Fiscal Multipliers and Monetary Policy: Reconciling Theory and Evidence*

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Abstract

Estimated fiscal multipliers are typically moderate, which should in theory be associated with spending hikes raising real interest rates. However, monetary policy rates actually fall, which should lead to large multipliers. We rationalize these puzzling observations with imperfect substitutability of assets. After spending hikes, the demand for less liquid assets falls relative to the demand for liquid assets. In consequence, liquidity premia rise for which we provide empirical evidence. A model with a structural specification of asset liquidity can replicate these findings and predicts that neither a policy rate reduction nor a fixation at the zero lower bound are sufficient for large multipliers.

JEL classification: E32, E42, E63
Keywords: Fiscal multiplier, monetary policy, real interest rates, liquidity premium, zero lower bound

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1 Introduction

The last decade has witnessed a resurgence of interest in the stimulative effects of government expenditures. One 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 (see, e.g., Christiano et al., 2011). Surprisingly, the literature has hardly recognized a closely connected clear-cut empirical evidence which implies that the impact of monetary policy on the output multiplier is typically overestimated: Standard macroeconomic theories predict that an increase in government spending crowds out private absorption due to an adverse wealth effect and that these responses are 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, data provide a different picture, as multipliers are moderate despite evidence for monetary accomodation of fiscal policy. Empirical studies for the U.S. commonly find an output multiplier around and mostly below one (see Hall, 2009, Barro and Redlick, 2011, Ramey, 2011, Caldara and Kamps, 2017, as well as the overview in Ramey, 2016). Simultaneously, the nominal and the real monetary policy rate tend to fall, as documented by Mountford and Uhlig (2009) and Ramey (2016), among others.[1] According to the widespread view – particularly emphasized by the New Keynesian paradigm – that real rates of return essentially follow the real monetary policy rate, this is a clear puzzle, since falling real rates should lead to an unambiguous increase in private absorption and a large output multiplier.

Remarkably, this puzzling empirical pattern has been almost unnoticed by the literature.[2] In this paper, we reconcile theory and empirical evidence on fiscal policy effects by focussing on assets' ability to serve for transaction purposes, summarized by the term "liquidity". We take into account that, while interest rates on assets that serve as substitutes for money are closely linked to the monetary policy rate, interest rates on assets that cannot be classified as near-money assets and that are typically more relevant for

[1] Other studies documenting an immediate fall in short-term interest rates include Edelberg et al. (1999) and Fisher and Peters (2010). To be precise, Edelberg et al. (1999), Fisher and Peters (2010), and Ramey (2016) consider short-term T-bill rates and Mountfort and Uhlig (2009) the federal funds rate. As for example shown by Simon (1990) and confirmed by our own empirical evidence, the T-bill rate and the federal funds rate behave very similarly at quarterly frequency – a finding that is also consistent with our theoretical model.

[2] An exception is Corsetti et al. (2012) who report ambiguous responses of longer-term interest rates, which are "regarded as difficult to reconcile with standard analyses of fiscal expansions" (p. 82). Theoretical studies emphasize that, when the monetary policy rate is held constant, for example at the ZLB, private absorption increases strongly 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.

private saving and borrowing than the federal funds rate differ systematically from the federal funds rate. We provide novel evidence that this fact matters for asymmetric interest rate responses to fiscal policy shocks and develop a simple model with imperfect asset substitutability. While the model is able to reproduce the observed 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 for a large fiscal multiplier.

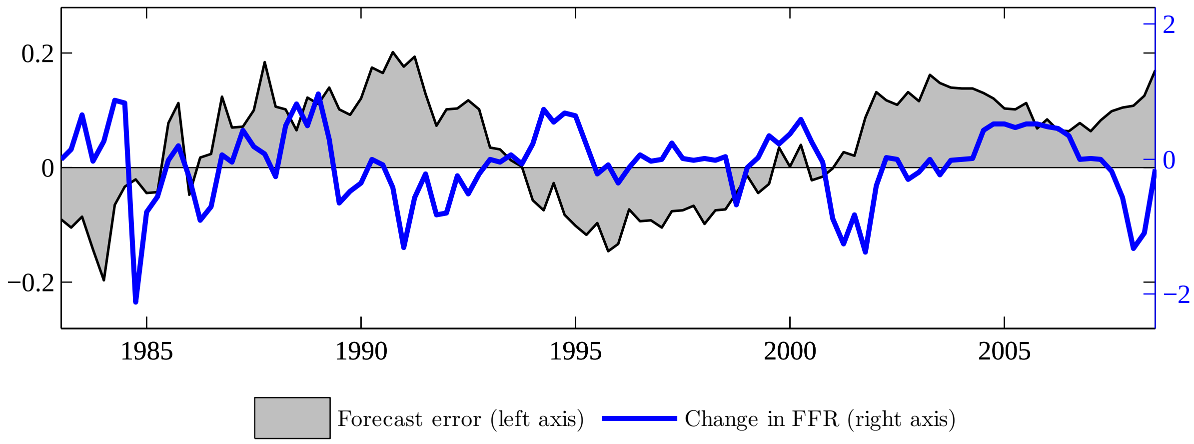
The starting point of our empirical analysis is that the real and nominal monetary policy rate decrease rather than increase in response to expansionary government spending shocks, see, e.g., Mountford and Uhlig (2009) and Ramey (2016). Relatedly, the apparent negative (unconditional) association between changes in the federal funds rate and unanticipated changes in government spending shown in Figure 1 suggests that monetary policy tends to be accommodative when government spending is raised in an unforeseen way.[3] Yet, the simultaneous reaction of output seems to constitute a puzzle since estimated fiscal multipliers are moderate. In a first step, we confirm these findings using Ramey's (2016) identification procedure based on defense spending news and an alternative identification using forecast errors. Given that the simultaneous responses of output and short-term interest rates cannot be rationalized by standard theories, we account for possibly divergent responses of other interest rates in a second step. We consider interest rates that are more relevant for private sector saving and borrowing decisions than interest rates on money market instruments. Specifically, we investigate a set of spreads which have been suggested to be primarily determined by liquidity premia as well as the common factor of these spreads.[4] We find that interest rate spreads increase after government spending hikes, which implies that interest rates on important illiquid assets, e.g., mortgage rates and Aaa corporate bonds, do not follow the federal funds rate. This is in line with Fama's (2013) findings regarding the Fed's "little control" over various important interest rates.[5] While we acknowledge that other factors might also contribute to the observed differential interest rate responses, we provide evidence that expectations about future short-term interest rates, increases in government debt, and changes in the risk-bearing capacity of the financial sector (see Gilchrist and Zakrajšek, 2012) are not decisive for our findings.

[3]In contrast, inflation shows a positive co-movement with the forecast error, indicating that the federal funds rate pattern does not follow from central bank reactions to price changes.

[4]These spreads are suggested by Longstaff (2004), Krishnamurthy and Vissing-Jorgensen (2012), and Nagel (2016). Our construction of the common liquidity premium follows Del Negro et al. (2017).

[5]Fama (2013) concludes by stating that "in sum, the evidence says that Fed actions with respect to its target rate have little effect on long-term interest rates, and there is substantial uncertainty about the extent of Fed control of short-term rates"

Figure 1: Time variation of forecast errors about government spending and of federal funds rate changes.



Notes: Figure shows the difference between actual government spending and the spending level implied by one-quarter ahead forecasts (for the respective quarter from the the previous quarter) from the Survey of Professional Forecasters (grey area with solid black line) and the quarter-to-quarter change in the effective federal funds rate (blue line). The sample period is 1983Q1 (end of reserve targeting) to 2008Q3 (before the recent ZLB episode).

The observed spread responses can be explained in a simple way: Due to an increase in government spending, aggregate demand tends to exceed supply. Excess demand implies that agents are willing to spend more for current relative to future consumption. As the willingness to save decreases, prices of assets that private agents use as a store of wealth tend to fall and their real rate of returns tend to rise. In fact, the natural rate of interest, i.e., the real interest rate that would prevail in a frictionless economy, increases unambiguously in response to an expansion in government spending (see Barro and King, 1984). Yet, this argument does not equally apply for near-money assets that serve as a close substitute for money and that are primarily held for payment purposes. Given their additional non-pecuniary return (from liquidity services), these assets offer lower interest rates, which are closely linked to the monetary policy rate. Being dominated in rate of return, these assets neither serve as a store of wealth nor can they be issued by households and firms. Hence, higher government spending induces a fall in the demand for less liquid assets relative to the demand for near-money assets, such that the interest rate spread (i.e., the liquidity premium) between these assets tends to widen. Due to this separation, one can therefore observe moderate output increases in response to government spending hikes even when the real monetary policy rate falls.[6]

[6]In general, a liquidity premium on near-money assets does not only depend on the opportunity costs of money, i.e., the interest rate on less liquid assets, but also on the supply of near-money assets and/or their interest rate (see, e.g., Nagel, 2016, and our discussion below).

If, however, one neglects that the monetary policy rate primarily determines the interest rate on near-money assets and that liquidity premia exist, the real monetary policy rate essentially controls agents' intertemporal choices, like in standard New Keynesian models. As a consequence, the joint response of the nominal policy rate and expected inflation to government spending can induce a fall in the real policy rate and therefore in real rates of return on savings, even though the natural interest rate rises. Then, the adverse wealth effect is dominated by the accommodative monetary policy. 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.

To replicate the observed fiscal policy effects, we develop a simple macroeconomic model with an interest rate spread between near-money assets and less liquid assets. We apply a structural approach to account for assets' imperfect substitutability, which is based on the pledgeability of assets for central bank transactions (see, e.g., Rocheteau et al., 2018). Concretely, we account for the fact that central banks typically supply money to commercial banks only against eligible assets, i.e., treasury bills, in open market operations. Replicating observed spreads requires the monetary policy rate to be set below the marginal rate of intertemporal substitution. Then, the price of money in terms of eligible assets is lower than the price agents are willing to pay, such that eligible assets are scarce. In contrast to a non-eligible asset, they are valued for their near-moneyness, which is reflected by a liquidity premium. This premium decreases with the monetary policy rate and increases with the marginal rate of intertemporal substitution; the latter being shifted upwards by an increase in government expenditures (which reduces the willingness to save). In line with empirical evidence, the T-bill rate closely follows the policy rate, whereas rates of return on non-eligible assets, e.g., corporate debt, tend to be higher. These illiquid assets therefore serve as store of wealth for private agents, such that their real returns relate to the marginal rate of intertemporal substitution which is separated from the policy rate by the liquidity premium. While this specification generally preserves empirically plausible effects of monetary policy,[7] its predictions regarding fiscal policy effects differ substantially from the predictions of standard models. Precisely, when the real policy rate falls, whether due to monetary accommodation of fiscal policy or because the nominal rate is stuck at the ZLB, standard models predict a large fiscal multiplier, whereas our model generates an increasing liquidity premium and

[7] This is shown by Bredemeier et al. (2018a), who further provide consistent empirical evidence on changes in liquidity premia after unanticipated monetary policy announcements, and by Linnemann and Schabert (2015), who find that liquidity premia help explaning observed exchange rate responses to monetary policy shocks.

a moderate fiscal multiplier in line with empirical evidence.[8]

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 corresponds to a standard New Keynesian model. To replicate the empirical findings, we calibrate the liquidity premium model and use it to study fiscal policy effects under two 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 with the liquidity premium generates moderate output multipliers and leads to an increase in the liquidity premium, quantitatively consistent with the data. Second, we study a scenario with the nominal policy rate at the ZLB, where a decline in the real policy rate is induced by the fixation of the nominal policy rate. Here, we obtain the intuitive result that fiscal multipliers at the ZLB are smaller than for the case of falling monetary policy rates, while output multipliers at the ZLB and under a conventional Taylor rule differ only slightly. In contrast, the model version without a liquidity premium predicts that the monetary policy stance alters the output multiplier by a substantially larger amount, as in Christiano et al. (2011). Thus, our model is able to reproduce – seemingly puzzling – observed responses of policy 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 alters the size of the fiscal multiplier, but it is much less influential than suggested by standard models that neglect liquidity premia. For example, our model implies that the multiplier is less than 10 percent larger at the ZLB than under a conventional Taylor rule while for the standard model without liquidity premia the multiplier increases by factor six. 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), we show that the role of monetary policy for the fiscal multiplier is hugely overestimated when only the responses of monetary policy rates are taken into account and other rates of return are ignored.

That our model is succesfull in generating the observed increase in liquidity premia after government spending shocks differentiates it from alternative models with interest rate spreads. Consider, for example, the most common specification of a non-pecuniary

[8]Notably, our model with the liquidity premium also implies that an increase in a labor income tax rate at the ZLB leads to contractionary effects, whereas a model without the liquidity premium paradoxically predicts expansionary effects (as in Eggertsson, 2011).

return (e.g., due to liquidity or safety) of a particular asset, say, a government bond, where it is assumed that this asset directly provides utility (see, e.g., Krishnamurthy and Vissing-Jorgensen, 2012, Nagel, 2016, or Michaillat and Saez, 2019). The spread between the interest rate on an asset that exclusively provides a pecuniary return and the interest rate on government bonds is then an increasing function of the marginal utility of government bond holdings divided by the marginal utility of consumption. Thus, for the spread to rise, as found in the data, the marginal utility of bonds would have to increase relative to the marginal utility of consumption. Empirically, government debt typically increases in response to expansionary spending shocks which tends to reduce the marginal utility of bonds while a strong crowding-in of consumption can hardly be observed. Hence, the liquidity premium in a bonds-in-the-utility-function setup would tend to decrease rather than increase after a government spending hike.

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, we derive analytical results regarding fiscal policy effects. The section further presents impulse responses for a calibrated version of the model. Section 6 concludes.

2 Related Literature

Our paper mainly relates to three strands of the literature. First, the results in Ramey (2016), who provides an overview and a synthesis of the current understanding of the effects of government spending shocks, are central for our analysis. 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 narrative defense news shocks (see Ramey, 2011 and Ramey and Zubairy, 2018) and defense news shocks with medium-run horizon (see Ben-Zeev and Pappa, 2017), 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 an impact output multiplier below one. Reductions in the nominal and real federal funds and T-bill rates in response to fiscal expansions are also found by other empirical studies on the effects of fiscal policy. Edelberg et al. (1999) exploit the Ramey-Shapiro (1997) war dates and find initial declines in the nominal and real 3-months and 1-year treasury rates. Fisher and Peters (2010) document a decline in the nominal 3-months T-bill rate in the first year after positive government spending shocks identified through the excess returns of large US military contractors. Ramey (2011) finds the nominal 3-months T-bill rate to fall in response to defense news shocks.

This result is confirmed by Ravn and Sørensen (2019), who also apply Blanchard-Perotti shocks and professional forecast errors.[9]

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 inflation. Most prominently, Christiano et al. (2011) and Eggertsson (2011) show that fiscal multipliers at the ZLB in a New Keynesian model become larger than typically observed in empirical studies, which has been confirmed by Woodford (2011) and Fahri and Werning (2016).[10] Erceg and Linde (2014) show that the fiscal multiplier depends on the duration of the ZLB episode. It can further be much smaller than one when equilibrium multiplicity is considered, see Mertens and Ravn (2014) and Cochrane (2017). Drautzburg and Uhlig (2015) find a multiplier at the ZLB of roughly one half when financing with distortionary taxation and transfers to borrowing-constrained agents are taken into account. Michaillat and Saez (2019) examine a New Keynesian model with government bonds in the utility function. They show that this assumption crucially affects equilibrium determinacy and generates muted effects of forward guidance and fiscal policy.[11] In contrast to the latter two studies, who consider an *exogenous* liquidity premium, we propose a mechanism that builds on endogenous liquidity premia and their response to fiscal policy, for which we provide direct empirical evidence.

Third, our paper is related to several recent studies analyzing endogenous liquidity premia on treasury debt in a macroeconomic context. Krishnamurthy and Vissing-Jorgensen (2012) show that the supply of treasuries affects spreads, indicating that short-term and long-term treasury debt is characterized by liquidity and safety reflected by interest rate premia. Nagel (2016) provides evidence on a systematic relation between the level of 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.[12] Our empirical analysis further implies short- and long-term treasury debt to pro-

[9] In contrast to our findings, Ravn and Sørensen (2018) also document a decline in the personal consumption expenditure price index which may contribute to the interest-rate response. Corsetti et al. (2012) further 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. Ben Zeev and Pappa (2017), who identify spending shocks through a maximum forecast error variance approach to defense spending, find the interest rate on 3-months T-Bills to increase in a VAR, which contrasts Ramey's (2016) findings using identical shocks for local projections.

[10] Rendahl (2016) shows that, under labor market frictions, fiscal multipliers can be large at the ZLB even when government spending does not increase future inflation.

[11] Similar effects on equilibrium determinacy and fiscal policy effects at the ZLB are found by Diba and Loisel (2017), who consider an extended New Keynesian model where the central bank simultaneously controls two instruments (instead of one).

[12] In contrast to our model, Nagel (2016) assumes that the central bank sets the interest rate on less liquid assets rather than on T-bills.

vide liquidity services to a different extent, which relates to Greenwood et al. (2015), who analyze optimal government debt maturity. The theoretical foundation of the liquidity premium in our model is similar to Williamson (2016), who applies a model with differential pledgeability of assets to study unconventional monetary policy. We specify collateral requirements as commonly imposed by major central banks, which can be endogenized by information frictions, as shown by Rocheteau et al. (2018). Short-term treasuries then serve as a substitute for money, which relates to Benigno and Nistico's (2017) specification of liquidity constraints accounting for holdings of money and treasuries. It is noteworthy that our particular specification of liquidity services has also proven to be helpful for solving puzzles related to uncovered interest rate parity and forward guidance, see Linnemann and Schabert (2015) and Bredemeier et al. (2018a).

3 Fiscal policy effects in the data

The starting point of our empirical analysis is Mountford and Uhlig's (2009) and Ramey's (2016) finding that, in postwar U.S. 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. Our first step is to replicate and extend these results by estimating responses of fiscal policy shocks for the sample period 1948-2015 using Ramey's (2016) military spending identification and estimation procedure. In a second step, we consider financial market data to assess the relevance of assets' imperfect substitutability for the transmission of fiscal shocks. Using the same econometric approach and the same sample period, we document that the spread between the Aaa rate and the 10-year government bonds rate increases significantly in response to defense news shocks. This supports our hypothesis that fiscal spending induces unequal effects in financial market segments for assets that differ with regard to their liquidity or convenience value. In a third step of the analysis, we extend the analysis and show that various measures for liquidity premia increase after government spending shocks. For this, we rely on a different identification procedure, given that relevant financial market data are only available for recent sample periods. Using professional forecasts for the identification of fiscal shocks (see also Figure 1), as suggested by Ramey (2011) for these sample periods, we again find falling monetary policy rates, moderate output multipliers, and, importantly, that interest rate spreads that measure liquidity premia increase significantly after a government spending hike. Overall, our findings point towards an important role of liquidity attributes of assets in explaining differential interest rate dynamics after fiscal policy shocks.

3.1 Monetary policy and the fiscal multiplier

To set the stage for our analysis, we start by replicating and extending Ramey's (2016) estimation of the effects of fiscal policy shocks on core macroeconomic variables, applying defense news shocks (see Ramey, 2011) and computing impulse responses with local projections (see Jorda, 2005).[13] As in Ramey (2016), the sample period is 1947Q1-2015Q3. In addition to Ramey's (2016) set of variables, we consider the responses of the nominal T-bill rate, the CPI inflation rate, and corporate bonds spreads.

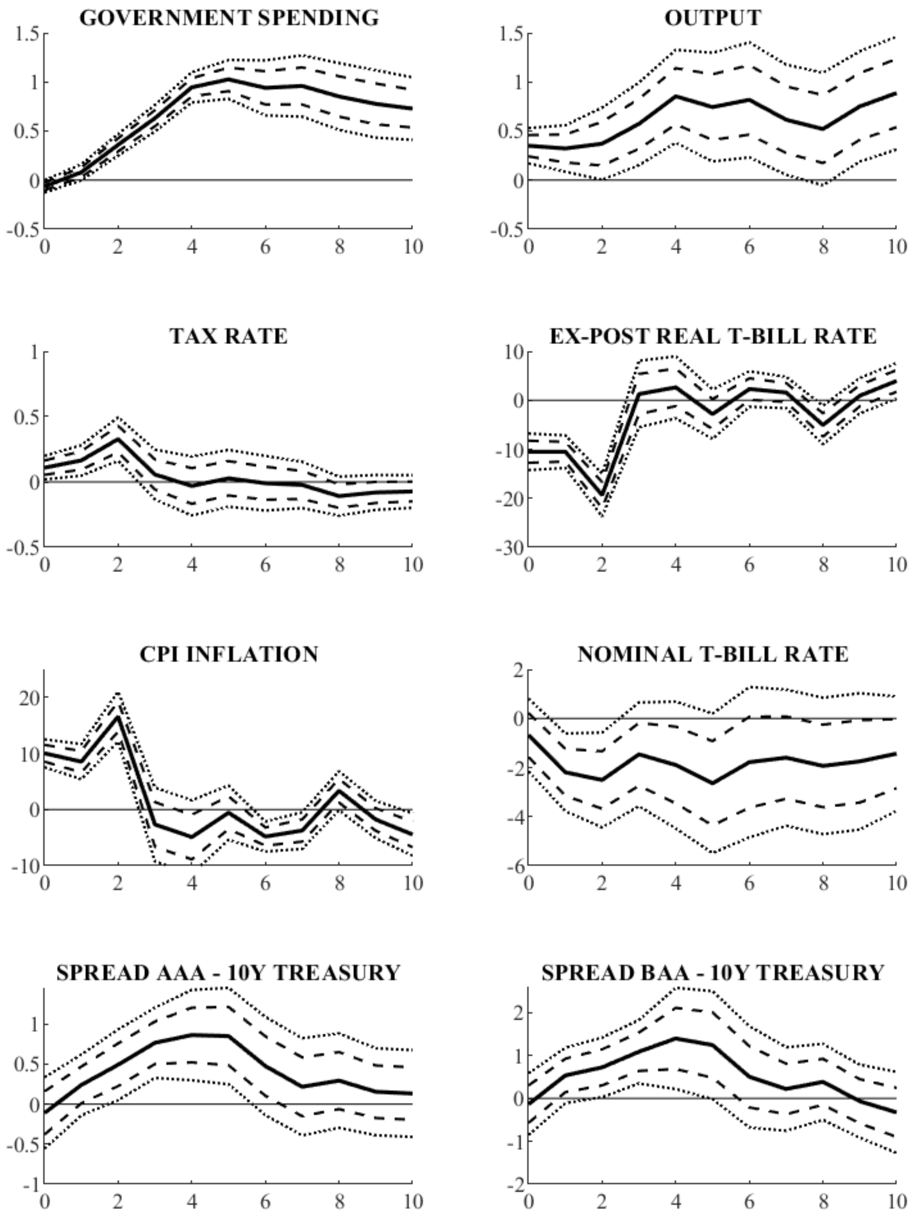
Figure 2 presents impulse responses of government spending, output, the nominal T-bill rate, the CPI inflation rate, and corporate bonds spreads. The response of government spending and output are expressed in percent while, for interest rates and inflation, we show absolute responses expressed in basis points. The dotted (dashed) lines show 68% (90%) confidence bands. The responses in the first row are identical with the responses in Ramey (2016) and show that output increases with positive spending shocks. The cumulated output multipliers differ with regard to the particular time horizon, as also documented in Ramey (2016), and are 1.37 after four quarters, 1.0 after six quarters, and 0.8 after eight quarters. At the same time, we observe a prolonged fall in the nominal T-bill rate, which is statistically significant in the quarters 1-3 after the shock.[14] Within the first three quarters, we further observe a significant and sharp increase in CPI inflation. Consistently, the ex-post real T-bill rate falls unambiguously in response to a fiscal expansion by almost 20 bps. The responses of the nominal T-bill rate, which is closely linked to the federal funds rate at quarterly frequency (see Simon, 1990), indicates a clear accommodating monetary policy stance towards fiscal policy. This observation together with the observed responses of inflation and output cannot be explained by monetary policy reactions implied by a conventional Taylor-type interest rate rule. Notably, falling real interest rates can – in theory – not be squared with a moderate output multiplier, which should instead take extremely large values even under a combination of a constant nominal interest rate (e.g., at the ZLB) and an increased inflation rate (see Christiano et al., 2011, or Eggertsson, 2011).

To understand these observations, recall that theory predicts government spending to induce excess demand for commodities. The reduced willingness to save tends to reduce

[13] For this approach, we estimate a set of regressions for each horizon, where we obtain the h-quarter-ahead impulse response for a specific variable z by regressing z_{t+h} on the identified government spending shock in period t as well as on control variables. The error terms in the local projection regressions will have a moving-average structure of the forecast errors between different horizons. Following Jorda (2005) and Ramey (2016) we correct the standard errors for serial correlation using the Newey-West (1987) procedure.

[14] The impact multiplier is negative here, as in Ramey (2016), since output increases, whereas government spending initially falls slightly in response to news shocks.

Figure 2: Responses to government spending shocks identified through defense news.



Notes: Identification based on narrative defense news shocks (see Ramey, 2011, Ramey and Zubairy, 2014, and Ramey 2016). Impulse responses computed using local projections as in Ramey (2016). Variable definitions (Gordon-Krenn 2010 transformation) and specification follow Ramey (2016). T-bill rates, inflation, and spreads in basis points. Sample period 1947Q1-2015Q3. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

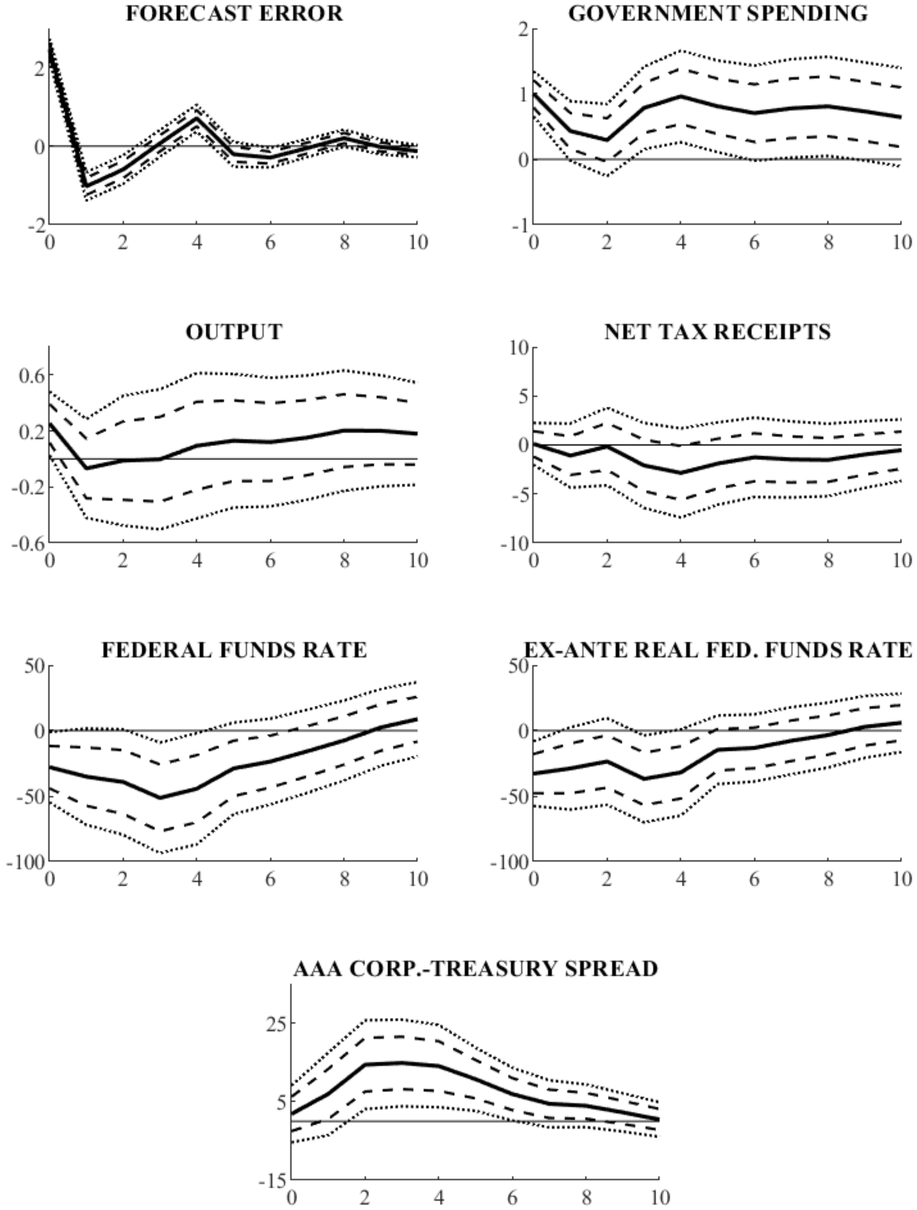
prices of assets that private agents use as a store of wealth and to increase their real interest rates. However, the federal funds rate is less related to the latter than to interest rates on near money assets (like T-bills), which are typically not held as a store of wealth and can – except for financial institutions – not be issued by private borrowers. Hence, interest rate spreads respond systematically to government spending shocks when the underlying assets differ with regard to their ability to serve as a substitute for money. To shed further light on this mechanism, we exploit additional information from financial markets. However, most informative financial market variables are not available before the end of the 1970s. As a typical measure for a liquidity premium or "convenience yield" (see e.g. Krishnamurthy and Vissing-Jorgensen, 2012) which is available for a longer period of time, we consider the spread between the yield on Aaa corporate bonds and 10-year government bonds. We find that this spread increases significantly after defense news shocks, see bottom-left panel in Figure 2. Thus, our analysis shows that the response of an interest rate that is relevant for private sector borrowing and savings differs substantially from the treasury rate response. We obtain a similar finding for the Baa coporate bonds spread, see the bottom-right panel in Figure 2. However, while Baa corporate rates are also relevant for private sector borrowing, they are further affected by other factors, in particular, by larger credit risk components, which we do not address in our analysis.

3.2 Liquidity premia as a central factor

We now include a larger set of financial data, i.e. interest rate spreads, in our analysis. This however limits the sample period as most informative financial market variables are not available before the end of the 1970s. Specifically, our baseline analysis considers quarterly data for the sample period 1979Q4 to 2015Q4. Ramey (2011, 2016) has shown that identification approaches based on narrative measures or military news perform poorly in identifying government spending shocks in samples that start after the Korean war. In the following, we therefore follow Ramey (2011) and use forecast errors from the Survey of Professional Forecasters (SPF) to capture exogenous and unforeseen variations in government spending and apply a well-established VAR framework to compute impulse responses. We extend Ramey's (2011) sample to end in 2015Q4, construct forecast errors from the SPF using real-time data, following Auerbach and Gorodnichenko (2012), and consider a shock to the forecast error which is ordered first in a recursive orthogonalization. As further variables in the baseline VAR, we include log real total government spending per capita, log real GDP per capita, log real net tax receipts per capita, and the nominal federal funds rate. Thus, we use the same variables as Auerbach and Gorodnichenko (2012), additionally controlling for monetary policy (as suggested by Ramey, 2011).[15] As Ramey (2011), we include four lags and account for linear-quadratic trends.

[15] Details on data sources and variable definitions are provided in Appendix A.

Figure 3: Responses to government spending shocks identified through forecast errors.



Notes: Identification based on forecast errors from the Survey of Professional Forecasters (Ramey, 2011). VAR includes forecast error, government spending, real GDP, net tax receipts, and the federal funds rate. Real federal funds rate and coporate bonds spread, respectively, replace nominal federal funds rate in VAR. Sample period 1979Q4-2015Q4. Responses in percent, interest rate responses in basis points. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

We follow Burnside et al.'s (2004) strategy and rotate further variables of interest into the baseline VAR. Figure 3 shows the responses to a 1% positive government spending shock in our baseline VAR. In line with Ramey (2011) who considers a sample period similar to ours, output increases on impact, while the expansionary effect of fiscal policy is found to be short-lived.[16] The cumulated output multiplier in our VAR equals 1.29 on impact, 0.39 after four quarters, 0.53 after six quarters, and 0.68 after eight quarters. Like in Ramey (2011), we do not find a significant response of taxes to government spending shocks. Most importantly, as in Figure 2, we find that the nominal federal funds rate decreases substantially and significantly in response to a government spending shock while estimated government spending multipliers are moderate. We also investigate the behavior of the real federal funds rate, since real rather than nominal interest rates are relevant for intertemporal decisions. Consistent with a forward-looking behavior of financial market participants whose investment decisions are based on expected inflation, we apply ex-ante real rates using real-time inflation forecasts (not available for the sample period underlying Figure 2) rather than ex-post real rates using realized inflation rates. We find that the ex-ante real federal funds rate also declines significantly, by up to 30 basis points, in response to government spending shocks.[17] In line with our previous analysis, we find that the corporate bonds spread increases significantly, see bottom panel in Figure 3. Thus, also in this sample period and for this identification approach, we obtain a similar set of results compared to the longer sample and the defense-news identification.

The main hypothesis of this paper is that differences in interest rate responses are mainly driven by asymmetric demands for assets with different liquidity characteristics, which are captured by endogenous liquidity premia. Direct evidence supporting this claim is summarized in Figure 4 which shows responses of interest rate spreads that have been identified to be predominantly determined by liquidity valuations, i.e., interest rate spreads between assets with similar maturity but differences in liquidity.[18]

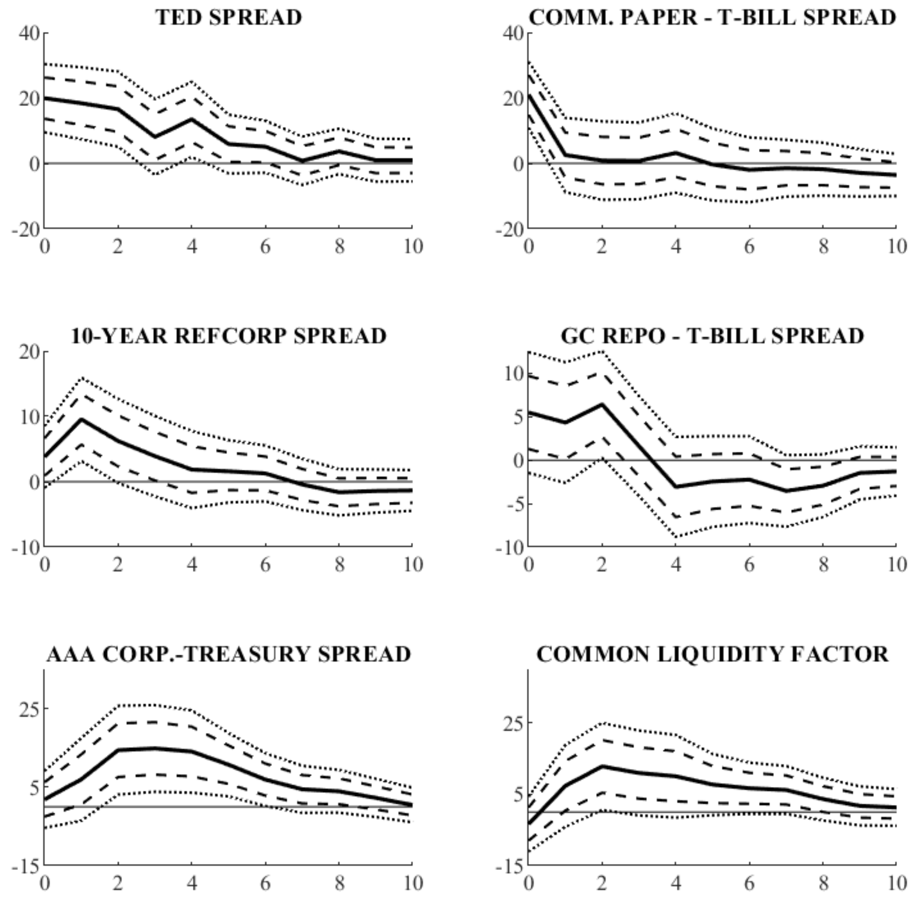
We investigate three spreads that measure liquidity premia on short-term assets and one additional spread on longer-term assets, next to the corporate bonds spread already investigated before. The short-term spreads are the spread between the US LIBOR rate and the T-bill rate (also known as the TED spread) 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 a credit risk component, while the latter spread is – according to Krishnamurthy and Vissing-Jorgensen (2012) – much less

[16] Figure XII in Ramey (2011) shows a very similar output response as documented in our Figure 3.

[17] We also include realized CPI inflation rates and real-time inflation forecasts into the set of variables and find that neither inflation measure display a significant response to government spending shocks (see Figure 8) in Appendix A.

[18] In Figure 7 in Appendix A, we show that the various liquidity 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 U.S. Fed's extended liquidity provision.

Figure 4: Responses of liquidity premia to government spending shocks identified through forecast errors.



Notes: Identification based on forecast errors from the Survey of Professional Forecasters (Ramey, 2011). VAR includes forecast error, government spending, real GDP, net tax receipts, and the respective liquidity spread shown in the figure. Sample period 1986Q1-2015Q4 for TED spread, 1997Q1-2015Q4 for commercial paper spread, 1991Q2-2015Q4 for Refcorp spread, 1992Q1-2015Q4 for GC repo spread, 1979Q4-2015Q4 for Aaa spread and common factor. Responses in basis points. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

affected by default risk. We further examine the spread between the interbank rate on 3-month general collateral (GC) repurchase agreements and the T-bill rate, which has been suggested by Nagel (2016) as a measure for illiquidity, as trading the former asset is – in contrast to the latter – costly. The additional long-term spread we consider is the spread between 10-year Refcorp bonds and treasury bonds, suggested by Longstaff (2004). Given that Refcorp bonds are guaranteed by the U.S. government and taxed as treasury bonds, the associated spread mainly captures relative illiquidity of Refcorp bonds and is hardly contaminated by other factors. Corresponding spreads for different maturities, e.g., 5 years, are not shown here, as they display very similar responses.

Figure 4 shows that liquidity premia increase significantly in response to the government spending shock. 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 is about 20 bps and is thus substantial, compared to the mean values for the spreads which range between 25 and 135 bps and the monetary policy response. We corroborate the effect of fiscal policy on liquidity premia by considering, following Del Negro et al. (2017), a common liquidity factor that extracts the common component of short-term and long-term spreads. The main advantage of the common factor is that, while individual interest rate spreads may include non-liquidity related components, these components are washed out by the common factor analysis which delivers a purified measure of liquidity premia. The bottom panel of Figure 4 shows that the common liquidity factor increases significantly in response to expansionary fiscal policy shocks. Quantitatively, liquidity premia rise by up to 25 bps which is in the ballpark of the fall in the real federal funds rate shown in Figures 2 and 3.

In a previous version of this article, we have considered several money market rates like treasury bills, commercial papers, or certificates of deposits, i.e., interest rates on assets and liabilities that are relevant for liquidity management as they serve as substitutes for money. As a second set of interest rates, we have examined interest rates on less liquid assets which are relevant for non-financial sector borrowing, like mortgage rates and corporate bond rates. Overall, we find that the response of an interest rate tends to deviate more from the monetary policy rate response the less the underlying asset serves as a substitute for money, see Bredemeier et al. (2018b).

3.3 Additional empirical evaluations

We also consider a sample period that excludes the recent ZLB episode which we find to have no substantial impact on the results. We further assess alternative explanations for our novel findings on differential interest rate responses, see Figure 9 in Appendix A. To examine if the increase in longer-term rates (like Aaa corporate bonds) are primarily driven by *expected future increases of short-term rates*, we compute the response of expected future short-term rates. For this, we apply the 5-8 quarter ahead forecast for the 3 months T-bill rate.[19] Given it does not exhibit any tendency to increase after a fiscal expansion, this potential explanation for increasing longer-term rates is not supported by empirical evidence. We further investigate the *excess bond premium* constructed by Gilchrist and Zakrajšek (2012), which according to the authors mainly captures the

[19] As an alternative, one could measure expectations about future federal funds rates exploiting prices on federal funds future contracts which are available from 1988 onwards.

risk-bearing capacity of the financial sector. We find that this premium reacts only insignificantly and less strongly compared to the measures of liquidity premia. Given this unsystematic response, a changing risk-taking capacity is unlikely to be a major driving force behind the observed interest rate responses. Next, we look at the *supply of debt securities*, which might affect prices and yields of treasury securities. In contrast to the total-debt-to-GDP ratio, the ratio of T-bills to GDP does not experience a significant increase in response to government spending shocks. As argued by Krishnamurthy and Vissing-Jorgensen (2012), an increase in the debt-to-GDP ratio, which raises the supply of relatively liquid assets, should however reduce the Aaa-treasury spread. Given that we actually find the latter to respond in the opposite way, this supply effect seems to be clearly dominated by the demand effect described above. A comparison of the total-debt-to-GDP ratio and the T-bills-to-GDP ratio further reveals that the supply of T-bills falls relative to total debt, which actually reinforces the demand driven relative scarcity of liquid assets. We re-assess the accommodating stance of monetary policy by including total reserves in the set of variables. Consistent with the decline in the federal funds rate, the latter tends to increase after fiscal expansions, corroborating that the monetary policy stance is accommodative after positive fiscal spending shocks.

Overall, our findings points towards an important role of liquidity attributes of assets in explaining differential interest rate dynamics after fiscal policy shocks. Specifically, fiscal policy affects the relative scarcity of liquidity thereby raising the valuation of near-money assets compared to less liquid assets.

4 A model with an endogenous liquidity premium

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 that might differ from the monetary policy rate by first order. To isolate the main mechanism and to facilitate comparisons with related studies, our model is based on a standard New Keynesian model and features a single non-standard element. We consider differential pledgeability of assets in open market operations, implying different degrees of liquidity, i.e., assets' ability to serve as a substitute for money.[20] Specifically, commercial banks demand reserves supplied by the central bank to serve withdrawals of demand deposits

[20] This 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.

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 financial crisis. Consistent with empirical evidence, the interest rate on T-bills therefore closely follows the monetary policy rate, whereas the interest rates on non-eligible assets exceed the monetary policy rate by a liquidity premium. As non-eligible assets serve as private agents' store of wealth, their interest rates relate to agents' marginal rate of intertemporal substitution.

In each period, the timing of events in the economy 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 Banking sector

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 while accounting – arguably in a stylized way – for the way the Fed has implemented monetary policy before 2008Q3: It announces a target for the federal funds rate, i.e., the interest rate at which depository institutions trade reserve balances overnight. Reserves are originally issued by the Fed via open market operations, which determine the overall amount of available federal funds that are further distributed via the federal funds market. Due to federal funds' unique ability to satisfy reserve requirements, banks rely on federal funds market transactions when their reserves demand within a maintenance period is not directly met by open market transactions. The latter are either carried out as outright transactions or as temporary sales or purchases (repos) of eligible securities, between the central bank and primary dealers. Outright transactions are conducted to accommodate trend growth of money, while repos are conducted by the Fed to fine-tune the supply of reserves such that the effective federal funds rate meets its target value.

Since banks have access to reserves via temporary open market transactions or via federal funds market transactions, 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 respective rates are in fact 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 less than one basis point on average (see

Figure 10), 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 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.

We consider an infinite time horizon and 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 $M_{i,t-1}$. The central bank supplies reserves via open market operations either outright or temporarily under repurchase agreements; the latter corresponding to a collateralized loan. In both cases, T-bills serve as collateral for central bank money, while the price of reserves in open market operations in terms of T-bills (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:

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

where $I_{i,t}$ denotes additional money received from the central bank. Hence, (1) 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 $B_{i,t-1}/R_t^m$. The price for reserves in an (unmodelled) interbank market is then closely linked to the repo rate, as in U.S. data, where the treasury repo rate and the federal funds rate are almost identical (see above). Consistently, we assume that the central bank sets the repo rate R_t^m. Reserves are held by bank i to meet the following constraint

$$\mu D_{i,t-1} \leq I_{i,t} + M_{i,t-1}, \tag{2}$$

where $D_{i,t-1}$ denotes demand deposits. The constraint (2) implies that a fraction μ of deposits have to be backed by reserves, which can either be rationalized by settlement of deposit transactions, a minimum reserve requirement, or withdrawals by depositors. To keep the exposition simple, we focus on the latter to motivate positive reserve demand. 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 $1/R_t$. 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, bank i's 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

$$\begin{aligned} P_t \varphi_{i,t}^B = & \left(D_{i,t}/R_t^D\right) - D_{i,t-1} - M_{i,t} + M_{i,t-1} - I_{i,t}\left(R_t^m - 1\right) \\ & - \left(B_{i,t}/R_t\right) + B_{i,t-1} - \left(L_{i,t}/R_t^L\right) + L_{i,t-1} + \left(A_{i,t}/R_t^A\right) - A_{i,t-1}, \end{aligned} \tag{3}$$

where P_t denote the aggregate price level and $A_{i,t}$ 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 which enter the TED spread considered in Section 3. Notably, the aggregate stock of reserves only changes with central bank money supply, $\int_0^1 M_{i,t} di = \int_0^1 (M_{i,t-1} + I_{i,t} - M_{i,t}^R) di$, whereas demand deposits can be created subject to (2).

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 a stochastic discount factor (see below), subject to the money supply constraint (1), the liquidity constraint (2), the budget constraint (3), and the borrowing constraints $\lim_{s\to\infty} E_t[p_{t,t+k}(D_{i,t+s} + A_{i,t+s})/P_{t+s}] \geq 0$, $B_{i,t} \geq 0$, and $M_{i,t} \geq 0$. The first order conditions with respect to deposits, T-bills, corporate and interbank loans, money holdings, and reserves can be written as

$$1/R_t^D = E_t[p_{t,t+1}(1 + \mu \varkappa_{i,t+1})/\pi_{t+1}], \tag{4}$$

$$1/R_t = E_t[p_{t,t+1}(1 + \eta_{i,t+1})/\pi_{t+1}], \tag{5}$$

$$1/R_t^L = 1/R_t^A = E_t p_{t,t+1} \pi_{t+1}^{-1}, \tag{6}$$

$$1 = E_t[p_{t,t+1}(1 + \varkappa_{i,t+1})/\pi_{t+1}], \tag{7}$$

$$\varkappa_{i,t} + 1 = R_t^m \left(\eta_{i,t} + 1\right), \tag{8}$$

where $\pi_{t+1} = P_{t+1}/P_t$, E_t is the expectation operator conditional on the time t information set, and $\varkappa_{i,t}$ and $\eta_{i,t}$ denote the multipliers on the liquidity constraint (2) and the money supply constraint (1), respectively. Apparently, the rates on corporate and interbank loans are identical (see 6), while they exceed the treasury rate R_t under a binding money supply constraint (1), $\eta_{i,t} > 0$ (see 5). This difference will give rise to a liquidity premium.[21]

[21] Further, complementary slackness and transversality conditions hold, see Appendix B.3.

4.2 Households and firms

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 $E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, n_t)$, 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, 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 $z_{-1} > 0$. 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 (see Lucas and Stokey, 1987). To purchase goods, households can in principle hold cash, which is dominated by the rate of return of other assets. Instead we assume that they hold demand deposits at banks, which can be converted into cash at any point in time. For simplicity, we consider an exogenous fraction $\mu \in [0,1]$ of withdrawn deposits such that the goods market constraint, which resembles a standard cash in advance constraint, can be summarized as

$$P_t c_t \leq \mu D_{t-1}. \tag{9}$$

The budget constraint of the representative household is $\left(D_t/R_t^D\right) + V_t z_t + P_t c_t + P_t \tau_t \leq D_{t-1} + (V_t + P_t \varrho_t) z_{t-1} + P_t w_t n_t + P_t \varphi_t$, 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 lifetime utility subject to the goods market constraint (9), the budget constraint, and $D_t \geq 0$ and $z_t \geq 0$ for given initial values leads to the following first order conditions for working time, shares of intermediate goods producing firms, consumption, and real deposits: $-u_{n,t} = w_t \lambda_t$, $\beta E_t \left[\lambda_{t+1} R_{t+1}^q \pi_{t+1}^{-1}\right] = \lambda_t$,

$$u_{c,t} = \lambda_t + \psi_t, \tag{10}$$

$$\lambda_t / R_t^D = \beta E_t \left[\left(\lambda_{t+1} + \mu \psi_{t+1}\right) \pi_{t+1}^{-1}\right], \tag{11}$$

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 real versions of the goods market constraint (9) and the budget constraint, respectively. Under a binding goods market constraint (9), $\psi_t > 0$, the deposit rate tends to be lower than the expected return on equity (see 11), as demand deposits provide transaction services.[22]

[22] This spread will not be analyzed further in the subsequent sections, given that it does not relate to spreads investigated in our empirical analysis.

There is further 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:

$$L_t/R_t^L \geq P_t w_t n_t. \tag{12}$$

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 $p_{t,t+k} = \beta^k \lambda_{t+k}/\lambda_t$ and 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 (12). The first order conditions for labor demand and loan demand are $1 + \gamma_t = R_t^L E_t[p_{t,t+1}\pi_{t+1}^{-1}]$ and $P_t^m/P_t = (1+\gamma_t)\, w_t$,where γ_t denotes the multiplier on the loan demand constraint (12). Given that we abstract from financial market frictions, the Modigliani-Miller theorem applies here. This immediately follows from banks' loan supply condition (6) and firms' loan demand condition, implying $\gamma_t = 0$. Hence, the loan demand constraint (12) is slack, such that firms' labor demand 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.2.

4.3 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 does not significantly respond to changes in government spending (see Figure 9), we can specify the supply of treasury bills by a constant constant growth rate Γ,

$$B_t^T = \Gamma B_{t-1}^T, \tag{13}$$

where $\Gamma > \beta$. For simplicity, we neither specify longer-term government debt nor total government debt.[23] The government budget constraint is thus given by $\left(B_t^T/R_t\right) + P_t\tau_t^m = P_t g_t + B_{t-1}^T + P_t\tau_t$, where $P_t\tau_t^m$ denotes central bank transfers 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 $\Delta B_t^C + B_{t-1}^C - B_t^R$.[24] Following central bank practice, we assume that interest earnings are transferred to the government, $P_t\tau_t^m = B_t^C\left(1 - 1/R_t\right) + \left(R_t^m - 1\right)\left(M_t - M_{t-1} + M_t^R\right)$, 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 $B_t^C = M_t$. 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 $\Omega \geq 0 : M_t^R = \Omega M_t$. We assume that Ω is sufficiently large such that central bank money injections I_t are non-negative.

4.4 Equilibrium properties

Given that households, firms, retailers, and banks behave symmetrically, we can omit the respective indices. A definition of the rational expectations equilibrium can be found in Appendix B.3. As mentioned above, the Modigliani-Miller theorem applies. Hence, the main difference to a standard New Keynesian model is the money supply constraint

[23] 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 the corporate debt rate, which roughly fits the empirical evidence provided in Section 3.

[24] Its budget constraint is thus given by $\left(B_t^C/R_t\right) + P_t\tau_t^m = \Delta B_t^C + B_{t-1}^C - B_t^R + M_t - M_{t-1} - \left(I_t - M_t^R\right)$, 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 $\left(B_t^C/R_t\right) - B_{t-1}^C = R_t^m\left(M_t - M_{t-1}\right) + \left(R_t^m - 1\right)M_t^R - P_t\tau_t^m$.

(1), 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 if the money supply constraint (1) is slack. The fiscal policy effects of this latter model version, which is summarized in Definition 2 in Appendix B.3, 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).

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 (1) 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

$$R_t^{IS} = u_{c,t}/\beta E_t \left(u_{c,t+1}/\pi_{t+1}\right), \tag{14}$$

which measures the marginal valuation of money by the private sector.[25] 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 (1) is then binding. To see this, combine (4) with (11) to get $E_t[\frac{\lambda_{t+1}+\mu\psi_{t+1}}{\lambda_t}\pi_{t+1}^{-1}] = E_t[\frac{\lambda_{t+1}}{\lambda_t}\left(1+\varkappa_{t+1}\mu\right)\pi_{t+1}^{-1}]$, which holds if the liquidity constraint multipliers satisfy $\varkappa_t = \psi_t/\lambda_t$. Hence, the equilibrium versions of the conditions (7) and (8) imply $\left(\psi_t+\lambda_t\right)/\lambda_t = R_t^m\left(\eta_t+1\right)$ and $\beta\pi_{t+1}^{-1}\left(\lambda_{t+1}+\psi_{t+1}\right) = \lambda_t$, which can – by using the equilibrium version of condition (10) – be combined to

$$\eta_t = \left(R_t^{IS}/R_t^m\right) - 1. \tag{15}$$

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 (5) with (7) and (8), $R_t \cdot E_t\varsigma_{1,t+1} = E_t[R_{t+1}^m \cdot \varsigma_{1,t+1}]$, where $\varsigma_{1,t+1} = \lambda_{t+1}\left(1+\eta_{t+1}\right)/\pi_{t+1}$. Thus, the T-bill rate equals the expected policy rate up to first order,

$$R_t = E_t R_{t+1}^m + \text{h.o.t.}, \tag{16}$$

where h.o.t. represents higher order terms.[26] Using $\beta E_t\pi_{t+1}^{-1}\left(\lambda_{t+1}+\psi_{t+1}\right) = \lambda_t$ and (10) to rewrite (6) shows that the loan rates R_t^L and R_t^A relate to the expected marginal rate of intertemporal substitution $(1/R_t^{L,A}) \cdot E_t\varsigma_{2,t+1} = E_t[\left(1/R_{t+1}^{IS}\right) \cdot \varsigma_{2,t+1}]$, where $\varsigma_{2,t+1} =$

[25] Agents 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.

[26] Notably, the relation (16) is in line with the empirical evidence provided by Simon (1990).

$\left(\lambda_{t+1}+\psi_{t+1}\right)/\pi_{t+1}$. Likewise, (11) implies that the expected rate of return on equity satisfies $E_t\varsigma_{2,t+1} = E_t\left[\left(R^q_{t+1}/R^{IS}_{t+1}\right)\cdot\varsigma_{2,t+1}\right]$. Hence, the corporate and interbank loan rates are equal to the expected marginal rate of intertemporal substitution up to first order,

$$R^L_t = R^A_t = E_t R^{IS}_{t+1} + \text{h.o.t.}, \tag{17}$$

while the expected rate of return on equity satisfies, $E_t R^q_{t+1} = E_t R^{IS}_{t+1} +$ h.o.t. Thus, the spread between the marginal rate of intertemporal substitution and the monetary policy rate, $R^{IS}_t - R^m_t$, summarizes how interest rates in the current model differ from those of a standard model.

It should further be noted that, as long as the nominal marginal rate of intertemporal substitution (rather than the policy rate R^m_t) exceeds one, i.e., $R^{IS}_t > 1$, the demand for money is well defined, as the liquidity constraints of households (9) and banks (2) are binding. This can be seen by substituting out the multiplier $\varkappa_t$ in the equilibrium version of (7) with $\varkappa_t = \psi_t/\lambda_t$ and combining with the equilibrium version of (10), which leads to $\psi_t = u_{c,t}\left(1 - 1/R^{IS}_t\right)$.This implies that the liquidity constraints (9) and (2) are binding if R^{IS}_t is strictly larger than one. Notably, liquidity might be positively valued by households and banks, i.e., $R^{IS}_t > 1$, even when the policy rate is at the zero lower bound, $R^m_t = 1$; this property being consistent with the observation that liquidity premia have been positive during the recent ZLB episode in the US (see Figure 7).

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 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. 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. We then examine the case where the monetary policy rate is below the marginal rate of intertemporal substitution. This version will be shown to be able to rationalize the empirical effects of government spending shocks.

5.1 Analytical results

To isolate the impact of the main non-standard model feature, we separately analyze the cases where either the money supply constraint (1) 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}. For this, we assume that the central bank sets the policy rate in the long run below (equal to) $R^{IS} = \pi/\beta$, where time indices are omitted to indicate steady state values, such that (1) is binding (not binding), see (15). For both cases, we examine the local dynamics in the neighborhood of the respective steady state.[27] There, the equilibrium sequences are approximated by the solutions to the linearized equilibrium conditions, where $\widehat{a}_t$ denotes relative deviations of a generic variable a_t from its steady state value $a : \widehat{a}_t = \log(a_t/a)$. To facilitate the derivation of analytical results, we assume that outright money supply is negligible, $\Omega \to \infty$, 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),[28] and that government spending shocks are i.i.d.

Definition 3 *A rational expectations equilibrium for $\Omega \to \infty$ and $\Gamma = \pi = 1$ is a set of convergent sequences $\{\widehat{c}_t, \pi_t, \widehat{b}_t, \widehat{R}_t^{IS}, \widehat{R}_t^m\}_{t=0}^\infty$ satisfying*

$$\widehat{c}_t = \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m < R_t^{IS}, \tag{18}$$

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

$$\sigma\widehat{c}_t = \sigma E_t\widehat{c}_{t+1} - \widehat{R}_t^{IS} + E_t\widehat{\pi}_{t+1}, \tag{19}$$

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \chi\left(\sigma_n c_y + \sigma\right)\widehat{c}_t + \chi\sigma_n g_y\widehat{g}_t + \chi\widehat{R}_t^{IS}, \tag{20}$$

$$\widehat{b}_t = \widehat{b}_{t-1} - \widehat{\pi}_t, \tag{21}$$

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

$$\widehat{R}_t^m = \rho_\pi\widehat{\pi}_t + \rho_g\widehat{g}_t, \tag{22}$$

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 (1) 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 (18)

[27] We 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.

[28] Notably, 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).

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 (20). 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 22), 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 real policy rate falls in response to an expansionary government spending shock, private consumption increases and the fiscal multiplier is larger than one in a uniquely determined locally stable equilibrium.*

Proof. See Appendix C. ■

As shown by Aiyagari et al. (1992) or Baxter and King (1993), 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 less than one. This basic transmission channel of government spending can, however, be dominated under the assumption that the monetary policy rate equals the marginal rate of intertemporal substitution. If the real policy rate actually falls in response to a government spending shock, private agents increase current consumption relative to future consumption, such that private consumption is crowded in. This mechanism is 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). Proposition 1 confirms this prediction of falling real policy rates being associated with a multiplier larger than one. The simultaneous observation of a fiscal multiplier below one and a decline in the real policy rate as found in the data is therefore a puzzle through the lens of a standard model.

Once the marginal rate of intertemporal substitution, which closely relates to the returns on non-eligible and thus illiquid assets (see 17), 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 (18) are binding, and that there exists a liquidity premium. Before we analyze the effects of fiscal policy shocks, we briefly examine equilibrium determinacy, i.e. existence and uniqueness of locally convergent equilibrium sequences.

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

$$\rho_\pi < [(1+\beta)\chi^{-1} + 1 - \sigma]/\sigma. \tag{23}$$

Proof. See Appendix C. ■

Condition (23) implies that, under a binding money supply constraint (1), the Taylor principle (i.e., an active monetary policy, $\rho_\pi > 1$) is not relevant for equilibrium determinacy. The central bank can even peg the policy rate ($\rho_\pi = 0$) without inducing indeterminacy. This property is mainly due to a bounded supply of money which provides 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). It should further be noted that the sufficient condition (23) 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. Consider first the case where the policy rate does not directly respond to government spending, $\rho_g = 0$. 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 $\rho_\pi > 1$ (see Appendix C). 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 (see Lemma 2 in Appendix C for the exact conditions).

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 18), which eases private sector access to money. Thus, a sufficiently large reduction of the policy rate in response to higher government spending can in principle stimulate private consumption (see Lemma 2 in Appendix C). Yet, 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 liquidity premium increases, consistent with the empirical facts documented in Section 3.

Proposition 2 *When a liquidity premium exists and (23) is satisfied, an unexpected increase in government spending can simultaneously lead to a fiscal multiplier between zero and one, a fall in the nominal and real policy rate, and a rise in the liquidity premium.*

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, i.e., below one. When monetary policy does not react too accommodatively, private consumption decreases in response to a fiscal shock.[29] While Proposition 2 establishes the model's principle ability to rationalize observed fiscal policy effects qualitatively, we further assess if the predictions of a calibrated version of the model accord with the empirical facts also quantitatively.

5.2 Effects under two monetary policy scenarios

In this subsection, we first introduce a minimum set of 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 two 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 predictions are consistent with the empirical observations. Second, we examine the case where the monetary policy rate is fixed at the ZLB.[30] We compare the results of a model version 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.

[29] It 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, implying that $E_t R_{t+1}^{IS}$ is positively related to R_t^{IS}.

[30] In Appendix C, we consider the case where the monetary policy rate counterfactually increases in response to higher government spending, according to a standard Taylor rule.

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 (22), 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 does not involve cash. Specifically, the instantaneous utility function is now given by $u(c_t, \bar{c}_t, n_t) = [(c_t - h\mathsf{c}_{t-1})^{1-\sigma}/(1-\sigma)] + \gamma[(\bar{c}_t - h\bar{\mathsf{c}}_{t-1})^{1-\sigma}/(1-\sigma)] - \theta n_t^{1+\sigma_n}/(1+\sigma_n)$, where $\gamma \geq 0$, $\bar{c}_t$ denotes consumption of credit goods, c_t ($\bar{\mathsf{c}}_t$) denotes the cross sectional average of cash (credit) goods, and $h \geq 0$ indicates external habit formation. Intermediate goods are now produced according to $y_t^m = n_t^{\alpha} k_{t-1}^{1-\alpha}$ with $\alpha \in (0,1)$, while physical capital k_t satisfies $k_t = (1-\delta) k_{t-1} + x_t \Lambda_t$, where δ is the rate of depreciation, x_t are investment expenditures, and the function Λ_t denotes 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,

$$R_t^m = \max\{1, (R_{t-1}^m)^{\rho_R} (R^m)^{1-\rho_R} (\pi_t/\pi)^{\rho_\pi(1-\rho_R)} (y_t/\widetilde{y}_t)^{\rho_y(1-\rho_R)} (g_t/g)^{\rho_g(1-\rho_R)}\}, \quad (24)$$

where $\rho_R \geq 0$, $\rho_y \geq 0$, and $\widetilde{y}_t$ denotes the efficient level of output. To account for the observed autocorrelation, 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 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 $E_0 \sum_{t=0}^{\infty} \beta^t \xi_t u_t$. The full set of equilibrium conditions for this extended version of the model can be found in Definition 4 in the Appendix B.

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 (for an interpretation of a period as a quarter) that are standard in the literature.[31] 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

[31] Note that the parameter μ in (2) and (9) is only required to determine real deposits and the deposit rate (see Definition 1), which are both not relevant for the subsequent analysis.

and the habit formation parameter are set at $g/y = 0.2$ and $h = 0.7$. The coefficients of the interest rate rule – except for ρ_g – are set at values typically applied in the literature, $\rho_\pi = 1.5$, $\rho_y = 0.05$, and $\rho_R = 0.8$.

The second set of parameters $\{R^m,\pi,\Gamma,\Omega,\beta,\zeta,\gamma\}$, which relate to the liquidity premium, are set as follows. For the policy rate and inflation, we set average values 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 Fed began to massively increase repos in response to the 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). We use information on the mean fraction of Fed repos to total reserves of depository institutions from Jan. 2003 to Aug. 2007 (where the sample period 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, matching 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 corresponds to Groth and Khan's (2010) estimate based on firm-level data.[32] 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 responses of the policy rate and of output, namely, the government spending feedback coefficient in the interest rate rule (see 24) 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, to roughly match the path of government spending in the VAR. 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 in the VAR (see Figure 5). For these parameter values, the equilibrium is locally determinate (consistent with Lemma 1) for all versions 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 the Appendix C.

[32] This value is much 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).

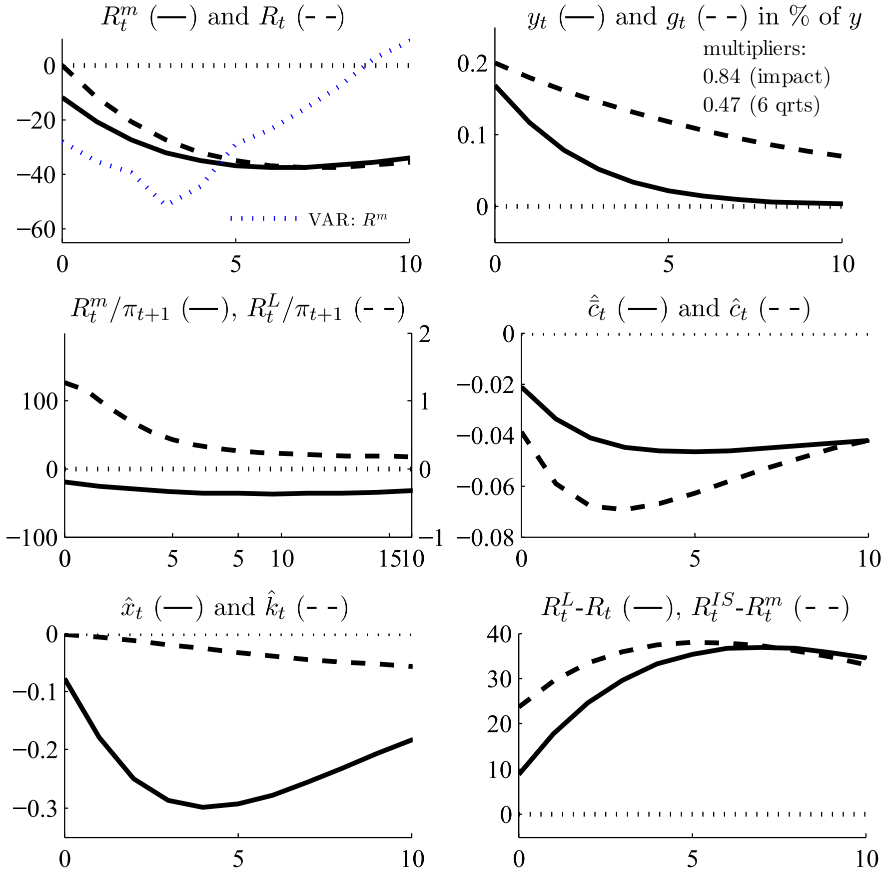
5.2.2 A falling monetary policy rate

Figure 5 shows impulse responses to an autocorrelated government spending shock amounting to one percent of steady state spending associated with a monetary policy rate that falls due to a negative feedback ($\rho_g = -0.75$). The black solid and the black dashed lines refer to the version with a liquidity premium, while the blue dotted line refers to the estimated federal funds rate response presented in Section 3.2. As in our empirical analysis, we show relative responses expressed in percent for level variables such as output, government spending, and absolute responses expressed in basis points for interest rates and interest rates spreads. We additionally show impulse responses of consumption and investment (also in percent), which are consistent with evidence from Ramey (2011).

The figure reveals that government spending exerts the well-known wealth effect in the model version with a liquidity premium: an increase in government spending crowds out private consumption. This is associated with an increase in labor supply such that output increases on impact. The impact output multiplier equals 0.84 and the cumulative output multiplier after six quarters is 0.47, which closely relates to its empirical counterpart of 0.53 (see Section 3.2). The associated decline in the marginal utility of consumption between the current and the next period implies a higher marginal rate of intertemporal substitution (which is separated from the monetary policy rate by the liquidity premium) and a higher natural rate of interest. Further, the real return on physical capital also increases and investment falls, such that total private absorption declines and the fiscal multiplier is smaller than one. While the natural rate of interest increases (see middle left panel, where values of the real loan rate response are given on the right axis), real rates on eligible assets (T-bills) R_t decrease due to the central bank's accommodation of the spending stimulus. Consequently, the spread between the loan rate R_t^L and the T-bill rate R_t increases, in accordance with our empirical findings, as well as the spread between the marginal rate of intertemporal substitution R_t^{IS} and the monetary policy rate R_t^m (as predicted in Proposition 2). Given that these spreads originate in a liquidity premium in our model, their responses to government spending shocks are in line with our empirical evidence on the responses of empirical liquidity premia from Section 3. The model in fact generates a response of the spread $R_t^L - R_t$ (10 bps on impact and 36 bps at maximum) that is similar to the response of liquidity premia estimated in the empirical analysis (about 0-20 bps on impact and 20 bps at maximum, see Figure 4).

Figure 5 thus shows that this simple model can quantitatively reproduce the seem-

Figure 5: 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.

ingly puzzling responses of the nominal and real policy rate and a moderate fiscal multiplier, as found in the data. Hence, 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.[33] It should further be noted that, a change of the parameter values, for example, setting $\rho_g = -1.25$ and $\rho = 0.98$, 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, 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 Appendix C).

[33] 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 (se Lemma 5 in Appendix C).

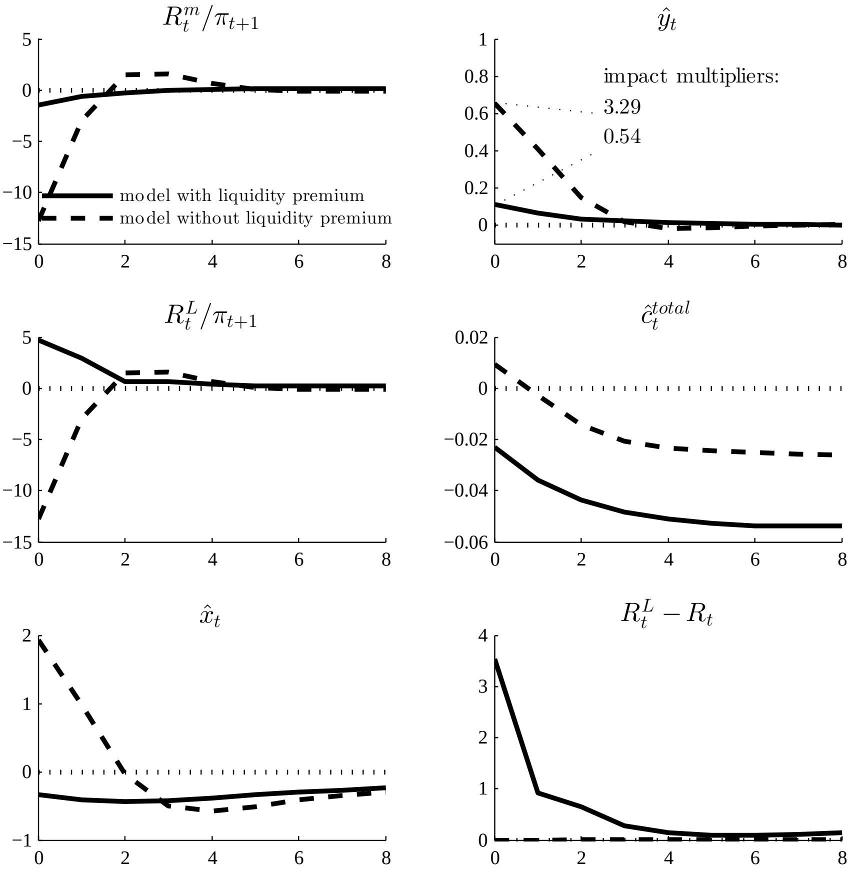
5.2.3 A monetary policy rate at the ZLB

Next, we analyze the fiscal multiplier for the prominent case where the monetary policy rate is initially stuck at the binding ZLB.[34] For this, we assume that the monetary policy rate is set according to the interest rate rule (see 24) 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. To induce a binding ZLB, we consider a discount factor shock ξ_t that causes the economy to reach the ZLB 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 ZLB is reached. In order to evaluate the effects of fiscal policy at the ZLB, 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. This expansionary fiscal policy mitigates the reduction in output and in inflation, which dampens the increase in the real policy rate (see Figure 11).

To focus on the effects of expansionary fiscal policy, Figure 6 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. The solid lines in Figure 6 show the net effects for the model version with the liquidity premium and the dashed lines show the net effects for the model version without the liquidity premium. For the former version, responses to the fiscal impulse are again mainly driven by the negative wealth effect, leading to a moderate impact multiplier of 0.54. Note that the fiscal multiplier is actually smaller in this ZLB scenario than in the off-ZLB scenario (0.84), since the expansionary output effects of fiscal policy are re-enforced through a proactive monetary accommodation. 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 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

[34] For the analysis of this scenario, we use the dynare supplement "occbin" developed by Guerrieri and Iacoviello (2014). "Occbin" 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 6: Net effects of a positive 1% government spending shock at the ZLB for a model version with (solid line) and without liquidity premium (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.

of 3.29, which relates to the fiscal multipliers found by Christiano et al., 2011, and Eggertsson, 2011).

For completeness, we also consider 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, $\rho_g = 0$ (see Figure 12 in Appendix C). Here, we find that the fiscal multipliers are almost identical in both versions. By contrast, comparing impact fiscal multipliers at the ZLB with those under a standard Taylor rule reveals stark differences for the model version without the liquidity premium (3.29 to 0.51) and very similar numbers for the model version with the liquidity premium (0.54 and 0.57). Thus, the monetary policy stance is far less crucial for the size of fiscal multipliers when liquidity premia are considered than in the case where they are neglected.

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, which constitutes a clear puzzle according to standard macroeconomic theories. Our empirical analysis however also suggests a solution to this puzzle, which relies on the observation that, 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 just augmented by a liquidity premium on near-money assets can 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.

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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). Original mimeos are given in square brackets. For the analysis using defense-news shocks we use the data provided online by Valerie Ramey.

Data from FRED We use the following series, 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], Government current tax receipts [W054RC1Q027SBEA], Contributions for Government Social Insurance [W782RC1Q027SBEA], Government Current Expenditures: Interest Payments [A180RC1Q027SBEA], Government Current Transfer Payments [A084RC1Q027SBEA], Effective Federal Funds Rate [FEDFUNDS], 3-Month Treasury Bill: Secondary Market Rate [TB3MS], 3-Month Certificate of Deposit: Secondary Market Rate [CD3M], 10-Year Treasury Constant Maturity Rate [DGS10], Moody's Seasoned Aaa Corporate Bond Yield [DAAA], TED Spread [TEDRATE], 3-Month AA Nonfinancial Commercial Paper Rate [DCPN3M], 3-Month Commercial Paper Rate [CP3M], Consumer Price Index for All Urban Consumers: All Items (CPIAUCSL), Federal Debt Held by the Public as Percent of Gross Domestic Product [FYGFGDQ188S], and Monthly Total Reserves of Depository Institutions [TOTRESNS]. We further use Monthly Repurchase Agreements [WARAL].

Data from the SPF We 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 provided on the SPF web pages. For Figure 1, we determine the log difference between the actual level of government spending and the level of government spending implied by one-quarter ahead forecasts, both expressed relative to the 1983Q1 value. We construct the actual level of government spending based on first-release information on its quarterly growth rates. For the VARs, we construct the forecast errors for the growth rate of total spending made by professional forecasters, exactly following Auerbach and Gorodnichenko (2012). CPI inflation forecasts are also taken from the SPF (mean forecasts). We refer to the forecast as SPFINF1. We finally use the mean forecast for the average T-bill rate in the next year (i.e., 5-8 quarters ahead) which we refer to as SPFTBILL.

Data from Bloomberg We 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. We use 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.

Further data sources We use the time series for the excess bond premium [EBP] that is provided by Simon Gilchrist under http://people.bu.edu/sgilchri/Data/data.htm. We 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 [TBILLVOL], 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).

A.2 Construction of the liquidity factor

We construct the common liquidity factor (clf) following Del Negro et al. (2017). We estimate a principal-component model with one component based on different liquidity spreads. 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. Following Del Negro et al. (2017), we use a linear transformation of the principal component which achieves a mean spread of 46 bps and a maximum spread of 342 bps at the height of the financial crisis. The liquidity spreads included in the estimation of the common factor 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

Table 1: Variables that enter the VARs and their definitions.

Symbol	Description	Definition
Figure 3:		
fe	professional forecast error for government spending growth	(see Auerbach and Gorodnichenko, 2012)
g	government spending	log((A782RC1Q027SBEA+ A955RC1Q027SBEA)/(GDPDEF+CNP16OV))
y	real output	log(GDP/(GDPDEF+CNP16OV))
tax	net tax receipts	log((W054RC1Q027SBEA +W782RC1Q027SBEA -A180RC1Q027SBEA-A084RC1Q027SBEA) /(GDPDEF+CNP16OV))
R^m	federal funds rate	FEDFUNDS
$R^m/E\pi_1$	real federal funds rate	(1+FEDFUNDS/100)/(1+SPFINF1/100)-1
$R^{Aaa} - R^{T-bond}$	spread between Aaa corporate bonds and government bonds	DAAA–DGS10
Figure 4:		
$R^{Libor3} - R^{T-bill3}$	TED spread (Libor–T-bill rate)	TEDRATE
$R^{cp} - R^{T-bill3}$	spread between the rates on commercial papers and T-bills	DCPN3M–TB3MS
$R^{refcorp} - R^{T-bond}$	10-year Refcorp spread	REFCORP10
GC	GC Repo - T-bill spread	GCREPO
clf	common liquidity factor	(see Section A.2)
Figure 8:		
π	CPI inflation	$\Delta log(CPIAUCSL)$
$E\pi_1$	1-year inflation forecast	SPFINF1
Figure 9:		
$ER^{T-bill3}$	5-8 quarters ahead T-bill rate forecast	SPFTBILL
EBP	excess bond premium	EBP
d/y	debt to GDP	FYGFGDQ188S/100
b/y	T-bills to GDP	TBILLVOL / GDP * 1000
m	total reserves	log(TOTRESNS)

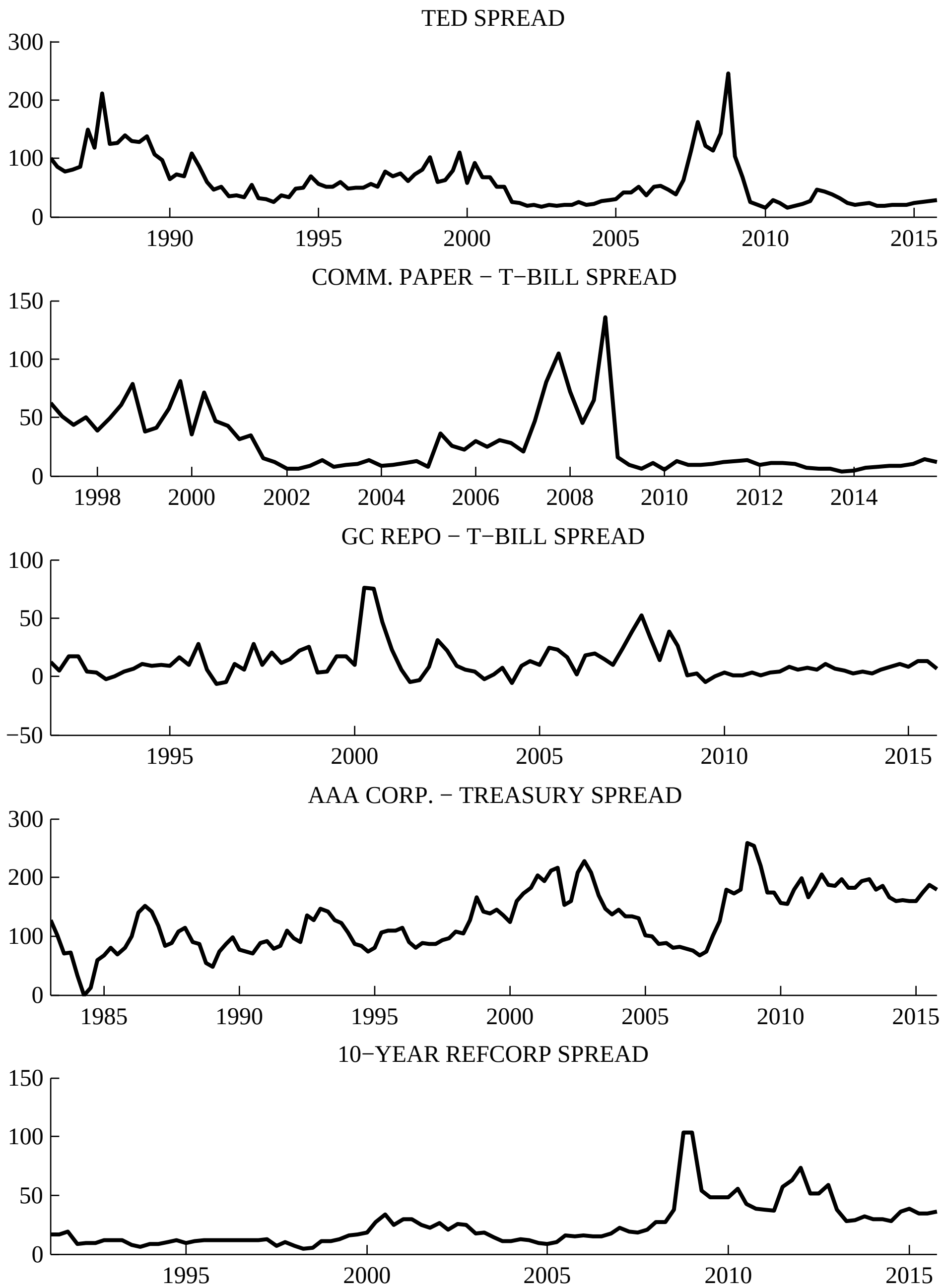
rate, and 7) the 10-year Refcorp rate and 10-year Treasury rate. In order to increase information on liquidity spreads in the first years of our sample when constructing the common factor, we combine data on non-financial commercial paper rates [DCPN3M] with discontinued information on commercial paper rates [CP3M] which is available before 1997 but no distinction between financial and non-financial commercial papers is possible. The principal-component model can deal with missing data such that we can construct the common factor also when we do not obs erve all included liquidity spreads. The sample period for the principal-component model starts in 1983Q1 (such that the sample contains at least two liquidity spreads per quarter).

A.3 Description of VARs

All VARs include a constant, a linear-quadratic trend, and four lags of the variables. The following four variables are included in all VARs: 1) the forecast error made by professional forecasters (fe), 2) log real government spending per capita (g), 3) log real GDP per capita (y), and 4) log real government net tax receipts per capita (tax). The fifth variable is either the nominal federal funds rate, the real federal funds rate, or a liquidity premium. When we consider further variables, we include the respective variable as a sixth variable in the VAR and the fifth variable is the federal funds rate. Details on included variables and sample periods are given in the respective figurenotes.

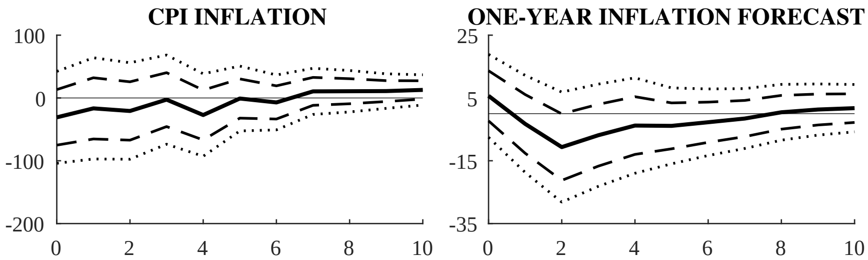
A.4 Additional empirical results

Figure 7: Time series of interest rate spreads analyzed in Section 3.3.



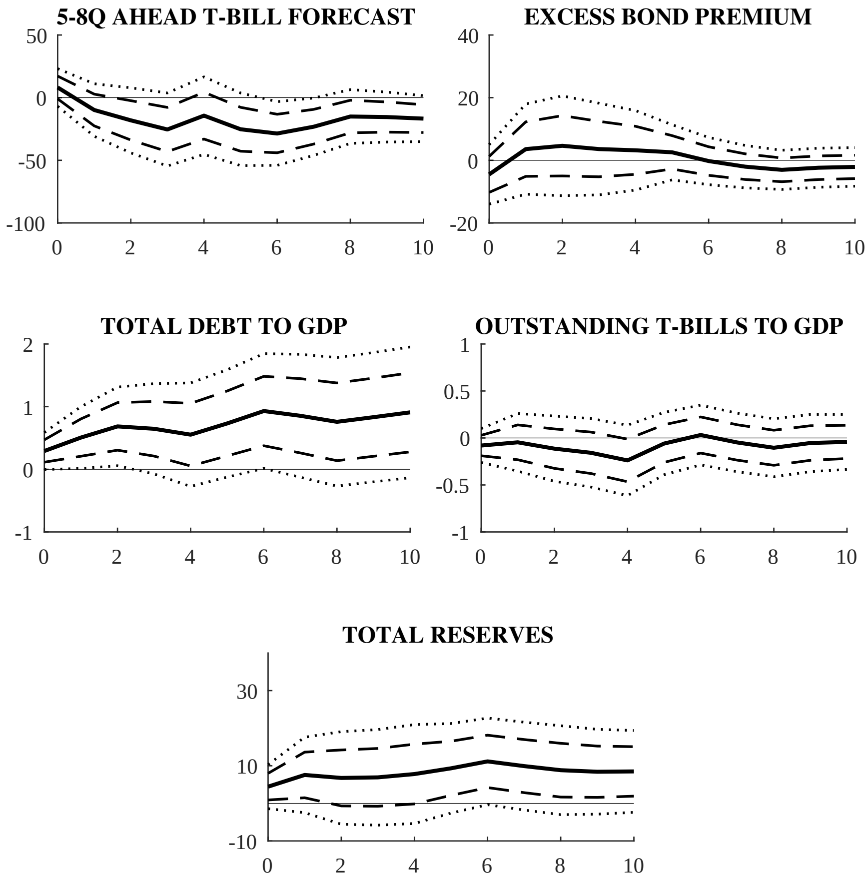
Notes: Spreads shown in basis points.

Figure 8: Responses of inflation and inflation forecast to positive government spending shocks identified through forecast errors.



Notes: Identification based on forecast errors from the Survey of Professional Forecasters (Ramey, 2011). VAR includes forecast error, government spending, real GDP, net tax receipts, the federal funds rate, and the respective variable shown in the figure. Sample period 1979Q4-2015Q4. Dotted (dashed) lines show 68% (90%) confidence bands. Horizontal axes show quarters.

Figure 9: Responses of further variables to positive government spending shocks identified through forecast errors.

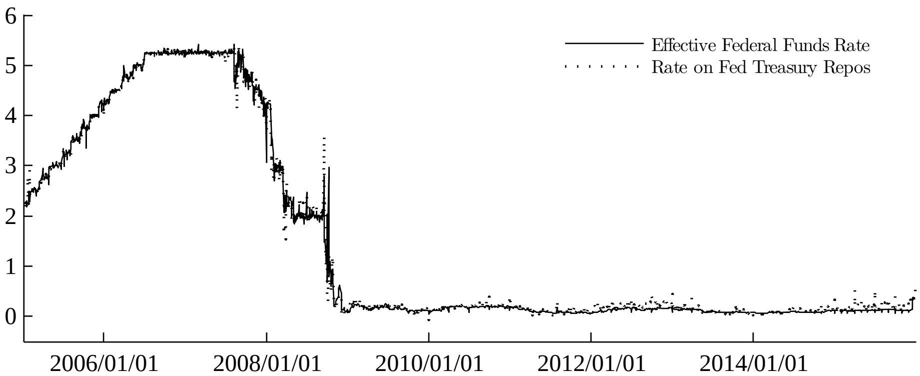


Notes: Identification based on forecast errors from the Survey of Professional Forecasters (Ramey, 2011). VAR includes forecast error, government spending, real GDP, net tax receipts, the federal funds rate, and the respective variable shown in the figure. Sample period 1979Q4-2015Q4 for excess bond premium, debt to GDP, and total reserves, 1981Q4-2015Q4 for 5-8 Quarter ahead T-bill rate forecast, 1983Q1-2013Q2 for T-bill to GDP. Dotted (dashed) lines show 68% (90%) confidence bands. Horizontal axes show quarters.

B Appendix to Section 4

B.1 Descriptive evidence on modeling choices

Figure 10: Federal funds rate and treasury repo rate.



Notes: Data source for rate on Fed Treasury Repos: DTCC GCF Repo Index. Mean spread is 0.995 bps.

B.2 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 $\max_{\widetilde{P}_{k,t}} E_t \sum_{s=0}^{\infty} \phi^s \beta^s \phi_{t,t+s}((\Pi_{k=1}^s \widetilde{P}_{k,t}/P_{t+s}) - mc_{t+s})y_{k,t+s}$, 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 $\tilde{Z}_t = \widetilde{P}_t/P_t$, $Z_t^1 = \xi_t c_t^{-\sigma} y_t mc_t + \phi\beta E_t \pi_{t+1}^{\varepsilon} Z_{t+1}^1$ 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.3 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*

$$c_t = m_t + m_t^R,\ if\ \ R_t^{IS} > 1,\quad or\ c_t \leq m_t + m_t^R,\ if\ \ R_t^{IS} = 1, \tag{25}$$

$$b_{t-1}/\left(R_t^m \pi_t\right) = m_t - m_{t-1}\pi_t^{-1} + m_t^R,\ if\ \ R_t^{IS} > R_t^m, \tag{26}$$

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

$$m_t^R = \Omega m_t, \tag{27}$$

$$b_t = b_t^T - m_t, \tag{28}$$

$$b_t^T = \Gamma b_{t-1}^T/\pi_t, \tag{29}$$

$$\theta n_t^{\sigma_n} = u_{c,t} w_t / R_t^{IS}, \tag{30}$$

$$1/R_t^{IS} = \beta E_t\left[u_{c,t+1}/\left(u_{c,t}\pi_{t+1}\right)\right], \tag{31}$$

$$w_t = mc_t, \tag{32}$$

$$\lambda_t = \beta E_t\left[u_{c,t+1}/\pi_{t+1}\right], \tag{33}$$

$$Z_{1,t} = \lambda_t y_t mc_t + \phi\beta E_t \pi_{t+1}^{\varepsilon} Z_{1,t+1}, \tag{34}$$

$$Z_{2,t} = \lambda_t y_t + \phi\beta E_t \pi_{t+1}^{\varepsilon-1} Z_{2,t+1}, \tag{35}$$

$$Z_t = \left[\varepsilon/\left(\varepsilon-1\right)\right] Z_{1,t}/Z_{2,t}, \tag{36}$$

$$1 = (1-\phi) Z_t^{1-\varepsilon} + \phi \pi_t^{\varepsilon-1}, \tag{37}$$

$$s_t = (1-\phi) Z_t^{-\varepsilon} + \phi s_{t-1}\pi_t^{\varepsilon}, \tag{38}$$

$$y_t = n_t/s_t, \tag{39}$$

$$y_t = c_t + g_t, \tag{40}$$

(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

$$R_t = E_t[u_{c,t+1}\pi_{t+1}^{-1}]/[E_t\left(R_{t+1}^m\right)^{-1} u_{c,t+1}\pi_{t+1}^{-1}], \tag{41}$$

$$\lambda_t/R_t^D = \beta E_t[(u_{c,t+1} + (1-\mu)\lambda_{t+1})/\pi_{t+1}], \tag{42}$$

$$1 = \beta E_t\left[\left(R_{t+1}^q/\pi_{t+1}\right)\left(\lambda_{t+1}/\lambda_t\right)\right], \tag{43}$$

$$1/R_t^L = E_t\left[1/R_{t+1}^{IS}\right], \tag{44}$$

If the money supply constraint (1) is not binding, which is the case if $R_t^m = R_t^{IS}$ (see 15), 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 (1) 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 $R_t^{IS} = R_t^m$, (30)-(40), 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 $s_{-1} \geq 1$.

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 (25)-(30), (34)-(38),*

$$\lambda_t = u_{\bar{c},t}, \tag{45}$$
$$1/R_t^{IS} = \beta E_t\left[\xi_{t+1}u_{c,t+1}/\left(\xi_t u_{c,t}\pi_{t+1}\right)\right], \tag{46}$$
$$w_t = mc_t\alpha n_t^{\alpha-1}k_{t-1}^{1-\alpha}, \tag{47}$$
$$\lambda_t = \beta E_t\left[\xi_{t+1}u_{c,t+1}/\pi_{t+1}\right], \tag{48}$$
$$1 = q_t\left[\Lambda_t + \left(x_t/x_{t-1}\right)\Lambda_t'\right] - E_t\beta\left[\left(\lambda_{t+1}/\lambda_t\right)q_{t+1}\left(x_{t+1}/x_t\right)^2\Lambda_{t+1}'\right], \tag{49}$$
$$q_t = \beta E_t\left[\left(\lambda_{t+1}/\lambda_t\right)\left((1-\alpha)mc_{t+1}\left(y_{t+1}/k_t\right) + (1-\delta)\,q_{t+1}\right)\right], \tag{50}$$
$$y_t = n_t^{\alpha}k_{t-1}^{1-\alpha}/s_t, \tag{51}$$
$$y_t = c_t + \bar{c}_t + x_t + g_t, \tag{52}$$
$$k_t = (1-\delta)\,k_{t-1} + x_t\Lambda_t, \tag{53}$$

(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 (24), $\Omega > 0$, $\pi \geq \beta$, given sequence $\{\widetilde{y}_t\}_{t=0}^{\infty}$ (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 (43), (44),

$$R_t = E_t[\xi_{t+1}u_{c,t+1}\pi_{t+1}^{-1}]/[E_t\left(R_{t+1}^m\right)^{-1}\xi_{t+1}u_{c,t+1}\pi_{t+1}^{-1}], \tag{54}$$
$$\lambda_t/R_t^D = \beta E_t[(\xi_{t+1}u_{c,t+1} + (1-\mu)\lambda_{t+1})/\pi_{t+1}]. \tag{55}$$

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

C Appendix to Section 5

C.1 Analytical Proofs

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., (19), (20), and (22), which can by substituting out $\widehat{R}_t^{IS}$ be summarized as

$$\rho_\pi \widehat{\pi}_t + \rho_g \widehat{g}_t - E_t \widehat{\pi}_{t+1} = \sigma E_t \widehat{c}_{t+1} - \sigma \widehat{c}_t, \tag{56}$$

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \delta_c \widehat{c}_t + \delta_g \widehat{g}_t + \chi \rho_\pi \widehat{\pi}_t, \tag{57}$$

where $\delta_c = \chi(\sigma_n c_y + \sigma) > 0$ and $\delta_g = \chi\left(\sigma_n g_y - \rho_g\right)$. 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 $\widehat{\pi}_t = \gamma_\pi \widehat{g}_t$ and $\widehat{c}_t = \gamma_c \widehat{g}_t$. Inserting these solutions in (56) and (57), 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

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

where $\Theta = (\chi\sigma_n c_y + \sigma/\rho_\pi)^{-1} > 0$. 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

$$\widehat{R_t^m} - E_t \widehat{\pi}_{t+1} = \widehat{R_t^m} = \sigma\left[\chi\sigma_n g_y + (-2\chi + 1/\rho_\pi)\rho_g\right]\Theta \cdot \widehat{g}_t.$$

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

$$\begin{aligned}\gamma_c &= -\left[\chi\sigma_n g_y + (-2\chi + 1/\rho_\pi)\rho_g\right]\Theta \\ &> -\left[\chi\sigma_n g_y - (-2\chi + 1/\rho_\pi)\chi\sigma_n g_y / (-2\chi + 1/\rho_\pi)\right]\Theta = 0.\end{aligned}$$

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

$$\gamma_c > -\left[\chi\sigma_n g_y + (-2\chi + 1/\rho_\pi)\chi\sigma_n g_y / (2\chi - 1/\rho_\pi)\right]\Theta = 0.$$

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

Proof of Lemma 1. The model given in Definition 3 for the version with $R_t^m < R_t^{IS}$, i.e., (18)-(22), is further simplified by substituting out $\widehat{R}_t^{IS}$ and $\widehat{R}_t^m$:

$$\delta_1 E_t \widehat{\pi}_{t+1} + \delta_3 \widehat{b}_t + \delta_2 \widehat{c}_t = \widehat{\pi}_t - \delta_g \widehat{g}_t, \tag{58}$$

$$\widehat{c}_t = \widehat{b}_{t-1} - (1 + \rho_\pi)\widehat{\pi}_t - \rho_g \widehat{g}_t, \tag{59}$$

and (21), where $\delta_1 = (\beta + \chi(1-\sigma) - \chi\sigma\rho_\pi) \gtreqless 0$, $\delta_2 = \chi\sigma_n c_y > 0$, $\delta_3 = \chi\sigma > 0$, and $\delta_g = \chi\sigma_n g_y > 0$. We further simplify the system (21), (58), and (59) by eliminating $\widehat{c}_t$ with (59) in (58) and then $\widehat{b}_{t-1}$ with (21). 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

$$\mathbf{A} = \begin{pmatrix} \delta_1 & \delta_3 + \delta_2 \\ 0 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 + \delta_2\rho_\pi & 0 \\ -1 & 1 \end{pmatrix} \tag{60}$$

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

$$2(1 + \beta + \chi(1-\sigma) - \chi\sigma\rho_\pi) + \chi\sigma + (2\rho_\pi + 1)\chi\sigma_n c_y > 0 \tag{61}$$

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 (61) holds, if but not only if

$$\rho_\pi \leq \frac{1+\beta}{\chi\sigma} + \frac{1-\sigma}{\sigma}, \tag{62}$$

where the RHS of (62) is strictly larger than $\frac{\beta+\chi(1-\sigma)}{\chi\sigma}$. Hence, (62) is sufficient for local equilibrium determinacy, which establishes the claim made in the lemma. ■

The following lemma presents conditions under which the model predictions regarding government spending effects are qualitatively consistent with the empirical results presented in Section 3. These conditions are expressed in terms of the direct feedback from government spending on the policy rate, measured by the coefficient ρ_g.

Lemma 5 *Suppose that $R_t^m < R_t^{IS}$ and that (23) 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 $\rho_g > \widetilde{\rho_g}(\rho_\pi)$ for $\widetilde{\rho_g}(\rho_\pi) < 0$ or $\rho_g < \widetilde{\rho_g}(\rho_\pi)$ for $\widetilde{\rho_g}(\rho_\pi) > 0$,*

where $\underline{\rho_g}(\rho_\pi) \equiv -(1+\rho_\pi)\chi\sigma_n g_y/\Gamma_1$, $\overline{\rho_g}(\rho_\pi) \equiv -\rho_\pi g_y \chi\sigma_n/(\chi\sigma_n c_y + \Gamma_1)$, $\widetilde{\rho_g}(\rho_\pi) \equiv -(\Gamma_2 + \rho_\pi\chi\sigma_n) g_y/(\Gamma_1 + (\chi\sigma_n - \Gamma_2) c_y)$, $\Gamma_1 = [\beta + \chi(1-\sigma) - \chi\sigma\rho_\pi](1-\gamma_b) + \chi\sigma + 1 > 0$, $\Gamma_2 = (1+\rho_\pi)(1-\gamma_b)\chi\sigma_n > 0$, *and* $\gamma_b \in (0,1)$.

Proof of Lemma 5. Consider the set of equilibrium conditions (21), (58), and (59). We aim at identifying the impact responses to fiscal policy shocks. For this, we assume that (62) is satisfied, which ensures existence and uniqueness of a locally stable solution. We then apply the following solution form for the system (21), (58), and (59):

$$\widehat{\pi}_t = \gamma_{\pi b}\widehat{b}_{t-1} + \gamma_{\pi g}\widehat{g}_t, \tag{63}$$

$$\widehat{b}_t = \gamma_b\widehat{b}_{t-1} + \gamma_{bg}\widehat{g}_t, \tag{64}$$

$$\widehat{c}_t = \gamma_{cb}\widehat{b}_{t-1} + \gamma_{cg}\widehat{g}_t. \tag{65}$$

Substituting out the endogenous variables in (21), (58), and (59) with the generic solutions in (63)-(65), leads to the following conditions for $\gamma_{\pi b}$, γ_{cb}, $\gamma_{\pi b}$, γ_{cg}, $\gamma_{\pi g}$, and γ_{bg} :

$$\gamma_{\pi b} = \delta_1\gamma_{\pi b}\gamma_b + \delta_3\gamma_b + \delta_2\gamma_{cb},\ 1 = (1+\rho_\pi)\gamma_{\pi b} + \gamma_{cb},\ 1 = \gamma_b + \gamma_{\pi b}, \tag{66}$$

$$-\delta_2\gamma_{cg} = (\delta_1\gamma_{\pi b} + \delta_3)\gamma_{bg} - \gamma_{\pi g} + \delta_g,\ -\gamma_{cg} = (1+\rho_\pi)\gamma_{\pi g} + \rho_g,\ \gamma_{bg} = -\gamma_{\pi g}, \tag{67}$$

Using the three conditions in (66) 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,

$$\gamma_b^2 - (\delta_1 + \delta_3 + \delta_2(\rho_\pi + 1) + 1)\gamma_b\delta_1^{-1} + (\rho_\pi\delta_2 + 1)\delta_1^{-1} = 0. \tag{68}$$

Note that the polynomial in (68) is the characteristic polynomial of $\mathbf{A}$ (see 60). Hence, under (62) 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 (67). 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

$$\gamma_{cg} = -\frac{(1+\rho_\pi)\delta_g + (\delta_1\gamma_{\pi b}+\delta_3+1)\rho_g}{(\delta_1\gamma_{\pi b}+\delta_3+1)+\delta_2(1+\rho_\pi)}. \tag{69}$$

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 (69) can be rewritten, such that

$$\gamma_{cg} = -\frac{(1+\rho_\pi)\chi\sigma_n g_y + \Gamma_1\rho_g}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}, \tag{70}$$

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 62) and $\gamma_{\pi b} \in (0,1)$. Hence, γ_{cg} is negative, implying a crowding out, if

$$\rho_g > \underline{\rho_g}, \text{ where } \underline{\rho_g}(\rho_\pi) \equiv -(1+\rho_\pi)\chi\sigma_n g_y/\Gamma_1 < 0. \tag{71}$$

The solution coefficient (70) 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 (70), the inflation response is given by

$$\gamma_{\pi g} = \frac{\left(g_y - \rho_g c_y\right)\chi\sigma_n}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}, \tag{72}$$

implying that $\gamma_{\pi g} > 0$, if $\rho_g < g_y/c_y$. Using (72), 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

$$\rho_g < \overline{\rho_g}, \text{ where } \overline{\rho_g}(\rho_\pi) \equiv -\rho_\pi\frac{g_y\chi\sigma_n}{\chi\sigma_n c_y + \Gamma_1} \leq 0. \tag{73}$$

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 (64)-(65), we get

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

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 (70), 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

$$\widetilde{\rho}_g(\rho_\pi) \equiv -\frac{((1+\rho_\pi)(1-\gamma_b)+\rho_\pi)\,\chi\sigma_n g_y}{(1-(1+\rho_\pi)(1-\gamma_b))\,\chi\sigma_n c_y+\Gamma_1}, \tag{74}$$

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

$$\rho_g > \widetilde{\rho}_g(\rho_\pi) \;\text{ for }\; \widetilde{\rho}_g(\rho_\pi) < 0 \quad\text{or}\quad \rho_g < \widetilde{\rho}_g(\rho_\pi) \;\text{ for }\; \widetilde{\rho}_g(\rho_\pi) > 0, \tag{75}$$

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 (71) and (73) in the proof of Lemma 5, shows that $\underline{\rho_g} < \overline{\rho_g}$, since

$$\underline{\rho_g} < \overline{\rho_g} \Leftrightarrow -\frac{(1+\rho_\pi)\,\chi\sigma_n g_y}{\Gamma_1} < -\rho_\pi \frac{g_y\chi\sigma_n}{\chi\sigma_n c_y+\Gamma_1} \Leftrightarrow (1+\rho_\pi)\,\chi\sigma_n c_y+\Gamma_1 > 0,$$

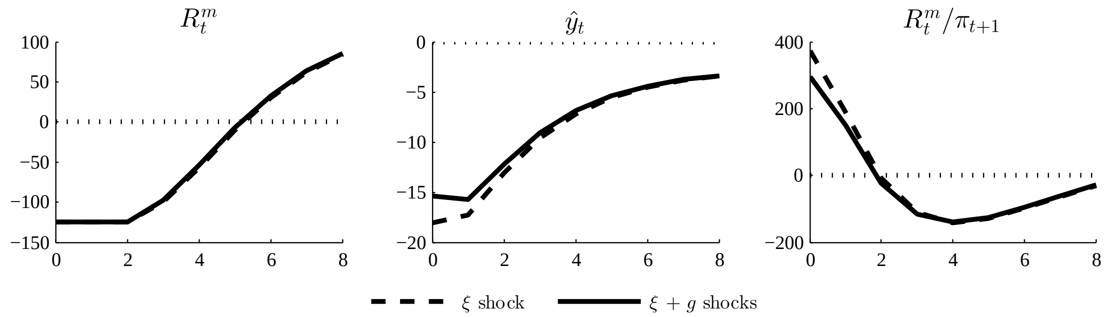
Thus, there exist values for ρ_g satisfying $\rho_g \in (\underline{\rho_g}, \overline{\rho_g})$ for which private consumption and the nominal policy rate simultaneously decline in response to a government spending hike, see (71) and (73). Given that inflation increases for $\rho_g < g_y/c_y$, which 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 $\widetilde{\rho}_g < 0$ (see 74), a rising real marginal rate of intertemporal substitution requires $\rho_g > \widetilde{\rho}_g(\rho_\pi)$ (see 75). This is also feasible, since

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

For $(1-(1+\rho_\pi)(1-\gamma_b))\,\chi\sigma_n c_y+\Gamma_1 < 0$ and $\widetilde{\rho}_g > 0$, a rising real marginal rate of intertemporal substitution requires $\rho_g < \widetilde{\rho}_g(\rho_\pi)$ (see 75), which is ensured for values $\rho_g \in (\underline{\rho_g}, \overline{\rho_g})$, since $\overline{\rho_g} \leq \widetilde{\rho}_g(\rho_\pi)$. We can therefore conclude that there exist values for ρ_g, which jointly satisfy (71), (73), and (75), 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 and thereby in the liquidity premium, $\eta_t > 0$ (see 15). ■

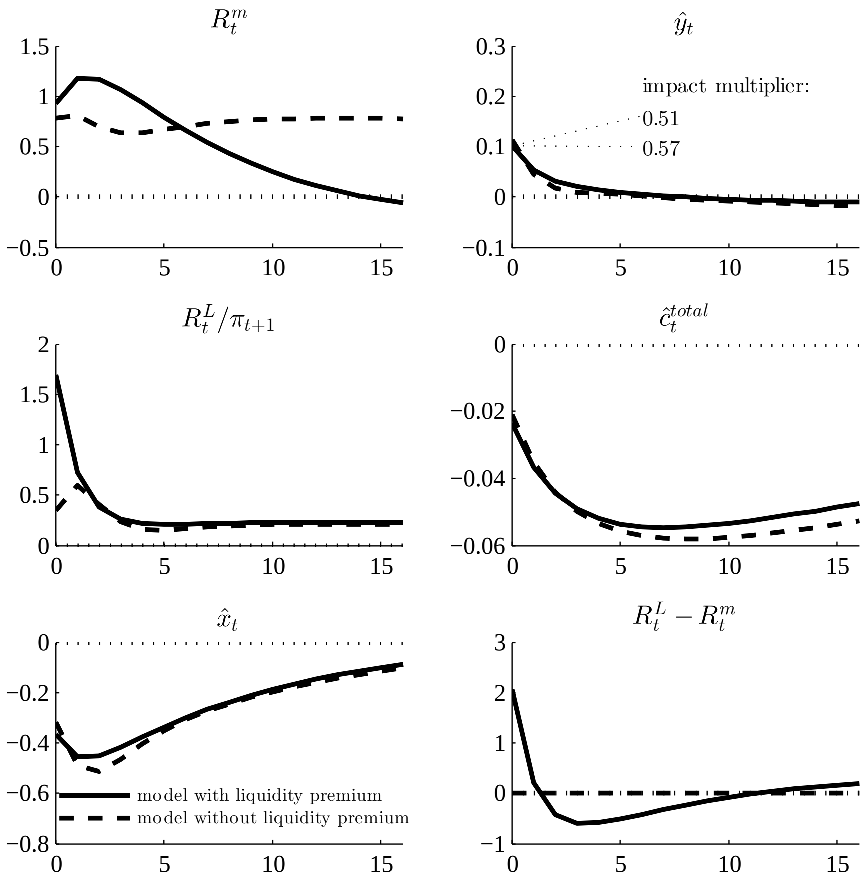
C.2 Additional numerical results

Figure 11: Paths of the nominal and real policy rate as well as output in our ZLB experiment analyzed in Section 5.2.3.



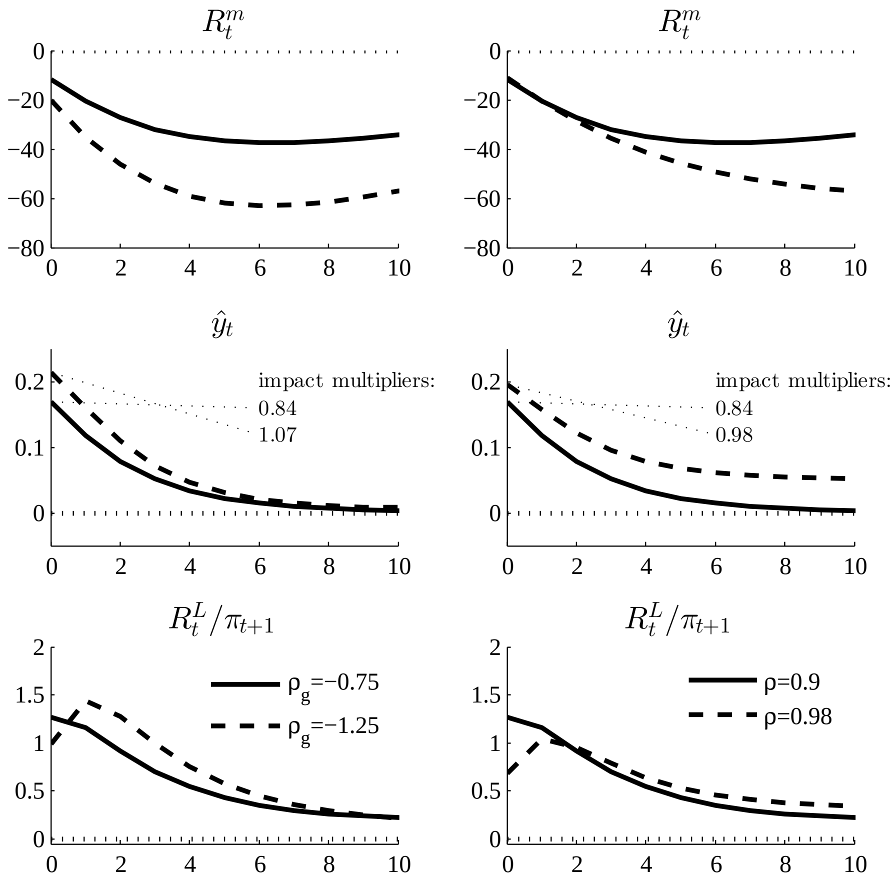
Notes: Smallest ξ shock that drives the economy to the ZLB for three periods (auto-correlation set to 0.8). g shock amounting to 5% of steady-state GDP in order to ensure visibility of the effects of fiscal policy. Absolute deviations of R_t^m and R_t^m/π_{t+1} from steady state in basis points. Relative deviation of y_t from steady state in percent.

Figure 12: Responses to a 1% government spending shock when the monetary policy rate counterfactually rises, achieved through a standard Taylor-rule ($\rho_g = 0$), for a model version with (solid line) and without liquidity premium (dashed line)



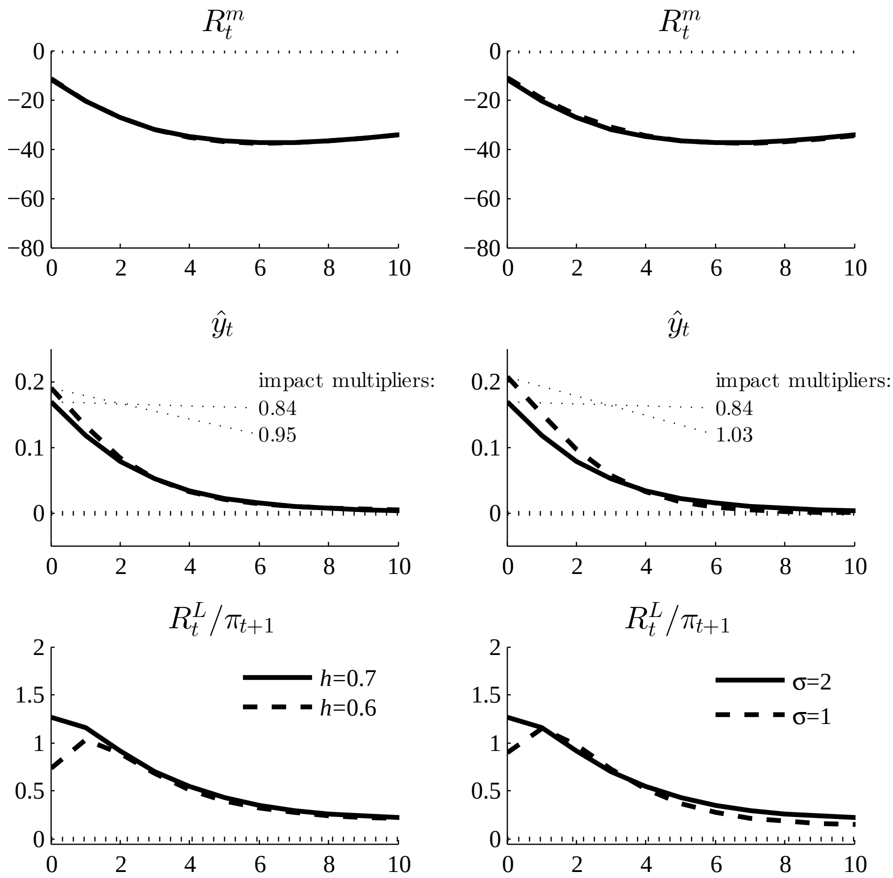
Notes: Relative responses of y_t, c_t^{total}, and x_t in percent. Absolute responses of R_t^m/π_{t+1}, R_t^L/π_{t+1}, $R_t^L - R_t$ in basis points.

Figure 13: Responses to a positive 1% government spending shock for the model version with positive liquidity premium: baseline calibration and variations in ρ_g (left column) and ρ (right column).



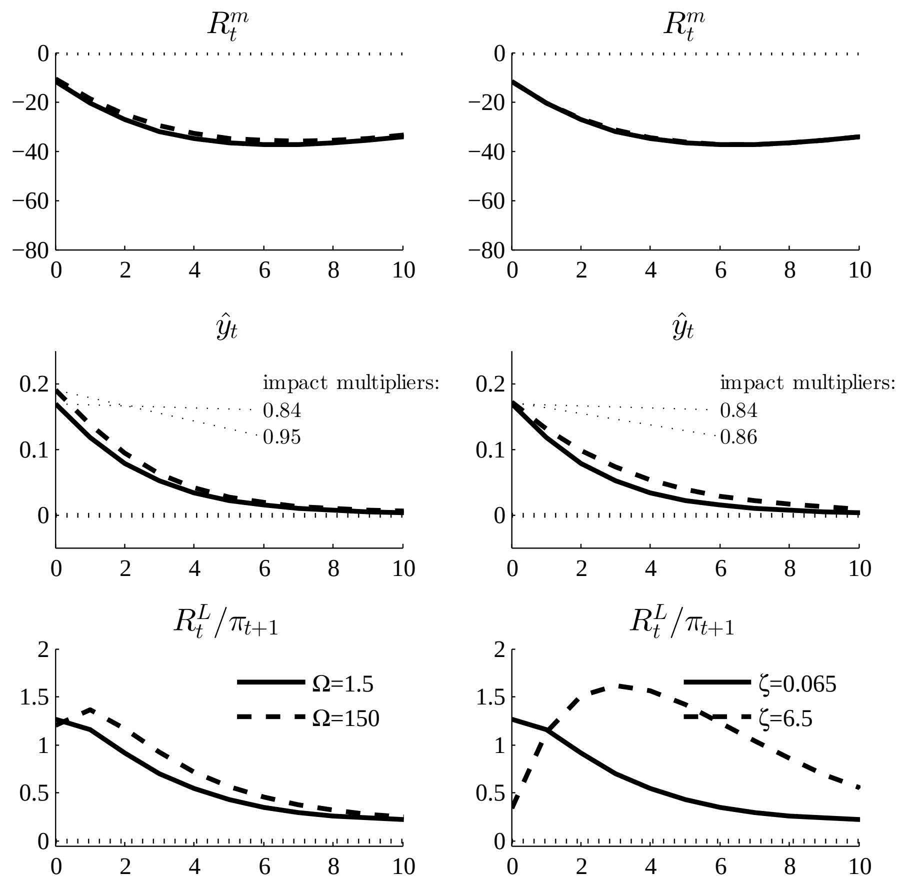
Notes: Absolute responses of R_t^m and R_t^L/π_{t+1} in basis points. Relative responses of y_t in percent.

Figure 14: Responses to a positive 1% government spending shock for the model version with positive liquidity premium: baseline calibration and variations in h (left column) and σ (right column).



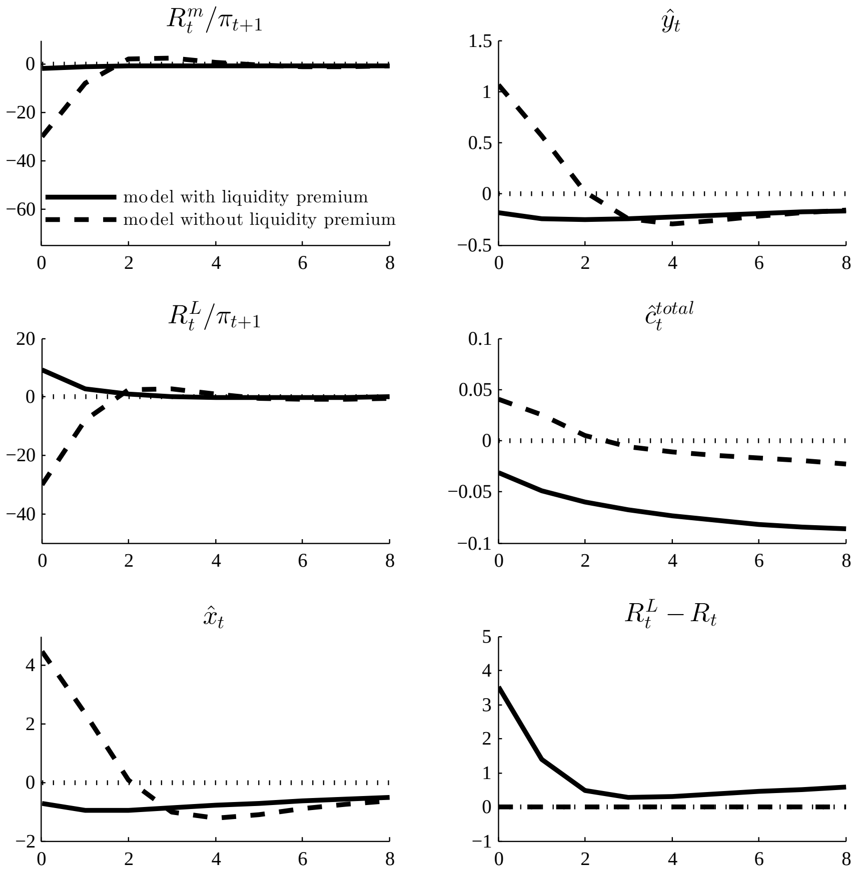
Notes: Absolute responses of R_t^m and R_t^L/π_{t+1} in basis points. Relative responses of y_t in percent.

Figure 15: Responses to a positive 1% government spending shock for the model version with positive liquidity premium: baseline calibration and variations in Ω (left column) and ζ (right column).



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

Figure 16: Net effects of a positive 1 pp increase in a labor income tax rate (mean 0.2, autocorrelation 0.9) at the ZLB.



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}, $R_t^L - R_t$, and $R_t^{IS} - R_t^m$ in basis points.