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# Why Are Fiscal Multipliers Moderate Even Under Monetary Accommodation?[1]

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**Abstract**

Estimated fiscal multipliers for the US are typically moderate, despite evidence for the Fed lowering, rather than raising, interest rates after government spending hikes. We rationalize these puzzling observations building on imperfect substitutability of assets. We document empirically that interest rates important for private borrowing/saving do not follow the response of the monetary policy rate, which is reflected by rising liquidity premia after spending hikes. A model with a structural specification of asset liquidity can replicate these findings and predicts moderate output effects of fiscal expansions even when monetary policy rates fall or are fixed at the zero lower bound.

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

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# 1 Introduction

Recent crises have led to 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. Macroeconomic theory typically suggests that the reaction of the central bank is key to the output effects of fiscal policy, exemplified by extraordinary large multipliers at the zero lower bound (ZLB) found in theoretical studies (see, e.g., Christiano et al., 2011). Yet, the data provide a different picture, as multipliers are moderate despite evidence for monetary accommodation of fiscal policy. Empirical studies for the U.S. commonly find an output multiplier around one (see Hall, 2009, Barro and Redlick, 2011, Ramey, 2011, Caldara and Kamps, 2017, as well as the overview in Ramey, 2016), while the nominal and the real monetary policy rate tend to fall, as documented by Edelberg et al. (1999), Mountford and Uhlig (2009), Fisher and Peters (2010), Ramey (2016), and D'Alessandro et al. (2019).[1] According to the widespread view – particularly emphasized by the New Keynesian paradigm – that the real rates of return that guide people's intertemporal decisions essentially follow the real monetary policy rate, this is a clear puzzle, since falling real rates should lead to a pronounced increase in private demand and a large output multiplier.

In this paper, we reconcile theory and empirical evidence on the role of monetary policy for the effects of fiscal policy by focusing on imperfect substitutability of assets based on their ability to serve for transaction purposes, summarized by the term "liquidity". Our approach is motivated by the observation of an interest rate disconnect between two groups of assets. Interest rates on assets that serve as substitutes for money (e.g., T-bills) are closely linked to the monetary policy rate. In contrast, interest rates on assets that cannot be classified as near-money assets and that are typically more relevant for private saving and borrowing than federal funds differ systematically from the federal funds rate. We provide novel evidence for asymmetric interest rate responses to fiscal policy shocks: Government spending expansions raise the returns on rather illiquid assets relative to those on near-money assets, i.e., liquidity premia increase after government spending shocks. We then develop a simple model with imperfect asset substitutability that can reproduce the observed fiscal policy effects on liquidity premia. The model 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,

[1] To be precise, Edelberg et al. (1999), Fisher and Peters (2010), and Ramey (2016) consider short-term T-bill rates while Mountfort and Uhlig (2009) and D'Alessandro et al. (2019) consider 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.

for example, at the ZLB, are sufficient for a large fiscal multiplier.

The starting point of our empirical analysis is the decrease in real and nominal monetary policy rates in response to expansionary government spending shocks. We confirm these findings using Ramey's (2016) identification procedure and an alternative identification for a different sample period 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. Specifically, we investigate a set of interest-rate spreads which have been suggested to be primarily determined by liquidity premia (by, e.g., see Longstaff, 2004, Krishnamurthy and Vissing-Jorgensen, 2012, and Nagel, 2016) as well as a common liquidity factor (following Del Negro et al., 2017). We find that these measures increase after government spending hikes, which implies that the responses of interest rates on less liquid assets systematically differ from the one of the federal funds rate. This indicates that monetary policy actually has "little control"(see Fama, 2013, p. 181) over various important interest rates on both long-term and short-term assets. 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.[2]

Our explanation builds on the fact that near-money assets that are primarily held for payment purposes, like short-run treasury debt, are imperfect substitutes for assets that private agents use as a store of wealth. This is reflected by the equilibrium prices of these two types of assets, which are typically separated and determined by different factors. Given their additional non-pecuniary return (from liquidity services), near-money assets offer lower interest rates than assets used as a store of wealth and cannot be issued by households nor firms, prohibiting arbitrage between the two types of assets. The returns on near-money assets are closely linked to the monetary policy rate while the returns on assets that serve as a store of wealth are determined by supply and demand for savings. The interest rate spread between the two types of assets captures a liquidity premium.

To rationalize the observed dynamics of prices and aggregate variables, we rely on the central (general equilibrium) effect of fiscal spending on asset prices (see Barro and King, 1984): For a given supply of goods, an expansion in government expenditures induces excess demand. Hence, private agents' willingness to spend for current consumption increases relative to future consumption. Prices of assets that private agents use as a store

[2] As we consider spreads between highly resaleable assets, our findings are also not driven by changes in premia for resaleability as documented by Bayer et al. (2020).

of wealth therefore tend to fall and their real rate of returns tend to rise. In a frictionless economy, the (natural) rate of interest would unambiguously rise in response to an expansion in government spending. When there are nominal rigidities, monetary policy can affect fiscal transmission, while the impact of the policy rate on fiscal multipliers depends on the substitutability of assets.

Under *imperfect* substitutability of assets, the interest rate on near-money assets is not linked to real rates of return on savings by arbitrage. Instead, the interest rates for assets that serve as a substitute for money closely follow the monetary policy rate, while the demand for these assets is determined by the volume of transactions for which money is required and not by agents' intertemporal choices. This separation implies that a lower real policy rate is not necessarily associated with current consumption exceeding future consumption. Given that higher inflation tends to reduce the real value of money and near-money assets, government spending can in principle crowd out private consumption even when the policy rate is reduced. Thus, an accommodative monetary policy response may induce an output multiplier close to one and an increasing liquidity premium, which we show for a simple model under a large set of reasonable parameter values.

Under *perfect* substitutability of assets, by contrast, monetary accommodation would induce large output responses. If 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 basic 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 when the natural interest rate rises. Then, households' and firms' intertemporal decisions are governed by the accommodative monetary policy. The latter scenario is relevant at the ZLB, where according to conventional New Keynesian models government spending crowds in private consumption strongly and fiscal multipliers are much larger than typically found in the data.

To replicate the observed fiscal policy effects, we develop a simple macroeconomic model with 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., Schabert, 2015, or 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 moneyness, which is reflected by a liquidity premium. In line with empirical evidence (see Simon, 1990), the short-term treasury rate closely follows the (expected) 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,[3] its predictions regarding fiscal policy effects differ substantially from the predictions of standard models. When the real policy rate falls, whether due to monetary accommodation of fiscal policy or because the nominal rate is stuck at the ZLB, conventional New Keynesian models predict a large fiscal multiplier, whereas our model generates an increasing liquidity premium and a moderate fiscal multiplier in line with empirical evidence.[4]

We present the main predictions of the model with the endogenous liquidity premium analytically and we compare these predictions 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 different monetary policy regimes. First, we consider a policy rate increase induced by a conventional policy rule. Second, we account for the observed fall in the monetary policy rate after defense news shocks. For simplicity, we allow for a direct response of the monetary policy rate to government spending, while we are agnostic about the reasons for this central bank behavior.[5] For both regimes, the model with the liquidity premium generates similar effects, specifically, moderate output multipliers (i.e., around one) and an increase in the liquidity premium, quantitatively consistent with the data. In contrast, monetary accommodation leads to an implausibly large fiscal multiplier for a model version without a liquidity premium. These results are confirmed under a regime with the nominal policy rate at the ZLB. Here, a decline in the real policy rate is induced by the fixation of the nominal policy rate and leads to large

[3]This is shown by Bredemeier et al. (2020), 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 explain observed exchange rate responses to monetary policy shocks.

[4]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).

[5]As an alternative, one might follow Dupor and Li (2015), reporting that government spending shocks can lead a reduction in expected inflation and assume this as an input to a monetary policy reaction function.

output multipliers, as in Christiano et al. (2011), for the model version without a liquidity premium. 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 liquidity premium model implies that the multiplier is less than 20% larger at the ZLB than under a conventional Taylor rule while for the version without liquidity premium the multiplier increases by factor 6. While we 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 substantially overestimated when only the responses of monetary policy rates are taken into account.

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 and present quantitative results 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 an identification using sign restrictions, 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 (1998) 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 Jørgensen (2021) and by D'Alessandro et al. (2019), both papers applying both Blanchard-Perotti shocks and professional forecast errors.[6]

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 are larger than typically observed in empirical studies, which has been confirmed by Woodford (2011) and Fahri and Werning (2016).[7] Erceg and Linde (2014) show that the fiscal multiplier depends on the duration of the ZLB episode. The multiplier 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 bonds in the utility function. They show that this assumption crucially affects equilibrium determinacy and generates muted effects of forward guidance and fiscal policy.[8] In contrast to the latter two studies, who consider *exogenous* liquidity premia, 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. 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. 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)

[6] In contrast to our findings, Ravn and Jørgensen (2021) 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.

[7] 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.

[8] Similar effects on equilibrium determinacy and fiscal policy effects at the ZLB are found by Diba and Loisel (2021), who consider an extended New Keynesian model where the central bank simultaneously controls two instruments (instead of one).

provides evidence for 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.[9] Our empirical analysis further implies short- and long-term treasury debt to provide liquidity services to a different extent, which relates to Greenwood et al. (2015), who analyze optimal government debt maturity. 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. Our specification of liquidity services is also helpful for solving puzzles related to uncovered interest rate parity and forward guidance, see Linnemann and Schabert (2015) and Bredemeier et al. (2020).[10]

Bayer et al. (2020) also examine the effects of fiscal policy on interest rate spreads and the implications for fiscal multipliers. However, they consider a different type of premia than we do. They focus on premia based on differences in the resaleability of securities, for example the premium between the yields on housing and those on long-term government bonds. By contrast, we analyze premia that arise because some assets are closer substitutes for money than others, in particular because they are eligible for transactions with the central bank. Bayer et al. (2020) show that a fiscal spending shock causes a fall in the premium for lack of resaleability due to an increase in long-term public debt, while we show that the premium for lack of central bank eligibility increases in response to a spending hike due to an increased demand for near-money assets. Both approaches contribute to explaining moderate and thus plausible fiscal multipliers. Bayer et al. (2020) show that accounting for endogenous resaleability premia increases the fiscal

[9]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.

[10]That our model is successful 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 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.

multiplier relative to a real model in which the interest rate on government bonds and the return on physical capital are equal by construction and the fiscal multiplier is therefore very small. We show that taking into account endogenous premia for central bank eligibility reduces the fiscal multiplier relative to a single-interest rate New Keynesian model with accommodative monetary policy and hence a very large multiplier. Similar to Canzoneri et al.'s (2016), their empirical analysis rather focusses on responses of risk premia, i.e., a spread between yield on assets that differ with regard to their riskiness, than on responses of liquidity premia, i.e., spreads between interest rate on assets with similar risk exposure but different abilities to serve as a substitute for money. Bayer et al.'s (2020) analysis is therefore complementary to ours, while both papers show mechanisms that speak against extreme (very small or very large) fiscal multipliers.

## 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 include financial market data in the analysis 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. Likewise, the spread between long-term and short-term treasury debt, i.e., a term premium, increases as well. These results support the 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, which is suggested by Ramey (2011) for these sample periods, we find that various measures for liquidity premia increase significantly after a government spending hike while output multipliers are moderate and policy rates fall also under this identification. Overall, our empirical findings point towards the relevance of imperfect substitutability of assets for fiscal policy effects and, specifically, highlight the role of liquidity attributes in explaining differential interest rate dynamics.

## 3.1 Monetary policy and the fiscal multiplier

As a starting point for our analysis, we replicate and extend 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).[11] As in Ramey (2016), the sample period is 1947Q1-2015Q3.

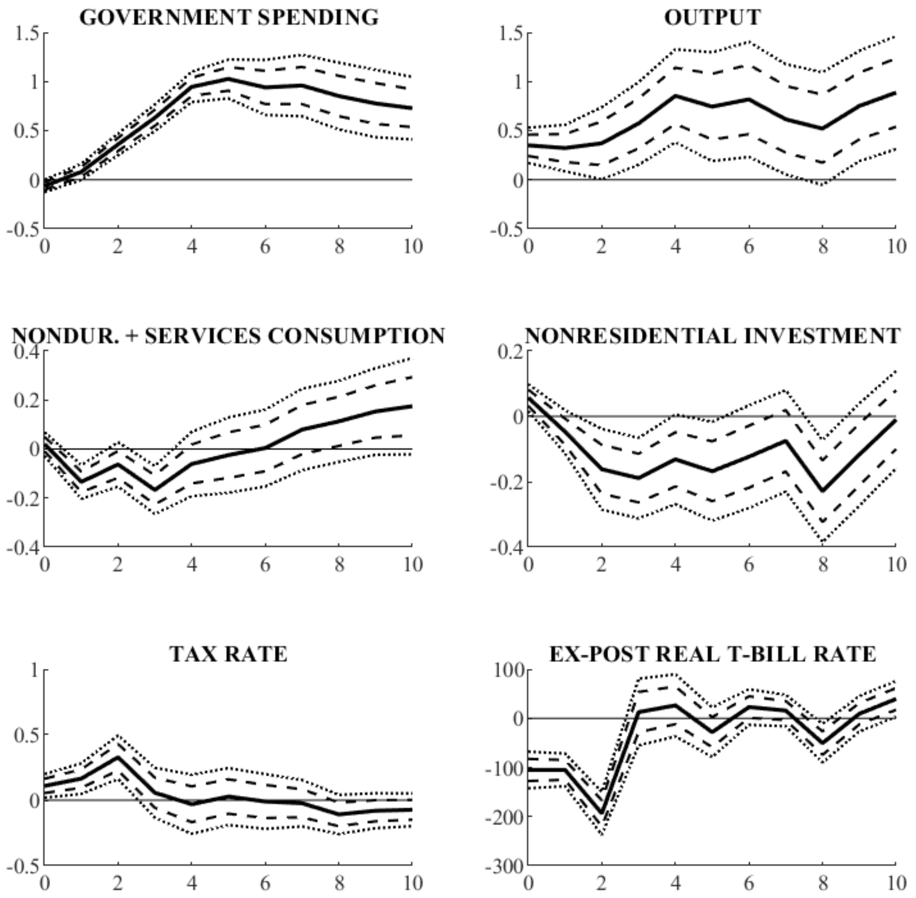
Figure 1 repeats impulse responses of government spending, output, consumption of nondurables and services, nonresidential investment, the average tax rate, and the ex-post T-bill rate from Ramey (2016). Figure 2 shows responses of variables that are important for our analysis and not included in Ramey (2016). We consider the nominal T-bill rate, inflation, and two interest rate spreads that are available for the sample period necessary for the Ramey (2016) identification. The first is the spread between yields on Aaa corporate bonds and government bonds, and the second is the spread between the returns on 10-year government bonds and 3-months T-bills. The responses of government spending, output, consumption, and investment are expressed in percent of trend GDP while, for interest rates, spreads, and inflation, we show absolute responses expressed in basis points. The dotted (dashed) lines show 68% (90%) confidence bands.

Output increases with positive spending shocks. The cumulated output multipliers differ with regard to the time horizon and are 1.37 after four quarters, 1.0 after six quarters, and 0.8 after eight quarters.[12] At the same time, there is a prolonged fall in the real T-bill rate which peaks at a reduction of almost 20 bps. Figure 2 shows that the fall in the real T-bill rate results from a reduction in the nominal T-bill rate in combination with an increase in inflation. The response 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

[11] 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.

[12] The impact multiplier is negative here, since output increases, whereas government spending initially falls slightly in response to news shocks.

**Figure 1:** Responses of **standard macroeconomic variables** to government spending shocks identified through defense news.

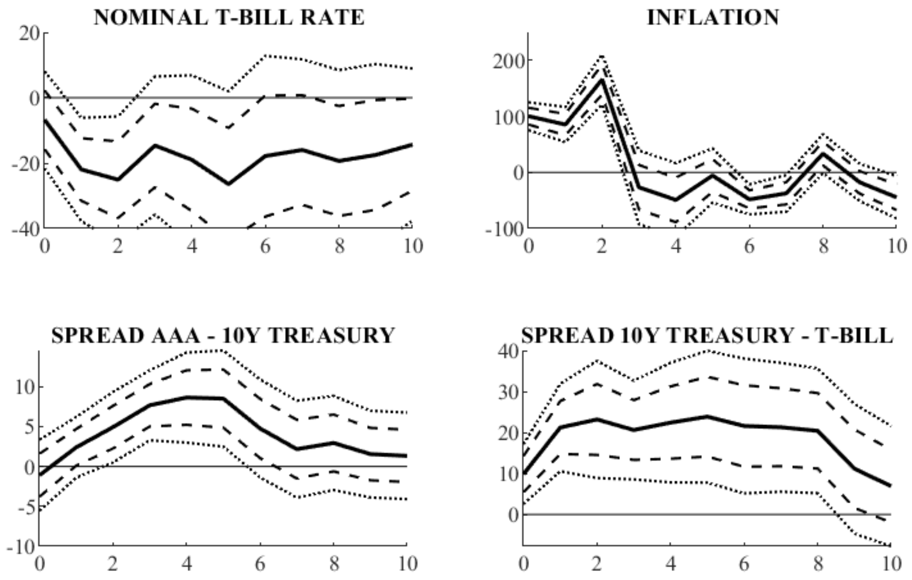



*Notes:* Identification based on narrative defense news shocks (see Ramey, 2011, Ramey and Zubairy, 2014, and Ramey 2016). Impulse responses computed using local projections as in Ramey (2016). Variable definitions (Gordon-Krenn 2010 transformation) and specification follow Ramey (2016). Government spending, output, consumption, and investment in percent of trend GDP. Average tax rate in percentage points. Real T-bill rate in basis points. Sample period 1947Q1-2015Q3. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

nominal interest rate (e.g., at the ZLB) and an increased inflation rate (see Christiano et al., 2011, or Eggertsson, 2011).

We observe that both, the corporate-treasury spread and the spread between long-term and short-term government debt increase in response to the spending expansion. These findings help understand the observed interest-rate/multiplier conundrum. Recall that theory predicts government spending to induce excess demand for commodities. The reduced willingness to save tends to reduce 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 assets that are valued also for

**Figure 2:** Responses of **interest rates and spreads** 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). Specification follows Ramey (2016). Responses in basis points. Sample period 1947Q1-2015Q3. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

their liquidity services or convenience (like treasury bills or bonds), which are typically not held as a store of wealth and cannot be issued by private borrowers. Hence, interest rate spreads should respond systematically to government spending shocks when the underlying assets differ with regard to their ability to serve as a substitute for money. This is what we see in Figure 2. The spread between the yield on Aaa corporate bonds and 10-year government bonds is a typical measure for a liquidity premium or "convenience yield" (see, e.g., Krishnamurthy and Vissing-Jorgensen, 2012). The observed increase in this spread thus shows that the response of an interest rate that is relevant for private sector borrowing and savings differs substantially from the treasury rate response. The observed increase in the term premium, i.e., the spread between the yields on long-term and short-term treasury debt, has a similar implication. Longer-term treasuries are typically more relevant for private sector savings than short term treasuries and the premium is affected by liquidity and convenience attributes (see, e.g., Greenwood et al., 2015), while admittedly they are further affected by other risk factors, which we do not address in our analysis.

## 3.2 Liquidity premia as a central factor

The main hypothesis of our 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. To provide direct evidence for this, we 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, we have to restrict the sample period to 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 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).[13] As Ramey (2011), we include four lags and account for linear-quadratic trends.

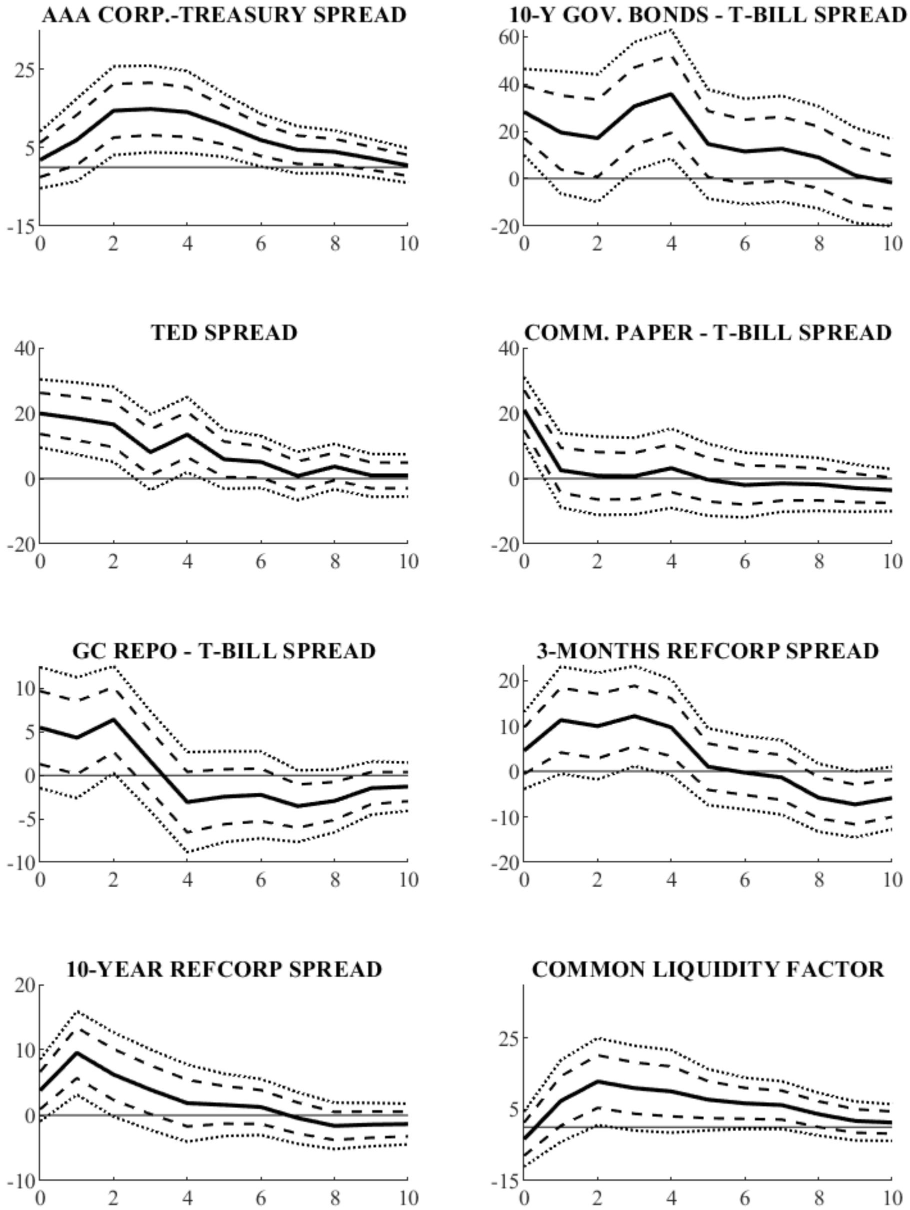
Our main interest is on estimating the reaction of liquidity premia to government spending shocks. Figure 3 summarizes the responses to a 1% increase in government spending for various interest rate spreads that have been identified to be predominantly determined by liquidity valuations, i.e., interest rate spreads between assets with similar maturity but differences in liquidity.[14] For completeness, Figure 8 in the Appendix shows the full results for the underlying baseline VAR, including a falling policy rate and a moderate output multiplier.[15] In addition to the corporate bonds spread and the term premium already investigated for the longer sample period (see Figure 1), we investigate five spreads that measure liquidity premia on short-term assets and one additional spread

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

[14]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.

[15]Note, however, that sample periods differ for the various interest rate spreads due to data availability. We follow Burnside et al.'s (2004) strategy and rotate the various interest rate spreads into our baseline VAR.

**Figure 3:** 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 1979Q4-2015Q4 for Aaa corporate-treasury spread, bonds-bills spread, and common factor, 1986Q1-2015Q4 for TED spread, 1997Q1-2015Q4 for commercial paper spread, 1992Q1-2015Q4 for GC repo spread, 1991Q2-2015Q4 for Refcorp spread. Responses in basis points. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

on longer-term assets. 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 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. We finally consider the spreads between Refcorp bonds and treasury bonds with maturities of 10 years and 3 months, respectively, 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.

In line with our previous analysis using the longer sample period and the defense-news identification (see Figure 1), we find that the corporate bonds spread increases significantly after government spending shocks, see top-left panel in Figure 3. Also in line with our previous analysis, we find that the term premium increases, see top-right panel in Figure 3. The remaining panels in the figure complement our analysis as they provide direct evidence that established measures for liquidity premia increase significantly in response to government spending shocks. Apparently, this result applies regardless of whether the liquidity premium is measured by short-term or long-term spreads. The increase of the individual spreads ranges between 6 and 35 bps and is thus substantial, compared to the mean values for the spreads which range between 12 and 198 bps. 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-right panel of Figure 3 shows that the common liquidity factor increases significantly in response to expansionary fiscal policy shocks.[16]

[16] In a previous version of this article, we additionally considered responses of the level of 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

## 3.3 Additional empirical evaluations

As a robustness check, we also consider a sample period that *excludes the recent ZLB episode* which we find to have no substantial impact on the results. The top-left panel of Figure 9 in Appendix A shows as an example the response of the corporate-treasury spread in a sample that ends in 2008.III. We cross-check 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 (see the top-right panel of Figure 9 in Appendix A). Next, we assess alternative explanations for our novel findings on differential interest rate responses. To examine if the increase in longer-term rates relative to short-term rates 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.[17] Given it does not exhibit any tendency to increase after a fiscal expansion (see middle-left panel of Figure 9 in Appendix A), 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 mainly captures the risk-bearing capacity of the financial sector. We find that this premium reacts only insignificantly and less strongly compared to our measures of liquidity premia (see middle-right panel of Figure 9 in Appendix A). Given this unsystematic response, a changing risk-taking capacity is unlikely to be a major driving force behind the observed spread responses. Finally, we look at the *supply of government debt*, which might affect prices and yields of treasury securities. In contrast to the total-debt-to-GDP ratio (see bottom-left panel of Figure 9), the ratio of T-bills to GDP does not experience a significant increase (see bottom-right panel of Figure 9). 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 corporate bonds spread (see also Bayer et al., 2020). Given that we find the latter to respond in the opposite way, this supply effect seems to be 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 reinforces the demand driven relative scarcity of liquid assets.

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. (2018).

[17] 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.

# 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.[18] Specifically, commercial banks demand reserves supplied by the central bank to serve withdrawals of demand deposits by households, who rely on money for goods market transactions. We account for the fact that reserves are only supplied against eligible assets, which were predominantly T-bills before the 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

[18] 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.

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, 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 and interest rates on non-money market instruments.

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 $R^m_t$. Specifically, reserves are supplied by the central bank only in exchange for treasuries $\widetilde{B}_{i,t}$, while the relative price of money is the repo rate $R^m_t$:

$$I_{i,t} = \widetilde{B}_{i,t}/R^m_t \quad \text{and} \quad \widetilde{B}_{i,t} \leq B_{i,t-1}, \tag{1}$$

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 $B_{i,t-1}/R^m_t$. 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 $\mu$ 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 $B_{i,t-1} + B_{i,t}^R - \widetilde{B}_{i,t}$ 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, money holdings, reserves, T-bills, corporate and interbank loans can be written as $1/R_t^D = E_t[p_{t,t+1}(1+\mu\varkappa_{i,t+1})/\pi_{t+1}]$, $1 = E_t[p_{t,t+1}(1+\varkappa_{i,t+1})/\pi_{t+1}]$,

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

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

$$1/R_t^L = 1/R_t^A = E_t p_{t,t+1} \pi_{t+1}^{-1}, \tag{5}$$

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 5), while they exceed the treasury rate $R_t$ under a binding money supply constraint (1), $\eta_{i,t} > 0$ (see 4). This difference will give rise to a liquidity premium.

## 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 $E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, n_t\right)$, where $u\left(c_t, n_t\right) = [c_t{}^{1-\sigma}/\left(1-\sigma\right)] - \theta n_t^{1+\sigma_n}/(1+\sigma_n)$, $\sigma \geq 1$, $\sigma_n \geq 0, \theta \geq 0$, $c_t$ 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

$$P_t c_t \leq \mu D_{t-1}. \tag{6}$$

The budget constraint of the representative household is $\left(D_t/R_t^D\right) + V_t z_t + P_t c_t + P_t \tau_t \leq D_{t-1} + \left(V_t + P_t \varrho_t\right) z_{t-1} + P_t w_t n_t + P_t \varphi_t$, where $\tau_t$ denotes a lump-sum tax, $\varrho_t$ dividends from intermediate goods producing firms, $w_t$ the real wage rate, and $\varphi_t$ profits from banks and retailers. Maximizing lifetime utility subject to the goods market constraint (6), 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: $-u_{n,t} = w_t\lambda_t$, $\beta E_t\left[\lambda_{t+1}R^q_{t+1}\pi^{-1}_{t+1}\right] = \lambda_t$,

$$u_{c,t} = \lambda_t + \psi_t, \tag{7}$$

$$\lambda_t/R^D_t = \beta E_t\left[\left(\lambda_{t+1} + \mu\psi_{t+1}\right)\pi^{-1}_{t+1}\right], \tag{8}$$

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, $R^q_t = \left(V_t + P_t\varrho_t\right)/V_{t-1}$ the nominal rate of return on equity, $\psi_t$ and $\lambda_t$ denote the multipliers on the real versions of the goods market constraint (6) and the budget constraint, respectively. Under a binding goods market constraint (6), $\psi_t > 0$, the deposit rate tends to be lower than the expected return on equity (see 8), as demand deposits provide transaction services.[19]

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 $y^m_t$ with labor $n_t$ according to $y^m_t = n_t$, and sell the intermediate good to retailers at the price $P^m_t$. 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:

$$L_t/R^L_t \geq P_t w_t n_t. \tag{9}$$

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 $\varrho_t$ denotes real dividends $\varrho_t = (P^m_t/P_t)n_t - w_t n_t - l_{t-1}\pi^{-1}_t + l_t/R^L_t$, subject to (9). The first order conditions for labor demand and loan demand are $1 + \gamma_t = R^L_t E_t[p_{t,t+1}\pi^{-1}_{t+1}]$ and $P^m_t/P_t = (1+\gamma_t)\,w_t$,where $\gamma_t$ denotes the multiplier on the loan demand constraint (9). Given that we abstract from financial market frictions, the Modigliani-Miller theorem applies in equilibrium. This immediately follows from banks' loan supply condition (5) and firms' loan demand condition, implying $\gamma_t = 0$. Hence, (9) is slack, such that firms' labor demand will be undistorted, $P^m_t/P_t = w_t$. 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

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

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 growth rate $\Gamma$,

$$B_t^T = \Gamma B_{t-1}^T, \tag{10}$$

where $\Gamma > \beta$. For simplicity, we neither specify longer-term government bonds nor total government debt. Notably, our main results would be qualitatively unchanged when bills and bonds were issued according to Bohn (1998)-type fiscal rules. 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 $\widetilde{B}_t$ 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 $\widetilde{B}_t + B_{t-1}^C - B_t^R$.[20] Following central bank practice, we assume that interest earnings are transferred to the government, $P_t\tau_t^m = B_t^C(1 - 1/R_t) + (R_t^m - 1)\left(M_t - M_{t-1} + M_t^R\right)$, 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 $\pi$ is controlled by the central bank and will be equal to the growth rate of treasuries $\Gamma$. 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 $\Omega \geq 0 : M_t^R = \Omega M_t$.

[20] Its budget constraint is thus given by $\left(B_t^C/R_t\right) + P_t\tau_t^m = \widetilde{B}_t + B_{t-1}^C - B_t^R + M_t - M_{t-1} - \left(I_t - M_t^R\right)$, which after substituting out $I_t$, $B_t^R$, and $\widetilde{B}_t$ using $\widetilde{B}_t = R_t^m I_t$, can be simplified to $\left(B_t^C/R_t\right) - B_{t-1}^C = R_t^m\left(M_t - M_{t-1}\right) + \left(R_t^m - 1\right)M_t^R - P_t\tau_t^m$.

## 4.4 Equilibrium properties

Given that households, firms, retailers, and banks behave symmetrically, we can omit the respective indices. As mentioned before, the Modigliani-Miller theorem applies. Hence, the main difference to a standard New Keynesian model is the money supply constraint (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 (see Definition 2 in Appendix B.3).

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

$$R_t^{IS} = u_{c,t}/\beta E_t\left(u_{c,t+1}/\pi_{t+1}\right), \tag{11}$$

which measures the marginal valuation of money by the private sector.[21] 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, (1) is then binding. A definition of a rational expectations equilibrium can be found in Appendix B.3. The equilibrium relations between interest rates can be summarized as follows:

**Corollary 1** *In a rational expectations equilibrium, the T-bill rate $R_t$ equals the expected policy rate $R_t^m$ up to first order,*

$$R_t = E_t R_{t+1}^m + h.o.t., \tag{12}$$

*the corporate $R_t^L$ and interbank loan rate $R_t^A$ equal the expected marginal rate of intertemporal substitution up to first order,*

$$R_t^L = R_t^A = E_t R_{t+1}^{IS} + h.o.t., \tag{13}$$

*(where h.o.t. represents higher order terms) and a spread between $R_t^{IS}$ and the policy rate is associated with a binding money supply constraint, i.e., $\eta_t = \left(R_t^{IS}/R_t^m\right) - 1 > 0$.*

Hence, the spread between the marginal rate of intertemporal substitution and the policy rate, $R_t^{IS} - R_t^m$, constitutes the main difference to a standard single-interest-rate model and induces spreads between loan rates and the treasury rate (see 12 and 13), which correspond to the empirical measures of liquidity premia examined in Section 3.

[21] 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.

It should further be noted that, as long as the nominal marginal rate of intertemporal substitution (rather than the policy rate $R_t^m$) exceeds one, i.e., $R_t^{IS} > 1$, the demand for money is well defined, as the liquidity constraints of households (6) and banks (2) are binding (see Appendix B.3). Notably, liquidity might be positively valued by households and banks, i.e., $R_t^{IS} > 1$, even when the policy rate is at the zero lower bound, $R_t^m = 1$. This property is 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 a basic New Keynesian model. Second, we investigate the model with the liquidity premium 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 either sets the policy rate in the long run below or equal to $R^{IS} = \pi/\beta$, where time indices are omitted to indicate steady state values, such that (1) is either binding or not. For both cases, we examine the local dynamics in the neighborhood of the respective steady state.[22] 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

[22]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.

assume that the growth rate of T-bills equals the inflation rate, $\Gamma = \pi$, in line with the data (see Section 5.2.1), that the central bank targets long-run price stability $\pi = 1$,[23] and that government spending shocks are i.i.d.

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, as observed empirically after defense news shocks (see Section 3). To induce a response of the monetary policy rate that is in line with this observation, we allow for a direct monetary policy reaction of changes in government spending $\rho_g$ (see 18), which, for example, relates to the specification in Nakamura and Steinsson (2014).

**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*

$$\widehat{c}_t = \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m < R_t^{IS}\ , \quad \text{or } \widehat{c}_t \leq \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m = R_t^{IS}, \tag{14}$$

$$\sigma\widehat{c}_t = \sigma E_t\widehat{c}_{t+1} - \widehat{R}_t^{IS} + E_t\widehat{\pi}_{t+1}, \tag{15}$$

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \chi\left(\sigma_n c_y + \sigma\right)\widehat{c}_t + \chi\sigma_n g_y\widehat{g}_t + \chi\widehat{R}_t^{IS}, \tag{16}$$

$$\widehat{b}_t = \widehat{b}_{t-1} - \widehat{\pi}_t, \tag{17}$$

*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*

$$\widehat{R}_t^m = \rho_\pi\widehat{\pi}_t + \rho_g\widehat{g}_t, \tag{18}$$

*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 (14) 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 (16).

**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.*

[23] 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).

**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 in single-interest-rate-models (like basic New Keynesian models) where it is assumed that the monetary policy rate equals the marginal rate of intertemporal substitution. If the real policy rate 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 extremely 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.

To reconcile empirical evidence and model predictions, we 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 (14) are binding, and that there exists a 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. 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. 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).

When the policy rate and the marginal rate of intertemporal substitution are separated, an expansionary monetary policy, i.e., a lower policy rate $R_t^m$, tends to stimulate current private consumption by lowering the price of money in terms of eligible assets (see 14), 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). It can be shown that there exists a non-empty set of values for the interest rate feedback parameter $\rho_g$ for which the fiscal multiplier is smaller than one, the policy rate falls and the liquidity premium increases, which cannot simultaneously be generated by a New Keynesian model without a liquidity premium.

**Proposition 2** *When a liquidity premium exists, 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 in a uniquely determined locally stable equilibrium.*

**Proof.** See Appendix C. ■

As summarized in Proposition 2, the model with a liquidity premium can simultaneously generate a fall in the real policy rate, a rise in the liquidity premium, and a moderate fiscal multiplier. While Proposition 2 establishes the model's 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 Quantitative effects

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 different scenarios for the monetary policy rate. We consider, first, that the monetary policy rate increases according to a conventional Taylor-rule and, second, that it falls after the fiscal shock as observed in the data (see Section 3), where we show that the model's predictions are consistent with the empirical observations. Third, we examine the case where the monetary policy rate is fixed at the ZLB.

### 5.2.1 Additional model features and calibration

To facilitate comparison, 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, policy rate inertia, 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, $\mathsf{c}_t$ ($\bar{\mathsf{c}}_t$) 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 $\delta$ is the rate of depreciation, $x_t$ are investment expenditures, and the function $\Lambda_t$ 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,

$$R_t^m = \max\{1, \left(R_{t-1}^m\right)^{\rho_R} (R^m)^{1-\rho_R} (\pi_t/\pi)^{\rho_\pi(1-\rho_R)} (y_t/\widetilde{y}_t)^{\rho_y(1-\rho_R)} (g_t/g)^{\rho_g(1-\rho_R)}\}, \qquad (19)$$

where $\rho_R \geq 0$, $\rho_y \geq 0$, and $\widetilde{y}_t$ denotes the efficient level of output. As in (18), we account for a direct response of the policy rate to government spending, measured by $\rho_g$, to generate the empirically observed policy rate responses. To account for persistence, 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 $\xi_t$ to the household objective, which then reads $E_0 \sum_{t=0}^{\infty} \beta^t \xi_t u_t$.

For transparency, we apply values for the first set of parameters $\{\sigma, \sigma_n, \alpha, \delta, \epsilon, \theta, \phi, g/y, h, \rho_\pi, \rho_y, \rho_R, \rho\}$ from sources that are unrelated to the model and that are standard in the literature (for an interpretation of a period as a quarter).[24] Specifically, we set the inverses of the elasticities of intertemporal substitution to $\sigma = 1$ and $\sigma_n = 1$, the labor income share to $\alpha = 2/3$, and the depreciation rate to $\delta = 0.025$. The elasticity of substitution $\epsilon$ is set to $\epsilon = 6$, and the utility parameter $\theta$ is chosen to lead to a steady state working time of $n = 1/3$. For the fraction of non-optimally price adjusting firms $\phi$ we apply $\phi = 0.8$. The mean government share and the habit formation parameter are set at $g/y = 0.2$ and $h = 0.7$. The coefficients of the interest rate rule – except for $\rho_g$ – are set at values typically applied in related studies, $\rho_\pi = 1.5$, $\rho_y = 0.05$, and $\rho_R = 0.8$. We set the autocorrelation of government spending $\rho$ to a standard value of 0.90.

For the second set of parameters, $\{R^m, \pi, \Gamma, \Omega, \beta, \zeta, \gamma, \rho_g\}$, we apply empirical information. For the policy rate and inflation, we set average values to the sample means of the T-bill rate and the CPI inflation rate for 1947.I-2015.III, $R^m = 1.0440^{1/4}$ and $\pi = 1.0329^{1/4}$. Regarding the supply of government liabilities, we apply US data until 2007.III, when the Fed began to massively increase repos in response to the subprime

[24] Note that the parameter $\mu$ in (2) and (6) is only required to determine real deposits and the deposit rate (see Definition 1), which are both not relevant for the subsequent analysis.

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 January 2003 to August 2007 (where the sample period is determined by data availability) implying a ratio of money supplied under repos to outright money holdings $\Omega$ equal to 1.5. The discount factor $\beta$ is set to $\beta = 0.9958$, 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 0.0059 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.III. The investment adjustment cost parameter $\zeta$ is set at 0.065, which corresponds to Groth and Khan's (2010) estimate based on firm-level data.[25] The utility weight of credit goods $\gamma$ is set at a conservative value 35, which replicates the 2012 US share of cash transactions of 14%, taken from Bennett et al. (2014). Finally, the fiscal feedback coefficient of the interest rate rule $\rho_g$ is set to $-0.1$ to approximate the observed 20 bps reduction in the nominal monetary policy rate (see Figure 1).

For these parameter values, the equilibrium is locally determinate (consistent with Lemma 1) for all versions considered below. For consistency, we solve the model using the dynare supplement "occbin"developed by Guerrieri and Iacoviello (2014) for all scenarios.[26] 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.

### 5.2.2 Results

Figure 4 shows impulse responses to a government spending shock that amounts to one percent of GDP as in the empirical analysis in Figure 1. We distinguish between two scenarios regarding the response of monetary policy to this impulse. In the first scenario (dotted lines), the monetary policy rate follows a conventional interest rate rule (with $\rho_g = 0$) and is thus raised in response to the fiscal expansion due the inflationary tendencies of the additional demand. In the second scenario (dashed lines), we consider the augmented Taylor rule with a negative feedback to government spending ($\rho_g = -0.1$), leading to a fall in the nominal policy rate as found in the data. As in the

[25] 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).

[26] "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.

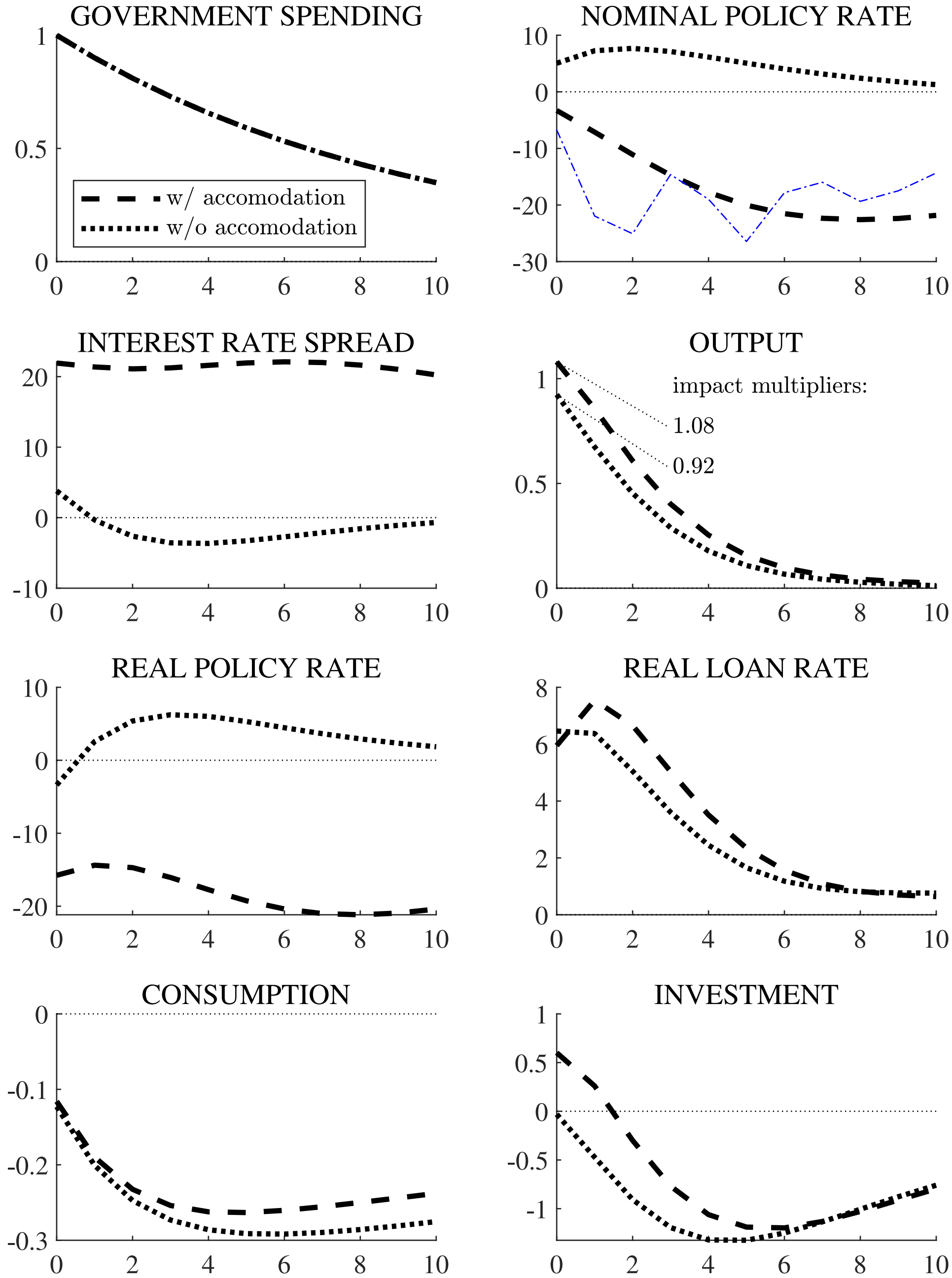
empirical figures, we show relative responses expressed in percent of steady-state GDP for level variables such as government spending, output, consumption, and investment and absolute responses expressed in basis points for interest rates and interest rate spreads.

Consider first the case of an increasing policy rate (dotted lines). The figure reflects 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 investment and consumption, where investment expenditures slightly increase on impact, consistent with our empirical findings. This leads to a multiplier below one and, quantitatively, output rises by 95 cents for every additional dollar spent. The reduction in private consumption is associated with a decline in the marginal utility of consumption. This implies a higher marginal rate of intertemporal substitution, which is reflected by a rise in the real rate on loans. The increase in the policy rate is less pronounced than the rise in the marginal rate of intertemporal substitution. Thus, the liquidity premium increases, reflecting that higher inflation reduces the real value of money and near-money assets.

Now consider the case where the central bank accommodates the spending stimulus and reduces its policy rate (dashed lines). The extended Taylor rule induces the policy rate to fall by up to 20 bps, which similar to the empirical response of the T-bill rate from Figure 2 (the latter being represented by the thin blue dashed-dotted line in Figure 4). In isolation, a lower policy rate stimulates private consumption and, consequently, private demand is crowded out by less than in the first scenario. Hence, in this scenario, the output multiplier is larger and the rise in the liquidity premium is more pronounced. Quantitatively, monetary accommodation raises the multiplier to 1.1 and the liquidity premium rises by somewhat more than 20 bps in the medium run, which lies in the range of observed spread responses in Section 3. Our simple model can thus reproduce the joint observations of reductions in the nominal and real rates on near-money assets, a moderate output multiplier, and an increase in liquidity premia.

A stark implication of our model is revealed by comparing the output responses in the two scenarios shown in Figure 4. Given the strong difference in the response of monetary policy across scenarios, the output responses are remarkably similar. When the central bank *lowers* the policy rate by about 20 bps instead of *raising* it by between 5 and 10 bps, this raises the spending multiplier by only about 18% (from 0.92 to 1.08). Notably, incorporating additional features (like borrowing-constrained households or productivity-enhancing public expenditures) that have been shown to make fiscal policy more expansionary would tend to raise the multiplier in both scenarios. The main insight of the analysis is that the change in the multiplier is small even when the

**Figure 4:** Responses to spending expansion with and without monetary accomodation - model with liquidity premium.

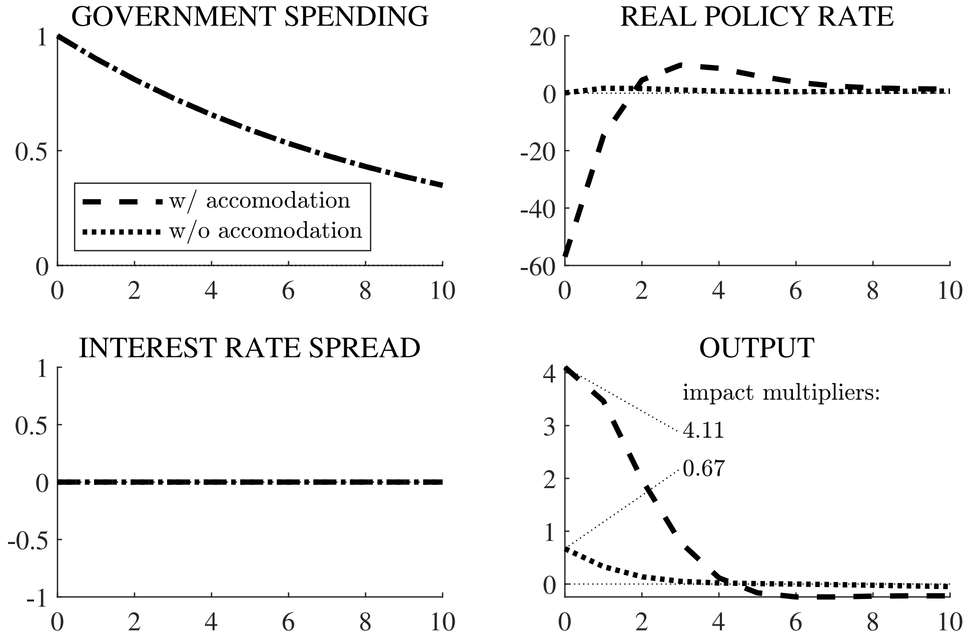



*Notes:* Responses of $g_t$, $y_t$, $c_t$, and $x_t$ in percent of steady-state GDP. Responses of $R_t^m$, $R_t^m/E_t\pi_{t+1}$, $R_t^L/E_t\pi_{t+1}$, and $R_t^L - R_t^m$ in basis points. Thin dashed-dotted line in upper-left panel shows empirical response of the T-bill rate, see Figure 2.

monetary policy stance is changed substantially. Our model thus helps understand why empirically estimated fiscal multipliers are moderate even when monetary policy is found to accommodate spending expansions.

Figure 5 illustrates the strong role monetary policy plays for the fiscal multiplier in

**Figure 5:** Responses to spending expansion with and without monetary accomodation - model without liquidity premium.




*Notes:* Responses of $g_t$ and $y_t$ in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in basis points.

a model version that corresponds to a simple single-interest-rate model, which stands in sharp contrast to the previous results. In the figure, we repeat the experiments shown in Figure 4 but, here, we perform them in an otherwise identically calibrated model version where the money-supply is slack (which reduces the model to a standard New Keynesian model with a cash-in-advance constraint). The figure reveals two main messages: first, monetary accommodation affects the output multiplier very strongly in this model, raising it by more than factor 6, from 0.67 to 4.11. This is so despite that, endogenously, the monetary accommodation is substantially more short-lived in this model version (see dashed line in the upper-left panel, with left axis). Second, when monetary policy follows a conventional Taylor rule, the quantitative implications of the model versions with and without the liquidity premium are rather similar. It is when monetary policy accommodates fiscal policy that taking into account liquidity premia and their response to spending shocks is essential. Without a liquidity premium, the drop in the real policy rate directly translates into a drop in the marginal rate of intertemporal substitution, leading to a strong consumption crowding in and a large fiscal multiplier.

**Sensitivity** We perform sensitivity checks with respect to the inverse elasticity of intertemporal substitution, $\sigma$, and the extent of habit formation, $h$, both affecting private agents' intertemporal consumption choice and thereby interest rates and spreads (see 11 in Appendix C.2). For a lower willingness to substitute consumption intertemporally, $\sigma = 2$. Therefore, rates on ineligible assets and hence the liquidity premium rise more strongly, while the fiscal multiplier is reduced to a value of 0.84. This confirms that our model can generate a multiplier below one even in presence of monetary accommodation (compare Proposition 2). When we shut off habit formation in consumption by setting $h = 0$, the responses of rates on ineligible assets and of the liquidity premium are weaker on impact. The multiplier is then increased but remains far from the levels which a model without liquidity premium would predict in presence of monetary accommodation.

When we consider a delayed peak in government spending, which relates to the pattern shown in Figure 1, we also find that our conclusions are robust to this variation (see Figure 12 in Appendix C.2). The model with the liquidity premium displays an increase in the interest-rate spread by about 20 bps, in line with Figure 2, and the output effects of fiscal policy remain moderate. By contrast, the model without the liquidity premium continues to predict large output effects of fiscal policy, witnessed by a peak-to-peak multiplier of 3.41.

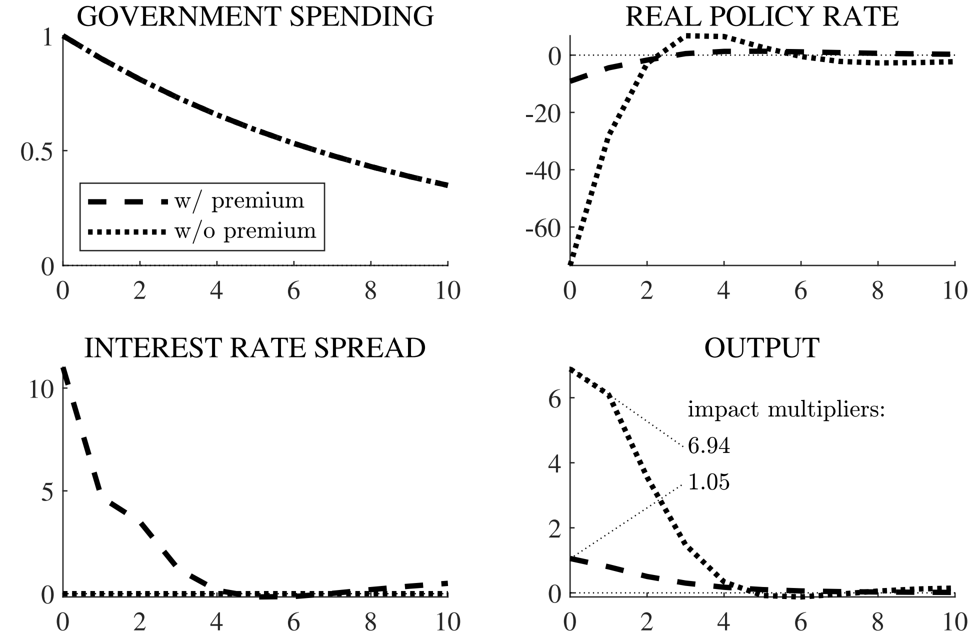
Further sensitivity checks – regarding the degree of price stickiness, the persistence of government spending shocks, the level of investment adjustment costs, and the importance of repos in open-market operations – are shown in Figures 13 and 14 in Appendix C.2. In these checks, we find our main results confirmed. While the exact value of the fiscal multiplier predicted by the model with the liquidity premium varies, it remains moderate for all parameter variations despite monetary accommodation.

### 5.2.3 Results at the ZLB

Finally, we analyze the fiscal multiplier for the prominent case where the monetary policy rate is initially stuck at the binding ZLB. For this, we assume that the monetary policy rate is set according to the interest rate rule (see 19) 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 $\xi_t$ that causes the economy to reach the ZLB in the impact period and to remain there for two further periods.[27] The preference shock causes output and inflation to fall such that the central bank lowers the policy rate until the ZLB is reached. 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.

[27] It should be noted that the results for the model with the liquidity premium are hardly affected when we consider longer ZLB durations.

**Figure 6:** Net effects of a positive government spending shock at the ZLB for a model version with (dashed lines) and without liquidity premium (dotted lines)




*Notes:* The preference shock $\xi_t$ that drives the economy to the ZLB follows an AR(1) process with autocorrelation 0.8. Responses of $g_t$ and $y_t$ in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in basis points.

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 dashed 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 1.05. Overall, the impulse responses from the model with the liquidity premium accord with the results with monetary accommodation shown before. The dotted lines further reveal that conducting the same experiment without the liquidity premium leads to much more pronounced responses of inflation and hence the real policy rate. Given that the latter equals the marginal rate of intertemporal substitution in this model, consumption and investment are crowded in, leading to an empirically implausibly large output multiplier of almost 7.

Thus, the monetary policy stance is far less crucial for the size of the fiscal multiplier 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 suggests a solution based on imperfect substitutability of assets reflected by the observation that measures of liquidity premia tend to rise. We show that a standard macroeconomic model that is augmented by a liquidity premium on near-money assets can 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 than 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 four main sources: the data provided online by Valerie Ramey (`https://econweb.ucsd.edu/~vramey/research.html#govt`), the FRED database of the Federal Reserve Bank of St. Louis (FRED), the survey of professional forecasters (SPF), and the Bloomberg financial database (Bloomberg). Mnemonics are given in square brackets.

**Data from Valerie Ramey.** We use the following series: The Ramey News variable [RAMEY_NEWS], real GDP [RAMEY_Y], real government purchases [RAMEY_G], real consumption of nondurables and services [RAMEY_C], real non-residential investment [RAMEY_X], federal current receipts divided by nominal GDP [RAMEY_TAX], the 3-month Treasury bill rate [RAMEY_RTB], the rate of inflation calculated using the GDP deflator [RAMEY_PI].

**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], 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. 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, following Auerbach and Gorodnichenko (2012). Mean CPI inflation forecasts are also taken from the SPF [SPFINF1]. We use the mean forecast for the average T-bill rate in the next year (i.e., 5-8 quarters ahead) [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]. 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] to calculate the GC repo rate. We denote the spread to the T-bill rate as GCREPO.

**Further data sources.** The time series for the excess bond premium [EBP] 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 common liquidity factor

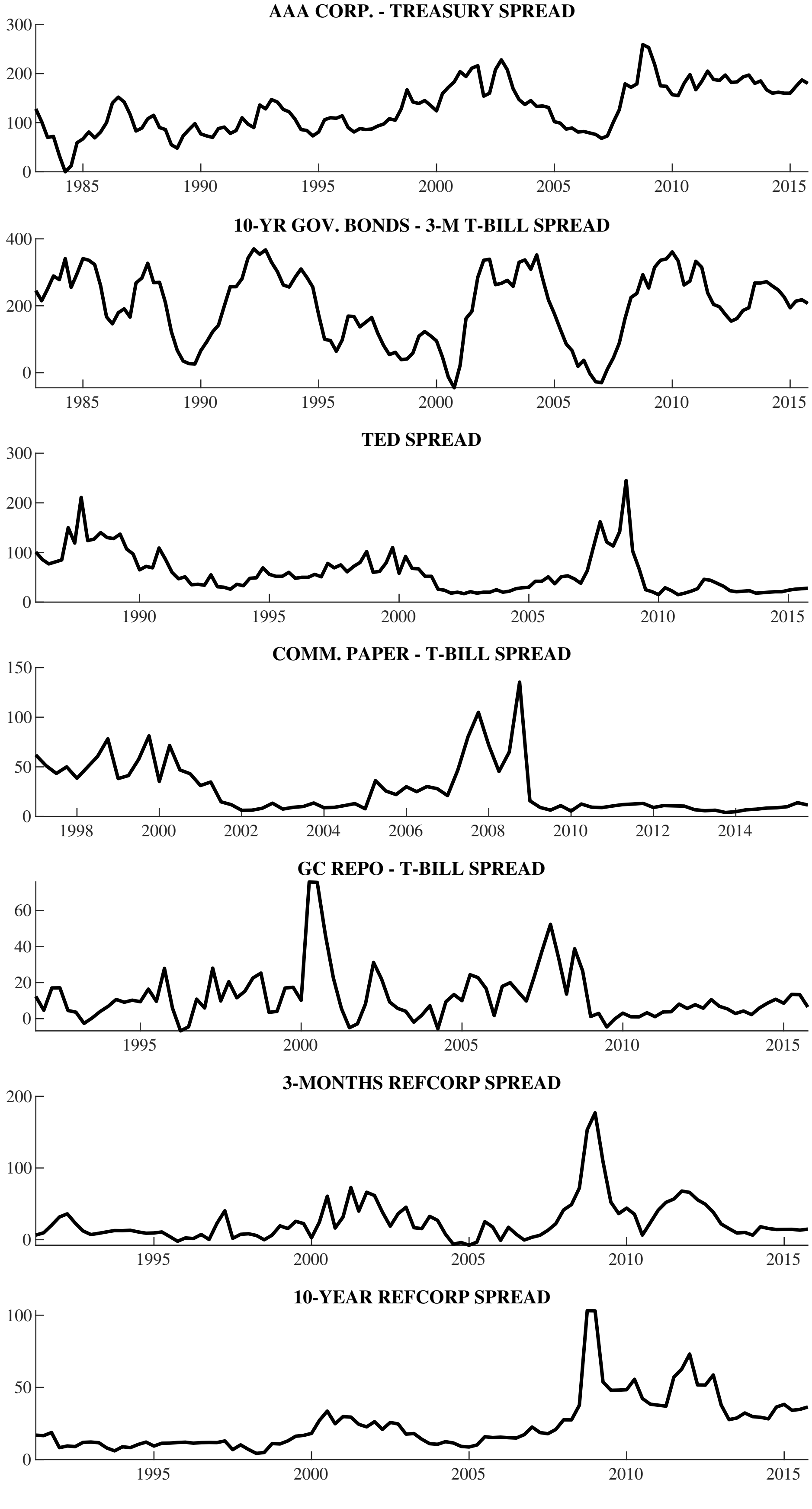
We construct the common liquidity factor ($clf$) following Del Negro et al. (2017). We estimate a principal-component model with one component based on different liquidity spreads. Based on the estimated model, we project the observed liquidity spreads on a common liquidity factor, thereby reducing the dimensionality of liquidity premia data to one. Following Del Negro et al. (2017), we use a linear transformation of the principal component so that the mean spread is 46 bps and the maximum spread is 342 bps at the height of the financial crisis. The liquidity spreads included in the estimation of the common factor are the differences 1) between the 3-months commercial papers rate and

**Table 1:** Variable definitions.

| Symbol | Description | Definition |
|---|---|---|
| *Figure 1:* | | |
| $g/\overline{y}$ | Govmt. spending to (trend) GDP | RAMEY_G / $\overline{y}$ |
| $y/\overline{y}$ | GDP (in percent of trend) | RAMEY_Y / $\overline{y}$ |
| $c/\overline{y}$ | Consumption to (trend) GDP | RAMEY_C / $\overline{y}$ |
| $x/\overline{y}$ | Investment to (trend) GDP | RAMEY_X / $\overline{y}$ |
| $tax/y$ | Average tax rate | RAMEY_TAX |
| $R^{T-bill3}-\pi_{3m}$ | Ex-post real T-bill rate | RAMEY_RTB - RAMEY_PI |
| *Figure 2:* | | |
| $R^{T-bill3}$ | Nominal T-bill rate | RAMEY_RTB |
| $\pi_{3m}$ | Log change in GDP deflator | RAMEY_PI |
| $R^{Aaa}-R^{T-bond}$ | spread between Aaa corporate bonds and government bonds | DAAA–DGS10 |
| $R^{T-bond}-R^{T-bill3}$ | spread between 10-yr govmt. bonds and three-months T-bills | DGS10–TB3MS |
| *Figure 3:* | | |
| $R^{T-bond}-R^{T-bill3}$ | spread between 10-yr govmt. | DAAA–DGS10 |
| $R^{T-bond}-R^{m}$ | spread between 10-yr govmt. bonds and federal funds rate | DAAA–FEDFUNDS |
| $R^{Libor3}-R^{T-bill3}$ | TED spread (Libor–T-bill rate) | TEDRATE |
| $R^{cp}-R^{T-bill3}$ | spread between the rates on commercial papers and T-bills | DCPN3M–TB3MS |
| GC | GC Repo - T-bill spread | GCREPO |
| $R^{refcorp,3m}-R^{T-bond}$ | 3-months Refcorp spread | REFCORP3M |
| $R^{refcorp,10y}-R^{T-bond}$ | 10-year Refcorp spread | REFCORP10 |
| $clf$ | common liquidity factor | (see Section A.2) |
| *Figure 8:* | | |
| $fe$ | professional forecast error for government spending growth | (see Auerbach and Gorodnichenko, 2012) |
| $g$ | log government spending p.c. | log((A782RC1Q027SBEA+ A955RC1Q027SBEA)/(GDPDEF×CNP16OV)) |
| $y$ | log real output p.c. | log(GDP/(GDPDEF×CNP16OV)) |
| $tax$ | log net tax receipts p.c. | 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 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) |

*Notes:* $\overline{y}$ is fitted value from regression of real GDP on time and time squared. p.c.=per capita.

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




*Notes:* Spreads shown in basis points.

3-months T-bill rate, 2) between the 3-months GC repo rate and the 3-months T-bill rate, 3) between the 3-months LIBOR and the 3-months T-bill rate, 4) between the 10-year Aaa corporate bonds rate and the 10-year treasury bond rate with 10-year maturity, 5) between the 3-months Refcorp rate and 3-months Treasury rate, 6) between the 1-year Refcorp rate and 1-year Treasury rate, and 7) between the 10-year Refcorp rate and 10-year Treasury rate. To increase information on liquidity spreads in the first years of our sample, 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.[28] The sample period for the principal-component model starts in 1983Q1 (the sample contains at least two liquidity spreads per quarter).

## A.3 Description of local projections

The specification is identical to Ramey (2016). All regressions include on the right-hand side the Ramey news variable, two lags of real GDP, two lags of real government spending, two lags of the average tax rate, two lags of the news variable, two lags of the independent variable, time and time squared, as well as a constant.

## A.4 Description of VARs

The VARs include a constant, a linear-quadratic trend, and four lags of the variables. All VARs include: 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 an interest rate spread. 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 figure notes.

## A.5 Baseline VAR results for sample period 1979.IV to 2015.IV

To estimate the responses of liquidity premia to government spending shocks, we have to restrict the sample period due to data availability. Since identification using narrative approaches is not possible for these sample periods, we follow Ramey (2011) and use

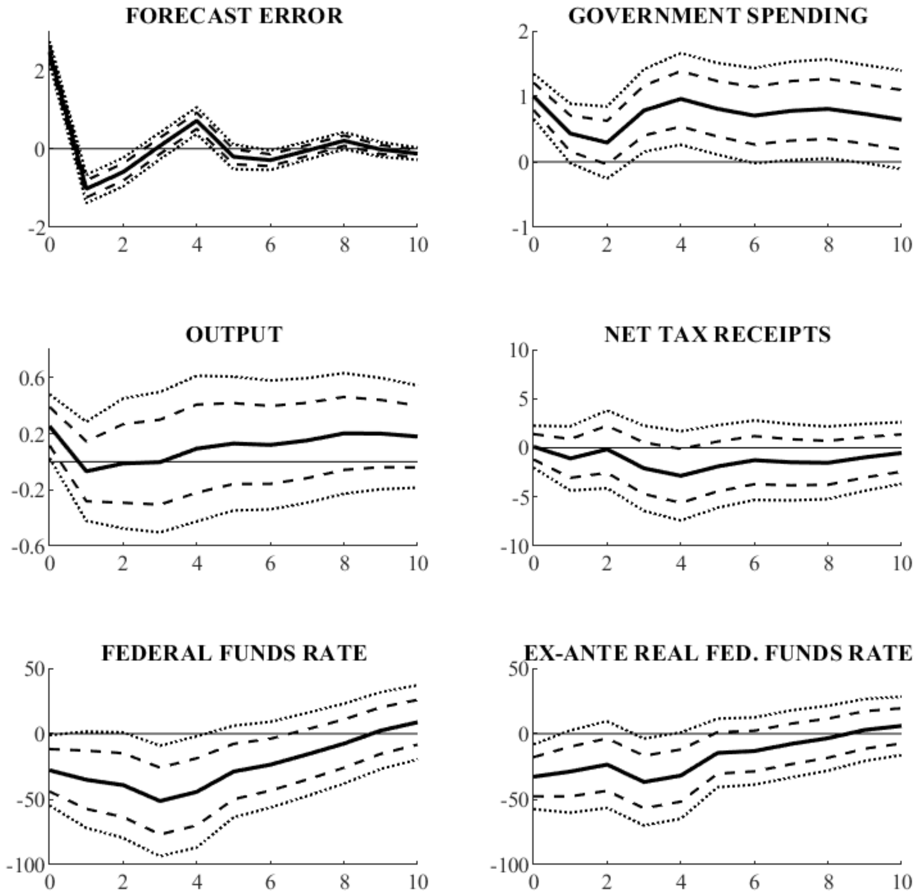
[28] The principal-component model can deal with missing data such that we can construct the common factor also when we do not observe all included liquidity spreads.

forecast errors from the Survey of Professional Forecasters (SPF) to capture exogenous and unforeseen variations in government spending.

Figure 8 shows the responses to a 1% positive government spending shock in our baseline VAR for the sample period 1979.IV to 2015.IV. 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 short-lived.[29] The cumulated output multiplier 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. As in Figure 1 in the main text, we find that the nominal federal funds rate decreases significantly in response to a government spending shock while estimated government spending multipliers are moderate. The ex-ante real federal funds rate also declines significantly, by up to 30 basis points, in response to government spending shocks. 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 1) rather than ex-post real rates using realized inflation rates.

[29] Figure XII in Ramey (2011) shows a very similar output response as documented in our Figure 8.

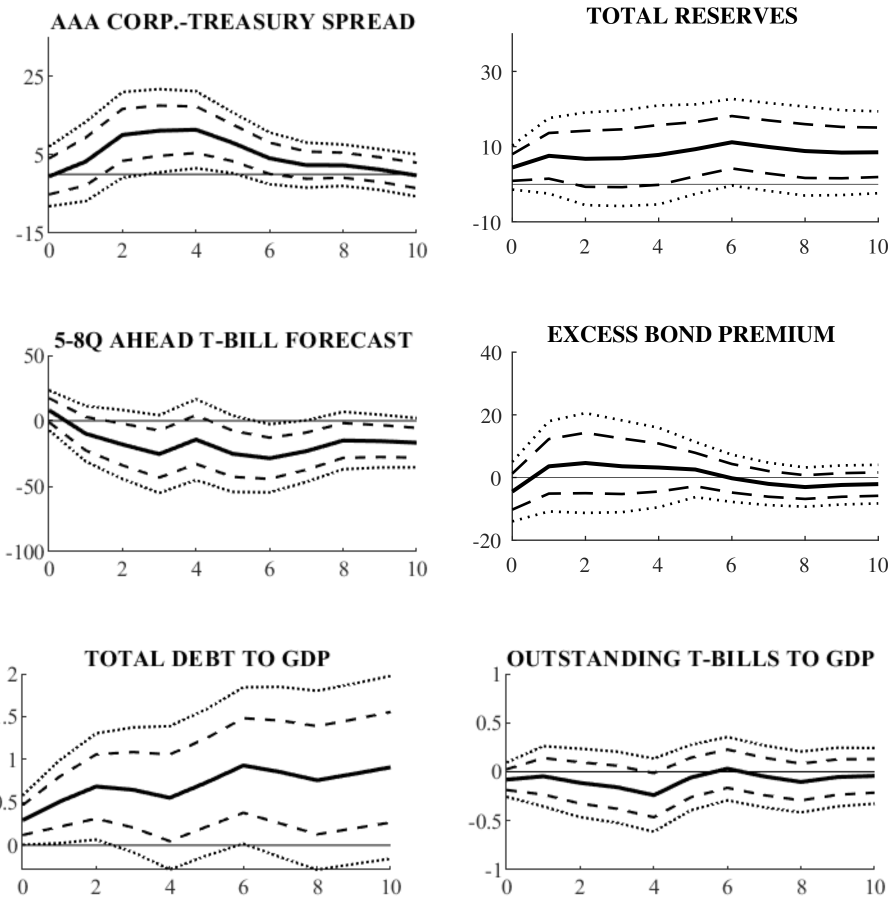
**Figure 8:** Responses to government spending shocks identified through forecast errors.




*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. Bottom-right panel: real federal funds rate replaces nominal federal funds rate in VAR. Sample period 1979Q4-2015Q4. Responses in percent, nominal and real federal funds rate in basis points. Dotted lines (dashed lines) show 68% (90%) confidence bands. Horizontal axes show quarters.

## A.6 Additional empirical results

**Figure 9:** Further responses to positive government spending shocks identified through forecast errors.

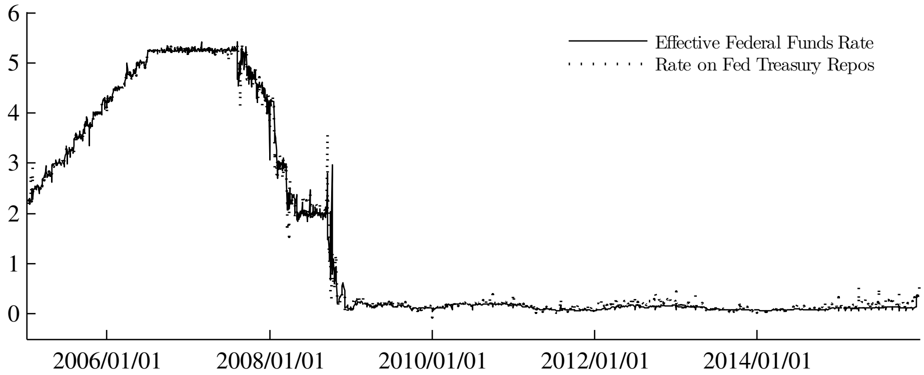



*Notes:* Identification based on forecast errors from the Survey of Professional Forecasters (Ramey, 2011). All VARs include forecast error, government spending, real GDP, net tax receipts, and the variable shown in the figure. For panels 2 through 8, the federal funds rate additionally included. Sample period 1979Q4-2015Q4 for excess bond premium, debt to GDP, and total reserves, 1979Q4-2008Q3 for corporate-treasury spread, 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

Consider a symmetric equilibrium. To distinguish the two cases of a binding and a non-binding money supply constraint, combine the banks' optimality condition $1/R_t^D = E_t[p_{t,t+1}(1+\mu\varkappa_{t+1})/\pi_{t+1}]$ with (8) to get $E_t[\frac{\lambda_{t+1}+\mu\psi_{t+1}}{\lambda_t}\pi_{t+1}^{-1}] = E_t[\frac{\lambda_{t+1}}{\lambda_t}(1+\varkappa_{t+1}\mu)\pi_{t+1}^{-1}]$, which holds if the multipliers of the liquidity constraints satisfy $\varkappa_t = \psi_t/\lambda_t$. The banks' optimality conditions $1 = E_t[p_{t,t+1}(1+\varkappa_{t+1})/\pi_{t+1}]$ and $\varkappa_t + 1 = R_t^m(\eta_t+1)$ imply $(\psi_t+\lambda_t)/\lambda_t = R_t^m(\eta_t+1)$ and $\beta E_t\pi_{t+1}^{-1}(\lambda_{t+1}+\psi_{t+1}) = \lambda_t$, which can – by using condition (7) – be combined to the following expression for the multiplier of the money supply constraint (1),

$$\eta_t = \left(R_t^{IS}/R_t^m\right) - 1. \tag{20}$$

Combining $\beta E_t\pi_{t+1}^{-1}(\lambda_{t+1}+\psi_{t+1}) = \lambda_t$ with (7) and (11), further shows that the multiplier of the liquidity constraints of households (6) and banks (2) satisfies $\psi_t = u_{c,t}\left(1 - 1/R_t^{IS}\right)$.

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

$$c_t = m_t + m_t^R,\ \text{if}\ \ \psi_t = u_{c,t}\left(1-1/R_t^{IS}\right) > 0, \tag{21}$$
$$\text{or}\ c_t \leq m_t + m_t^R,\ \text{if}\ \ \psi_t = u_{c,t}\left(1-1/R_t^{IS}\right) = 0,$$
$$b_{t-1}/\left(R_t^m\pi_t\right) = m_t - m_{t-1}\pi_t^{-1} + m_t^R,\ \text{if}\ \ \eta_t = \left(R_t^{IS}/R_t^m\right) - 1 > 0, \tag{22}$$
$$\text{or}\ b_{t-1}/\left(R_t^m\pi_t\right) \geq m_t - m_{t-1}\pi_t^{-1} + m_t^R,\ \text{if}\ \ \eta_t = \left(R_t^{IS}/R_t^m\right) - 1 = 0,$$
$$m_t^R = \Omega m_t, \tag{23}$$
$$b_t = b_t^T - m_t, \tag{24}$$
$$b_t^T = \Gamma b_{t-1}^T/\pi_t, \tag{25}$$
$$\theta n_t^{\sigma_n} = u_{c,t}w_t/R_t^{IS}, \tag{26}$$
$$1/R_t^{IS} = \beta E_t\left[u_{c,t+1}/\left(u_{c,t}\pi_{t+1}\right)\right], \tag{27}$$
$$w_t = mc_t, \tag{28}$$
$$\lambda_t = \beta E_t\left[u_{c,t+1}/\pi_{t+1}\right], \tag{29}$$
$$Z_{1,t} = \lambda_t y_t mc_t + \phi\beta E_t\pi_{t+1}^{\varepsilon}Z_{1,t+1}, \tag{30}$$
$$Z_{2,t} = \lambda_t y_t + \phi\beta E_t\pi_{t+1}^{\varepsilon-1}Z_{2,t+1}, \tag{31}$$
$$Z_t = \left[\varepsilon/\left(\varepsilon-1\right)\right]Z_{1,t}/Z_{2,t}, \tag{32}$$
$$1 = (1-\phi)Z_t^{1-\varepsilon} + \phi\pi_t^{\varepsilon-1}, \tag{33}$$
$$s_t = (1-\phi)Z_t^{-\varepsilon} + \phi s_{t-1}\pi_t^{\varepsilon}, \tag{34}$$
$$y_t = n_t/s_t, \tag{35}$$
$$y_t = c_t + g_t, \tag{36}$$

*(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 residually determined: The T-bill rate $R_t$ relates to the expected future policy rate, which can be seen from combining (4) with $1 = E_t[p_{t,t+1}(1+\varkappa_{t+1})/\pi_{t+1}]$ and $\varkappa_t + 1 = R_t^m(\eta_t + 1)$,

$$R_t = E_t[u_{c,t+1}\pi_{t+1}^{-1}]/[E_t\left(R_{t+1}^m\right)^{-1}u_{c,t+1}\pi_{t+1}^{-1}]. \tag{37}$$

Using $\beta E_t \pi_{t+1}^{-1}\left(\lambda_{t+1} + \psi_{t+1}\right) = \lambda_t$ and (7) to rewrite (5) further shows that the loan rates $R_t^L$ and $R_t^A$ closely relate to the expected marginal rate of intertemporal substitution

$$(1/R_t^{L,A}) \cdot E_t[u_{c,t+1}/\pi_{t+1}] = E_t[\left(1/R_{t+1}^{IS}\right) \cdot u_{c,t+1}/\pi_{t+1}]. \tag{38}$$

Likewise, the expected rate of return on equity satisfies $E_t[u_{c,t+1}/\pi_{t+1}] = E_t\left[\left(R_{t+1}^q/R_{t+1}^{IS}\right) \cdot u_{c,t+1}/\pi_{t+1}\right]$, and (8) implies the deposit rate to satisfy $\lambda_t/R_t^D = \beta E_t[(u_{c,t+1} + (1-\mu)\lambda_{t+1})/\pi_{t+1}]$.

If the money supply constraint (1) is not binding, which is the case if $R_t^m = R_t^{IS}$ (see 20), 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* $R_t^{IS} = R_t^m$, *(26)-(36), the transversality condition, a monetary policy* $\{R_t^m \geq 1\}_{t=0}^\infty$, $\pi \geq \beta$, *and a fiscal policy* $\{g_t\}_{t=0}^\infty$, *for a given initial value* $s_{-1} \geq 1$.

# C Appendix to Section 5

## C.1 Analytical results

**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., (15), (16), and (18), which can by substituting out $\widehat{R}_t^{IS}$ be summarized as

$$\rho_\pi \widehat{\pi}_t + \rho_g \widehat{g}_t - E_t \widehat{\pi}_{t+1} = \sigma E_t \widehat{c}_{t+1} - \sigma \widehat{c}_t, \tag{39}$$

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \delta_c \widehat{c}_t + \delta_g \widehat{g}_t + \chi \rho_\pi \widehat{\pi}_t, \tag{40}$$

where $\delta_c = \chi\left(\sigma_n c_y + \sigma\right) > 0$ 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 (39) and (40), leads to the following two conditions in $\gamma_\pi$ and $\gamma_c$ : $\gamma_\pi \rho_\pi + \rho_g + \sigma\gamma_c = 0$ 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. ■

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

$$\rho_\pi < [(1+\beta)\chi^{-1} + 1 - \sigma]/\sigma. \tag{41}$$

**Proof.** The model given in Definition 3 for the version with $R_t^m < R_t^{IS}$, i.e., (14)-(18), is further simplified by substituting out $\widehat{R}_t^{IS}$ and $\widehat{R}_t^m$ :

$$\delta_1 E_t\widehat{\pi}_{t+1} + \delta_3\widehat{b}_t + \delta_2\widehat{c}_t = \widehat{\pi}_t - \delta_g\widehat{g}_t, \tag{42}$$

$$\widehat{c}_t = \widehat{b}_{t-1} - (1+\rho_\pi)\widehat{\pi}_t - \rho_g\widehat{g}_t, \tag{43}$$

and (17), 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 (17), (42), and (43) by eliminating $\widehat{c}_t$

with (43) in (42) and then $\widehat{b}_{t-1}$ with (17). 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

$$\mathbf{A} = \begin{pmatrix} \delta_1 & \delta_3 + \delta_2 \\ 0 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 + \delta_2 \rho_\pi & 0 \\ -1 & 1 \end{pmatrix} \tag{44}$$

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 $\delta_1$, $F(0) = (\rho_\pi \delta_2 + 1)/\delta_1$, 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 $\delta_1$ 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

$$2(1 + \beta + \chi(1-\sigma) - \chi\sigma\rho_\pi) + \chi\sigma + (2\rho_\pi + 1)\chi\sigma_n c_y > 0 \tag{45}$$

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 (45) holds, if but not only if

$$\rho_\pi \leq \frac{1+\beta}{\chi\sigma} + \frac{1-\sigma}{\sigma}, \tag{46}$$

where the RHS of (46) is strictly larger than $\frac{\beta + \chi(1-\sigma)}{\chi\sigma}$. Hence, (46) is sufficient for local equilibrium determinacy, which establishes the claim made in the lemma. ■

Condition (41) 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. For example, the central bank can 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). It should further be noted that the sufficient condition (41) is far from being restrictive for a broad range of reasonable parameter values.

**Lemma 2** *Suppose that $R_t^m < R_t^{IS}$ and that (41) 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.** Consider the set of equilibrium conditions (17), (42), and (43). We aim at identifying the impact responses to fiscal policy shocks. For this, we assume that (46) is satisfied, which ensures existence and uniqueness of a locally stable solution. We then apply the following solution form for the system (17), (42), and (43):

$$\widehat{\pi}_t = \gamma_{\pi b}\widehat{b}_{t-1} + \gamma_{\pi g}\widehat{g}_t, \tag{47}$$

$$\widehat{b}_t = \gamma_b \widehat{b}_{t-1} + \gamma_{bg}\widehat{g}_t, \tag{48}$$

$$\widehat{c}_t = \gamma_{cb}\widehat{b}_{t-1} + \gamma_{cg}\widehat{g}_t. \tag{49}$$

Substituting out the endogenous variables in (17), (42), and (43) with the generic solutions in (47)-(49), leads to the following conditions for $\gamma_{\pi b}$, $\gamma_{cb}$, $\gamma_{\pi b}$, $\gamma_{cg}$, $\gamma_{\pi g}$, and $\gamma_{bg}$ :

$$\gamma_{\pi b} = \delta_1\gamma_{\pi b}\gamma_b + \delta_3\gamma_b + \delta_2\gamma_{cb},\ 1 = (1+\rho_\pi)\gamma_{\pi b} + \gamma_{cb},\ 1 = \gamma_b + \gamma_{\pi b}, \tag{50}$$

$$-\delta_2\gamma_{cg} = (\delta_1\gamma_{\pi b} + \delta_3)\gamma_{bg} - \gamma_{\pi g} + \delta_g,\ -\gamma_{cg} = (1+\rho_\pi)\gamma_{\pi g} + \rho_g,\ \gamma_{bg} = -\gamma_{\pi g}, \tag{51}$$

Using the three conditions in (50) 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 $\gamma_{cb}$, 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 $\gamma_b$,

$$\gamma_b^2 - (\delta_1 + \delta_3 + \delta_2(\rho_\pi + 1) + 1)\gamma_b\delta_1^{-1} + (\rho_\pi\delta_2 + 1)\delta_1^{-1} = 0. \tag{52}$$

Note that the polynomial in (52) is the characteristic polynomial of $\mathbf{A}$ (see 44). Hence, under (46) 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 (51). 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 $\gamma_{bg}$ 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

$$\gamma_{cg} = -\frac{(1+\rho_\pi)\delta_g + (\delta_1\gamma_{\pi b} + \delta_3 + 1)\rho_g}{(\delta_1\gamma_{\pi b} + \delta_3 + 1) + \delta_2(1+\rho_\pi)}. \tag{53}$$

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 (53) can be rewritten, such that

$$\gamma_{cg} = -\frac{(1+\rho_\pi)\chi\sigma_n g_y + \Gamma_1\rho_g}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}, \tag{54}$$

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

$$\rho_g > \underline{\rho_g}, \text{ where } \underline{\rho_g}(\rho_\pi) \equiv -(1+\rho_\pi)\chi\sigma_n g_y/\Gamma_1 < 0. \tag{55}$$

The solution coefficient (54) 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 (54), the inflation response is given by

$$\gamma_{\pi g} = \frac{(g_y - \rho_g c_y)\chi\sigma_n}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}, \tag{56}$$

implying that $\gamma_{\pi g} > 0$, if $\rho_g < g_y/c_y$. Using (56), 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

$$\rho_g < \overline{\rho_g}, \text{ where } \overline{\rho_g}(\rho_\pi) \equiv -\rho_\pi\frac{g_y\chi\sigma_n}{\chi\sigma_n c_y + \Gamma_1} \leq 0. \tag{57}$$

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 (48)-(49), 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 (54), 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

$$\widetilde{\rho_g}(\rho_\pi) \equiv -\frac{((1+\rho_\pi)(1-\gamma_b)+\rho_\pi)\chi\sigma_n g_y}{(1-(1+\rho_\pi)(1-\gamma_b))\chi\sigma_n c_y + \Gamma_1}, \tag{58}$$

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

$$\rho_g > \widetilde{\rho_g}(\rho_\pi) \text{ for } \widetilde{\rho_g}(\rho_\pi) < 0 \quad \text{or} \quad \rho_g < \widetilde{\rho_g}(\rho_\pi) \text{ for } \widetilde{\rho_g}(\rho_\pi) > 0, \tag{59}$$

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 (55) and (57) in the proof of Lemma 2, shows that $\underline{\rho_g} < \overline{\rho_g}$, since

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

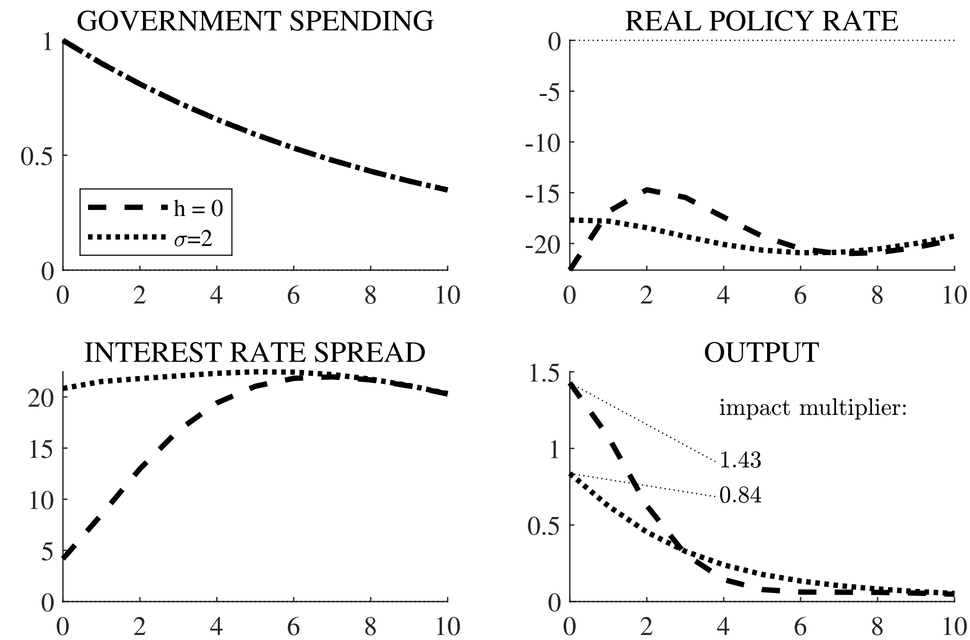
Thus, there exist values for $\rho_g$ satisfying $\rho_g \in (\underline{\rho_g}, \overline{\rho_g})$ for which private consumption and the nominal policy rate simultaneously decline in response to a government spending hike, see (55) and (57). Given that inflation increases for $\rho_g < g_y/c_y$, which 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 58), a rising real marginal rate of intertemporal substitution requires $\rho_g > \widetilde{\rho_g}(\rho_\pi)$ (see 59). 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 59), 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 $\rho_g$, which jointly satisfy (55), (57), and (59), 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 20). ■

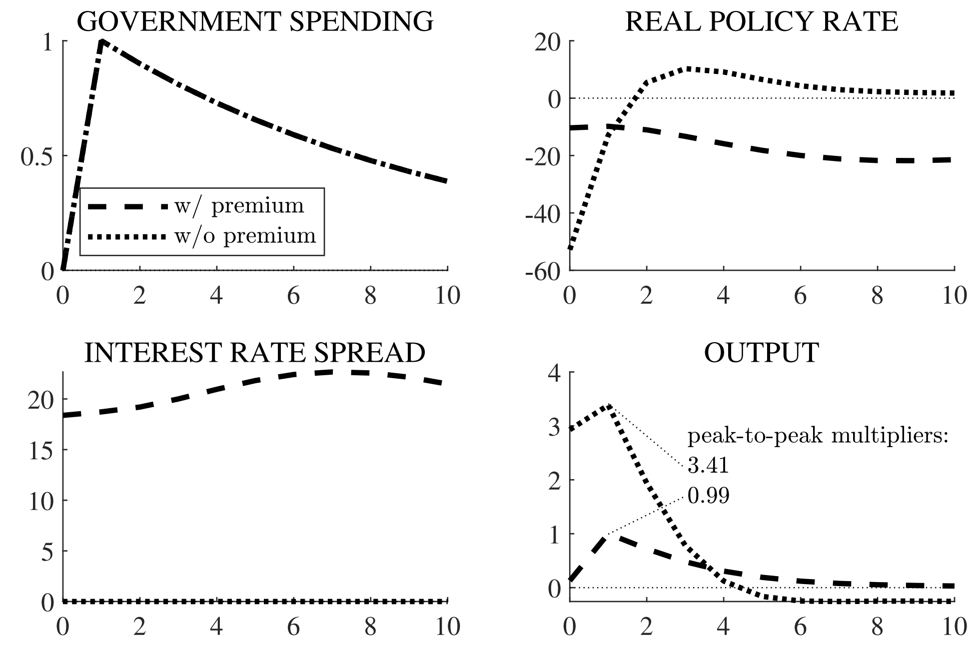
## C.2 Sensitivity analysis

**Figure 11:** Responses to spending expansion: Variations in the elasticity of intertemporal substitution and the extent of habit formation.



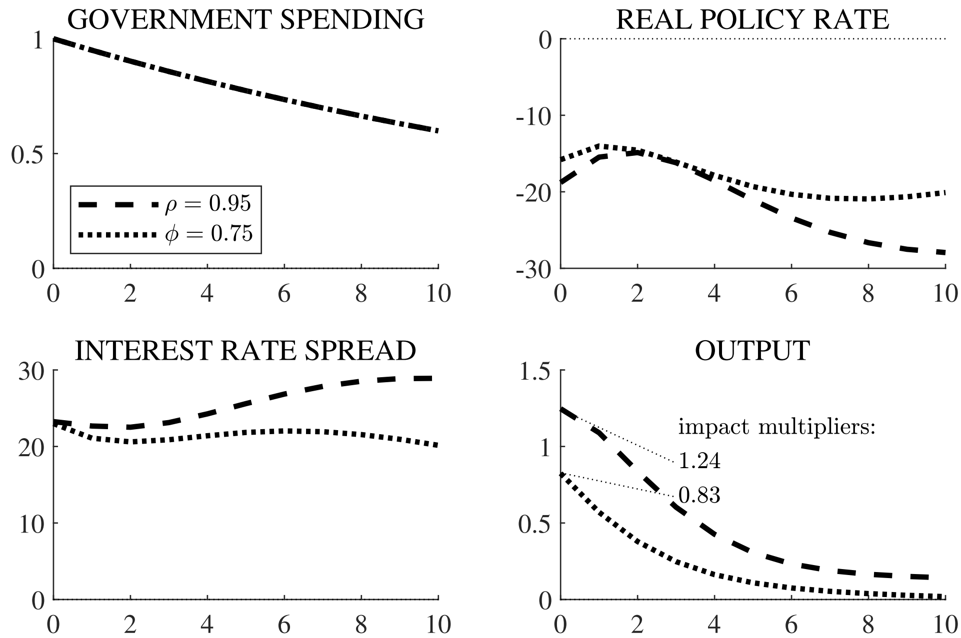

*Notes:* Responses of $g_t$ and $y_t$ in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in basis points.

**Figure 12:** Responses to hump-shaped spending expansion.



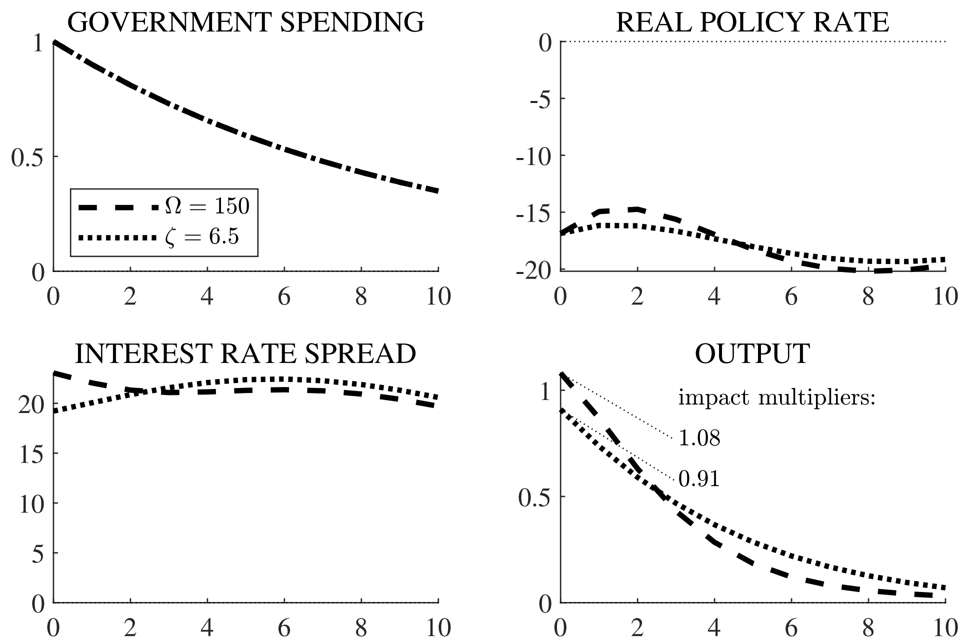

*Notes:* Responses of $g_t$ and $y_t$ in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in basis points.

**Figure 13:** Responses to spending expansion: Variations in the persistence of government spending and the degree of price stickiness.




*Notes:* Responses of $g_t$ and $y_t$ in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in basis points.

**Figure 14:** Responses to spending expansion: Variations in the ratio of repos to injections and investment adjustment costs.




*Notes:* Responses of $g_t$ and $y_t$ in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in basis points.