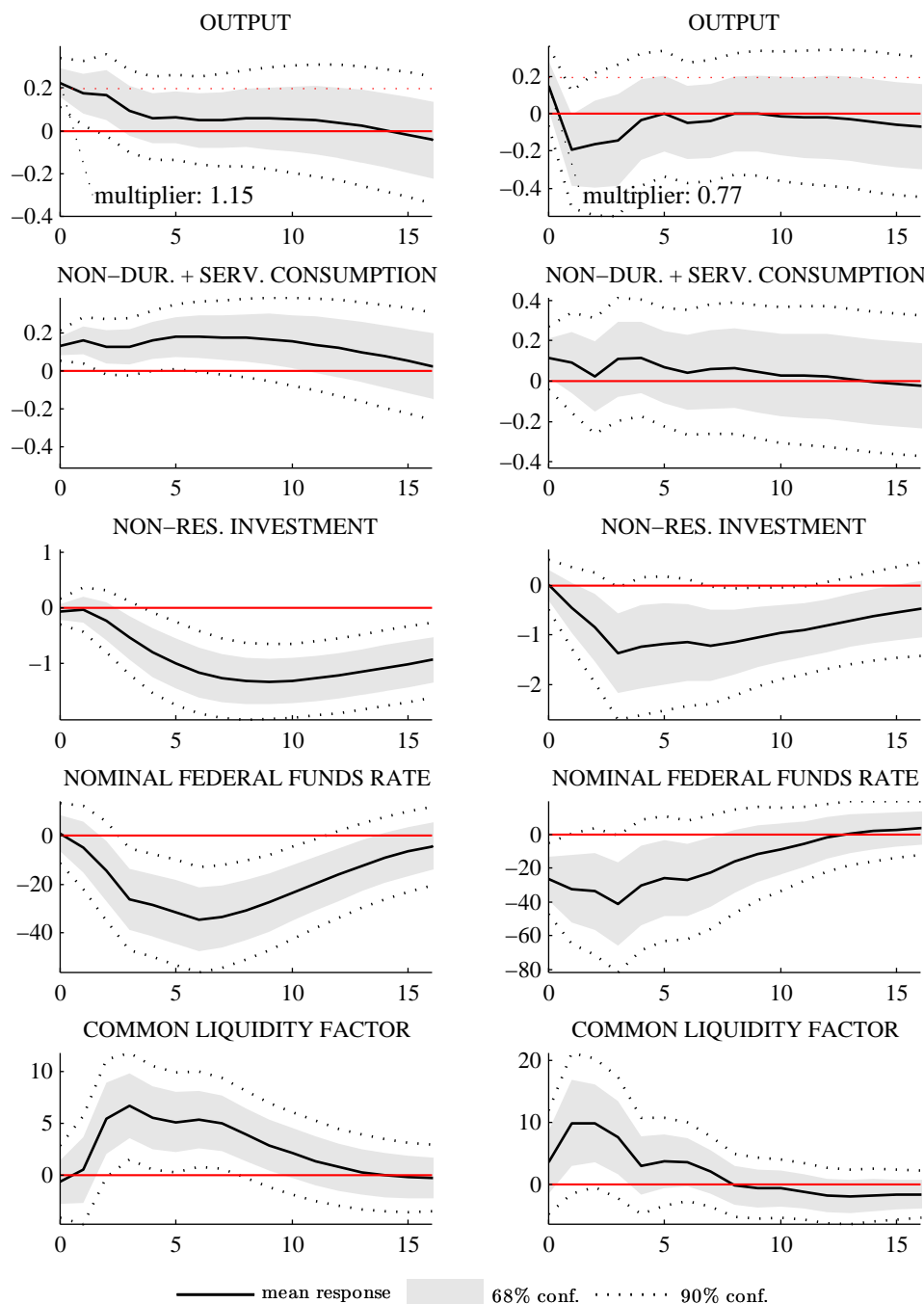
sample period to have as many observations for these rates as possible. Nevertheless, we also consider specifications where we exclude the financial crisis and its aftermath. For these specifications, we obtain generally similar results, while the precision of the estimates is higher in our baseline sample.

3.2 Federal funds rate response and the output multiplier

Figure 1 shows the responses to a positive government spending shock for our baseline VARs, where the first column displays responses for the identification based on implementation lags (*BP*) and the second column for the identification based on professional forecast errors (*AG*). Responses of output, consumption, and investment are shown in relative terms and expressed in percent while, for interest rates and the liquidity factor, we show absolute responses expressed in basis points. The shaded area (dotted line) shows 68% (90%) confidence bands. For both types of identification schemes, we find that a positive government spending shock raises real GDP, while the impact output multipliers are estimated to be around one. Specifically, they are equal to 1.15 for the *BP* VAR and 0.77 in the *AG* VAR.¹⁶ It is well known (see, e.g., Mountford and Uhlig, 2009, and Ramey, 2011) that identification à la Blanchard and Perotti (2002) tends to yield a consumption crowding-in and sometimes fiscal multipliers above one, as we find in our estimations. According to Ramey (2011), this pattern can partially be attributed to the timing of the shocks identified through Blanchard and Perotti’s (2002) approach. If changes in government spending are anticipated, a Blanchard-Perotti identification captures the shocks too late, which – based on standard analysis of fiscal policy – implies that the wealth effect responsible for the crowding-out of consumption is not fully taken into account. This critique is addressed by expectations-augmented VARs such as our *AG* specification where identification is based on professional forecast errors ensuring that the identified fiscal shocks are in fact unanticipated. Accordingly, we find no significant consumption crowding-in in this specification and a smaller output response, which is further relatively short-lived, in line with Ramey (2011) and Auerbach and Gorodnichenko (2012). Consistent with the results of Mountford and Uhlig (2009) and Ramey (2016), who report a decline in the nominal and the real federal funds rate, our estimations exploiting two alternative identification schemes corroborate that the nominal federal funds rate falls significantly. This also holds for the implied real federal funds rate, constructed from the mean responses of the nominal rate and the inflation forecast from our baseline VARs, as well as for the real-time real interest rate (see Figure 4). One might conjecture that the VAR responses reflect the reaction of both fiscal and monetary policy to a variable not included in the VAR. However, we are confident that our results do not merely pick up reactions to an omitted shock but truly display reactions to fiscal policy measures, in particular, under the *AG* identification approach. In particular, the

¹⁶Note that the figures show percent responses to a one percent change in government spending which is roughly one fifth of a percent of GDP.

Figure 1: The effects of a positive 1% government spending shock on output, consumption, investment, the federal funds rate, and the common liquidity factor. **Sample period: 1979.IV-2015.IV.** Left column: Blanchard-Perotti identification, right column: Auerbach-Gorodnichenko identification.



Notes: Responses of y , c , R^m , and clf stem from VARs that include g , y , tax , $E\pi$, c , R^m , and clf . d additionally included in *BP* identification. fe additionally included in *AG* identification. Response of x from the VAR where c is replaced by x . Shocks to g or fe , respectively, ordered first in Cholesky decomposition. See Table 1 for description and definition of variables. Horizontal axis show quarters. Responses of the federal funds rate and the liquidity factor in basis points, responses of the other variables in percent.

AG approach is not subject to this potential problem as long as professional forecasts take all relevant information into account. We further find reductions in net tax receipts (as Auerbach and Gorodnichenko, 2012), increases in the debt-to-GDP ratio, and mixed responses of inflation forecasts (see Figures 9 and 10 in Appendix D).

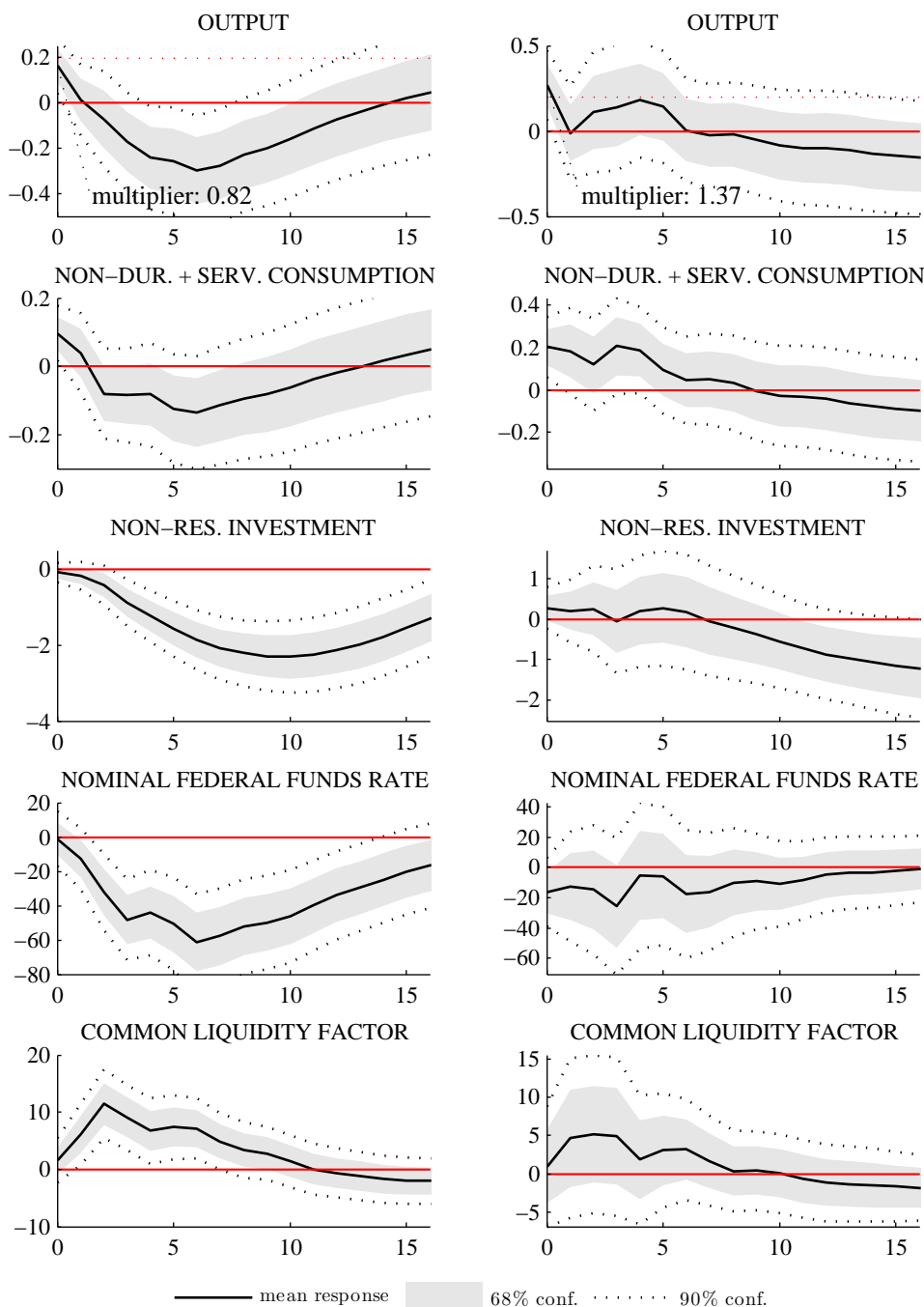
We further estimate the VARs for an alternative sample period excluding the Great Recession and its aftermath, i.e., for the sample period 1979.IV-2008.IV (see Figure 2). Overall, the results are estimated with less precision and we observe some quantitative changes in the responses, e.g., of real GDP or consumption. Nevertheless, we again find that a fall in the federal funds rate is associated with a moderate fiscal multiplier and an increase in the common liquidity factor, confirming our main results from the full sample. Notably, neither the empirical analysis nor the theoretical model accounts for unconventional monetary policy measures, which has been introduced by the US Federal Reserve (Fed) since 2009. We do not expect that this – undeniably important – shift in the monetary policy regime affects the relation between the fiscal multiplier and the conventional monetary policy instrument, i.e., the monetary policy rate, which is the focus of our analysis.

The finding of a decreasing policy rate indicates a clear accommodative monetary policy stance, which is in principle even more expansionary than a fixed policy rate, for example at the zero lower bound, implying that the output multiplier should – according to New Keynesian macroeconomics (see Christiano et al., 2011) – be much larger than those we find empirically. While the joint observation of a falling federal funds rate and a fiscal multiplier around one seems to constitute a clear puzzle, the response of the common liquidity factor provides a possible explanation. In response to the government spending shock, there is a clear increase in the common liquidity factor (see Figure 1). The response of the common liquidity factor apparently indicates that responses of returns on relatively less liquid assets differ from those on more liquid assets. Thus, interest rates on assets that are more relevant for private agents than the federal funds rate can in principle respond differently and might even increase. Given that the common factor just captures the joint movement of individual spreads, we take a closer look at the latter to unveil the main effects of government spending shocks.

3.3 Responses of liquidity premia

Before we take a closer look at the responses of specific rates of return, we zoom in on the common liquidity factor and present responses of several liquidity spreads that feed into the common factor. Notably, these spreads have also been positive in the last part of the sample, 2008.IV-2015.IV, indicating a positive valuation of liquidity even during the time of the Fed’s unconventional monetary policy measures (see Figure 11 in Appendix D). Figure 3 again presents the common factor response, for convenience, as well as responses of four measures of liquidity premia, which are estimated using the baseline VARs where the common factor is replaced by the particular liquidity premium. Responses are in absolute terms and displayed

Figure 2: The effects of a positive 1% government spending shock on output, consumption, investment, the federal funds rate, and the common liquidity factor in a sample excluding the financial crisis. **Sample period: 1979.IV-2008.IV.** Left column: Blanchard-Perotti identification, right column: Auerbach-Gorodnichenko identification.



Notes: Responses of y , c , R^m , and clf stem from VARs that include g , y , tax , $E\pi$, c , R^m , and clf . d additionally included in *BP* identification. fe additionally included in *AG* identification. Response of x from VAR where c is replaced by x . Shocks to g or fe , respectively, ordered first in Cholesky decomposition. Sample: 1979.IV-2008.IV. See Table 1 for description and definition of variables. Responses of the federal funds rate and the liquidity factor in basis points, responses of the other variables in percent.

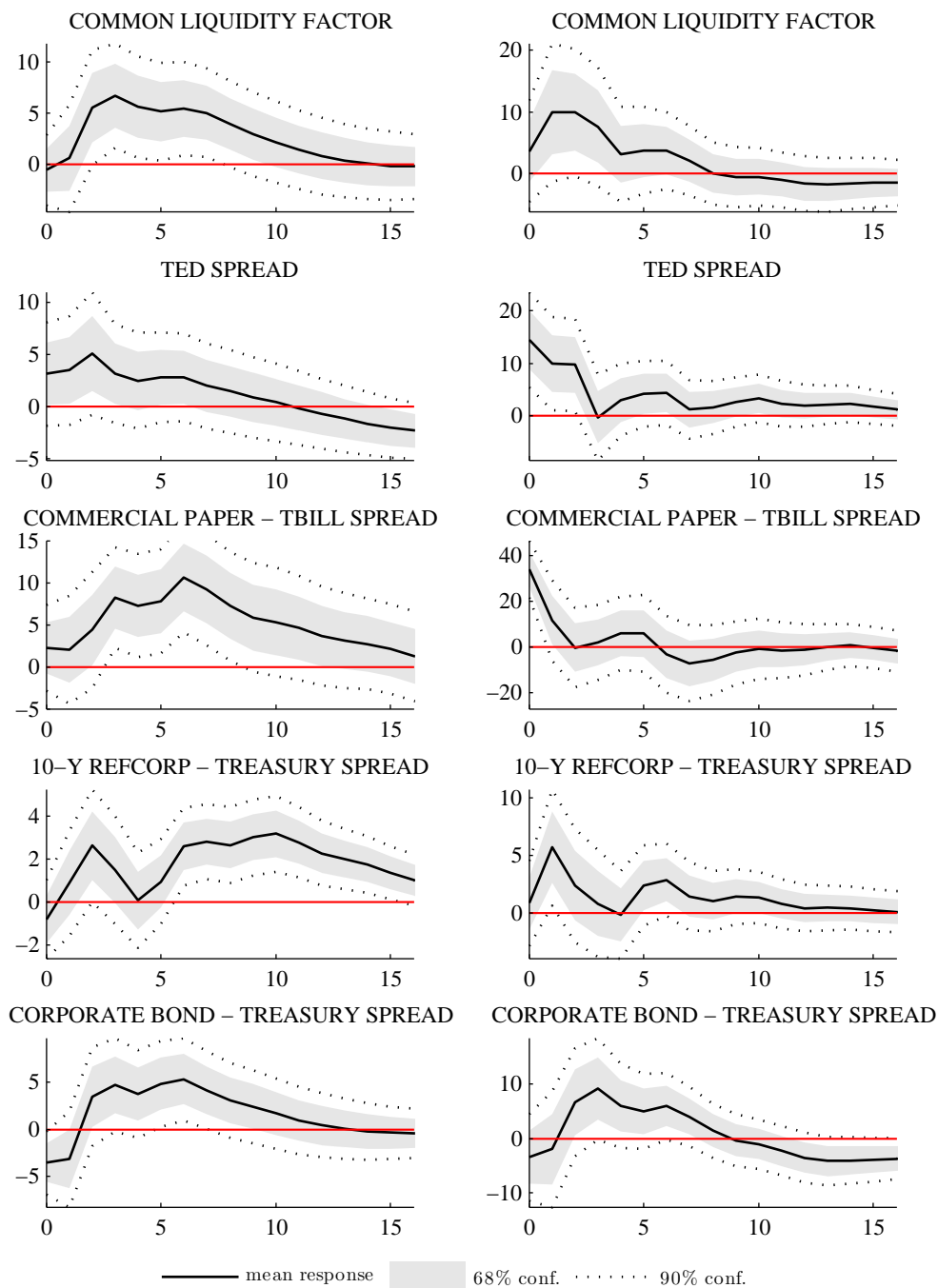
in basis points. Due to data availability for the different spreads, the sample periods differ between the different VARs considered in Figure 3 (see the figure notes for details). We use two spreads on short-term assets and two spreads on longer-term assets. The short-term spreads are the spread between the 3-months US LIBOR rate and the T-bill rate (also known as the TED spread) and the spread between the rates on commercial papers and T-bills, which are associated with an average maturity of three months. The former spread is widely used as an illiquidity measure (see, e.g., Brunnermeier, 2009), though it arguably contains some credit risk component, while the latter spread is – as argued by Krishnamurthy and Vissing-Jorgensen (2012) – hardly affected by default risk. The long-term spreads we consider are the spread between the rates on AAA corporate bonds and long-term treasury bonds, which mainly measures a liquidity premium or "convenience yield" according to Krishnamurthy and Vissing-Jorgensen (2012), as well as the spread between 10-year Refcorp bonds and treasury bonds, suggested by Longstaff (2004). Given that Refcorp bonds are guaranteed by the US government and taxed as treasury bonds, the associated spread mainly captures relative illiquidity of Refcorp bonds and is less contaminated by credit risk than the AAA-treasury spread.

Figure 3 shows that, under both identification schemes, all measures of liquidity premia increase significantly in response to the government spending shock. The responses of the common liquidity factor are repeated for convenience. Apparently, this result applies regardless of whether the liquidity premium is measured by short-term or long-term spreads. The maximum increase of the individual spreads equals 34 bps and is thus substantial, given that the mean values for the spreads range between 25 and 135 bps. It should further be noted that the AAA-treasury spread increases even though total government debt as a share of GDP tends to increase in response to a government spending hike. According to Krishnamurthy and Vissing-Jorgensen (2012), an increase in the debt-to-GDP ratio, which raises the supply of safe assets, tends to reduce the AAA-treasury spread. Yet, a downward shift in the latter spread only appears on impact, whereas the subsequent pronounced increase indicates that the dynamics of this spread in response to spending expansions are dominated by the increased valuation of liquidity rather than by changes in public debt. It should be noted that, in contrast to the total-debt-to-GDP ratio, the ratio of T-bills to GDP, which will be relevant for our theoretical analysis (see Section 4), does not experience a significant increase in response to government spending shocks (see Figure 15 in Appendix D).

3.4 Responses of various real returns

The responses of the liquidity measures suggest that other returns respond differently to fiscal shocks than the federal funds rate. Yet, we want to assess whether this difference can be large enough to reconcile theory and empirical observations. Put differently, if other interest rates just fall by less than the federal funds rate in response to fiscal shocks, liquidity premia indeed increase, as we have documented, whereas the aforementioned puzzle would remain

Figure 3: The effects of a positive 1% government spending shock on selected interest-rate spreads measuring liquidity premia. Left column: Blanchard-Perotti identification, right column: Auerbach-Gorodnichenko identification.



Notes: All VARs include $g, y, d, tax, E\pi, c, R^m$, and the variable whose response is shown. d additionally included in *BP* identification. fe additionally included in *AG* identification. Shocks to g or fe , respectively, ordered first in Cholesky decomposition. Sample: 1979.IV-2015.IV for clf , 1986.I-2015.IV for $R^{Libor3} - R^{T-bill}$, 1997.I-2015.IV for $R^{cp} - R^{T-bill}$, 1991.II-2015.IV for $R^{refcorp} - R^{T-bond}$, and 1983.I-2015.IV for $R^{AAA} - R^{T-bond}$. See Table 1 for description and definition of variables. All responses in basis points.

unsolved. To address this issue, we consider a set of interest rates and yields that are more relevant for private sector investment and saving decisions than the federal funds rate. We examine the responses of these returns by including them in the baseline fiscal VARs, where they replace the common liquidity factor.¹⁷ We express all rates in real per annum terms and compute real returns by applying real-time inflation expectations, which is a particularly reasonable procedure for long-term rates. While this procedure is also applied for short-term rates for consistency, it should be noted that the main results are qualitatively unaffected when we instead use realized inflation rates, which, for example, are applied by Ramey (2016) to compute the real federal funds rate.¹⁸

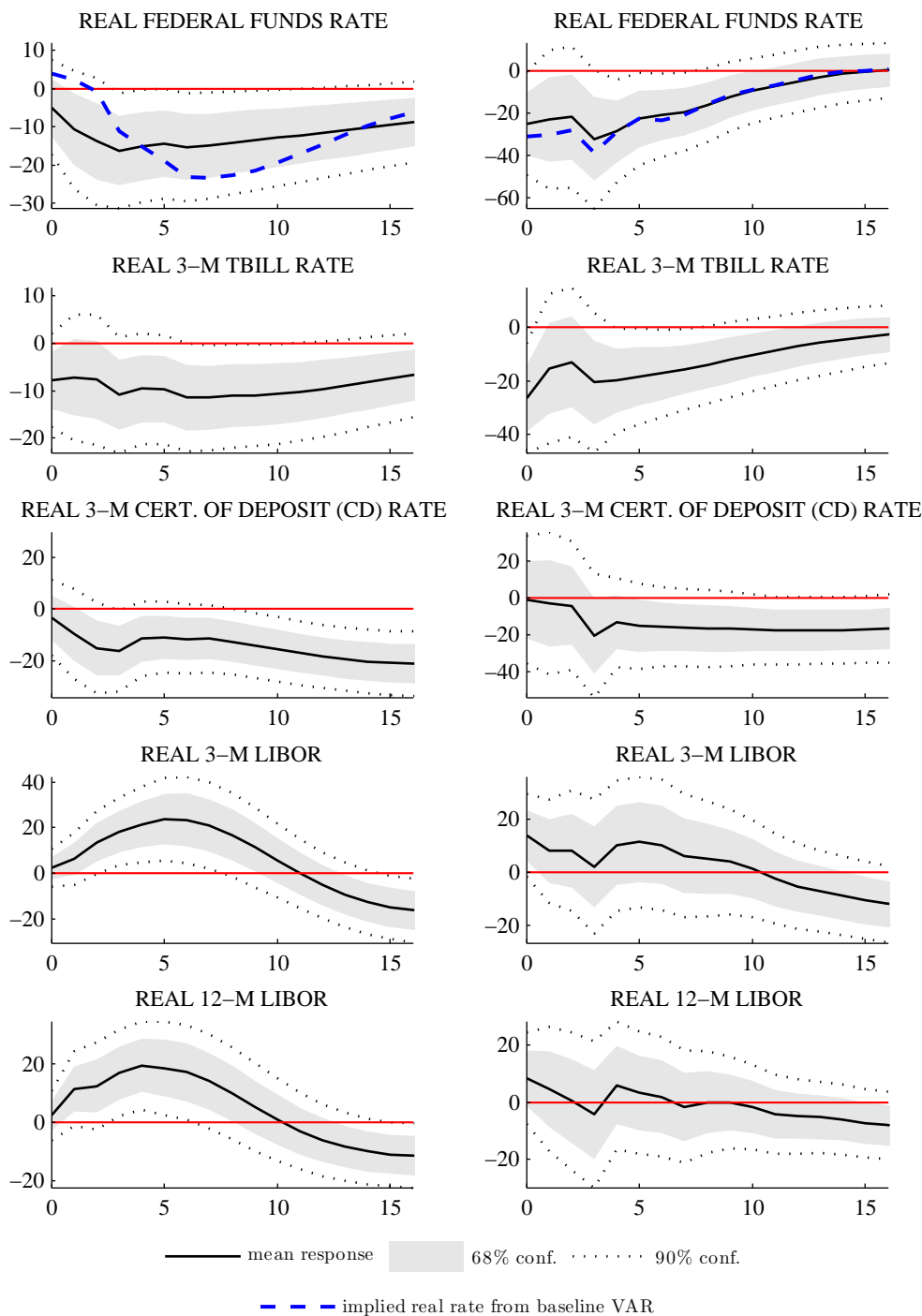
Figure 4 shows the responses of several money market rates, i.e., interest rates on assets and liabilities that serve as substitutes for high powered money to different degrees (see Cook and Laroche, 1993). Again, responses are in absolute terms and displayed in basis points. Most importantly, we find a persistent decline in the real federal funds rate, which accords with the findings of Ramey (2016). The real rate on T-bills, which are commonly viewed as being close substitutes for federal funds, responds to the fiscal shock in a similar way as the federal funds rate. The difference between the response of the rate on certificates of deposits (CDs), which are issued by banks and other depository institutions, and the federal funds rate response is more pronounced. The difference to the federal funds rate is most apparent for the response of the 3-months US LIBOR rate, which applies to interbank borrowing and lending in terms of time deposit liabilities and is commonly viewed as the most important short-term interest rate (see e.g., IMF, 2012). The 12-months US LIBOR rate behaves similarly, both LIBOR rates tend to increase rather than to decrease in response to the government spending hike. Overall, the responses presented in Figure 4 show that the difference to the federal funds rate response tends to be more pronounced the less the underlying asset serves as a substitute for money.

Figure 5 shows the responses of real returns on assets or liabilities that are characterized by a longer maturity than the ones considered in Figure 4 (absolute responses in basis points). For example, we consider long-term treasury securities, i.e., treasury bonds, which are typically viewed as being safe and liquid (see Krishnamurthy and Vissing-Jorgensen, 2012), while they are less liquid than T-bills according to Greenwood et al. (2015). Consistently, the treasury bond rate, which refers to a constant maturity of 10 years, shows some upward movement in response to the fiscal shock, particularly for the *BP* identification. Regarding assets that are even less liquid according to Krishnamurthy and Vissing-Jorgensen (2012), we find that AAA and BAA corporate bond rates tend to increase on impact in the *BP* VAR, while we observe longer lasting increases for the *AG* VAR. We obtain similar responses for MBS yields and

¹⁷Exceptions are the real federal funds rate and the real T-bill rate which apply to relatively illiquid assets and hence enter the VARs instead of the nominal federal funds rate with the common liquidity factor remaining. Since we consider real rates here, we do not include the inflation forecast as a separate variable (see Appendix A for details).

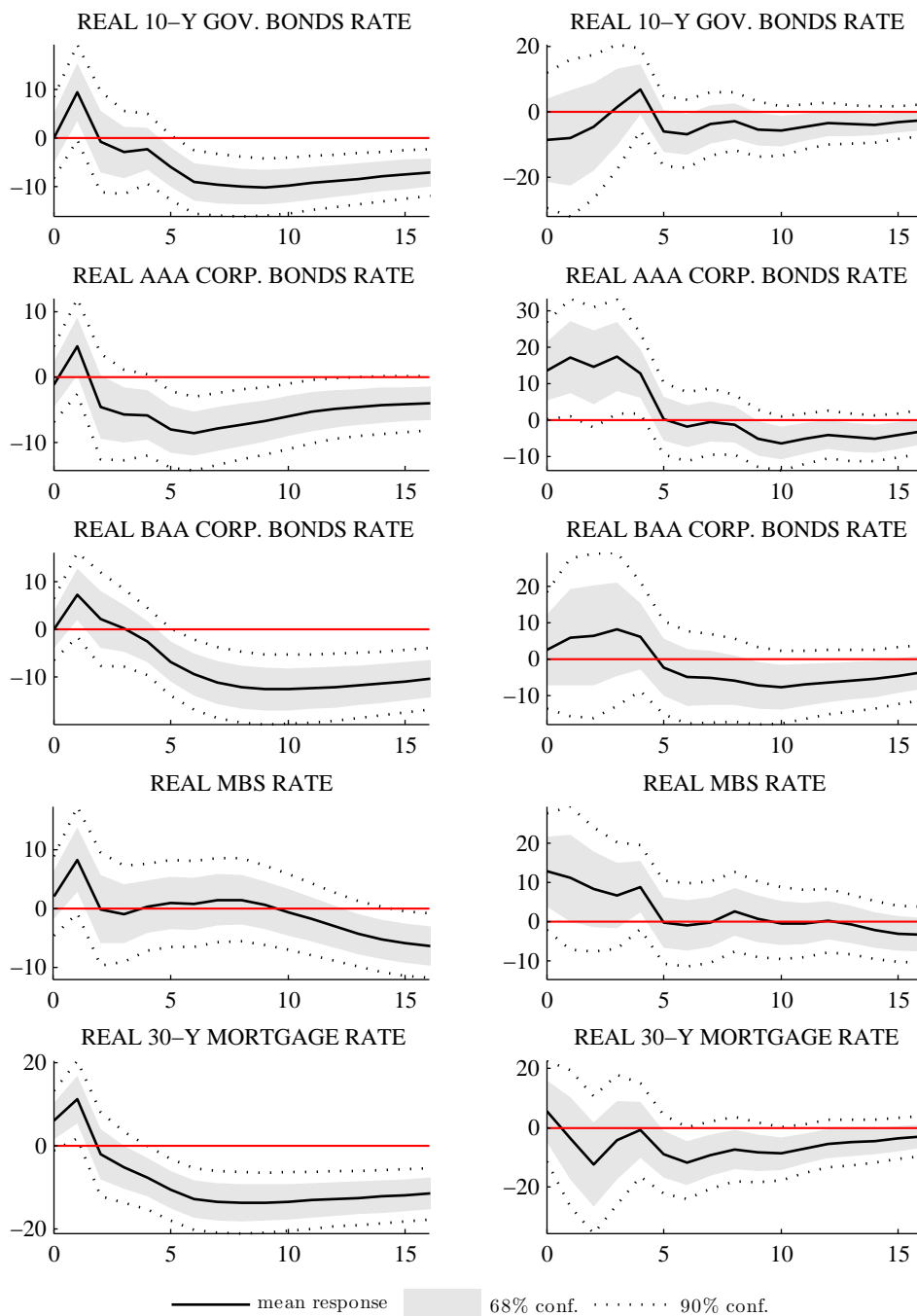
¹⁸Notably, the responses of nominal rates to government spending shocks show a pattern similar to the real rate responses, which can be found in Figures 12 and 13 in Appendix D.

Figure 4: The effects of a positive 1% government spending shock on selected short-term real interest rates. Left column: Blanchard-Perotti identification, right column: Auerbach-Gorodnichenko identification.



Notes: All VARs include g , y , tax , $E\pi$, c , and the variable whose response is shown. d additionally included in BP identification. fe additionally included in AG identification. VARs with $R^m/E\pi$ and $R^{T-bill}/E\pi$ further include clf . VARs with $R^{cd}/E\pi$, $R^{Libor3}/E\pi$, and $R^{Libor12}/E\pi$ further include $R^m/E\pi$. Shocks to g or fe , respectively, ordered first in Cholesky decomposition. Sample: 1979.IV-2015.IV for $R^m/E\pi$ and $R^{T-bill}/E\pi$, 1979.I-2013.II for $R^{cd}/E\pi$, 1986.I-2015.IV for $R^{Libor3}/E\pi$ and $R^{Libor12}/E\pi$. See Table 1 for description and definition of variables. All responses in basis points.

Figure 5: The effects of a positive 1% government spending shock on selected long-term real interest rates. Left column: Blanchard-Perotti identification, right column: Auerbach-Gorodnichenko identification.



Notes: All VARs include $g, y, tax, E\pi, c, R^m/E\pi^1$ and the variable whose response is shown. d additionally included in *BP* identification. fe additionally included in *AG* identification. Shocks to g or fe , respectively, ordered first in Cholesky decomposition. Sample: 1979.IV-2015.IV for $R^{T-bond}/E\pi^{10}$, $R^{BAA}/E\pi^{10}$, and $R^{mortg}/E\pi^{10}$, 1983.I-2015.IV for $R^{AAA}/E\pi^{10}$, and 1984.IV-2015.IV for $R^{MBS}/E\pi^{10}$. See Table 1 for description and definition of variables. All responses in basis points.

the 30-year fixed mortgage rate, for which we apply 10 year inflation forecasts due to a lack of availability of longer term inflation forecasts. It should further be noted that our findings suggest that the increase in long-term interest rates is hardly induced by expectations about future short-term interest rates, given that the cumulative response of the federal funds rate over 10 years is negative for both identification schemes.

To summarize, the VAR analysis has shown that while the federal funds rate declines in nominal and real terms in response to government spending hikes, liquidity premia and real returns on less liquid assets tend to rise. Thus, if one restricts attention to the federal funds rate, a clear puzzle emerges, since the New Keynesian paradigm predicts much larger output multipliers for the case of falling interest rates. Yet, a theoretical framework that simultaneously generates a decreasing real policy rate and increasing real returns on less liquid assets, which relate to agents' intertemporal consumption and investment choices, can in principle be consistent with the previously shown effects of government spending shocks. The subsequent section develops a model that is able to replicate these findings, which we then use to assess analytically and numerically fiscal policy effects for different paths of the monetary policy rate.

4 The model

In this section, we develop a macroeconomic model for the analysis of fiscal policy effects. The model is sufficiently simple such that its main properties can be derived analytically. In Section 5.2, we calibrate an extended version of the model. Motivated by the empirical evidence on diverging interest rates, we account for interest rates on assets and liabilities that might differ from the monetary policy rate by first order and, in particular, respond differently to fiscal policy shocks. To isolate the main mechanism and to facilitate comparisons with related studies, our model is based on a standard New Keynesian model, neglecting financial market frictions. However, we incorporate banks in order to be able to replicate, admittedly in a stylized way, the way the Fed implements monetary policy. In fact, the model is constructed to feature only a single non-standard element, i.e., an endogenous liquidity premium, which is induced by monetary policy implementation.

To explain the interest-rate dynamics documented in Section 3, we consider differential pledgeability of assets in open market operations, implying different degrees of (il-)liquidity.¹⁹ Specifically, commercial banks demand high powered money, i.e., reserves supplied by the central bank, to serve withdrawals of demand deposits by households, who rely on money for goods market transactions. We account for the fact that reserves are only supplied against eligible assets, which were predominantly T-bills before the Great Recession. While the interest rate on T-bills therefore closely follows the monetary policy rate, the interest rates on non-eligible assets exceed the monetary policy rate by a liquidity premium. As non-eligible assets

¹⁹This specification follows Schabert (2015), who analyses optimal monetary policy in a more stylized model, and closely relates to Williamson's (2016) assumption of differential pledgeability of assets for private debt issuance.

serve as private agents' store of wealth, the associated interest rates relate to agents' marginal rate of intertemporal substitution. The liquidity premium therefore endogenously varies with changes in the policy rate as well as with the associated growth rate of private consumption, which determines agents' valuation of liquidity.

In each period, the timing of events in the economy, which consists of households, banks, intermediate goods producing firms, retailers, and the public sector, unfolds as follows: At the beginning of each period, aggregate shocks materialize. Then, banks can acquire reserves from the central bank via open market operations. Subsequently, the labor market opens, goods are produced, and the goods market opens, where money serves as a means of payment. At the end of each period, the asset market opens. Throughout the paper, upper case letters denote nominal variables and lower case letters real variables.

4.1 Households

There is a continuum of infinitely lived and identical households of mass one. The representative household enters a period t with holdings of bank deposits $D_{t-1} \geq 0$ and shares of firms $z_{t-1} \in [0, 1]$. It maximizes the expected sum of a discounted stream of instantaneous utilities $u_t = u(c_t, n_t)$,

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, n_t), \quad (1)$$

where $u(c_t, n_t) = [c_t^{1-\sigma} / (1-\sigma)] - \theta n_t^{1+\sigma_n} / (1+\sigma_n)$, $\sigma \geq 1$, $\sigma_n \geq 0$, $\theta \geq 0$, c_t denotes consumption, n_t working time, E_0 the expectation operator conditional on the time 0 information set, and $\beta \in (0, 1)$ is the subjective discount factor. Households can store their wealth in shares of firms $z_t \in [0, 1]$ valued at the price V_t with the initial stock of shares $z_{-1} > 0$. Here, we assume that households rely on money for purchases of consumption goods, whereas in Section 5.2 we also allow for purchases of goods via credit.²⁰ To purchase goods, households can in principle hold cash, which is dominated by the rate of return of other assets. Instead, we consider demand deposits that are offered by banks (see below) and that are assumed to serve the same purpose. Households typically hold more deposits than necessary for consumption expenditures such that the goods market constraint, which resembles a standard cash in advance constraint, can be summarized as

$$P_t c_t \leq \mu D_{t-1}, \quad (2)$$

where P_t denotes the price level and $\mu \in [0, 1]$ an exogenously determined fraction of deposits withdrawn by the representative household. Given that households can withdraw deposits at any point in time, they have no incentive to hold non-interest-bearing money outright. We assume that banks offer demand deposits at the period t price $1/R_t^D$. The budget constraint

²⁰Specifically, for the calibration of the model in Section 5.2, we account for consumption of cash and credit goods (as, e.g., in Lucas and Stokey, 1987).

of the representative household is

$$(D_t/R_t^D) + V_t z_t + P_t c_t + P_t \tau_t \leq D_{t-1} + (V_t + P_t \varrho_t) z_{t-1} + P_t w_t n_t + P_t \varphi_t, \quad (3)$$

where τ_t denotes a lump-sum tax, ϱ_t dividends from intermediate goods producing firms, w_t the real wage rate, and φ_t profits from banks and retailers. Maximizing the objective (1) subject to the goods market constraint (2), the budget constraint (3), and $z_t \geq 0$ for given initial values leads to the following first order conditions for working time, consumption, shares, and deposits:

$$-u_{n,t} = w_t \lambda_t, \quad (4)$$

$$u_{c,t} = \lambda_t + \psi_t, \quad (5)$$

$$\beta E_t [\lambda_{t+1} R_{t+1}^q \pi_{t+1}^{-1}] = \lambda_t, \quad (6)$$

$$\beta E_t [(\lambda_{t+1} + \mu \psi_{t+1}) \pi_{t+1}^{-1}] = \lambda_t / R_t^D, \quad (7)$$

where $u_{n,t} = \partial u_t / \partial n_t$ and $u_{c,t} = \partial u_t / \partial c_t$ denote the marginal (dis-)utilities from labor and consumption, $R_t^q = (V_t + P_t \varrho_t) / V_{t-1}$ the nominal rate of return on equity, ψ_t and λ_t denote the multipliers on the goods market constraint (2) and the budget constraint (3), respectively. Finally, the following complementary slackness conditions hold in the household's optimum, *i.*) $0 \leq \mu d_{t-1} \pi_t^{-1} - c_t$, *ii.*) $\psi_t \geq 0$, *iii.*) $\psi_t (\mu d_{t-1} \pi_t^{-1} - c_t) = 0$, where $d_t = D_t / P_t$, as well as (3) with equality and an associated transversality condition. Under a binding goods market constraint (2), $\psi_t > 0$, the deposit rate tends to be lower than the expected return on equity (see 6 and 7), as demand deposits provide transaction services. It should be noted that this spread will not be analyzed further in the subsequent sections, given that it does – in contrast to other spreads introduced below – not relate to spreads investigated in our empirical analysis.

4.2 Banks

As mentioned above, banks receive demand deposits from households, supply loans to firms, and hold treasury bills and reserves for liquidity needs. The banking sector is modelled as simple as possible to facilitate comparisons to related studies, while accounting – arguably in a stylized way – for the way the Fed has typically implemented monetary policy: It announces a target for the federal funds rate, i.e., the interest rate at which depository institutions lend reserve balances to one another overnight. Reserves are originally issued by the Fed via open market operations, which determine the overall amount of available federal funds that are distributed over the banking sector via the federal funds market. Due to federal funds' unique ability to be used to satisfy reserve requirements, banks rely on federal funds market transactions when their reserves demand within a maintenance period is not directly met by central bank open market transactions. These open market operations are either carried out as outright transactions or as repurchase agreements, i.e., as permanent or temporary sales or purchases of

eligible securities, between the central bank and primary dealers (i.e., banks or broker-dealers). Outright transactions are conducted to accommodate trend growth of currency in circulation, while repurchase agreements are conducted by the Fed to fine-tune the supply of reserves such that the effective federal funds rate meets its target value.

In the short run, banks thus have access to reserves via temporary open market transactions with the central bank or via overnight transactions in the federal funds market. This implies that rates charged for both types of transactions should be similar. Although borrowing from the central bank (via repos) differs from borrowing via the federal funds market, as, e.g., interbank loans are unsecured, the rates/costs at which banks can acquire reserves are almost identical. The data show that the effective federal funds rate and the rate on Fed treasury repurchase agreements for January 2005 (where the availability of data on repo rates starts) to June 2014 differ by slightly less than one basis point on average (see Figure 14 in Appendix D), such that the spread is negligible (see also Bech et al., 2012), in particular, compared to the spreads considered above, which are typically more than 20-times larger. To account for this observation in our macroeconomic model, we assume that the federal funds rate is identical to the treasury repo rate in open market operations, while we endogenously derive spreads between these rates on the one hand and interest rates on other assets on the other hand.²¹

For the model, we consider a continuum of perfectly competitive banks $i \in [0, 1]$. A bank i receives demand deposits $D_{i,t}$ from households and supplies risk-free loans to firms $L_{i,t}$. Bank i further holds short-term government debt (i.e., treasury bills) $B_{i,t-1}$ and reserves $M_{i,t-1}$ for withdrawals of deposits by households. The central bank supplies reserves via open market operations either outright or temporarily under repurchase agreements; the latter corresponding to a collateralized loan offered by the central bank. In both cases, T-bills serve as collateral for central bank money, while the price of reserves in open market operations in terms of treasuries (the repo rate) equals R_t^m . Specifically, reserves are supplied by the central bank only in exchange for treasuries $\Delta B_{i,t}^C$, while the relative price of money is the repo rate R_t^m :

$$I_{i,t} = \Delta B_{i,t}^C / R_t^m \quad \text{and} \quad \Delta B_{i,t}^C \leq B_{i,t-1}, \quad (8)$$

where $I_{i,t}$ denotes additional money received from the central bank. Hence, (8) describes a central bank money supply constraint, which shows that bank i can acquire reserves $I_{i,t}$ in exchange for the discounted value of treasury bills carried over from the previous period $B_{i,t-1} / R_t^m$. As discussed above, we abstract from modeling an interbank market for intra-period (overnight) loans in terms of reserves and assume – consistent with US data – that the treasury repo rate and the federal funds rate are identical, and that the central bank sets the repo rate R_t^m . Reserves are held by bank i to meet liquidity demands from withdrawals of

²¹The introduction of interest on reserves by the Fed during the recent financial crisis has aimed at enhancing the control over the effective federal funds rate even under large holdings of excess reserves. In this situation, reversed repurchase agreements, which have recently been expanded by the Fed, facilitate controlling the federal funds rate.

deposits

$$\mu D_{i,t-1} \leq I_{i,t} + M_{i,t-1}. \quad (9)$$

By imposing the constraint (9), we implicitly assume that a reserve requirement is either identical to the expected withdrawals or slack. Banks supply one-period risk-free loans $L_{i,t}$ to firms at a period t price $1/R_t^L$ and a payoff $L_{i,t}$ in period $t+1$. Thus, R_t^L denotes the rate at which firms can borrow and corresponds to the AAA corporate bond rate in the empirical analysis in Section 3. Banks further hold T-bills issued at the price $1/R_t$, which are eligible for open market operations (see 8). Given that bank i transferred T-bills to the central bank under outright sales and that it repurchases a fraction of T-bills, $B_{i,t}^R = R_t^m M_{i,t}^R$, from the central bank, its holdings of T-bills before it enters the asset market equal $B_{i,t-1} + B_{i,t}^R - \Delta B_{i,t}^C$ and its money holdings equal $M_{i,t-1} - R_t^m M_{i,t}^R + I_{i,t}$. Hence, bank i 's profits $P_t \varphi_{i,t}^B$ are given by

$$\begin{aligned} P_t \varphi_{i,t}^B &= (D_{i,t}/R_t^D) - D_{i,t-1} - M_{i,t} + M_{i,t-1} - I_{i,t} (R_t^m - 1) \\ &\quad - (B_{i,t}/R_t) + B_{i,t-1} - (L_{i,t}/R_t^L) + L_{i,t-1} + (A_{i,t}/R_t^A) - A_{i,t-1}. \end{aligned} \quad (10)$$

where $A_{i,t}$ denotes a risk-free one-period interbank deposit liability issued at the price $1/R_t^A$, which cannot be withdrawn before maturity. Thus, R_t^A is the rate at which banks can freely borrow and lend among each other, which relates closely to the US-LIBOR rates investigated in the empirical analysis (see Section 3). Notably, the aggregate stock of reserves only changes with central bank money supply, $\int_0^1 M_{i,t} di = \int_0^1 (M_{i,t-1} + I_{i,t} - M_{i,t}^R) di$, and is fully backed by treasury bills, whereas demand deposits can be created by the banking sector subject to (9).

Banks maximize the sum of discounted profits, $E_t \sum_{k=0}^{\infty} p_{t,t+k} \varphi_{i,t+k}^B$, where $p_{t,t+k}$ denotes the stochastic discount factor $p_{t,t+k} = \beta^k \lambda_{t+k}/\lambda_t$, subject to the money supply constraint (8), the liquidity constraint (9), the budget constraint (10), and the borrowing constraints $\lim_{s \rightarrow \infty} E_t [p_{t,t+k} (D_{i,t+s} + A_{i,t+s})/P_{t+s}] \geq 0$, $B_{i,t} \geq 0$, and $M_{i,t} \geq 0$. The first order conditions of the representative bank with respect to deposits, T-bills, corporate and interbank loans, money holdings, and reserves can be written as

$$\frac{1}{R_t^D} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1 + \mu \varkappa_{i,t+1}}{\pi_{t+1}}, \quad (11)$$

$$\frac{1}{R_t} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1 + \eta_{i,t+1}}{\pi_{t+1}}, \quad (12)$$

$$\frac{1}{R_t^L} = \frac{1}{R_t^A} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \pi_{t+1}^{-1}, \quad (13)$$

$$1 = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1 + \varkappa_{i,t+1}}{\pi_{t+1}}, \quad (14)$$

$$\varkappa_{i,t} + 1 = R_t^m (\eta_{i,t} + 1), \quad (15)$$

where $\varkappa_{i,t}$ and $\eta_{i,t}$ denote the multipliers on the liquidity constraint (9) and the money supply constraint (8), respectively. Apparently, the rates on corporate and interbank loans are identical (see 13). Further, the following complementary slackness conditions hold in the bank's optimum

i.) $0 \leq b_{i,t-1}\pi_t^{-1} - R_t^m i_{i,t}$, $\eta_{i,t} \geq 0$, $\eta_{i,t} (b_{i,t-1}\pi_t^{-1} - R_t^m i_{i,t}) = 0$, and *ii.*) $0 \leq i_{i,t} + m_{i,t-1}\pi_t^{-1} - \mu d_{i,t-1}\pi_t^{-1}$, $\varkappa_{i,t} \geq 0$, $\varkappa_{i,t} (i_{i,t} + m_{i,t-1}\pi_t^{-1} - \mu d_{i,t-1}\pi_t^{-1}) = 0$, where $d_{i,t} = d_{i,t}/P_t$, $m_{i,t} = M_{i,t}/P_t$, $b_{i,t} = B_{i,t}/P_t$, and $i_{i,t} = I_{i,t}/P_t$, and the associated transversality condition.

4.3 Firms

There is a continuum of intermediate goods producing firms, which sell their goods to monopolistically competitive retailers. The latter sell a differentiated good to bundlers who assemble final goods using a Dixit-Stiglitz technology. Intermediate goods producing firms are identical, perfectly competitive, owned by households, and produce an intermediate good y_t^m with labor n_t according to $y_t^m = n_t$, and sell the intermediate good to retailers at the price P_t^m . We neglect retained earnings and assume that firms rely on bank loans to finance wage outlays before goods are sold. Hence, firms' loan demand satisfies:

$$L_t/R_t^L \geq P_t w_t n_t. \quad (16)$$

Firms are committed to fully repay their liabilities, such that bank loans are default-risk free. The problem of a representative firm can then be summarized as $\max E_t \sum_{k=0}^{\infty} p_{t,t+k} \varrho_{t+k}$, where ϱ_t denotes real dividends $\varrho_t = (P_t^m/P_t)n_t - w_t n_t - l_{t-1}\pi_t^{-1} + l_t/R_t^L$, subject to (16). The first order conditions for labor demand and loan demand are then given by

$$1 + \gamma_t = R_t^L E_t [p_{t,t+1}\pi_{t+1}^{-1}], \quad (17)$$

$$P_t^m/P_t = (1 + \gamma_t) w_t, \quad (18)$$

where γ_t denotes the multiplier on the loan demand constraint (16). Given that we abstract from financial market frictions, the Modigliani-Miller theorem applies here, such that the multiplier γ_t equals zero. This can immediately be seen from combining banks' loan supply condition (13) with the firm's loan demand condition (17), implying $\gamma_t = 0$. Hence, the loan demand constraint (16) is slack, such that the firm's labor demand (18) will be undistorted, $P_t^m/P_t = w_t$. Monopolistically competitive retailers and their price setting decisions are specified as usual in New Keynesian models and are described in Appendix B.1.

4.4 Public sector

The public sector consists of a government and a central bank. The government purchases goods and issues short-term bonds B_t^T . Short-term debt is held by banks, B_t , and by the central bank, B_t^C , i.e., $B_t^T = B_t + B_t^C$, and corresponds to T-bills (as a period is interpreted as three months). To isolate effects of government spending shocks and to facilitate comparisons with related studies (see, e.g., Christiano et al., 2011), we assume that the government can raise or transfer revenues in a non-distortionary way, $P_t \tau_t$. Given that, in contrast to total government debt, the supply of T-bills is typically not significantly related to changes in government spending

(see Figure 15 in Appendix D), we neglect a direct feedback from government spending and assume that the supply of treasury bills is exogenously determined by a constant growth rate Γ ,

$$B_t^T = \Gamma B_{t-1}^T, \quad (19)$$

where $\Gamma > \beta$. For simplicity, we neither model longer-term government debt nor total government debt. To appropriately account for the role of long-term treasury debt, which has in particular been purchased by the Fed in their recent large scale asset purchase programmes, they should be specified as partially eligible for central bank operations. It can be shown that the associated yields would then behave like a combination of the T-bill rate and corporate debt rate, which roughly accords with the empirical evidence provided in Section 3. The government budget constraint is thus given by

$$(B_t^T/R_t) + P_t\tau_t^m = P_t g_t + B_{t-1}^T + P_t\tau_t,$$

where $P_t\tau_t^m$ denotes the transfers from the central bank and government expenditures g_t are stochastic (see below).

The central bank supplies money in exchange for T-bills either outright, M_t , or under repos M_t^R . At the beginning of each period, the central bank's stock of T-bills equals B_{t-1}^C and the stock of outstanding money equals M_{t-1} . It then receives an amount ΔB_t^C of T-bills in exchange for newly supplied money $I_t = M_t - M_{t-1} + M_t^R$, and, after repurchase agreements are settled, its holdings of treasuries and the amount of outstanding money reduce by B_t^R and by M_t^R , respectively. Before the asset market opens, where the central bank can reinvest its payoffs from maturing securities in T-bills B_t^C , it holds an amount equal to $\Delta B_t^C + B_{t-1}^C - B_t^R$. Its budget constraint is thus given by $(B_t^C/R_t) + P_t\tau_t^m = \Delta B_t^C + B_{t-1}^C - B_t^R + M_t - M_{t-1} - (I_t - M_t^R)$, which after substituting out I_t , B_t^R , and ΔB_t^C using $\Delta B_t^C = R_t^m I_t$, can be simplified to $(B_t^C/R_t) - B_{t-1}^C = R_t^m (M_t - M_{t-1}) + (R_t^m - 1) M_t^R - P_t\tau_t^m$. Following central bank practice, we assume that interest earnings are transferred to the government, $P_t\tau_t^m = B_t^C (1 - 1/R_t) + (R_t^m - 1) (M_t - M_{t-1} + M_t^R)$, such that holdings of treasuries evolve according to $B_t^C - B_{t-1}^C = M_t - M_{t-1}$. Further restricting initial values to $B_{-1}^C = M_{-1}$ leads to the central bank balance sheet

$$B_t^C = M_t. \quad (20)$$

Regarding the implementation of monetary policy, we assume that the central bank sets the policy rate R_t^m following a Taylor-type feedback rule (see below). The target inflation rate π is controlled by the central bank and will be equal to the growth rate of treasuries Γ . This assumption is supported by the data (see Section 5.2.1) and is not associated with a loss of generality, as the central bank can implement its inflation targets even if $\pi \neq \Gamma$, as shown in Schabert (2015). Finally, the central bank fixes the fraction of money supplied under repurchase agreements relative to money supplied outright at $\Omega \geq 0$: $M_t^R = \Omega M_t$. For the subsequent

analysis, Ω will be set at a sufficiently large value ensuring that central bank money injections I_t are non-negative.

4.5 Equilibrium properties

Given that households, firms, retailers, and banks behave in an identical way, we can omit indices. A definition of the rational expectations equilibrium can be found in Appendix B.2. It should be noted that the Modigliani-Miller theorem applies here as financial markets are frictionless. The main difference to a standard New Keynesian model is the money supply constraint (8), which ensures that reserves are fully backed by treasuries. The model in fact reduces to a New Keynesian model with a conventional cash-in-advance constraint (see also Christiano et al.'s, 2011, medium scale model) if the money supply constraint (8) is slack. The fiscal policy effects of this latter model version, which is summarized in Definition 2 in Appendix B.2, closely relate to the predictions of a standard New Keynesian model without cash (see Proposition 1). By contrast, the results of our model with a binding money supply constraint and therefore with a liquidity premium differ markedly (see Proposition 2).

In our model, rates of return on non-eligible assets (i.e., loans and equity) exceed the policy rate and the T-bill rate by a liquidity premium if (8) is binding. This is the case when the central bank supplies money at a lower price than households are willing to pay, $R_t^m < R_t^{IS}$, where R_t^{IS} denotes the nominal marginal rate of intertemporal substitution of consumption

$$R_t^{IS} = u_{c,t}/\beta E_t(u_{c,t+1}/\pi_{t+1}), \quad (21)$$

which measures the marginal valuation of money by the private sector.²² For $R_t^m < R_t^{IS}$, households thus earn a positive rent and are willing to increase their money holdings. Given that access to money is restricted by holdings of treasury bills, the money supply constraint (8) is then binding. To see this, combine (7) with (11) to get $E_t[\frac{\lambda_{t+1} + \mu\psi_{t+1}}{\lambda_t} \pi_{t+1}^{-1}] = E_t[\frac{\lambda_{t+1}}{\lambda_t} (1 + \varkappa_{t+1}\mu) \pi_{t+1}^{-1}]$, which holds if the liquidity constraint multipliers satisfy $\varkappa_t = \psi_t/\lambda_t$. Hence, the equilibrium versions of the conditions (14) and (15) imply $(\psi_t + \lambda_t)/\lambda_t = R_t^m(\eta_t + 1)$ and $\beta\pi_{t+1}^{-1}(\lambda_{t+1} + \psi_{t+1}) = \lambda_t$, which can – by using the equilibrium version of condition (5) – be combined to

$$\eta_t = (R_t^{IS}/R_t^m) - 1. \quad (22)$$

Condition (22) implies that the money supply constraint (8) is binding, $\eta_t > 0$, if the central bank sets the policy rate R_t^m below R_t^{IS} . Given that short-term treasuries and money are close substitutes, the T-bill rate R_t relates to the expected future policy rate, which can be seen from combining (12) with (14) and (15), $R_t \cdot E_t \varsigma_{1,t+1} = E_t[R_{t+1}^m \cdot \varsigma_{1,t+1}]$, where $\varsigma_{1,t+1} =$

²²Agents are willing to spend $R_t^{IS} - 1$ to transform one unit of an illiquid asset, i.e. an asset that is not accepted as a means of payment today and delivers one unit of money tomorrow, into one unit of money today.

$\lambda_{t+1} (1 + \eta_{t+1}) / \pi_{t+1}$. Thus, the T-bill rate equals the expected policy rate up to first order,

$$R_t = E_t R_{t+1}^m + \text{h.o.t.}, \quad (23)$$

where h.o.t. represents higher order terms.²³ Combining (13), with $\beta E_t \pi_{t+1}^{-1} (\lambda_{t+1} + \psi_{t+1}) = \lambda_t$ (see 13) shows that the loan rates R_t^L and R_t^A relate to the expected marginal rate of intertemporal substitution $(1/R_t^{L,A}) \cdot E_t \varsigma_{2,t+1} = E_t [(1/R_{t+1}^{IS}) \cdot \varsigma_{2,t+1}]$, where $\varsigma_{2,t+1} = (\lambda_{t+1} + \psi_{t+1}) / \pi_{t+1}$. Likewise, (7) implies that the expected rate of return on equity is related to the expected marginal rate of intertemporal substitution: $E_t \varsigma_{2,t+1} = E_t [(R_{t+1}^q / R_{t+1}^{IS}) \cdot \varsigma_{2,t+1}]$. Hence, the corporate and interbank loan rates are equal to the expected marginal rate of intertemporal substitution up to first order,

$$R_t^L = R_t^A = E_t R_{t+1}^{IS} + \text{h.o.t.}, \quad (24)$$

while the expected rate of return on equity satisfies, $E_t R_{t+1}^q = E_t R_{t+1}^{IS} + \text{h.o.t.}$. Accordingly, the spread between the marginal rate of intertemporal substitution and the monetary policy rate, $R_t^{IS} - R_t^m$, captures how rates of return on non-eligible assets deviate from the monetary policy rate and summarizes how interest rates in the current model differ from those of a standard model. When we derive analytical results in Section 5.1, we therefore focus on the difference between R_t^{IS} and R_t^m to unveil the main mechanism at work, while in the quantitative analysis in Section 5.2 we present impulse responses of the loan rate R_t^L that corresponds to the 3-months US LIBOR rate and the AAA corporate bond rate investigated in Section 3.

It should further be noted that, as long as the nominal marginal rate of intertemporal substitution (rather than the policy rate R_t^m) exceeds one, i.e., $R_t^{IS} > 1$, the demand for money is well defined, as the liquidity constraints of households (2) and banks (9) are binding. This can be seen by substituting out the multiplier \varkappa_t in the equilibrium version of (14) with $\varkappa_t = \psi_t / \lambda_t$ and combining with the equilibrium version of (5), which leads to

$$\psi_t = u_{c,t} (1 - 1/R_t^{IS}). \quad (25)$$

Thus, (25) implies that the household's liquidity constraint (2) as well as the bank's liquidity constraint (9) are binding if R_t^{IS} is strictly larger than one. Notably, liquidity might also be positively valued by households and banks, i.e., $R_t^{IS} > 1$, even when the policy rate is at the zero lower bound, $R_t^m = 1$; this property also being relevant during the recent US zero lower bound episode where liquidity premia have still been positive (see Figure 11 in Appendix D).

5 Fiscal policy effects predicted by the model

In this section, we examine the models' predictions regarding the macroeconomic effects of government spending shocks, paying particular attention to the role of monetary policy. In the

²³Notably, the relation (23) accords with the empirical evidence provided by Simon (1990).

first part of this section, we analytically derive results on fiscal policy effects. In the second part, we add some model features that are typically applied for quantitative purposes in related studies and present impulse response functions. Throughout this section, we separately analyze two versions of the model which differ with regard to the relation between the monetary policy rate and the marginal rate of intertemporal substitution. As a reference case, we consider the case where the monetary policy rate and the marginal rate of intertemporal substitution are identical, as in the standard New Keynesian model. From this conventional point of view, the empirical results on government spending shocks in Section 3 constitute a clear puzzle. We then examine the case where the monetary policy rate is set below the marginal rate of intertemporal substitution. Given that the latter closely relates to the rates on non-eligible corporate and interbank loans (see 24), a liquidity premium exists in this case, which corresponds to spreads between the federal funds rate and other rates of return considered in the empirical analysis, such as the AAA corporate bond rate and the US LIBOR. This version will be shown to be able to rationalize the empirical effects of government spending shocks on output and interest rates.

5.1 Analytical results

To disclose the impact of the main non-standard model feature, we separately analyze the cases where either the money supply constraint (8) is binding, which leads to an endogenous liquidity premium, or where money supply is de-facto unconstrained, implying that the policy rate R_t^m equals the marginal rate of intertemporal substitution R_t^{IS} . Technically, this means that we assume (for the former case) that the central bank sets the policy rate in the long run below or (for the latter case) equal to $R^{IS} = \pi/\beta$, where time indices are omitted to indicate steady state values. For both cases, we examine the local dynamics in the neighborhood of the respective steady state.²⁴ There, the equilibrium sequences are approximated by the solutions to the linearized equilibrium conditions, where \hat{a}_t denotes relative deviations of a generic variable a_t from its steady state value a : $\hat{a}_t = \log(a_t/a)$. To facilitate the derivation of analytical results, we assume that outright money supply is negligible, $\Omega \rightarrow \infty$, which reduces the set of endogenous state variables. We further assume that the central bank targets long-run price stability $\pi = 1$, that the growth rate of T-bills equals the inflation rate $\Gamma = \pi$, in line with the data (see Section 5.2.1),²⁵ and that government spending shocks are i.i.d..

Definition 3 *A rational expectations equilibrium for $\Omega \rightarrow \infty$ and $\Gamma = \pi = 1$ is a set of*

²⁴We further assume that shocks are sufficiently small such that the ZLB is never binding. See Section 5.2.3 for an analysis of fiscal policy effects at the ZLB.

²⁵Notably, the latter assumption is not necessary for the implementation of long-run price stability, since the central bank can in principle adjust the share of short-term treasuries that are eligible for money supply operations to implement the desired inflation target, as shown by Schabert (2015).

convergent sequences $\{\widehat{c}_t, \pi_t, \widehat{b}_t, \widehat{R}_t^{IS}, \widehat{R}_t^m\}_{t=0}^\infty$ satisfying

$$\widehat{c}_t = \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m < R_t^{IS}, \quad (26)$$

$$\text{or } \widehat{c}_t \leq \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m = R_t^{IS},$$

$$\sigma \widehat{c}_t = \sigma E_t \widehat{c}_{t+1} - \widehat{R}_t^{IS} + E_t \widehat{\pi}_{t+1}, \quad (27)$$

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \chi(\sigma_n c_y + \sigma) \widehat{c}_t + \chi \sigma_n g_y \widehat{g}_t + \chi \widehat{R}_t^{IS}, \quad (28)$$

$$\widehat{b}_t = \widehat{b}_{t-1} - \widehat{\pi}_t, \quad (29)$$

where $c_y = \frac{c}{c+g}$, $g_y = \frac{g}{c+g}$, and $\chi = (1 - \phi)(1 - \beta\phi)/\phi$ for a monetary policy rate satisfying

$$\widehat{R}_t^m = \rho_\pi \widehat{\pi}_t + \rho_g \widehat{g}_t, \quad (30)$$

where $\rho_\pi \geq 0$, government expenditures satisfying $g_t/g = \exp \varepsilon_t^g$, with $g \in (0, c)$ and $E_{t-1} \varepsilon_t^g = 0$, and given $b_{-1} > 0$.

We start by analyzing the reference case where the money supply constraint (8) is not binding, such that the policy rate equals the marginal rate of intertemporal substitution, $R_t^m = R_t^{IS}$, and there is no liquidity premium. Given that condition (26) is then slack, the model reduces to a standard New Keynesian model with a cash-in-advance constraint; the latter being responsible for the nominal interest rate to affect the marginal rate of substitution between consumption and working time and therefore to enter the aggregate supply constraint (28). While the effects of fiscal policy shocks under a standard Taylor rule in this model are well established, we focus on the situation where the monetary policy rate falls in response to government expenditures, which is observed empirically (see Section 3) and is induced by a direct monetary policy reaction to government spending, ρ_g (see 30), as specified in Nakamura and Steinsson (2014).

Proposition 1 *Suppose that the policy rate equals the marginal rate of intertemporal substitution, $R_t^m = R_t^{IS}$, such that there is no liquidity premium. If the nominal or the real policy rate fall in response to an expansionary government spending shock, private consumption increases and the fiscal multiplier is larger than one.*

Proof. See Appendix. ■

As shown by Aiyagari et al. (1992) or Baxter and King (1993), in a dynamic general equilibrium model government spending leads to a negative wealth effect. Private agents therefore tend to reduce consumption and leisure, which is associated with a decline in the real interest rate and a positive fiscal multiplier. This basic transmission channel of government spending can, however, be dominated under the assumption – applied in New Keynesian models – that the monetary policy rate equals the nominal marginal rate of intertemporal substitution R_t^{IS} . If the real policy rate actually falls in response to a government spending shock, whether due to a direct response of the nominal rate (as in 30), a combination of a fixed nominal rate and higher expected inflation, private agents increase current consumption relative to future consumption, such that private consumption is crowded in. This mechanism has been made responsible for large multipliers when the nominal policy rate is stuck at the ZLB and the inflationary

effect of a government spending shock leads to a fall in real rates (see Christiano et al., 2011). For the version of our model where the policy rate equals the marginal rate of intertemporal substitution, Proposition 1 confirms the prediction of falling real policy rates being associated with a multiplier larger than one, which is, in general, not supported by the data in Section 3. Put differently, the simultaneous observation of a fiscal multiplier below one and a decline in the real policy rate is a puzzle through the lens of a standard New Keynesian model.

Once the marginal rate of intertemporal substitution, which closely relates to the returns on non-eligible and thus illiquid assets (see 24), and the policy rate are separated, it is possible to explain the empirical facts. We therefore turn to the case where the policy rate is set below the marginal rate of intertemporal substitution, $R_t^m < R_t^{IS}$, which implies that the money supply constraint and therefore (26) are binding, and that there exists a liquidity premium. Before we analyze the effects of fiscal policy shocks, we briefly examine equilibrium determinacy conditions, i.e., conditions for the existence and the uniqueness of locally convergent equilibrium sequences, which are summarized in the following lemma.

Lemma 1 *Suppose that $R_t^m < R_t^{IS}$. Then, a rational expectations equilibrium is locally determined if but not only if*

$$\rho_\pi < [(1 + \beta)\chi^{-1} + 1 - \sigma]/\sigma. \quad (31)$$

Proof. See Appendix C. ■

Condition (31) in Lemma 1 implies that, under a binding money supply constraint (8), an active monetary policy ($\rho_\pi > 1$) is not relevant for equilibrium determinacy and that the central bank can even peg the policy rate ($\rho_\pi = 0$) without inducing indeterminacy.²⁶ It should further be noted that the sufficient condition (31) is far from being restrictive for a broad range of reasonable parameter values. Consider, for example, the parameter values $\beta = 0.9946$, $\sigma = 2$ and $\phi = 0.75$ which we use in our numerical model evaluations in Section 5.2. Then, $\chi = 0.084$ and the upper bound equals 11.233, which is much larger than values typically estimated for the inflation feedback ρ_π .

We now analyze fiscal policy effects for the model version with the liquidity premium. We first derive conditions under which the model is able to generate predictions regarding government spending effects that are qualitatively consistent with the empirical results presented in Section 3. Specifically, we are interested in conditions for which a government spending shock leads to a decline in the policy rate and in private consumption (implying a fiscal multiplier below one) as well as to an increase in the real marginal rate of intertemporal substitution R_t^{IS}/π_{t+1} ; the latter corresponding to an increase in real rates of return on illiquid assets. These conditions are expressed in terms of the direct feedback from government spending on

²⁶This property is mainly due to a bounded supply of eligible assets, i.e., treasuries, by which reserves are backed and which provide a nominal anchor for monetary policy (similar to a constant growth rate of money). Therefore, a passive interest rate policy ($\rho_\pi < 1$) does not per se lead to multiple equilibria (as in standard New Keynesian models).

the policy rate, measured by the coefficient ρ_g , and are summarized in the following lemma.²⁷

Lemma 2 *Suppose that $R_t^m < R_t^{IS}$ and that (31) is satisfied. Then, an unexpected increase in government spending leads on impact to*

1. *a fall in the nominal and real policy rate if $\rho_g < \overline{\rho}_g(\rho_\pi)$ where $\overline{\rho}_g(\rho_\pi) \leq 0$,*
2. *a fall in private consumption if $\rho_g > \underline{\rho}_g(\rho_\pi)$, where $\underline{\rho}_g(\rho_\pi) < 0$,*
3. *a rise in aggregate output if $\rho_g < 1$, and*
4. *a rise in the real marginal rate of intertemporal substitution if $\rho_g > \tilde{\rho}_g(\rho_\pi)$ for $\tilde{\rho}_g(\rho_\pi) < 0$ or $\rho_g < \tilde{\rho}_g(\rho_\pi)$ for $\tilde{\rho}_g(\rho_\pi) > 0$.*

Proof. See Appendix C. ■

Consider first the case where the policy rate does not directly respond to government spending, $\rho_g = 0$, such that the parameter restrictions 2.-4. in Lemma 2 are satisfied. Then, an increase in government spending leads to a positive fiscal multiplier below one and raises the marginal rate of intertemporal substitution, regardless of monetary policy fulfilling the Taylor principle ($\rho_\pi < 1$) or not ($\rho_\pi > 1$). In fact, the separation of the real policy rate and the real marginal rate of intertemporal substitution due to the liquidity premium is responsible for real effects of government spending to be dominated by the negative wealth effect discussed above. Given that government expenditures are inflationary, as they tend to increase firms' real marginal costs, the real policy rate tends to increase if the inflation feedback satisfies $\rho_\pi > 1$ (which would be consistent with a consumption crowding-out according to both model versions, see Section 5.2.4). A rise in the policy rate is however not observed in the data (see Section 3). Thus, reproducing the observed negative responses of the nominal and the real policy rate in response to a positive government spending shock requires a negative value for the direct government spending feedback, $\rho_g < \overline{\rho}_g$ (where the threshold is declining in the inflation feedback, $\overline{\rho}_g'(\rho_\pi) < 0$).

As indicated by the equilibrium conditions in Definition 3, monetary policy is (also) non-neutral when the policy rate and the marginal rate of intertemporal substitution are separated. An expansionary monetary policy, i.e., a lower policy rate R_t^m , then tends to stimulate current private consumption by lowering the price of money in terms of eligible assets (see 26), which eases private sector access to means of payments. Thus, a reduction of the policy rate in response to higher government spending can in principle stimulate private consumption. Precisely, the model predicts a consumption crowding-out and thus a fiscal multiplier below one only if the policy rate response is not too negative, i.e., $\rho_g > \underline{\rho}_g(\rho_\pi)$ where $\underline{\rho}_g(\rho_\pi) < 0$. By contrast, a standard New Keynesian model can generate a consumption crowding-out and a fiscal multiplier below one only for positive responses of the policy rate to government spending

²⁷The composite coefficients defining the thresholds in Lemma 2 are given by $\underline{\rho}_g(\rho_\pi) \equiv -(1 + \rho_\pi) \chi \sigma_n g_y / \Gamma_1$, $\overline{\rho}_g(\rho_\pi) \equiv -\rho_\pi g_y \chi \sigma_n / (\chi \sigma_n c_y + \Gamma_1)$, $\tilde{\rho}_g(\rho_\pi) \equiv -(\Gamma_2 + \rho_\pi \chi \sigma_n) g_y / (\Gamma_1 + (\chi \sigma_n - \Gamma_2) c_y)$, $\Gamma_1 = [\beta + \chi(1 - \sigma) - \chi \sigma \rho_\pi] (1 - \gamma_b) + \chi \sigma + 1 > 0$, and $\Gamma_2 = (1 + \rho_\pi) (1 - \gamma_b) \chi \sigma_n > 0$, where $\gamma_b \in (0, 1)$.

(see Proposition 1). For the model version with a liquidity premium, it can be shown that there exists a non-empty set of values for the interest rate feedback parameter ρ_g for which the fiscal multiplier lies between zero and one, while the policy rate falls and the real marginal rate of intertemporal substitution increases, implying an increase in the liquidity premium. Thus, the model is able to generate output and interest rate responses to a government spending shock that are consistent with the empirical facts documented in Section 3.

Proposition 2 *When a liquidity premium exists and (31) is satisfied, an unexpected increase in government spending can simultaneously lead to a fiscal multiplier between zero and one associated with a fall in the nominal and real policy rate as well as with a rise in the real marginal rate of intertemporal substitution.*

Proof. See Appendix C. ■

As summarized in Proposition 2, the model with a liquidity premium can reproduce the – seemingly puzzling – joint observation of a fall in the real policy rate and a moderate fiscal multiplier, particularly, below one. Since the real marginal rate of intertemporal substitution rises in this case, i.e., when the feedback coefficient satisfies $\rho_g \in A$, real rates of return on non-eligible assets (e.g., corporate debt and bank loans) tend to increase in response to a fiscal shock consistent with the empirical evidence.²⁸ While these results establish the model’s principle ability to qualitatively rationalize observed fiscal policy effects, we further assess if the predictions of a calibrated version of the model accord with the empirical facts. For this, we extend the model in the subsequent section by adding some standard features, which are typically considered in related studies, and examine the responses to government spending shocks for a calibrated version.

5.2 Effects under three monetary policy scenarios

In this subsection, we first introduce some additional model features, which are widely viewed as useful for a quantitative analysis of New Keynesian models, before we describe the model’s calibration. We then examine the impulse responses of the model to government spending shocks under three scenarios for the monetary policy rate. First, we analyze the case where the monetary policy rate responds to the fiscal shock as observed in the data (see Section 3), and show that the model’s main predictions are consistent with the empirical counterparts. Second, we examine the prominent case where the monetary policy rate is fixed at the ZLB. Third, we consider the case where the monetary policy rate counterfactually increases in response to higher government spending. We compare the results of our model with the liquidity premium to the results of a model version without the liquidity premium, where the latter confirms results known from New Keynesian models.

²⁸It should be noted that even though government spending shocks are i.i.d. in this simple version of the model, the model exhibits history dependence due to a stable eigenvalue associated with short-term public debt, which here implies that $E_t R_{t+1}^{IS}$ is positively related to R_t^{IS} .

5.2.1 Additional model features and calibration

To analyze the model's impulse responses to government spending shocks, we introduce additional features to the basic model of Section 4 that are also considered by Christiano et al. (2011) for a quantitative analysis of the fiscal multiplier. These additional features are (external) habit persistence, endogenous capital formation, adjustment costs of capital, an interest rate rule that is more realistic than (30), and serial correlation of government spending. We further introduce credit goods (see Lucas and Stokey, 1987) to account for the fact that the majority of transactions do not involve cash.

Specifically, the instantaneous utility function is now given by $u(c_t, \bar{c}_t, n_t) = [(c_t - hc_{t-1})^{1-\sigma}/(1-\sigma)] + \gamma[(\bar{c}_t - h\bar{c}_{t-1})^{1-\sigma}/(1-\sigma)] - \theta n_t^{1+\sigma_n}/(1+\sigma_n)$, where $\gamma \geq 0$, \bar{c}_t denotes consumption of credit goods, c_t (\bar{c}_t) denotes the cross sectional average of cash (credit) goods, and $h \geq 0$ indicates external habit formation. Intermediate goods are now produced according to the production function $y_t^m = n_t^\alpha k_{t-1}^{1-\alpha}$ with $\alpha \in (0, 1)$, while physical capital k_t is accumulated according to $k_t = (1-\delta)k_{t-1} + x_t \Lambda_t$, where δ is the rate of depreciation, x_t are investment expenditures, and the function Λ_t denotes investment adjustment costs satisfying $\Lambda(x_t/x_{t-1}) = 1 - \zeta \frac{1}{2} (x_t/x_{t-1} - 1)^2$. Further, the interest rate feedback rule allows for inertia and output-gap responses, such that the policy rate satisfies

$$R_t^m = \max\{1, (R_{t-1}^m)^{\rho_R} (R^m)^{1-\rho_R} (\pi_t/\pi)^{\rho_\pi(1-\rho_R)} (y_t/\tilde{y}_t)^{\rho_y(1-\rho_R)} (g_t/g)^{\rho_g(1-\rho_R)}\}, \quad (32)$$

where $\rho_R \geq 0$, $\rho_y \geq 0$, and \tilde{y}_t denotes the efficient level of output (instead of 30). To allow for the observed autocorrelation in government spending, we assume that government spending is generated by $g_t = \rho g_{t-1} + (1-\rho)g + \varepsilon_{g,t}$, where $\varepsilon_{g,t}$ are mean zero i.i.d. innovations, $\rho \in (0, 1)$, and $g > 0$. For the analysis of the fiscal multiplier at the ZLB, we follow Christiano et al. (2011) and add an autocorrelated (mean one) discount factor shock ξ_t to the household objective, which then reads $E_0 \sum_{t=0}^{\infty} \beta^t \xi_t u_t$, instead of (1). The full set of equilibrium conditions for this extended version of the model can be found in Definition 4 in Appendix C.

For the first set of parameters $\{\sigma, \sigma_n, \alpha, \delta, \epsilon, \theta, \phi, g/y, h, \rho_\pi, \rho_y, \rho_R\}$ we apply values (according to an interpretation of a period as a quarter) that are standard in the literature, facilitating comparisons with related studies.²⁹ Specifically, we set the inverses of the elasticities of intertemporal substitution to $\sigma = 2$ and $\sigma_n = 2$, the labor income share to $\alpha = 2/3$, and the depreciation rate to $\delta = 0.025$. The elasticity of substitution ϵ is set to $\epsilon = 6$, and the utility parameter θ is chosen to lead to a steady state working time of $n = 1/3$. For the fraction of non-optimally price adjusting firms ϕ we apply the standard value $\phi = 0.75$. The mean government share and the habit formation parameter are set at $g/y = 0.2$ and $h = 0.7$. The coefficients of the interest rate rule that do not relate directly to government spending are set at values typically applied in the literature, $\rho_\pi = 1.5$, $\rho_y = 0.05$, and $\rho_R = 0.8$.

²⁹Note that the parameter μ that relates consumption of cash goods to deposits (see 2) is only required to determine real deposits and the deposit rate, which are both not relevant for the subsequent analysis.

The second set of parameters $\{R^m, \pi, \Gamma, \Omega, \beta, \zeta, \gamma\}$, which relate to the liquidity premium as the model's main difference compared to standard models, are set as follows. For the policy rate and the inflation rate, we set the average values equal to the sample means of the federal funds rate and the CPI inflation rate for 1979.IV-2015.IV, $R^m = 1.0510^{1/4}$ and $\pi = 1.0315^{1/4}$. Regarding the supply of government liabilities, we apply US data until 2007.III, where the US Federal Reserve began to massively increase repurchase agreements in response to the recent subprime crisis. In the sample 1979.IV-2007.III, the average growth rate of nominal T-bills relative to real GDP was almost identical to the average rate of CPI inflation and, accordingly, we set $\Gamma = \pi$ (as in the simplified model of Section 5.1). Given that we do not model cash holdings of households, we use information on the mean fraction of repos to total reserves of depository institutions from Jan. 2003 to Aug. 2007 (where the starting point of the sample is determined by data availability) implying a ratio of money supplied under repos to outright money holdings Ω equal to 1.5. The discount factor β is set to $\beta = 0.9946$, which implies that the steady state spread between the nominal marginal rate of intertemporal substitution R^{IS} and the monetary policy rate R^m equals 0.0028 for annualized rates, in accordance with the mean spread between the 3-month US-LIBOR and the federal funds rate for 1986.I (when LIBOR was introduced) to 2015.IV. The investment adjustment cost parameter ζ is set at 0.065, which accords with Groth and Khan's (2010) estimate based on firm-level data and is lower than values typically applied for models without liquidity premia, where changes in the real policy rate would otherwise lead to extreme changes in investment (see, e.g., Christiano et al., 2011). The utility weight of credit goods γ is set at a conservative value 35, which replicates the 2012 US share of cash transactions of 14%, taken from Bennett et al. (2014).

Two parameter values that are crucial for the relation between the responses of the policy rate and of output, namely, the government spending feedback coefficient in the interest rate rule (see 32) and the autocorrelation of government spending $\{\rho_g, \rho\}$ are chosen in accordance with our empirical analysis. In particular, we set the autocorrelation of government spending to 0.90, which roughly matches the paths of government spending in the VARs. Finally, the fiscal feedback coefficient of the interest rate rule ρ_g is set at -0.75 to approximate the responses of the federal funds rate to a 1% government expenditure shock in the *AG* VAR and in the *BP* VAR (see Figure 6). For these parameter values, the equilibrium is locally determinate (which accords with the result summarized in Lemma 1) for all versions of the model considered below. To demonstrate the robustness of the main results we present results for alternative values for the parameters $\{\rho_g, \rho, h, \sigma, \Omega, \zeta\}$ in Appendix D.

5.2.2 A falling monetary policy rate

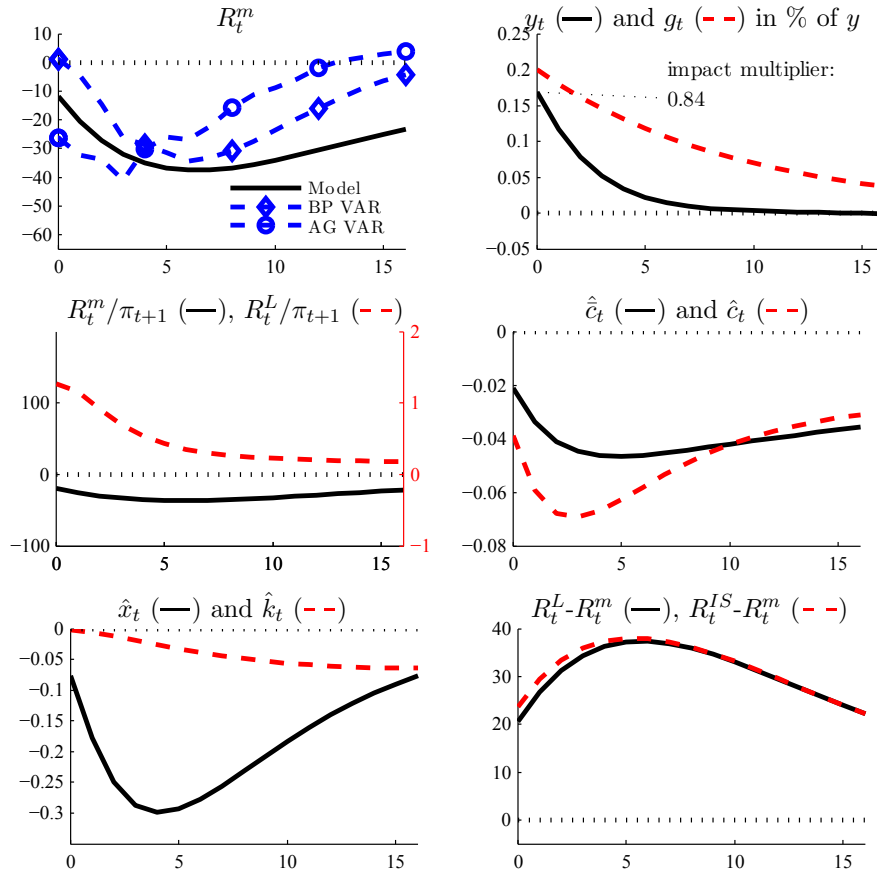
Figure 6 shows impulse responses to an autocorrelated government spending shock amounting to one percent of steady state spending for a monetary policy rate that falls due to a negative feedback ($\rho_g = -0.75$). In light of the analytical results above, we now evaluate whether this

observed degree of monetary accommodation still leads to a moderate fiscal multiplier. The black solid and the red dashed lines refer to the calibrated version, while the blue dashed lines with stars (circles) refer to the estimated impulse responses of the *BP* VAR (*AG* VAR) presented in Section 3. As in our empirical analysis, we show relative responses expressed in percent for level variables such as output, government spending, consumption, and investment and absolute responses expressed in basis points for interest rates and interest rates spreads.

The figure reveals that government spending exerts the well-known wealth effect in our model: an increase in government spending crowds out private consumption. This leads to an increase in labor supply such that output increases on impact. The impact output multiplier equals 0.84 and lies between the empirical counterparts estimated with both VARs for the baseline sample period (see Figure 1). The associated decline in the marginal utility of consumption between the current and the next period implies a lower relative price of future consumption and thus a higher real interest rate on non-eligible assets R_t^L/π_{t+1} , i.e., corporate and interbank loans. Further, the real return on physical capital also increases and investment expenditures fall, such that total private absorption declines and the fiscal multiplier is smaller than one. While real rates on non-eligible assets such as loans and physical capital increase, real rates on eligible assets can decrease due to the central bank's accommodation of the spending stimulus such that real interest rates diverge as found in our empirical analysis (in the middle left panel, which shows this divergence of interest rates, values of the real loan rate response are given on the right vertical axis). Consequently, the spread between the loan rate R_t^L and the monetary policy rate as well as the spread between the marginal rate of intertemporal substitution R_t^{IS} and the monetary policy rate increase. Given that these spreads are due to a liquidity premium in our model, their responses to government spending shocks accord with our evidence on the responses of empirical liquidity premia from Section 3. The model in fact generates a maximum spread response (37 bps) that relates to the maximum response of individual spreads considered in the empirical analysis (34 bps, see Figure 3).

Figure 6 thus confirms the analytical results derived in Section 5.1, namely, that the model with the liquidity premium is able to rationalize the overall pattern of impulse responses to government spending shocks as found in the data. Put differently, it can reproduce the seemingly puzzling observation of a fall in the nominal and real policy rate being associated with a moderate fiscal multiplier. Most importantly, a monetary policy that accommodates the expansionary fiscal policy shock to an extent as found in the data does not suffice to induce a large fiscal multiplier. Notably, the model is able to generate a fiscal multiplier exceeding one if monetary policy accommodation were even more pronounced, for example, induced by lower values of the feedback parameter ρ_g . Notably, a change of the parameter values, for example, setting $\rho_g = -1.25$ and $\rho = 0.98$, where the latter would strongly affect fiscal policy effects in New Keynesian models (see Section 5.2.4), or a change of other parameters to values that are also often used in the literature, i.e., $h = 0.6$, $\sigma = 1$, and $\zeta = 6.5$, or setting the parameter Ω ,

Figure 6: Responses to a positive 1% government spending shock for the model version with positive liquidity premium.



Notes: Relative responses of y_t , g_t , c_t , \bar{c}_t , x_t , and k_t in percent. Absolute responses of R_t^m , R_t^m/π_{t+1} , R_t^L/π_{t+1} , $R_t^L - R_t^m$, and $R_t^{IS} - R_t^m$ in basis points.

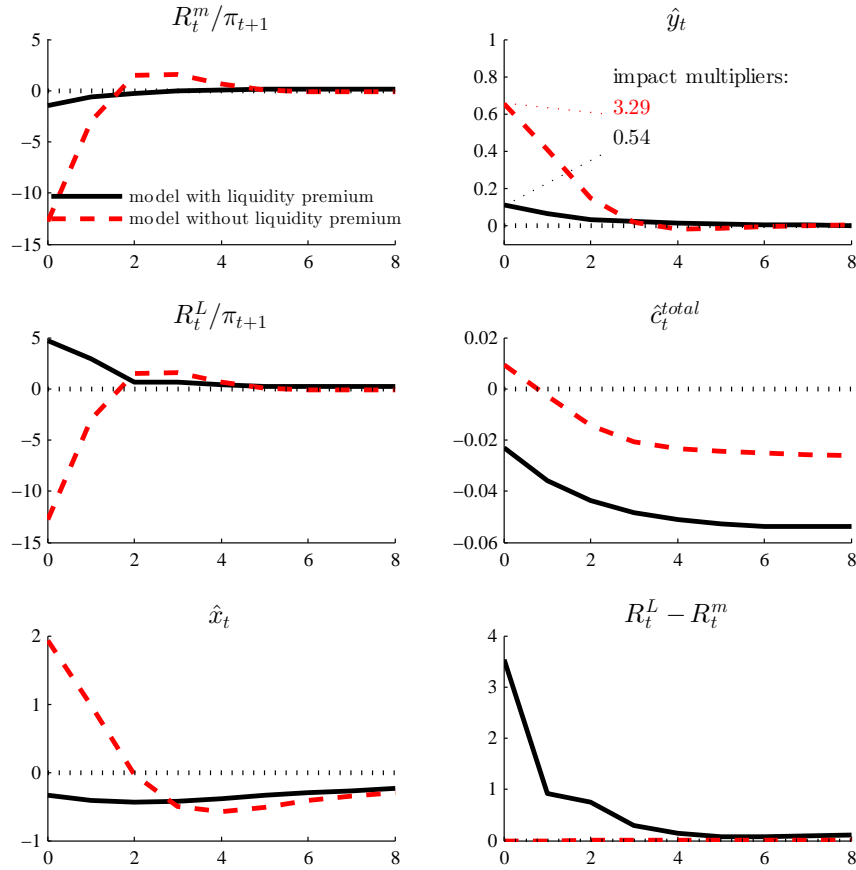
which is specific to our model, to an extreme value, i.e. $\Omega = 150$ instead of $\Omega = 1.5$, leads to similar results and, in particular, to impact output multipliers around one (see Figures 16-18 in Appendix D).

5.2.3 A monetary policy rate at the ZLB

Next, we analyze the fiscal multiplier for the case where the monetary policy rate is initially stuck at the binding zero lower bound. For this, we assume that the monetary policy rate is set according to the interest rate rule (see 32) without a fiscal feedback, $\rho_g = 0$, facilitating comparisons to related studies. At the ZLB, the real monetary policy rate tends to fall in response to a fiscal shock due to an increase in inflation.³⁰ To induce a binding ZLB, we consider the smallest discount factor shock ξ_t that causes the economy to reach the zero lower

³⁰For the analysis of this scenario, we use the dynare supplement "occbin" developed by Guerrieri and Iacoviello (2014). "Ocbin" solves dynamic models with occasionally binding constraints using a first-order perturbation approach. It handles occasionally binding constraints as different regimes of the same model to obtain a piecewise linear solution.

Figure 7: Net effects of a positive 1% government spending shock at the ZLB for a model version with (black solid line) and without liquidity premium (red dashed line)



Notes: The preference shock ξ_t that drives the economy to the ZLB follows an AR(1) process with autocorrelation 0.8. Relative responses of y_t , c_t^{total} , and x_t in percent. Absolute responses of R_t^m / π_{t+1} , R_t^L / π_{t+1} , $R_t^L - R_t^m$ in basis points.

bound in the impact period and to remain there for two further periods. It should be noted that the results for the model with the liquidity premium are hardly affected when we consider longer ZLB durations. The preference shock causes output and inflation to fall such that the central bank lowers the policy rate until the zero lower bound is reached. In order to evaluate the effects of fiscal policy at the zero lower bound, we examine the responses to a government spending shock that hits the economy in the same period as the preference shock that brings it to the ZLB. As in related studies (see Christiano et al., 2011, and Eggertsson, 2011), this expansionary fiscal policy mitigates the reduction in output and in inflation, which cushions the increase in the real policy rate (see Figure 19 in Appendix D).

To focus on the effects of expansionary fiscal policy, Figure 7 presents the net effects of the government spending shock, i.e., the responses to both shocks net of the responses to the preference shock alone.³¹ The solid lines in Figure 7 show the net effects for the model with the liquidity premium and the red dashed lines show the net effects for the version of

³¹Here, we show responses for eight quarters (instead of 16) to highlight the dynamics during the ZLB episode.

the model without the liquidity premium. For the former version, responses to the fiscal impulse are mainly driven by the negative wealth effect as it leads to a moderate impact multiplier of 0.54 and increases inflation. Note that the fiscal multiplier is actually smaller in this ZLB scenario than in the off-ZLB scenario considered in Section 5.2.2 above. The reason is that, in the analysis of Section 5.2.2, the expansionary output effects of fiscal policy are re-enforced through a pronounced monetary accommodation which is absent here. As before, the government spending shock crowds out private absorption and further leads to a rise in the spread $R_t^L - R_t^m$. Overall, the impulse responses from the model with the liquidity premium accord with the results shown before. The red dashed lines further reveal that conducting the same experiment without the liquidity premium leads to much more pronounced responses of the inflation rate and the real policy rate. Given that the latter equals the marginal rate of intertemporal substitution in this model, consumption and investment are crowded in, leading to an empirically implausibly large output multiplier of 3.29, which is similar to results found by other studies applying sticky price models without a liquidity premium (see Christiano et al., 2011, and Eggertsson, 2011).³²

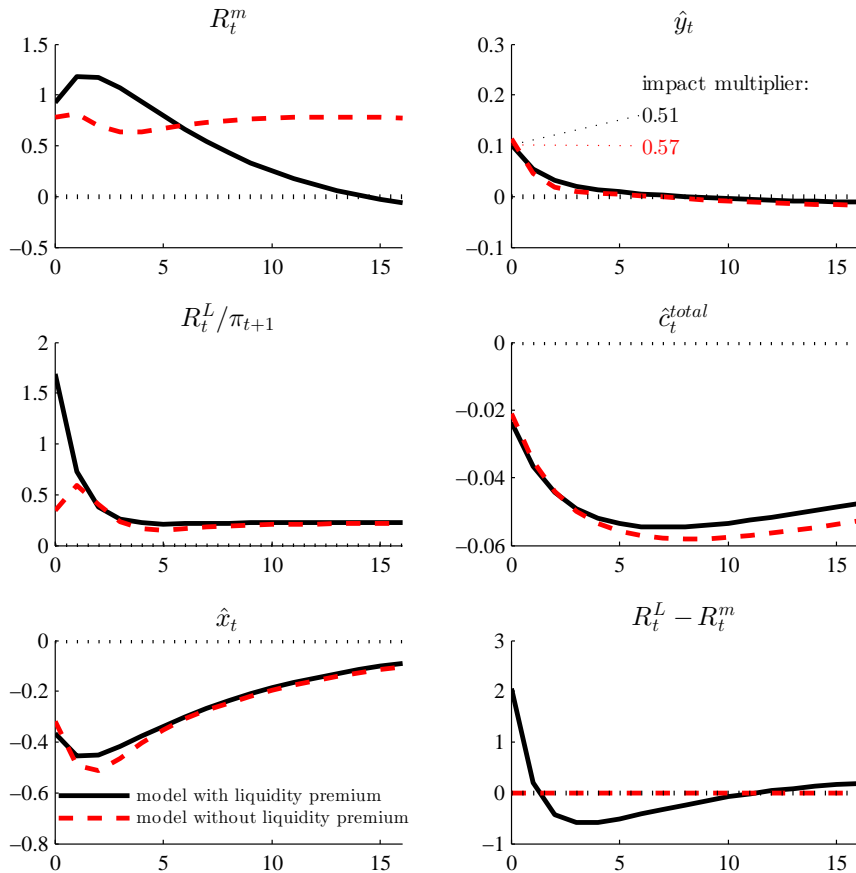
5.2.4 A policy rate set according to a standard Taylor rule

To complete our analysis of the role of monetary policy for fiscal policy effects, we finally consider a theoretically well-known monetary policy scenario. Specifically, we examine the effects of government spending for the (counterfactual) case where off the ZLB the monetary policy rate increases due to a standard Taylor-rule without a direct feedback from government spending. Technically, we again set $\rho_g = 0$ for this exercise while the other parameter values remain unchanged. Figure 8 shows the impulse responses to the same increase in government spending in the versions of the model with (black solid line) and without (red dashed line) the liquidity premium. Under this monetary policy regime, the real interest rate R_t^L / π_{t+1} increases in both versions, which is consistent with the negative wealth effect of fiscal policy as well as with the non-accommodative monetary policy stance.

Most importantly, the output responses to the fiscal shock hardly show any difference between the two model versions, implying that the impact multipliers are almost identical in both versions (0.51 and 0.57). This property as well as the similarity in the responses of total consumption and investment stand in stark contrast to the previous ZLB scenario, where the fiscal multiplier is found to differ substantially between both versions. The fact that the multiplier in under a standard Taylor rule is very similar to the multiplier at the ZLB (0.54) for the version with the liquidity premium (see Figure 7) apparently indicates that the monetary policy stance is actually far less crucial for the size of fiscal multipliers than in the case where

³²As can be expected from the previous analysis, the model further implies that an increase in a labor income tax rate at the ZLB leads to contractionary effects in the model with the liquidity premium, whereas the model without the liquidity premium paradoxically predicts expansionary effects (as in Eggertsson, 2011). Impulse responses for both model versions can be found in Figure 20 in Appendix D.

Figure 8: Responses to a 1% government spending shock when the monetary policy counterfactually rises, achieved through a standard Taylor-rule ($\rho_g = 0$), for a model version with (black solid line) and without liquidity premium (red dashed line)



Notes: Relative responses of y_t , c_t^{total} , and x_t in percent. Absolute responses of R_t^L / π_{t+1} , R_t^L / π_{t+1} , $R_t^L - R_t^m$ in basis points.

the liquidity premium is neglected (as in New Keynesian models), for which the fiscal multiplier at the ZLB is more almost six times as large as under a standard Taylor rule off the ZLB.

6 Conclusion

In this paper, we reconsider the role of monetary policy for the output effects of government spending. We confirm the empirical finding that a government spending hike tends to reduce the (nominal and real) monetary policy rate and, at the same time, leads to a moderate output multiplier (below one), which constitutes a clear puzzle according to the New Keynesian paradigm. Our empirical analysis however also suggests a solution to this puzzle, which relies on the observation that, simultaneously, real interest rates that are more relevant for private sector transactions as well as measures of liquidity premia tend to rise. We show that a standard macroeconomic model that is augmented by a liquidity premium on near-money assets can indeed rationalize differential interest rate responses and moderate multipliers, as found in the

data. It further implies that fiscal multipliers are also not exceptionally large during episodes where the monetary policy rate is fixed at the ZLB, which contrasts predictions based on standard New Keynesian models. According to our analysis, the stance of monetary policy measured by the interest rate controlled by the central bank is therefore much less relevant for fiscal policy effects as suggested by the New Keynesian paradigm. Yet, we acknowledge that monetary policy understood broadly can in principle exert a stronger impact on fiscal multipliers, if other dimensions of central banking (e.g., balance sheet expansions) are taken into account, which might contribute to substantial differences in fiscal multipliers found for episodes with similar policy rate paths. We leave this issue for future research.

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A Appendix to Section 3

A.1 Data sources

For our empirical analysis and the model calibration, we combine data from three main sources: the FRED database of the Federal Reserve Bank of St. Louis (FRED), the survey of professional forecasters (SPF), and the Bloomberg financial database (Bloomberg). In the following, we describe the data we use and the respective sources. Original mimeos are given in square brackets.

Data from FRED We use the following series from FRED, all at quarterly frequency and aggregated as means where applicable. Gross Government Investment [A782RC1Q027SBEA], Government Consumption Expenditures [A955RC1Q027SBEA], Gross Domestic Product: Implicit Price Deflator [GDPDEF], Civilian Noninstitutional Population [CNP16OV], Gross Domestic Product [GDP], Civilian Noninstitutional Population [CNP160V] Personal Consumption Expenditures: Nondurable Goods [PCND], Personal Consumption Expenditures: Services [PCESV], Effective Federal Funds Rate [FEDFUNDS], Federal Debt Held by the Public as Percent of Gross Domestic Product [FYGFGDQ188S], Government current tax receipts [W054RC1Q027SBEA], Contributions for Government Social Insurance [W782RC1Q027SBEA], Government Current Transfer Payments [A084RC1Q027SBEA], Government Current Expenditures: Interest Payments [A180RC1Q027SBEA], Private Nonresidential Fixed Investment [PNFI], Consumer Price Index for All Urban Consumers: All Items [CPIAUCSL], TED Spread [TEDRATE], 3-Month Treasury Bill: Secondary Market Rate [TB3MS], 3-Month Commercial Paper Rate [DCP3M and CP3M stacked, in the following referred to as CP3M], 3-Month London Interbank Offered Rate based on US Dollar [USD3MTD156N], 12-Month London Interbank Offered Rate based on US Dollar [USD12MD156N], 3-Month Certificate of Deposit: Secondary Market Rate [CD3M], Moody’s Seasoned Aaa Corporate Bond Yield [DAAA], Moody’s Seasoned Baa Corporate Bond Yield [BAA], 10-Year Treasury Constant Maturity Rate [DGS10], and 30-Year Conventional Mortgage Rate [MORTG]. We further use Monthly Repurchase Agreements [WARAL], and Monthly Total Reserves of Depository Institutions [TOTRESNS] for the calibration of our model (see Section 5.2.1). In the following, we refer to these series by their FRED mimeos.

Data from the SPF We take one-year CPI inflation forecasts from the SPF (mean forecasts). For the ten-year inflation forecast, we combine the mean SPF forecast (from 1991 on) with the respective forecast from the Blue Chip Indicators (until 1991, data also provided by the Federal Reserve Bank of Philadelphia on the SPF webpages). During the time where the Blue Chip Indicators are reported only twice a year, we rely on linear interpolation. In the following, we refer to the two forecasts as SPFINF1 and SPFINF10. We further use the forecasts for real federal government consumption expenditures and gross investment [RFEDGOV] and for real state and local government consumption expenditures and gross investment [RSLGOV].

We combine the mean forecasts with the respective first-release information on these variables which are also provided on the SPF webpages. We use these variables to construct the forecast errors for the growth rate of total spending made by professional forecasters, exactly following Auerbach and Gorodnichenko (2012).

Data from Bloomberg We follow Del Negro et al. (2016) and construct the 3-months, 1-year, and 10-year Refcorp spreads as the differences between the constant maturity 3-months, 1-year, and 10-year points on the Bloomberg fair value curves for Refcorp and Treasury zero-coupon bonds [C0793M Index and C0913M Index for 3-months maturity, C0911Y Index and C0791Y Index for 1-year maturity as well as between C09110Y Index and C07910Y Index for 10-year maturity, respectively]. In the following, we denote the quarterly averages as REFCORP3M, REFCORP1 and REFCORP10, respectively. Further, for the liquidity spread used by Nagel (2016), we apply the interest rate on 3-months general collateral repurchase agreements ("3 Month GC Govt Repo"). We follow Nagel (2016) in taking the averages between bid and ask prices [USRGCGC ICUS Curncy and USRGCGC ICUS Curncy, respectively]. In the following, we denote the stacked series of quarterly averages as GCREPO. Finally, we use quarterly averages of the rates on 30-year Fannie Mae mortgage-backed securities, "Mtge Current Cpnns Fnma 30 Year" [MTGEFNCL].

Further data sources We further extract data on the volume of outstanding T-bills from the "Monthly Statement of the Public Debt of the United States" published in the quarterly Treasury bulletins, Table FD.-2, Column 3, and we use data for the rate on Fed Treasury Repos [DTCC GCF Repo Index] from Depository Trust & Clearing Corporation (see <http://www.dtcc.com/charts/dtcc-gcf-repo-index.aspx#download>).

Construction of the liquidity factor We construct the common liquidity factor following Del Negro et al. (2016). We estimate a principal-component model with one component based on data for different liquidity spreads from our baseline sample 1979.IV to 2015.IV. Based on the estimated model, we project the observed liquidity spreads on a common liquidity factor, thereby reducing the dimensionality of liquidity premia data to one. The liquidity spreads included in the estimation of the common liquidity factor are suggested by Longstaff (2004), Brunnermeier (2009), Krishnamurthy and Vissing-Jorgensen (2012), and Nagel (2017), and are given by the differences between 1) the 3-months commercial papers rate and 3-months T-bills rate, 2) the 3-months GC repo rate and the 3-months T-bill rate, 3) the 3-months LIBOR and the 3-months T-bill rate, 4) the 10-year AAA corporate bonds rate and the 10-year treasury bond rate with 10-year maturity, 5) the 3-months Refcorp rate and 3-months Treasury rate, 6) the 1-year Refcorp rate and 1-year Treasury rate, and 7) the 10-year Refcorp rate and 10-year Treasury rate. In order to have information on liquidity spreads for a sample as long as possible, we use the discontinued FRED series AAA and CP3M for AAA corporate bonds rates and commercial paper rates when estimating the common liquidity factor while we rely on the

Table 1: Variables that enter the VARs and their definitions

Symbol	Description	Definition
g	government spending	$\log((A782RC1Q027SBEA + A955RC1Q027SBEA)/(GDPDEF + CNP16OV))$
y	real output	$\log(GDP/(GDPDEF + CNP16OV))$
c	non-durable and service consumption	$\log((PCND + PCESV)/(GDPDEF + CNP16OV))$
cf	common liquidity factor	(see above)
R^m	federal funds rate	FEDFUNDS
d	debt to GDP	FYGFQDQ188S/100
tax	net tax receipts	$\log((W054RC1Q027SBEA + W782RC1Q027SBEA - A180RC1Q027SBEA - A084RC1Q027SBEA)/(GDPDEF + CNP16OV))$
$E\pi$	one-year SPF inflation forecast	SPFINF1
fe	professional forecast error for government spending growth	(see above)
x	private investment	$\log((PNFI)/(GDPDEF + CNP16OV))$
$R^{Libor3} - R^{T-bill}$	TED spread (Libor–T-bill rate)	TEDRATE
$R^{cp} - R^{T-bill}$	spread between the rates on commercial papers and T-bills	DCPF3M–TB3MS
$R^{refcorp} - R^{T-bond}$	10-year Refcorp spread	REFCORP10
$R^{AAA} - R^{T-bond}$	spread between AAA corporate bonds and government bonds	DAAA–GS10
$R^m/E\pi$	real federal funds rate	$(1 + FEDFUNDS/100)/(1 + SPFINF1/100) - 1$
$R^{T-bill}/E\pi$	real 3-months T-bill rate	$(1 + TB3MS/100)/(1 + SPFINF1/100) - 1$
$R^{cd}/E\pi$	real 3-months CD rate	$(1 + CD3M/100)/(1 + SPFINF1/100) - 1$
$R^{Libor3}/E\pi$	real 3-months LIBOR	$(1 + USD3MTD156N/100)/(1 + SPFINF1/100) - 1$
$R^{Libor12}/E\pi$	real one-year LIBOR	$(1 + USD12MD156N/100)/(1 + SPFINF1/100) - 1$
$R^{T-bond}/E\pi_{10}$	real return on gov. bonds	$(1 + DGS10/100)/(1 + SPFINF10/100) - 1$
$R^{AAA}/E\pi_{10}$	real return on AAA corp. bonds	$(1 + DAAA/100)/(1 + SPFINF10/100) - 1$
$R^{BAA}/E\pi_{10}$	real return on BAA corp. bonds	$(1 + BAA/100)/(1 + SPFINF10/100) - 1$
$R^{MBS}/E\pi_{10}$	real MBS rate	$(1 + MTGEFNCL/100)/(1 + SPFINF10/100) - 1$
$R^{mortg}/E\pi_{10}$	real mortgage rate	$(1 + MORTG/100)/(1 + SPFINF10/100) - 1$

series DAAA and DCPF3M when considering the respective liquidity spreads separately in a VAR.

A.2 Detailed description of VARs

All our VARs include 1) log real government spending per capita (g), 2) log real government net tax receipts per capita (tax), 3) log real GDP per capita (y), 4) the government debt-to-GDP ratio (d), 5) log real non-durable consumption per capita (c) or log real private investment per capita (x), 6) the common liquidity factor (clf), an interest rate spread or the real rate of

return on an illiquid asset, and 7) the (nominal or real) federal funds rate (R^m , $R^m/E\pi$) or the real T-bill rate ($R^{T-bill}/E\pi$), and 8) the one-year inflation forecast from the SPF ($E\pi$). In the VARs identified using the Auerbach-Gorodnichenko (2012) identification scheme (*AG*), we replace the debt-to-GDP ratio (d) by the forecast error made by professional forecasters (fe). Identification is achieved through a Cholesky decomposition and we consider the shock to the first variable, which is g in the *BP* specification and fe in the *AG* specification. Table 1 describes the variables that enter our VARs and their definitions.

In order to analyze various interest rates and liquidity spreads but still keep the number of variables in the VARs limited, we follow the strategy of Burnside et al. (2004) and consider a fixed set of variables and rotate in further variables. In particular, variables 1-4 above in the *BP* case as well as variables 1-3 and fe in the *AG* case are always included while variables 5 through 7 above are replaced by other variables during the rotation. The inflation forecast (8) is not included as a separate variable when we consider real rates as variables 6 or 7. The three rotating variables are chosen to always include a component of the right-hand side of the national income identity, a rate of return on a liquid asset, and an interest rate spread between an illiquid and a liquid asset. This way, we replace a variable from the baseline VAR (c , R^m , or clf) by a variable that – based on our argumentation – contains similar information. Specifically, the sixth, seventh and eighth variables are rotated in the following way. The sixth variable is log real private non-residential investment per capita (x) in the VAR from which we show the investment response and it is log real consumption of non-durables and services per capita (c) in all other VARs. The seventh variable is a particular interest rate spread or a return on an illiquid asset in the VARs from which the respective responses are shown. It is the common liquidity factor (clf) in all other VARs. The eighth variable is the nominal federal funds rate (R^m) or the real T-bill rate ($R^{T-bill}/E\pi^1$) in the VARs from which the responses of the respective rates are shown. It is the real federal funds rate ($R^m/E\pi^1$) in all other VARs.

All VARs include a constant and three lags. Variables are measured as deviations from linear trends. Our baseline sample is 1979.IV to 2015.IV. The use of some variables requires a shorter sample period due to data availability. Therefore, the sample start is 1983.I in VARs where the AAA corporate bonds rate or the spread between this rate and the T-bill rate is considered, 1984.II when MBS rates are considered, 1986.I in VARs where LIBORs or the TED spread is considered, 1991.II in the VARs where the Refcorp spreads are considered, and 1997.I in VARs where the commercial paper rate or the spread between this rate and the T-bill rate is considered. The availability of CD rate data restricts the sample of the respective VARs to end in 2013.II. The estimation of the common liquidity factor allows missing values and, for this reason, does not further restrict sample periods.

B Appendix to Section 4

B.1 Appendix to the price setting of retailers

A monopolistically competitive *retailer* $k \in [0, 1]$ buys intermediate goods y_t^m at the price P_t^m , relabels the intermediate goods to $y_{k,t}$, and sells the latter at the price $P_{k,t}$ to perfectly competitive *bundlers*. The latter bundle the goods $y_{k,t}$ to the final consumption good y_t with the technology, $y_t^{\frac{\varepsilon-1}{\varepsilon}} = \int_0^1 y_{k,t}^{\frac{\varepsilon-1}{\varepsilon}} dk$, where $\varepsilon > 1$ is the elasticity of substitution and the cost minimizing demand for $y_{k,t}$ is $y_{k,t} = (P_{k,t}/P_t)^{-\varepsilon} y_t$. A fraction $1 - \phi$ of the retailers set their price in an optimizing way. The remaining fraction $\phi \in (0, 1)$ of retailers keep the previous period price, $P_{k,t} = P_{k,t-1}$. The problem of a price adjusting retailer is $\max_{\tilde{P}_{k,t}} E_t \sum_{s=0}^{\infty} \phi^s \beta^s \phi_{t,t+s} ((\prod_{k=1}^s \tilde{P}_{k,t}/P_{t+s}) - mc_{t+s}) y_{k,t+s}$, where $mc_t = P_t^m/P_t$. The first order condition can be written as $\tilde{Z}_t = \frac{\varepsilon}{\varepsilon-1} Z_t^1/Z_t^2$, where $\tilde{Z}_t = \tilde{P}_t/P_t$, $Z_t^1 = \xi_t c_t^{-\sigma} y_t mc_t + \phi \beta E_t \pi_{t+1}^{\varepsilon} Z_{t+1}^1$ and $Z_t^2 = \xi_t c_t^{-\sigma} y_t + \phi \beta E_t \pi_{t+1}^{\varepsilon-1} Z_{t+1}^2$. With perfectly competitive bundlers and the homogenous bundling technology, the price index P_t for the final consumption good satisfies $P_t^{1-\varepsilon} = \int_0^1 P_{k,t}^{1-\varepsilon} dk$. Hence, we obtain $1 = (1 - \phi) \tilde{Z}_t^{1-\varepsilon} + \phi \pi_t^{\varepsilon-1}$. In a symmetric equilibrium, $y_t^m = \int_0^1 y_{k,t} dk$ and $y_t = a_t n_t^{\alpha} k_{t-1}^{1-\alpha}/s_t$ will hold, where $s_t = \int_0^1 (P_{k,t}/P_t)^{-\varepsilon} dk$ and $s_t = (1 - \phi) \tilde{Z}_t^{-\varepsilon} + \phi s_{t-1} (\pi_t)^{\varepsilon}$ given $s_{-1} > 0$.

B.2 Equilibrium definition

Definition 1 A rational expectations equilibrium is a set of sequences $\{c_t, y_t, n_t, w_t, \lambda_t, m_t^R, m_t, b_t, b_t^T, mc_t, Z_{1,t}, Z_{2,t}, Z_t, s_t, \pi_t, R_t^{IS}\}_{t=0}^{\infty}$ satisfying

$$c_t = m_t + m_t^R, \text{ if } R_t^{IS} > 1, \text{ or } c_t \leq m_t + m_t^R, \text{ if } R_t^{IS} = 1, \quad (33)$$

$$b_{t-1}/(R_t^m \pi_t) = m_t - m_{t-1} \pi_t^{-1} + m_t^R, \text{ if } R_t^{IS} > R_t^m, \quad (34)$$

$$\text{or } b_{t-1}/(R_t^m \pi_t) \geq m_t - m_{t-1} \pi_t^{-1} + m_t^R, \text{ if } R_t^{IS} = R_t^m,$$

$$m_t^R = \Omega m_t, \quad (35)$$

$$b_t = b_t^T - m_t, \quad (36)$$

$$b_t^T = \Gamma b_{t-1}^T / \pi_t, \quad (37)$$

$$\theta n_t^{\sigma} = u_{c,t} w_t / R_t^{IS}, \quad (38)$$

$$1/R_t^{IS} = \beta E_t [u_{c,t+1} / (u_{c,t} \pi_{t+1})], \quad (39)$$

$$w_t = mc_t, \quad (40)$$

$$\lambda_t = \beta E_t [u_{c,t+1} / \pi_{t+1}], \quad (41)$$

$$Z_{1,t} = \lambda_t y_t mc_t + \phi \beta E_t \pi_{t+1}^{\varepsilon} Z_{1,t+1}, \quad (42)$$

$$Z_{2,t} = \lambda_t y_t + \phi \beta E_t \pi_{t+1}^{\varepsilon-1} Z_{2,t+1}, \quad (43)$$

$$Z_t = [\varepsilon / (\varepsilon - 1)] Z_{1,t} / Z_{2,t}, \quad (44)$$

$$1 = (1 - \phi) Z_t^{1-\varepsilon} + \phi \pi_t^{\varepsilon-1}, \quad (45)$$

$$s_t = (1 - \phi) Z_t^{-\varepsilon} + \phi s_{t-1} \pi_t^{\varepsilon}, \quad (46)$$

$$y_t = n_t / s_t, \quad (47)$$

$$y_t = c_t + g_t, \quad (48)$$

(where $u_{c,t} = c_t^{-\sigma}$), the transversality condition, a monetary policy $\{R_t^m \geq 1\}_{t=0}^\infty$, $\Omega > 0$, $\pi \geq \beta$, and a fiscal policy $\{g_t\}_{t=0}^\infty$, $\Gamma \geq 1$, for a given initial values $M_{-1} > 0$, $B_{-1} > 0$, $B_{-1}^T > 0$, and $s_{-1} \geq 1$.

Given a rational expectations equilibrium as summarized in Definition 1, the equilibrium sequences $\{R_t, R_t^D, R_{t+1}^q, R_t^L = R_t^A\}_{t=0}^\infty$ can be determined by

$$R_t = E_t[u_{c,t+1}\pi_{t+1}^{-1}]/[E_t(R_{t+1}^m)^{-1}u_{c,t+1}\pi_{t+1}^{-1}], \quad (49)$$

$$\lambda_t/R_t^D = \beta E_t[(u_{c,t+1} + (1 - \mu)\lambda_{t+1})/\pi_{t+1}], \quad (50)$$

$$1 = \beta E_t[(R_{t+1}^q/\pi_{t+1})(\lambda_{t+1}/\lambda_t)], \quad (51)$$

$$1/R_t^L = E_t[1/R_{t+1}^{IS}], \quad (52)$$

If the money supply constraint (8) is not binding, which is the case if $R_t^m = R_t^{IS}$ (see 22), the model given in Definition 1 reduces to a standard New Keynesian model with a cash-in-advance constraint, where government liabilities can residually be determined.

Definition 2 A rational expectations equilibrium under a non-binding money supply constraint (8) is a set of sequences $\{c_t, y_t, n_t, w_t, \lambda_t, mc_t, Z_{1,t}, Z_{2,t}, Z_t, s_t, \pi_t, R_t^{IS}\}_{t=0}^\infty$ satisfying $R_t^{IS} = R_t^m$, (38)-(48), the transversality condition, a monetary policy $\{R_t^m \geq 1\}_{t=0}^\infty$, $\pi \geq \beta$, and a fiscal policy $\{g_t\}_{t=0}^\infty$, for a given initial value $s_{-1} \geq 1$.

C Appendix to Section 5

Proof of Proposition 1. To establish the claims made in the Proposition, we apply the model given in Definition 3 for $R_t^m = R_t^{IS}$, i.e., (27), (28), and (30), which can by substituting out \widehat{R}_t^{IS} be summarized as

$$\rho_\pi \widehat{\pi}_t + \rho_g \widehat{g}_t - E_t \widehat{\pi}_{t+1} = \sigma E_t \widehat{c}_{t+1} - \sigma \widehat{c}_t, \quad (53)$$

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \delta_c \widehat{c}_t + \delta_g \widehat{g}_t + \chi \rho_\pi \widehat{\pi}_t, \quad (54)$$

where $\delta_c = \chi(\sigma_n c_y + \sigma) > 0$ and $\delta_g = \chi(\sigma_n g_y - \rho_g)$. The system's characteristic polynomial is given by $F(X) = X^2 - \frac{\sigma + \delta_c + \sigma\beta - \sigma\chi\rho_\pi}{\sigma\beta}X + \frac{\sigma + \rho_\pi\delta_c - \sigma\chi\rho_\pi}{\sigma\beta}$, satisfying $F(0) = \frac{\sigma + \rho_\pi\chi\sigma_n c_y}{\sigma\beta} > 1$, $F(1) = \frac{\delta_c}{\sigma\beta}(\rho_\pi - 1)$, and $F(-1) = \frac{2\sigma + \chi(\sigma_n c_y + \sigma) + 2\sigma\beta + \rho_\pi\chi(\sigma_n c_y - \sigma)}{\sigma\beta}$. Sufficient conditions for local equilibrium determinacy are $1 < \rho_\pi < 1 + 2\frac{\sigma + \chi\sigma_n c_y + \sigma\beta}{\chi(\sigma - \sigma_n c_y)}$ for $c_y < \sigma/\sigma_n$, or $1 < \rho_\pi$ for $c_y > \sigma/\sigma_n$, which are assumed to be ensured. Then, the solutions take the following generic form

$$\widehat{\pi}_t = \gamma_\pi \widehat{g}_t \text{ and } \widehat{c}_t = \gamma_c \widehat{g}_t.$$

Inserting these solutions in (53) and (54), leads to the following two conditions in γ_π and γ_c : $\gamma_\pi \rho_\pi + \rho_g + \sigma \gamma_c = 0$ and $-\gamma_\pi(1 - \chi \rho_\pi) + \delta_c \gamma_c + \delta_g = 0$, which can be combined to

$$\gamma_c = -\frac{\chi\sigma_n g_y + (-2\chi + 1/\rho_\pi)\rho_g}{(\chi\sigma_n c_y + \sigma/\rho_\pi)} \text{ and } \gamma_\pi = \frac{1}{\rho_\pi} \frac{\sigma\chi\sigma_n g_y - \chi(2\sigma + \sigma_n c_y)\rho_g}{(\chi\sigma_n c_y + \sigma/\rho_\pi)}.$$

To assess the policy rate, we use that it satisfies $\widehat{R}_t^m - E_t \widehat{\pi}_{t+1} = (\rho_\pi \gamma_\pi + \rho_g) \widehat{g}_t$ and thus

$$\widehat{R}_t^m - E_t \widehat{\pi}_{t+1} = \widehat{R}_t^m = \sigma \frac{\chi \sigma_n g_y + (-2\chi + 1/\rho_\pi) \rho_g}{(\chi \sigma_n c_y + \sigma/\rho_\pi)} \widehat{g}_t.$$

For $(-2\chi + 1/\rho_\pi) > 0$, the policy rate falls if $\rho_g < -\frac{\chi \sigma_n g_y}{(-2\chi + 1/\rho_\pi)}$. Using this upper bound, shows that consumption then increases

$$\gamma_c = -\frac{\chi \sigma_n g_y + (-2\chi + 1/\rho_\pi) \cdot \rho_g}{(\chi \sigma_n c_y + \sigma/\rho_\pi)} > -\frac{\chi \sigma_n g_y - (-2\chi + 1/\rho_\pi) \cdot \frac{\chi \sigma_n g_y}{(-2\chi + 1/\rho_\pi)}}{(\chi \sigma_n c_y + \sigma/\rho_\pi)} = 0.$$

For $(-2\chi + 1/\rho_\pi) < 0$, the policy rate falls if $\rho_g > \frac{\chi \sigma_n g_y}{-(-2\chi + 1/\rho_\pi)}$. Using this lower bound, shows that consumption then again increases

$$\gamma_c = -\frac{\chi \sigma_n g_y + (-2\chi + 1/\rho_\pi) \cdot \rho_g}{(\chi \sigma_n c_y + \sigma/\rho_\pi)} > -\frac{\chi \sigma_n g_y + (-2\chi + 1/\rho_\pi) \cdot \frac{\chi \sigma_n g_y}{-(-2\chi + 1/\rho_\pi)}}{(\chi \sigma_n c_y + \sigma/\rho_\pi)} = 0.$$

Thus, if the real or the nominal policy rate declines, consumption increases, implying an output multiplier larger than one. ■

Proof of Lemma 1. To establish the claims made in the Lemma, the model given in Definition 3 for the version with $R_t^m < R_t^{IS}$, i.e., (26)-(30), is further simplified by substituting out \widehat{R}_t^{IS} and \widehat{R}_t^m :

$$\delta_1 E_t \widehat{\pi}_{t+1} + \delta_3 \widehat{b}_t + \delta_2 \widehat{c}_t = \widehat{\pi}_t - \delta_g \widehat{g}_t, \quad (55)$$

$$\widehat{c}_t = \widehat{b}_{t-1} - (1 + \rho_\pi) \widehat{\pi}_t - \rho_g \widehat{g}_t, \quad (56)$$

and (29), where $\delta_1 = (\beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi) \gtrless 0$, $\delta_2 = \chi\sigma_n c_y > 0$, $\delta_3 = \chi\sigma > 0$, and $\delta_g = \chi\sigma_n g_y > 0$. We further simplify the system (29), (55), and (56) by eliminating \widehat{c}_t with (56) in (55) and then \widehat{b}_{t-1} with (29). Rewriting in matrix form, gives

$$\begin{pmatrix} \delta_1 & \delta_3 + \delta_2 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} E_t \widehat{\pi}_{t+1} \\ \widehat{b}_t \end{pmatrix} = \begin{pmatrix} 1 + \delta_2 \rho_\pi & 0 \\ -1 & 1 \end{pmatrix} \begin{pmatrix} \widehat{\pi}_t \\ \widehat{b}_{t-1} \end{pmatrix} + \begin{pmatrix} \delta_2 \rho_g - \delta_g \\ 0 \end{pmatrix} \widehat{g}_t.$$

The characteristic polynomial of

$$\mathbf{A} = \begin{pmatrix} \delta_1 & \delta_3 + \delta_2 \\ 0 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 + \delta_2 \rho_\pi & 0 \\ -1 & 1 \end{pmatrix} \quad (57)$$

is given by $F(X) = X^2 - \frac{\delta_1 + \delta_2 + \delta_3 + \rho_\pi \delta_2 + 1}{\delta_1} X + \frac{\rho_\pi \delta_2 + 1}{\delta_1}$. Given that there is one backward-looking variable and one forward-looking variable, stability and uniqueness require $F(X)$ to be characterized by one stable and one unstable root. At $X = 0$, the sign of $F(X)$ equals the sign of δ_1 , $F(0) = (\rho_\pi \delta_2 + 1)/\delta_1$, while $F(X)$ exhibits the opposite sign at $X = 1$: $F(1) = -\frac{1}{\delta_1} (\delta_2 + \delta_3)$. Consider first the case where $\delta_1 = \beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi > 0$. Given that $\sigma \geq 1$ and $\beta < 1$, we know that δ_1 is then strictly smaller than one. Hence, $F(1) < 0$ and

$F(0) > 1$, which implies that exactly one root is unstable and the stable root is strictly positive. Now consider the second case where $\delta_1 = \beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi < 0 \Leftrightarrow \rho_\pi > \frac{\beta + \chi(1 - \sigma)}{\chi\sigma}$, such that $F(1) > 0$ and $F(0) < 0$. We then know that there is at least one stable root between zero and one. To establish a condition which ensures that there is exactly one stable root, we further use $F(-1) = [2(1 + \delta_1) + \delta_3 + (2\rho_\pi + 1)\delta_2]/\delta_1$. Rewriting the numerator with $\delta_1 = \beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi$, $\delta_2 = \chi\sigma_n c_y$ and $\delta_3 = \chi\sigma$, the condition

$$2(1 + \beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi) + \chi\sigma + (2\rho_\pi + 1)\chi\sigma_n c_y > 0 \quad (58)$$

ensures that $F(0)$ and $F(-1)$ exhibit the same sign, implying that there is no stable root between zero and minus one. We now use that (58) holds, if but not only if

$$\rho_\pi \leq \frac{1 + \beta}{\chi\sigma} + \frac{1 - \sigma}{\sigma}, \quad (59)$$

where the RHS of (59) is strictly larger than $\frac{\beta + \chi(1 - \sigma)}{\chi\sigma}$. Hence, (59) is sufficient for local equilibrium determinacy, which establishes the claim made in the lemma. ■

Proof of Lemma 2. Consider the set of equilibrium conditions (29), (55), and (56). We aim at identifying the impact responses to fiscal policy shocks. For this, we assume that (59) is satisfied, which ensures existence and uniqueness of a locally stable solution. We then apply the following solution form for the system (29), (55), and (56):

$$\widehat{\pi}_t = \gamma_{\pi b} \widehat{b}_{t-1} + \gamma_{\pi g} \widehat{g}_t, \quad (60)$$

$$\widehat{b}_t = \gamma_b \widehat{b}_{t-1} + \gamma_{bg} \widehat{g}_t, \quad (61)$$

$$\widehat{c}_t = \gamma_{cb} \widehat{b}_{t-1} + \gamma_{cg} \widehat{g}_t. \quad (62)$$

Substituting out the endogenous variables in (29), (55), and (56) with the generic solutions in (60)-(62), leads to the following conditions for $\gamma_{\pi b}$, γ_{cb} , $\gamma_{\pi b}$, γ_{cg} , $\gamma_{\pi g}$, and γ_{bg} :

$$\gamma_{\pi b} = \delta_1 \gamma_{\pi b} \gamma_b + \delta_3 \gamma_b + \delta_2 \gamma_{cb}, \quad 1 = (1 + \rho_\pi) \gamma_{\pi b} + \gamma_{cb}, \quad 1 = \gamma_b + \gamma_{\pi b}, \quad (63)$$

$$-\delta_2 \gamma_{cg} = (\delta_1 \gamma_{\pi b} + \delta_3) \gamma_{bg} - \gamma_{\pi g} + \delta_g, \quad -\gamma_{cg} = (1 + \rho_\pi) \gamma_{\pi g} + \rho_g, \quad \gamma_{bg} = -\gamma_{\pi g}, \quad (64)$$

Using the three conditions in (63) and substituting out $\gamma_{\pi b}$ with $\gamma_{\pi b} = 1 - \gamma_b$, gives $0 = (\delta_1 \gamma_b - 1)(1 - \gamma_b) + \delta_3 \gamma_b + \delta_2 \gamma_{cb}$, $1 = (1 + \rho_\pi)(1 - \gamma_b) + \gamma_{cb}$, and eliminating γ_{cb} , leads to $0 = (\delta_1 \gamma_b - 1)(1 - \gamma_b) + \delta_3 \gamma_b + \delta_2(1 - (1 + \rho_\pi)(1 - \gamma_b))$, which is a quadratic equation in γ_b ,

$$\gamma_b^2 - (\delta_1 + \delta_3 + \delta_2(\rho_\pi + 1) + 1)\gamma_b \delta_1^{-1} + (\rho_\pi \delta_2 + 1)\delta_1^{-1} = 0. \quad (65)$$

Note that the polynomial in (65) is the characteristic polynomial of \mathbf{A} (see 57). Hence, under (59) there exists exactly one stable and positive solution (see proof of Lemma 1), which is assigned to $\gamma_b \in (0, 1)$. We then use $\gamma_{\pi b} = 1 - \gamma_b \in (0, 1)$ to identify the effects of government expenditure shocks with the three conditions in (64). The latter imply that the impact

responses of inflation and consumption are related by $-\gamma_{cg} = (1 + \rho_\pi)\gamma_{\pi g} + \rho_g$. Eliminating γ_{bg} with $\gamma_{bg} = -\gamma_{\pi g}$ and $\gamma_{\pi g}$ with $-\delta_2\gamma_{cg} = -(\delta_1\gamma_{\pi b} + \delta_3)\gamma_{\pi g} - \gamma_{\pi g} + \delta_g$, gives

$$\gamma_{cg} = -\frac{(1 + \rho_\pi)\delta_g + (\delta_1\gamma_{\pi b} + \delta_3 + 1)\rho_g}{(\delta_1\gamma_{\pi b} + \delta_3 + 1) + \delta_2(1 + \rho_\pi)}. \quad (66)$$

Using $\delta_1 = \beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi$, $\delta_2 = \chi\sigma_n c_y > 0$, $\delta_3 = \chi\sigma > 0$, and $\delta_g = \chi\sigma_n g_y$, the term on the RHS of (66) can be rewritten, such that

$$\gamma_{cg} = -\frac{(1 + \rho_\pi)\chi\sigma_n g_y + \Gamma_1\rho_g}{\Gamma_1 + \chi\sigma_n c_y(1 + \rho_\pi)}, \quad (67)$$

where $\Gamma_1 \equiv (\beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi)\gamma_{\pi b} + \chi\sigma + 1 > 0$, since $\beta + \chi(1 - \sigma) - \chi\sigma\rho_\pi + 1 > 0$ (see 59) and $\gamma_{\pi b} \in (0, 1)$. Hence, γ_{cg} is negative, implying a crowding out, if

$$\rho_g > \underline{\rho}_g, \text{ where } \underline{\rho}_g(\rho_\pi) \equiv -(1 + \rho_\pi)\chi\sigma_n g_y/\Gamma_1 < 0. \quad (68)$$

The solution coefficient (67) further implies that the fiscal multiplier is positive, $\gamma_{cg} > -1$, if $(c_y - g_y)\chi\sigma_n(1 + \rho_\pi) + \Gamma_1(1 - \rho_g) > 0$, which is satisfied if but not only if $\rho_g < 1$ given that $c_y > g_y$. Using $\gamma_{\pi g} = -\frac{\gamma_{cg} + \rho_g}{(1 + \rho_\pi)}$ and (67), the inflation response is given by

$$\gamma_{\pi g} = \frac{(g_y - \rho_g c_y)\chi\sigma_n}{\Gamma_1 + \chi\sigma_n c_y(1 + \rho_\pi)}, \quad (69)$$

implying that $\gamma_{\pi g} > 0$, if $\rho_g < g_y/c_y$. Using (69), the response of the policy rate, which satisfies $\widehat{R}_t^m = \rho_\pi \widehat{\pi}_t + \rho_g \widehat{g}_t$, to a change in government spending is given by

$$\partial \widehat{R}_t^m / \partial \widehat{g}_t = \frac{\rho_\pi g_y \chi \sigma_n + \rho_g (\chi \sigma_n c_y + \Gamma_1)}{\Gamma_1 + \chi \sigma_n c_y (1 + \rho_\pi)},$$

and is thus negative if

$$\rho_g < \overline{\rho}_g, \text{ where } \overline{\rho}_g(\rho_\pi) \equiv -\rho_\pi \frac{g_y \chi \sigma_n}{\chi \sigma_n c_y + \Gamma_1} \leq 0. \quad (70)$$

To further identify the response of the real marginal rate of intertemporal substitution, we use the log-linearized form $\widehat{R}_t^{IS} - E_t \widehat{\pi}_{t+1} = \sigma E_t \widehat{c}_{t+1} - \sigma \widehat{c}_t$. Applying the solutions (61)-(62), we get the following expressions for the impact effect of a government spending shock

$$\partial (\widehat{R}_t^{IS} - E_t \widehat{\pi}_{t+1}) / \partial \widehat{g}_t = \sigma \gamma_{cb} \gamma_{bg} - \sigma \gamma_{cg}.$$

Further using $\gamma_{cb} = 1 - (1 + \rho_\pi)(1 - \gamma_b)$, $\delta_g = \chi\sigma_n g_y$, $\gamma_{bg} = \frac{\gamma_{cg} + \rho_g}{(1 + \rho_\pi)}$, and (67), leads to

$$\frac{\partial (\widehat{R}_t^{IS} - E_t \widehat{\pi}_{t+1})}{\partial \widehat{g}_t} = \sigma \frac{((1 + \rho_\pi)(1 - \gamma_b) + \rho_\pi)\chi\sigma_n g_y + ((1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1)\rho_g}{\Gamma_1 + \chi\sigma_n c_y(1 + \rho_\pi)},$$

Hence, $\partial(\widehat{R}_t^{IS} - E_t \widehat{\pi}_{t+1})/\partial \widehat{g}_t$ is positive for $(1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1 > 0$ if $\rho_g > \widetilde{\rho}_g(\rho_\pi)$,

where

$$\tilde{\rho}_g(\rho_\pi) \equiv -\frac{((1 + \rho_\pi)(1 - \gamma_b) + \rho_\pi)\chi\sigma_n g_y}{(1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1}, \quad (71)$$

and for $(1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1 < 0$ if $\rho_g < \tilde{\rho}_g(\rho_\pi)$. The real marginal rate of intertemporal substitution therefore increases with government spending if

$$\rho_g > \tilde{\rho}_g(\rho_\pi) \text{ for } \tilde{\rho}_g(\rho_\pi) < 0 \quad \text{or} \quad \rho_g < \tilde{\rho}_g(\rho_\pi) \text{ for } \tilde{\rho}_g(\rho_\pi) > 0, \quad (72)$$

which establishes the claim made in the lemma. ■

Proof of Proposition 2. A comparison of the thresholds $\underline{\rho}_g$ and $\overline{\rho}_g$, defined in (68) and (70) in the proof of Lemma 2, shows that $\underline{\rho}_g < \overline{\rho}_g$, since

$$\begin{aligned} & \underline{\rho}_g < \overline{\rho}_g \\ \Leftrightarrow & -\frac{(1 + \rho_\pi)\chi\sigma_n g_y}{\Gamma_1} < -\rho_\pi \frac{g_y \chi \sigma_n}{\chi \sigma_n c_y + \Gamma_1} \\ \Leftrightarrow & (1 + \rho_\pi)\chi\sigma_n c_y + \Gamma_1 > 0, \end{aligned}$$

Thus, there exists values for ρ_g satisfying $\rho_g \in (\underline{\rho}_g, \overline{\rho}_g)$ for which private consumption and the nominal policy rate simultaneously decline in response to a government spending hike, see (68) and (70). Given that inflation increases for $\rho_g < g_y/c_y$, which is then ensured (as $\overline{\rho}_g < 0$), the real policy rate then declines as well. To assess the possibility that the real marginal rate of intertemporal substitution increases in response to a government spending hike, we distinguish two cases. For $(1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1 > 0$ and $\tilde{\rho}_g < 0$ (see 71), a rising real marginal rate of intertemporal substitution requires $\rho_g > \tilde{\rho}_g(\rho_\pi)$ (see 72). This is also feasible, since

$$\begin{aligned} & \tilde{\rho}_g < \overline{\rho}_g \\ \Leftrightarrow & -\frac{((1 + \rho_\pi)(1 - \gamma_b) + \rho_\pi)\chi\sigma_n g_y}{((1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1)} < -\rho_\pi \frac{g_y \chi \sigma_n}{\chi \sigma_n c_y + \Gamma_1} \\ \Leftrightarrow & \frac{(1 + \rho_\pi)(1 - \gamma_b) + \rho_\pi}{((1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1)} > \frac{\rho_\pi}{\chi \sigma_n c_y + \Gamma_1} \\ \Leftrightarrow & ((1 + \rho_\pi)(1 - \gamma_b) + \rho_\pi)(\chi\sigma_n c_y + \Gamma_1) - \rho_\pi((1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1) > 0 \\ \Leftrightarrow & (1 - \gamma_b)(1 + \rho_\pi)(\Gamma_1 + (1 + \rho_\pi)\chi\sigma_n c_y) > 0, \end{aligned}$$

For $(1 - (1 + \rho_\pi)(1 - \gamma_b))\chi\sigma_n c_y + \Gamma_1 < 0$ and $\tilde{\rho}_g > 0$, a rising real marginal rate of intertemporal substitution requires $\rho_g < \tilde{\rho}_g(\rho_\pi)$ (see 72), which is ensured for values $\rho_g \in (\underline{\rho}_g, \overline{\rho}_g)$, since $\overline{\rho}_g \leq \tilde{\rho}_g(\rho_\pi)$. We can therefore conclude that there exists values for ρ_g , which jointly satisfy (68), (70), and (72), such that a positive government spending shock simultaneously leads to a decline in private consumption, and in the nominal and the real policy rate, as well as to an increase in the real marginal rate of intertemporal substitution, which establishes the claims made in the proposition. ■

Definition 4 A rational expectations equilibrium of the model with endogenous capital formation, credit goods, and habit persistence is a set of sequences $\{c_t, \bar{c}_t, y_t, n_t, x_t, k_t, w_t, q_t, \lambda_t, m_t^R, m_t, b_t, b_t^T, mc_t, Z_{1,t}, Z_{2,t}, Z_t, s_t, \pi_t, R_t^{IS}\}_{t=0}^\infty$ satisfying (33)-(38), (42)-(46),

$$\lambda_t = u_{\bar{c},t}, \quad (73)$$

$$1/R_t^{IS} = \beta E_t [\xi_{t+1} u_{c,t+1} / (\xi_t u_{c,t} \pi_{t+1})], \quad (74)$$

$$w_t = mc_t \alpha n_t^{\alpha-1} k_{t-1}^{1-\alpha}, \quad (75)$$

$$\lambda_t = \beta E_t [\xi_{t+1} u_{c,t+1} / \pi_{t+1}], \quad (76)$$

$$1 = q_t [\Lambda_t + (x_t/x_{t-1}) \Lambda'_t] - E_t \beta [(\lambda_{t+1}/\lambda_t) q_{t+1} (x_{t+1}/x_t)^2 \Lambda'_{t+1}], \quad (77)$$

$$q_t = \beta E_t [(\lambda_{t+1}/\lambda_t) ((1-\alpha) mc_{t+1} (y_{t+1}/k_t) + (1-\delta) q_{t+1})], \quad (78)$$

$$y_t = n_t^\alpha k_{t-1}^{1-\alpha} / s_t, \quad (79)$$

$$y_t = c_t + \bar{c}_t + x_t + g_t, \quad (80)$$

$$k_t = (1-\delta) k_{t-1} + x_t \Lambda_t, \quad (81)$$

(where $u_{\bar{c},t} = \gamma(\bar{c}_t - h\bar{c}_{t-1})^{-\sigma}$, $u_{c,t} = (c_t - hc_{t-1})^{-\sigma}$, $\Lambda_t = 1 - \zeta \frac{1}{2} (x_t/x_{t-1} - 1)^2$), the transversality conditions, a monetary policy satisfying (32), $\Omega > 0$, $\pi \geq \beta$, given sequence $\{\tilde{y}_t\}_{t=0}^\infty$ (see below), a fiscal policy $g_t = \rho g_{t-1} + (1-\rho)g + \varepsilon_{g,t}$ and $\Gamma \geq 1$, a process $\xi_t = \rho_\xi \xi_{t-1} + (1-\rho_\xi) + \varepsilon_{\xi,t}$, random sequences $\{\varepsilon_{g,t}, \varepsilon_{\xi,t}\}_{t=0}^\infty$ and initial values $M_{-1} > 0$, $B_{-1} > 0$, $B_{-1}^T > 0$, $k_{-1} > 0$, $x_{-1} > 0$, $s_{-1} \geq 1$, $c_{-1} > 0$ and $\bar{c}_{-1} > 0$.

Given a rational expectations equilibrium as summarized in Definition 4, the equilibrium sequences $\{R_t, R_t^D, R_{t+1}^q, R_t^L = R_t^A\}_{t=0}^\infty$ can be determined by (51), (52),

$$R_t = E_t [\xi_{t+1} u_{c,t+1} \pi_{t+1}^{-1}] / [E_t (R_{t+1}^m)^{-1} \xi_{t+1} u_{c,t+1} \pi_{t+1}^{-1}], \quad (82)$$

$$\lambda_t / R_t^D = \beta E_t [(\xi_{t+1} u_{c,t+1} + (1-\mu)\lambda_{t+1}) / \pi_{t+1}]. \quad (83)$$

To identify the efficient output level \tilde{y}_t , one has to jointly solve for the sequences $\{\tilde{y}_t, \tilde{n}_t, \tilde{c}_t, \tilde{k}_t, \tilde{x}_t, \tilde{q}_t\}_{t=0}^\infty$ satisfying $\theta \tilde{n}_t^{1+\sigma_n} = \tilde{u}_{ct} \alpha \tilde{y}_t$, $\tilde{y}_t = \tilde{n}_t^\alpha \tilde{k}_{t-1}^{1-\alpha}$, $\tilde{y}_t = \tilde{c}_t + \tilde{x}_t$, $\tilde{k}_t = (1-\delta) \tilde{k}_{t-1} + \tilde{x}_t \Lambda(\tilde{x}_t/\tilde{x}_{t-1})$, $1 = \tilde{q}_t [\Lambda(\tilde{x}_t/\tilde{x}_{t-1}) + (\tilde{x}_t/\tilde{x}_{t-1}) \Lambda'(\tilde{x}_t/\tilde{x}_{t-1})] - E_t \beta [\xi_{t+1} \tilde{u}_{c,t+1} (\xi_t \tilde{u}_{c,t})^{-1} \tilde{q}_{t+1} (\tilde{x}_{t+1}/\tilde{x}_t)^2 \Lambda'(\tilde{x}_{t+1}/\tilde{x}_t)]$, and $\tilde{q}_t = \beta E_t [\xi_{t+1} \tilde{u}_{c,t+1} (\xi_t \tilde{u}_{c,t})^{-1} ((1-\alpha)(\tilde{y}_{t+1}/\tilde{k}_t) + (1-\delta) \tilde{q}_{t+1})]$, where $\tilde{u}_{c,t} = (\tilde{c}_t - h\tilde{c}_{t-1})^{-\sigma}$, given $\{\xi_t\}_{t=0}^\infty$, $\tilde{x}_{-1} > 0$ and $\tilde{k}_{-1} > 0$.

D Additional figures

This Appendix can be downloaded [here](#).