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.

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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) and confirmed by our own evidence in this paper. 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 to an output multiplier considerably larger than one.

In this paper, we reconcile theory and empirical evidence on the role of monetary policy for the effects of fiscal policy by accounting for imperfect substitutability of assets based on their ability to serve for transaction purposes, summarized by the term "liquidity". This approach is motivated by the disconnect between interest rates on assets that are close substitutes for money (e.g., T-bills) and interest rates on assets that are typically more relevant for private saving and borrowing (see Duffee, 1996). We provide novel evidence for asymmetric responses of these interest rates to fiscal policy shocks: 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 increase after government spending hikes, i.e., interest rates on less liquid assets increase relative to interest rates on near-money assets.[1] While the federal funds rate and interest rates on near-money assets fall in response to fiscal expansions, interest rates on less liquid assets do not follow this decline one-to-one. This indicates that monetary policy actually has "little control" (see

[1] 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.

Fama, 2013, p. 181) over various important interest rates. We then develop a simple model with imperfect asset substitutability, which is based on the pledgeability of assets for central bank transactions.[2] The model reproduces the observed fiscal policy effects on liquidity premia and implies that neither the empirically observed reduction in monetary policy rates nor the policy rate being fixed, for example, at the ZLB, imply a large fiscal multiplier.

Our explanation builds on the fact that interest rates on near-money assets, like short-term treasury debt, are separated from interest rates on assets that private agents use as a store of wealth. Given their additional non-pecuniary return (from liquidity services), near-money assets offer lower interest rates than assets used as a store of wealth while they cannot be issued by households or firms, prohibiting arbitrage between the two types of assets. To rationalize the observed dynamics of prices and aggregate variables, we rely on the central (wealth) effect of fiscal spending (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 of wealth therefore tend to fall and their real rates of return tend to rise.[3] Under 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 *perfect substitutability* of assets, interest rates are linked by arbitrage implying that the real monetary policy rate controls agents' intertemporal choices, like in basic New Keynesian models. As a consequence, the joint responses of the nominal policy rate and expected inflation determine the real return on savings and thereby the growth rate of consumption. A fall in the real policy rate under an accommodative monetary policy then leads to an increase in current consumption after fiscal expansions, inducing a large output multiplier. This mechanism also applies at the ZLB where, according to basic New Keynesian models, government spending crowds in private consumption strongly and multipliers are much larger than typically found in the data.

Under *imperfect substitutability* of assets, by contrast, the interest rate on near-money assets is not directly linked to real rates of return on savings by arbitrage. Instead, the interest rates on assets that serve as a substitute for money closely follow the monetary

[2]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. Notably, a less structural specification, e.g., like bonds in the utility function, might lead to opposite responses of the premium to fiscal shocks than we find in the data.

[3]In a frictionless economy, the (natural) rate of interest would unambiguously rise in response to an expansion in government spending.

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 does not necessarily cause households to save less and consume more. Given that higher inflation tends to reduce the real value of money and near-money assets, government spending can crowd out private consumption even when the policy rate is reduced. A fall in the real policy rate under an accommodative monetary policy can therefore be associated with a moderate output multiplier, above or at the ZLB.

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. We then calibrate the liquidity premium model and use it to study the effects of an increase in government spending under different monetary policy regimes. We consider *i)* a policy rate increase induced by a conventional monetary policy rule, *ii)* a fall in the policy rate, in accordance with our empirical evidence, and *iii)* a policy rate at the ZLB. The model with the liquidity premium generates similar effects in all three cases, specifically, moderate output multipliers, i.e., around one, and an increase in the liquidity premium.[4] In contrast, monetary accommodation (under *ii* and *iii*) leads to implausibly large fiscal multipliers for the model version without the liquidity premium. Thus, our model generally predicts that neither the empirically observed degree of monetary accommodation nor fixed monetary policy rates are sufficient to generate large fiscal multipliers, consistent with our empirical evidence.[5] The response of the monetary policy rate to government spending shocks does alter 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 only around 10% larger at the ZLB than under positive policy rates following a conventional Taylor rule while for the version without liquidity premium the multiplier increases by factor 5.

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 for fiscal policy effects and present quantitative results for a calibrated version of the model. Section 6 concludes.

[4] For reasonable variations in the parameter values and the monetary policy stance, the output multiplier lies between 0.69 and 1.20.

[5] 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.

2 Related literature

Our paper contributes to the empirical literature on the effects of fiscal policy. Ramey (2016) provides an overview and a synthesis of the current understanding of the effects of government spending shocks. 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. Edelberg et al. (1999) exploit the Ramey-Shapiro (1998) war dates and find initial declines in the nominal and real 3-month and 1-year treasury rates. Fisher and Peters (2010) document a decline in the nominal 3-month 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-month T-bill rate to fall in response to defense news shocks. Similar interest rate responses are found by Jørgensen and Ravn (2021) and D'Alessandro et al. (2019), who both apply Blanchard-Perotti shocks as well as professional forecast errors.[6] Our empirical results also document falling short-term interest rates and moderate output effects, and we present a novel finding on interest rate spreads that can reconcile theory with these observations.

Our paper further contributes to the literature on the effects of fiscal spending on output and private consumption in New Keynesian models. Under a conventional monetary policy regime, basic New Keynesian models predict that output multipliers are less than one, implying a consumption crowding-out (see Linnemann and Schabert, 2003, or Woodford, 2011), while augmented model versions, for example including spending constraints or alternative preference specifications (see, e.g., Gali et al., 2007, or Bilbiie, 2011), can in principle induce a crowding-in and larger output multipliers. As central banks in many countries started to act under low policy rates, attention switched to the implications of inflation responses to fiscal shocks in a liquidity trap. Most prominently, Christiano et al. (2011) and Eggertsson (2011) show that fiscal multipliers can take values that are much larger than typically observed in empirical studies when the

[6] Corsetti et al. (2012) and Auerbach et al. (2020) further find that longer-term interest rates and interest rates on consumer loans, respectively, tend to fall after expansionary fiscal shocks. The latter finding can in principle be rationalized by government spending causing an increase in credit supply (see Murphy and Walsh, 2020). Our empirical analysis suggests that monetary policy directly reacts to fiscal policy which we account for in our model.

monetary policy rate is at the ZLB. When the liquidity trap is entered due to a fundamental contractionary shock, a positive fiscal spending shock increases inflation and reduces the real interest rate, which disincentivizes savings and induces a consumption crowding-in.[7] More generally, in models where the intertemporal allocation is determined by the real monetary policy rate, a passive monetary policy, i.e. a monetary policy rate that is not raised with inflation by more than one-for-one, can lead to large output multipliers (see Davig and Leeper, 2011). In contrast, our model with endogenous interest rate separation predicts that fiscal multipliers are not substantially affected by the monetary policy stance, including the ZLB.[8] Mertens and Ravn (2014), Boneva et al. (2016), Cochrane (2017), and Bilbiie (2021) consider alternative (non-fundamental) liquidity trap equilibria under equilibrium multiplicity at the ZLB. For the case where a liquidity trap is entered due to self-fulfilling expectations, Mertens and Ravn (2014) show that the impact of fiscal policy shocks on inflation can be reversed. Under sufficiently persistent adverse confidence states, government spending can lead to higher real rates, a consumption crowding-out, and smaller output multipliers. Given the structural differences to a fundamental liquidity trap equilibrium, Cochrane (2017) and Bilbiie (2021) extend the analysis to other policy measures and address implications for optimal policies. The transmission of shocks in non-fundamental liquidity traps leads to so-called "neo-Fisherian effects" (see Bilbiie, 2021) and is characterized by reversed inflation responses, including deflationary fiscal policy effects. Yet, empirical evidence (see, e.g., Miramoto et al., 2018) suggests that inflation rather increases in response to positive government spending shocks at the ZLB, consistent with our mechanism.

Like our paper, other theoretical studies considering interest rate spreads also report moderate fiscal multipliers. Drautzburg and Uhlig (2015) propose a model with distortionary taxation, borrowing-constrained agents, and a time-varying wedge between bond rates and the monetary policy rate, and Michaillat and Saez (2021) assume that relative wealth of individuals provides direct utility. Both models feature exogenous interest rate spreads, whereas we propose a mechanism that is based on a structural specification leading to an endogenous liquidity premium. Bayer et al. (2021) also examine the effects of fiscal policy on liquidity premia and the implications for fiscal multipliers. While our empirical analysis focuses on interest rates on assets that differ in the extent they serve

[7]See Fahri and Werning (2016) for an overview and a comparison to fiscal multipliers in currency unions. Erceg and Linde (2014) show that the fiscal multiplier further depends on the duration of the ZLB episode. 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]Our model with the liquidity premium further 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 (see Eggertsson, 2011).

as substitutes for money, Bayer et al. (2021) compare returns on longer-term and more illiquid assets that differ in resaleability. Notably, long-term government bonds serve as the more liquid asset in their analysis, for example, compared to housing or equity. They show that a fiscal spending shock causes a fall in these premia, while they also report that the spread between bond returns and returns on more liquid assets (federal funds) increases, consistent with our evidence. Bayer et al. (2021) show that, relative to a model where bond rates and the return on physical capital are equal by construction and the fiscal multiplier is very small, including interest rate spreads leads to a larger multiplier. We show that, relative to a single-interest-rate New Keynesian model where the multiplier is very large under monetary accommodation, taking into account premia on near-money assets reduces the fiscal multiplier. Both papers are thus complementary, proposing mechanisms accompanied with changes in (distinct) interest rate spreads that lead to moderate rather than extreme, i.e., 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 using Ramey's (2016) military spending identification. 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. We document that the spread between the Aaa rate and the 10-year government bonds rate and the spread between long-term and short-term treasury debt increase in response to government spending expansions, indicating that fiscal spending induces unequal effects on the returns of assets that differ regarding their liquidity or convenience value. In a third step, we extend the analysis and show that cleaner measures for liquidity premia increase after government spending expansions. For this, we apply professional forecasts for the identification of fiscal shocks, as suggested by Ramey (2011) for recent sample periods for which the relevant financial market data are available. We find that established measures of liquidity premia increase significantly after a government spending hike while output multipliers are moderate and policy rates fall. 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

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). 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. Specifically,

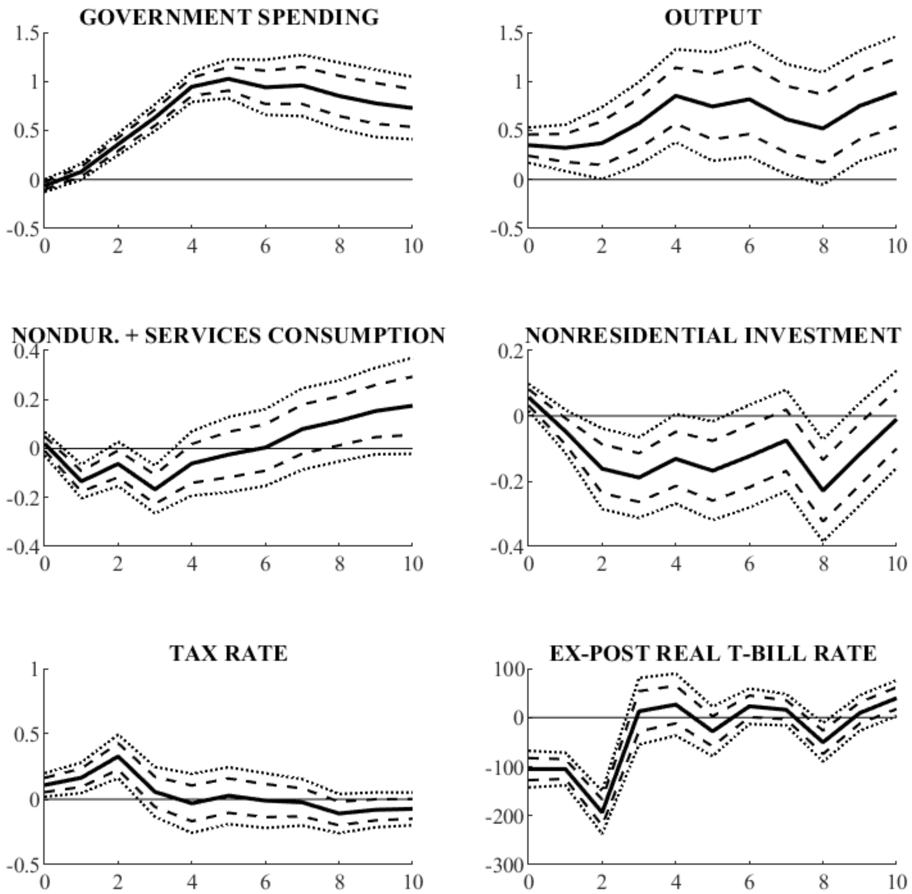
$$z_{t+h} = \kappa_h^z + \omega_h^z N_t + \Theta_1^z X_{t-1}^{LP} + \Theta_2^z X_{t-2}^{LP} + \iota_1^z (t+h) + \iota_2^z (t+h)^2 + v_{t+h}^z,$$

where N_t is the Ramey news variable and the vector X_{t-k}^{LP} includes lag k of real GDP, real government spending (both relative to trend GDP), the average tax rate, the news variable, and the dependent variable. κ_h^z, ι_1^z, ι_2^z, Θ_1^z and Θ_2^z are parameter (vectors) to be estimated. The sequence ω_h^z measures the response of the dependent variable to the shock. As in Ramey (2016), the sample period is 1947Q1-2015Q3.

Figure 1 shows impulse responses of government spending, output, consumption of nondurables and services, nonresidential investment, the average tax rate, and the ex-post T-bill rate. 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-month 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 are 1.37 after four quarters, 1.0 after six quarters, and 0.8 after eight quarters. These moderate multipliers are accompanied by 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 accommodative monetary policy stance towards fiscal policy. This observation together with the observed responses of inflation and output is inconsistent with monetary policy reactions implied by a conventional Taylor-type interest rate rule. Further, falling real

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

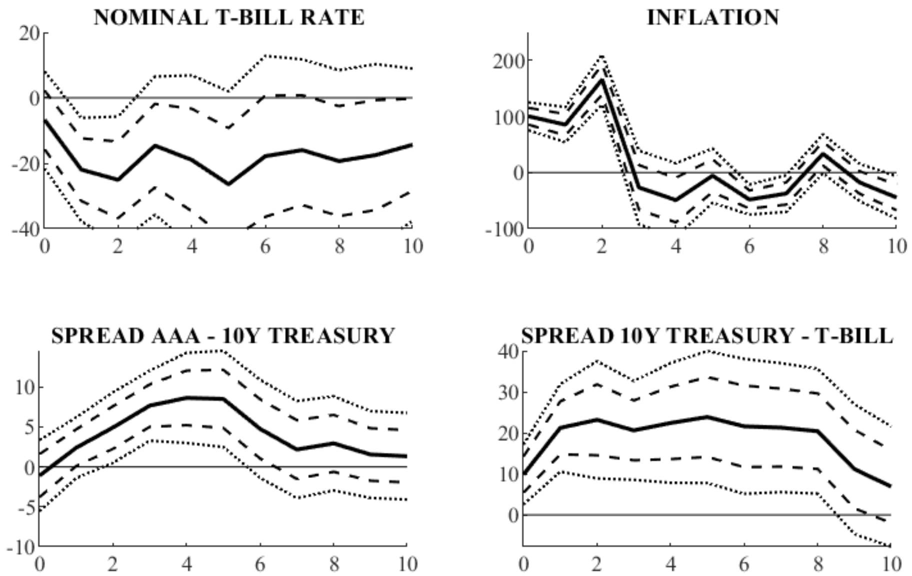


Notes: Identification based on narrative defense news shocks (see Ramey, 2011, Ramey and Zubairy, 2014, and Ramey, 2016). Impulse responses computed using local projections as in Ramey (2016). Variable definitions (Gordon-Krenn 2010 transformation) and specification follow Ramey (2016). Government spending, 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 based on Newey-West (1987) adjusted standard errors. Horizontal axes show quarters.

interest rates are inconsistent with a moderate output multiplier according to basic New Keynesian models, which predict extremely large multipliers already under a combination of a constant nominal interest rate (e.g., at the ZLB) and an increased inflation rate (see Christiano et al., 2011, or Eggertsson, 2011).

Figure 2 shows 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 and

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 based on Newey-West (1987) adjusted standard errors. Horizontal axes show quarters.

that the reduced willingness to save tends to reduce prices of assets that private agents use as a store of wealth, such that their real interest rates tend to increase. However, the federal funds rate is less related to these interest rates than to interest rates on assets that are valued also for 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 serves as a 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 has a similar implication. Longer-term treasuries are typically more relevant for private sector saving than short-term treasuries, and the premium is affected by liquidity and convenience attributes (see, e.g., Greenwood et al., 2015), while admittedly it is also affected by other risk factors.

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 now include a larger set of financial data, i.e., interest rate spreads, in our analysis. This however limits the sample period as most informative financial market variables are not available before the end of the 1970s. Specifically, 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 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 Ramey (2011), we include four lags and account for linear-quadratic trends. The VAR reads

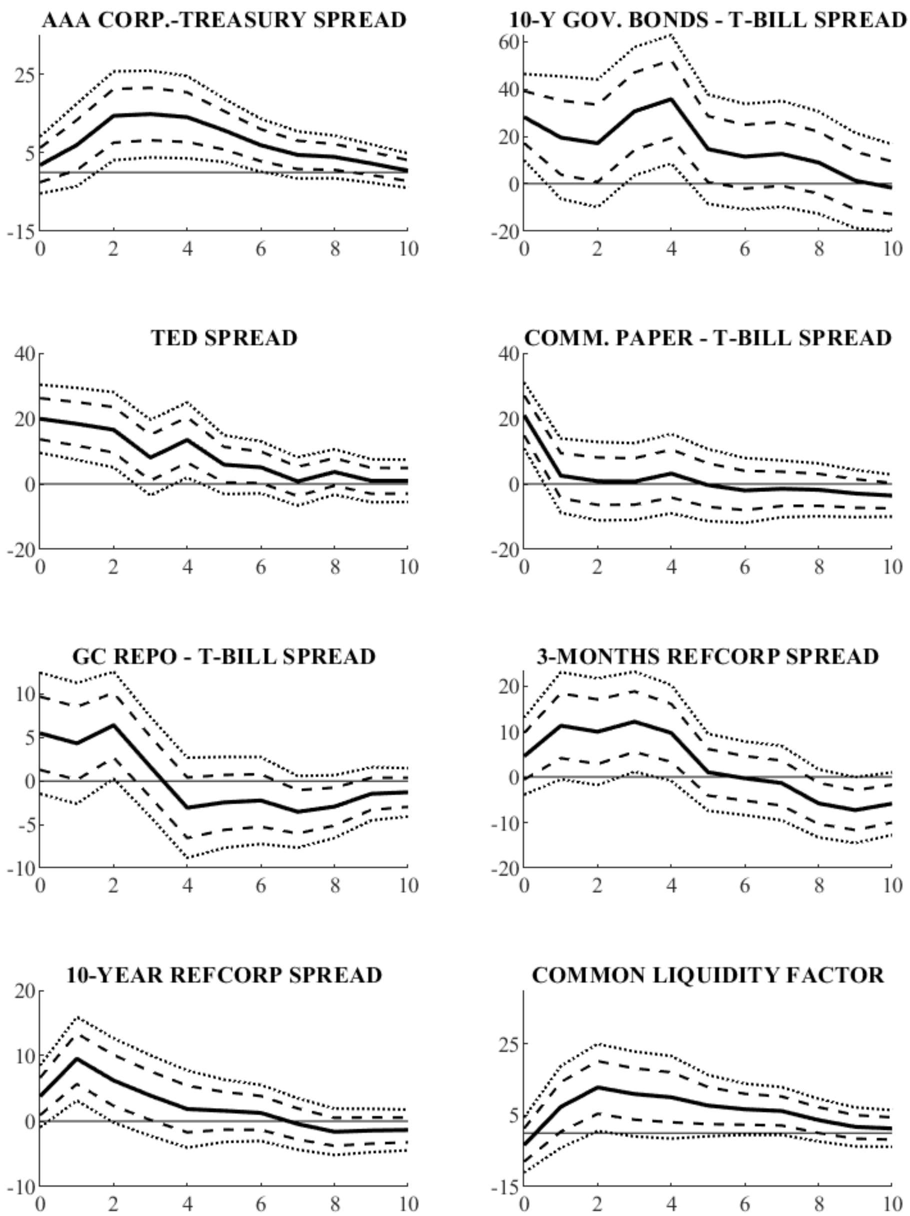
$$X_t^{VAR} = K + \sum_{k=1}^{4} \Phi_0^{-1} \Phi_k X_{t-k}^{VAR} + \Phi_0^{-1} V_t,$$

where X_t^{VAR} is the vector of endogenous variables, K is a vector of constants, Φ_k is a matrix of coefficients with Φ_0 comprising the parameters on the contemporaneous endogenous variables and V_t is a vector of serially and mutually uncorrelated shocks. Formally, the identification assumption amounts to Φ_0 being lower triangular. The vector X_t^{VAR} includes the forecast error, log real total government spending per capita, log real GDP per capita, log real net tax receipts per capita, and different financial market variables described below (all in deviations from quadratic trends). Our analysis thus includes the same variables as Auerbach and Gorodnichenko (2012), additionally controlling for monetary policy (as suggested by Ramey, 2011) and including financial market information.[9] For details, see Appendix A, which also presents data sources and variable definitions as well as plots of the different liquidity premia (Figure 7).

Our main interest is on 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 risk and

[9] Note 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.

maturity but differences in liquidity. 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. In addition to the corporate bonds spread and the term premium already investigated for the longer sample (see Figure 1), we investigate four spreads that measure liquidity premia on short-term assets and one additional spread between longer-term assets. Specifically, we consider the spread between the US LIBOR and the T-bill rate (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 "the cleanest measure of the liquidity premium" since 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, recommended by Longstaff (2004). Given that Refcorp bonds are guaranteed by the U.S. government and taxed as treasury bonds, these spreads capture the relative illiquidity of Refcorp bonds and are 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 the 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. 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.

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 expansionary 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 is 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-month T-bill rate. 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 an increasing term premium 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), indicating that 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., 2021). 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.

3.3 Further evidence on monetary accommodation

Our empirical results have shown that the central bank accommodates fiscal policy by lowering the monetary policy rate after an unexpected expansion in government spending. We now assess the possible explanation that both monetary and fiscal policy react to a looming downturn caused by some other shock, such that monetary policy reacts to a decline in expected inflation and real activity induced by this other shock and fiscal policy reacts countercyclically to the threat of a downturn. Given the timing assumption in our baseline VARs, the estimated responses are conditional on macroeconomic conditions in the previous quarter such that, with the typically assumed implementation lag of fiscal policy, only the arrival of advance information of a looming downturn that is not yet reflected in GDP could be a challenge to identification. We therefore re-estimate our VARs additionally conditioning on leading indicators of business cycle developments, for which use the number of initial unemployment claims, the University of Michigan consumer sentiment index, and stock prices measured by the Wilshire 5000 index. We find that including these leading indicators in the forecast error VAR does not affect our finding of a significant drop in the federal funds rate after the government spending shock.[10]

To assess monetary accommodation of fiscal spending in a more direct way, we provide additional evidence based on isolated estimations of the monetary policy reaction function. In particular, we investigate whether responses of monetary policy to fiscal spending can still be found once we condition on expected inflation and the output gap. In other words, we test the hypothesis that the central bank solely reacts to the changes in inflation and output induced by the spending expansion with no direct response to the spending expansion itself. For this, we extend Clarida et al.'s (2000) seminal estimation of monetary policy reaction functions by including a direct response to government spending (next to the conventional responses to inflation and the output gap) in the central bank reaction function, see Appendix A.5 for technical details.[11] We find a significant negative coefficient, see column (2) of Table 1 which reports estimates of the augmented monetary policy reaction function for our forecast error VAR sample. Column (3) refers to a restricted sample period that excludes policy rates at the ZLB. We find very similar coefficients for this sample period. For completeness, column (1) shows (for the full sample period) the results for a standard specification of the reaction function where we omit the dependence on government spending, i.e., a conventional Taylor rule. In all three columns, the coefficients on inflation and the output gap resemble estimates of Clarida et al. (2000) and other related studies, with slight differences due to different sample periods. The negative coefficient on government spending reported in columns (2) and (3) is of plausible magnitude (e.g., compared to the output gap coefficient), and is consistent with our impulse response analysis.

[10]The leading indicators are only available for the sample period of our forecast error VAR but not for the longer sample period necessary for the Ramey news approach.

[11]This specification of a monetary policy reaction function resembles the one applied by Nakamura and Steinsson (2014) to construct a constant-monetary policy scenario, the predictions of which are comparable to the diff-in-diff evidence from cross-sectional studies.

Table 1: Estimation results for monetary policy reactions functions, with and without direct feedback to government spending.

	(1)	(2)	(3)
smoothing	0.882	0.792	0.783
parameter (ρ_R)	(0.040)	(0.060)	(0.066))
inflation (ρ_π)	2.306	1.556	1.614
	(0.772)	(0.486)	(0.475)
output gap (ρ_y)	0.710	0.467	0.720
	(0.365)	(0.210)	(0.323)
government		-0.131	-0.153
spending (ρ_g)		(0.023)	(0.031)
sample period	1979.IV-2015.IV	1979.IV-2015.IV	1979.IV-2008.III

Notes: Table shows estimated coefficients ρ_R, ρ_π, ρ_y, and ρ_g in a monetary policy reaction function specified as $R_t^m = \rho_R R_{t-1}^m + (1-\rho_R)\left[R^m + \rho_\pi\left(E_t\left(\pi_{t+1}-\pi\right)\right) + \rho_y\left(E_t\left(y_{t+1}-\tilde{y}\right)\right) + \rho_g\left(E_t\left(g_{t+1}-g\right)\right) + \varrho_t\right]$, where R_t^m and π_t are the federal funds rate and inflation in quarter t, with r^m and π denoting their respective long-run targets, $y_t - \tilde{y}$ is the output gap, $g_t - g$ government spending relative to its mean, and ϱ_t is a monetary policy shock. Standard errors in parentheses. Estimation by GMM, see Appendix A.5 for details. ρ_g restricted to zero in column (1). Federal funds rate and inflation in percentage points per quarter.

Finding a negative coefficient on government spending in the estimated monetary policy reaction function supports the view that the observed decline in the monetary policy rate is driven by a direct monetary policy response to changes in fiscal policy. We understand the direct accommodation of fiscal spending as a potential reluctance of the central bank to lean against the aggregate effects of government spending expansions (which are inflationary and hence tend to lead the central bank to raise rates) or even its readiness to support such stimulative fiscal policy measures.

4 A model with an endogenous liquidity premium

In this section, we develop a macroeconomic model which is sufficiently simple such that its main properties can be derived analytically. 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.[12] Specifically, commercial banks demand reserves supplied by the central bank as a fraction of deposits. We account for the fact that reserves are only supplied against eligible assets, which were predominantly T-bills before the financial crisis. Consistent with empirical evidence, the interest rate on T-bills therefore closely follows the monetary policy rate, whereas the interest rates on non-eligible assets exceed the monetary policy rate by a liquidity premium. As non-eligible assets serve as private agents' store of wealth, their interest rates relate to agents' marginal rate of intertemporal substitution.

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

4.1 Banking sector

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

Since banks have access to reserves via temporary open market transactions or via federal funds market transactions, rates charged for both types of transactions should be

[12] 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.

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_t^m. 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_t^m:

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

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

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

where $D_{i,t-1}$ denotes demand deposits. The constraint (2) implies that a fraction μ of deposits have to be backed by reserves, which can either be rationalized by settlement of deposit transactions, a minimum reserve requirement, or withdrawals by depositors. To keep the exposition simple, we focus on the latter to motivate positive reserve demand. Banks supply one-period risk-free loans $L_{i,t}$ to firms at a period t price $1/R_t^L$ and a payoff

$L_{i,t}$ in period $t+1$. Thus, R_t^L denotes the rate at which firms can borrow and corresponds to the Aaa corporate bond rate in the empirical analysis in Section 3. Banks further hold T-bills issued at the price $1/R_t$. Given that bank i transferred T-bills to the central bank under outright sales and that it repurchases a fraction of T-bills, $B_{i,t}^R = R_t^m M_{i,t}^R$, from the central bank, bank i's holdings of T-bills before it enters the asset market equal $B_{i,t-1} + B_{i,t}^R - \widetilde{B}_{i,t}$ 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 $E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, n_t)$, where $u(c_t, n_t) = [c_t{}^{1-\sigma}/(1-\sigma)] - \theta n_t^{1+\sigma_n}/(1+\sigma_n)$, $\sigma \geq 1$, $\sigma_n \geq 0, \theta \geq 0$, c_t denotes consumption, n_t working time, and $\beta \in (0,1)$ is the subjective discount factor. Households can store their wealth in shares of firms $z_t \in [0,1]$ valued at the price V_t with the initial stock of shares $z_{-1} > 0$. We assume that households rely on money for purchases of consumption goods, whereas in Section 5.2 we also allow for purchases of goods via credit (see Lucas and Stokey, 1987). To purchase goods, households can in principle hold cash, which is dominated by the rate of return of other assets. Instead we assume that they hold demand deposits at banks, which can be converted into cash at any point in time. For simplicity, we consider an exogenous fraction $\mu \in [0,1]$ of withdrawn deposits such that the goods market constraint, which resembles a standard cash in advance constraint, can be summarized as[13]

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

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

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

$$\lambda_t / R_t^D = \beta E_t \left[\left(\lambda_{t+1} + \mu \psi_{t+1}\right) \pi_{t+1}^{-1}\right], \tag{8}$$

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, $R_t^q = (V_t + P_t \varrho_t)/V_{t-1}$ the nominal rate of return on equity, ψ_t and λ_t denote the multipliers on the real versions of the goods market constraint (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.

[13] Note that the parameter μ in (2) and (6) will in equilibrium only be required to determine real deposits and the deposit rate (see Definition 1 below), which are both not relevant for the main results.

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

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

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 ϱ_t denotes real dividends $\varrho_t = (P_t^m/P_t)n_t - w_t n_t - l_{t-1}\pi_t^{-1} + l_t/R_t^L$, subject to (9). The first order conditions for labor demand and loan demand are $1 + \gamma_t = R_t^L E_t[p_{t,t+1}\pi_{t+1}^{-1}]$ and $P_t^m/P_t = (1 + \gamma_t)\, w_t$,where γ_t denotes the multiplier on the loan demand constraint (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, $P_t^m/P_t = w_t$. Monopolistically competitive retailers and their price setting decisions are specified as usual in New Keynesian models and are described in Appendix B.2.

4.3 Public sector

The public sector consists of a government and a central bank. The government purchases goods and issues short-term bonds B_t^T. Short-term debt is held by banks, B_t, and by the central bank, B_t^C, i.e., $B_t^T = B_t + B_t^C$, and corresponds to T-bills (as a period is interpreted as three months). To isolate effects of government spending shocks and to facilitate comparisons with related studies (see, e.g., Christiano et al., 2011), we assume that the government can raise or transfer revenues in a non-distortionary way, $P_t \tau_t$. Given that, in contrast to total government debt, the supply of T-bills does not significantly respond to changes in government spending (see Figure 9), we can specify the supply of treasury bills by a constant growth rate Γ,

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

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 $\widetilde{B}_t + B_{t-1}^C - B_t^R$.[14] Following central bank practice, we assume that interest earnings are transferred to the government, $P_t\tau_t^m = B_t^C\left(1 - 1/R_t\right) + \left(R_t^m - 1\right)\left(M_t - M_{t-1} + M_t^R\right)$, such that holdings of treasuries evolve according to $B_t^C - B_{t-1}^C = M_t - M_{t-1}$. Further restricting initial values to $B_{-1}^C = M_{-1}$ leads to the central bank balance sheet $B_t^C = M_t$. We assume that the central bank sets the policy rate R_t^m following a Taylor-type feedback rule (see below). The target inflation rate π is controlled by the central bank and will be equal to the growth rate of treasuries Γ. This assumption is supported by the data (see Section 5.2.1) and is not associated with a loss of generality, as the central bank can implement its inflation targets even if $\pi \neq \Gamma$, as shown in Schabert (2015). Finally, the central bank fixes the fraction of money supplied under repurchase agreements relative to money supplied outright at $\Omega \geq 0 : M_t^R = \Omega M_t$.

4.4 Interest rates and spreads

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

[14] 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 $\left(B_t^C/R_t\right) - B_{t-1}^C = R_t^m\left(M_t - M_{t-1}\right) + \left(R_t^m - 1\right)M_t^R - P_t\tau_t^m$.

of consumption

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

Since R_t^{IS} equals the nominal rate of return at which agents are willing to transform one unit of account today into one unit of account tomorrow, $R_t^{IS} - 1$ measures their marginal valuation of holding non-interest bearing money. For $R_t^m < R_t^{IS}$, households thus earn a positive rent and are willing to increase their money holdings. Given that access to money is restricted by holdings of treasury bills, the money supply constraint (1) is then binding. 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 monetary 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. Using (11), the spread $R_t^{IS} - R_t^m$ can be written as $R_t^{IS} - R_t^m = (c_t^{-\sigma}/P_t)/\left(\beta E_t[c_{t+1}^{-\sigma}/P_{t+1}]\right) - R_t^m$, or in log–linear terms

$$\widehat{R}_t^{IS} - \widehat{R}_t^m = \sigma \left(E_t \widehat{c}_{t+1} - \widehat{c}_t \right) + E_t \hat{\pi}_{t+1} - \widehat{R}_t^m, \tag{14}$$

where hats denote log deviations from steady state.

Equation (14) is helpful to understand the determinants of the spread. When consumption growth, $E_t \widehat{c}_{t+1} - \widehat{c}_t$, is expected to increase, $\widehat{R}_t^{IS}$ and therefore the spread tend to rise. This can, for example, be induced by an immediate drop in consumption followed by a subsequent recovery. Note however that, as indicated by (14), a drop in current consumption is not required for the spread to rise. On a humped-shaped response path, for example, an initial surge in consumption is still associated with expected consumption growth which tends to raise the spread.[15] Under alternative preference specifications, for example with consumption habits (see below) or complementarities, marginal utility is further not determined by the level of consumption alone. And even if expected consumption growth were to fall, the spread could still increase when an increase in expected inflation or direct monetary accommodation dominate the consumption response, i.e., when $E_t\hat{\pi}_{t+1}$ rises or $\widehat{R}_t^m$ falls sufficiently (also see Section 5.1).

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, money might therefore 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, we derive analytical results. 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. We first consider the reference 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 case of a positive 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 and, in particular, that monetary accommodation does not necessarily imply large fiscal multipliers.

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

[15] A similar argument applies for the response of the growth rate of prices, which also tends to raise R_t^{IS}. Yet, plausible monetary policy rules include an endogenous inflation feedback, whereby the monetary policy rate R_t^m is typically raised by more than one for one with inflation, offsetting the effect on R_t^{IS}.

R_t^{IS}. For this, we assume that the central bank 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, see Corollary 1. For both cases, we examine the local dynamics in the neighborhood of the respective steady state, abstracting from the ZLB (see Section 5.2.3 for a ZLB analysis). There, the equilibrium sequences are approximated by the solutions to the linearized equilibrium conditions, where $\widehat{a}_t$ denotes relative deviations of a generic variable a_t from its steady state value $a : \widehat{a}_t = \log(a_t/a)$. To facilitate the derivation of analytical results, we assume that outright money supply is negligible, $\Omega \to \infty$, which reduces the set of endogenous state variables. We further assume that the 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 $\pi = 1$, and that government spending shocks are i.i.d.

A particular focus of our analysis is to examine how the effects of fiscal policy depend on the stance of monetary policy. Given the empirical evidence on monetary accommodation (see Section 3), we include a direct feedback to changes in government spending in the monetary policy reaction function, such that the monetary policy rate satisfies

$$\widehat{R}_t^m = \rho_\pi \widehat{\pi}_t + \rho_g \widehat{g}_t, \tag{15}$$

where $\rho_\pi \geq 0$. To keep the notation compact, we use the same symbols as in the estimated reaction function from Section 3.3, that accounts for expected values and that we adopt for the quantitative analysis (see Section 5.2.1). When the parameter ρ_g is negative, as we found in Section 3.3, monetary policy is directly accommodating fiscal policy, reflecting its reluctance to lean against expansionary, yet inflationary, effects of government spending expansions. The parameter ρ_g can thus be used to shut on and off direct monetary accommodation of fiscal policy.

Definition 3 *A rational expectations equilibrium for $\sigma \geq 1$, $\Omega \to \infty$ 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*

$$\widehat{c}_t = \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m < R_t^{IS}\ , \quad \text{or } \widehat{c}_t \leq \widehat{b}_{t-1} - \widehat{\pi}_t - \widehat{R}_t^m \text{ if } R_t^m = R_t^{IS}, \tag{16}$$

$$\sigma \widehat{c}_t = \sigma E_t \widehat{c}_{t+1} - \widehat{R}_t^{IS} + E_t \widehat{\pi}_{t+1}, \tag{17}$$

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \chi \left(\sigma_n c_y + \sigma\right) \widehat{c}_t + \chi \sigma_n g_y \widehat{g}_t + \chi \widehat{R}_t^{IS}, \tag{18}$$

$$\widehat{b}_t = \widehat{b}_{t-1} - \widehat{\pi}_t, \tag{19}$$

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 (15) 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 (16) is then slack, the model reduces to a standard New Keynesian model with a cash-in-advance constraint (see Linnemann and Schabert, 2003). In this environment, monetary accommodation of fiscal policy, in the sense of a fall in the real policy rate, always leads to a large fiscal multiplier. The following proposition summarizes this property.

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

Proof. See Appendix C. ■

The intuition is as follows. 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 actually falls in response to a government spending shock, private agents increase current consumption relative to future consumption. 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. Notice that the proposition states that a fall in the real policy rate implies a consumption crowding-in, for which a "passive" monetary policy in the tradition of Leeper (1991), i.e. $\rho_\pi < 1$ and $\rho_g = 0$, is already sufficient. When there is direct monetary accommodation as we found in our empirical analysis with even the nominal policy rate falling, the fall in the real rate is more pronounced.

We now 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 (16) are binding, and that there exists a positive liquidity premium. The following proposition summarizes the macroeconomic effects of spending expansions, where the conditions feature the inflation feedback on the policy rate, measured by the coefficient ρ_π, and the direct feedback from government spending, measured by the coefficient ρ_g. Notably, the restriction $\rho_\pi \leq \frac{1+\beta}{\chi\sigma} + \frac{1-\sigma}{\sigma}$, which is hardly restrictive under reasonable parameter values, ensures equilibrium determinacy (see Lemma 1 in Appendix C.1).

Proposition 2 *Suppose that* $R_t^m < R_t^{IS}$ *and* $\rho_\pi \leq \frac{1+\beta}{\chi\sigma} + \frac{1-\sigma}{\sigma}$ *are satisfied. Then, an unexpected increase in government spending leads on impact to*

1. *a fall in the nominal policy rate iff*

$$\rho_g < -\rho_\pi g_y \chi \sigma_n / (\chi \sigma_n c_y + \Gamma_1) \leq 0, \tag{20}$$

where $\Gamma_1 = (\beta + \chi(1-\sigma) - \chi\sigma\rho_\pi)(1-\gamma_b) + \chi\sigma + 1 > 0$,

2. *a fall in private consumption (a fiscal multiplier below one) iff*

$$\rho_g > -(1+\rho_\pi)\chi\sigma_n g_y / \Gamma_1, \tag{21}$$

3. *a rise in inflation iff* $\rho_g < g_y / c_y$,

4. *a rise in aggregate output iff* $\rho_g < 1 + (c_y - g_y)\chi\sigma_n(1+\rho_\pi)\Gamma_1^{-1}$, *and*

5. *a rise in the spread* $\widehat{R}_t^{IS} - \widehat{R}_t^m$ *iff*

$$(\rho_\pi\Gamma_3 - \Gamma_2)\rho_g < ((\sigma - 1 + \sigma(1-\gamma_b))\rho_\pi + (\sigma-1)(1-\gamma_b)) g_y \chi \sigma_n, \tag{22}$$

where $\gamma_b \in (0,1)$, $\Gamma_2 = \sigma\chi(1-\gamma_b)(\sigma - 1 + \sigma_n c_y) > 0$ *and* $\Gamma_3 = (\sigma-1)(\chi\sigma_n c_y \gamma_b + \beta(1-\gamma_b) + \chi(\sigma\gamma_b + 1 - \gamma_b) + 1) > 0$.

Proof. See Appendix C. ■

The proposition makes clear that fiscal multipliers can be smaller than one even under monetary accommodation, which can either be induced by a direct policy rate reduction in response to fiscal spending or a decline in the real policy rate induced by higher inflation. Consider first the case without a direct reduction of the policy in response to government spending, $\rho_g = 0$. Of course, the condition in part 1 of Proposition 2 is violated and the nominal policy rate does not fall, whereas the conditions given in parts 2-4 of Proposition 2 are satisfied, such that inflation increases and the fiscal multiplier is positive and below one. Given that the RHS of condition (22) is strictly positive, the spread unambiguously increases for $\rho_g = 0$. The intuition for these results is that the separation of the policy rate R_t^m and the marginal rate of intertemporal substitution R_t^{IS} induces the real effects of government spending to be governed by the negative wealth effect (as discussed above), such that the real policy rate response it not crucial. At the same time, the increase in aggregate demand pushes up firms' real marginal costs and thereby inflation. Hence, when there is no monetary accommodation, the aggregate effects of fiscal expansions are qualitatively similar to the situation without a liquidity premium.

Consider now the case where $\rho_g < 0$ such that the central bank directly accommodates fiscal policy. Then, current private consumption can be stimulated after a fiscal spending hike. Yet, neither a negative feedback coefficient, $\rho_g < 0$, nor a fall in the monetary policy rate are sufficient to induce a positive consumption response to government spending, which can immediately be seen from comparing conditions (20) and (21), i.e. $-(1+\rho_\pi)\chi\sigma_n g_y/\Gamma_1 < -\rho_\pi g_y \chi\sigma_n/(\chi\sigma_n c_y + \Gamma_1)$. Thus, only a sufficiently large reduction of the policy rate in response to higher government spending can lead to a crowding-in and therefore to a fiscal multiplier larger than one. Put differently, Proposition 2 establishes that there exist (negative) values for ρ_g which lead to both, a consumption crowding-out and a fall in the monetary policy rate, which appears impossible from the perspective of a standard New Keynesian model without the liquidity premium (see Proposition 1).

A robust finding in our empirical analysis is the spike in liquidity premia in response to spending expansions, supporting the separation between R_t^{IS} and R_t^m. Proposition 2 is informative about the model's ability to rationalize this response which is not necessarily associated with a decline in current consumption as discussed in Section 4.4. According to part 5 of Proposition 2, the response of the spread $R_t^{IS} - R_t^m$ depends on the feedbacks from inflation and government spending to the policy rate, ρ_π and ρ_g, in a non-trivial way. On the one hand, R_t^{IS} increases when expected future consumption increases relative to current consumption and when an increase in inflation is expected. The former requires a *reduction* in the monetary policy rate not to be too pronounced, whereas the latter requires the policy rate not to *increase* too strongly. On the other hand, the spread decreases with the monetary policy rate, implying that direct monetary accommodation, $\rho_g < 0$, tends to raise the spread. For the special case of log utility, $\sigma = 1$, condition (22) simplifies to $0 < \rho_\pi \chi (1-\gamma_b)\sigma_n (g_y - c_y \rho_g)$, implying that a positive spread response is ensured if the response of the policy rate to government spending is not too positive $\rho_g < g_y/c_y$.

To provide a simple comparison of the cases with and without the liquidity premium, suppose that condition (20) holds as an equality, implying that the policy rate is held constant (like at the ZLB) and that the real policy rate falls. Then, one can observe a crowding-out (see part 2 of Proposition 2) and an output multiplier below one under a positive liquidity premium. In contrast, consumption is crowded in and the output multiplier exceeds one in an economy without the liquidity premium, as summarized in Proposition 1.

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). 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 most transactions do not involve cash and to avoid overstating the importance of the money supply constraint upon which our main results hinge. Specifically, the instantaneous utility function is now given by $u(c_t, \overline{c}_t, n_t) = [(c_t - h\mathsf{c}_{t-1})^{1-\sigma}/(1-\sigma)] + \gamma[(\overline{c}_t - h\overline{\mathsf{c}}_{t-1})^{1-\sigma}/(1-\sigma)] - \theta n_t^{1+\sigma_n}/(1+\sigma_n)$, where $\gamma \geq 0$, $\overline{c}_t$ denotes consumption of credit goods, c_t ($\overline{\mathsf{c}}_t$) denotes the cross sectional average of cash (credit) goods, and $h \geq 0$ indicates external habit formation. Intermediate goods are now produced according to $y_t^m = n_t^{\alpha} k_{t-1}^{1-\alpha}$ with $\alpha \in (0,1)$, while physical capital k_t satisfies $k_t = (1-\delta) k_{t-1} + x_t \Lambda_t$, where δ is the depreciation rate , x_t are investment expenditures, and the function Λ_t denotes adjustment costs satisfying $\Lambda(x_t/x_{t-1}) = 1 - \zeta \frac{1}{2}(x_t/x_{t-1} - 1)^2$. Further, the monetary policy rule allows for inertia and output gap responses and incorporates expected next-period values, as in Section 3.3:

$$R_t^m = \max\{1, \left(R_{t-1}^m\right)^{\rho_R} \left(R^m (E_t \pi_{t+1}/\pi)^{\rho_\pi} \left(E_t \left(y_{t+1}/\widetilde{y}_{t+1}\right)\right)^{\rho_y} \left(E_t \left(g_{t+1}/g\right)\right)^{\rho_g}\right)^{1-\rho_R}\}, \quad (23)$$

where $\rho_R \geq 0$, $\rho_y \geq 0$, and $\widetilde{y}_t$ denotes the efficient level of output. 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 ξ_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 $\{\sigma, \sigma_n, \alpha, \delta, \epsilon, \theta, \phi, g/y, h, \rho\}$ from sources that are unrelated to the model and that are standard in the literature (for an interpretation of a period as a quarter). Specifically, we set the inverses of the elasticities of intertemporal substitution to $\sigma = 2$ and $\sigma_n = 1$, the labor income share to $\alpha = 2/3$, and the depreciation rate to $\delta = 0.025$. The elasticity of substitution ϵ is set to $\epsilon = 6$, and the utility parameter θ is chosen to lead to a steady state working time of $n = 1/3$. For the fraction of non-optimally price adjusting firms ϕ we apply $\phi = 0.8$. The mean government share and the habit formation parameter are set at $g/y = 0.2$ and $h = 0.7$. We set the autocorrelation of government spending ρ to a standard value of 0.90.

For the second set of parameters, $\{R^m, \pi, \Gamma, \Omega, \beta, \zeta, \gamma, \rho_R, \rho_\pi, \rho_y, \rho_g\}$, 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.IV, $R^m = 1.0440^{1/4}$ 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 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 (sample period determined by data availability) implying a ratio of money supplied under repos to outright money holdings Ω equal to 1.5. The discount factor β is set to $\beta = 0.9958$, 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.IV. The investment adjustment cost parameter ζ is set to 0.065, which corresponds to Groth and Khan's (2010) estimate based on firm-level data.[16] The utility weight of credit goods γ is set at a conservative value 35, which replicates the 2012 US share of cash transactions of 14%, taken from Bennett et al. (2014). Finally, the coefficients of the interest rate rule are taken from our empirical estimates presented in Table 1, i.e., for quarter-to-quarter values, $\rho_R = 0.792$, $\rho_\pi = 1.566$, $\rho_y = 0.467/4$, and $\rho_g = -0.131/4$.

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

[16] 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).

the Dynare supplement “occbin” developed by Guerrieri and Iacoviello (2014) for all scenarios.[17] 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

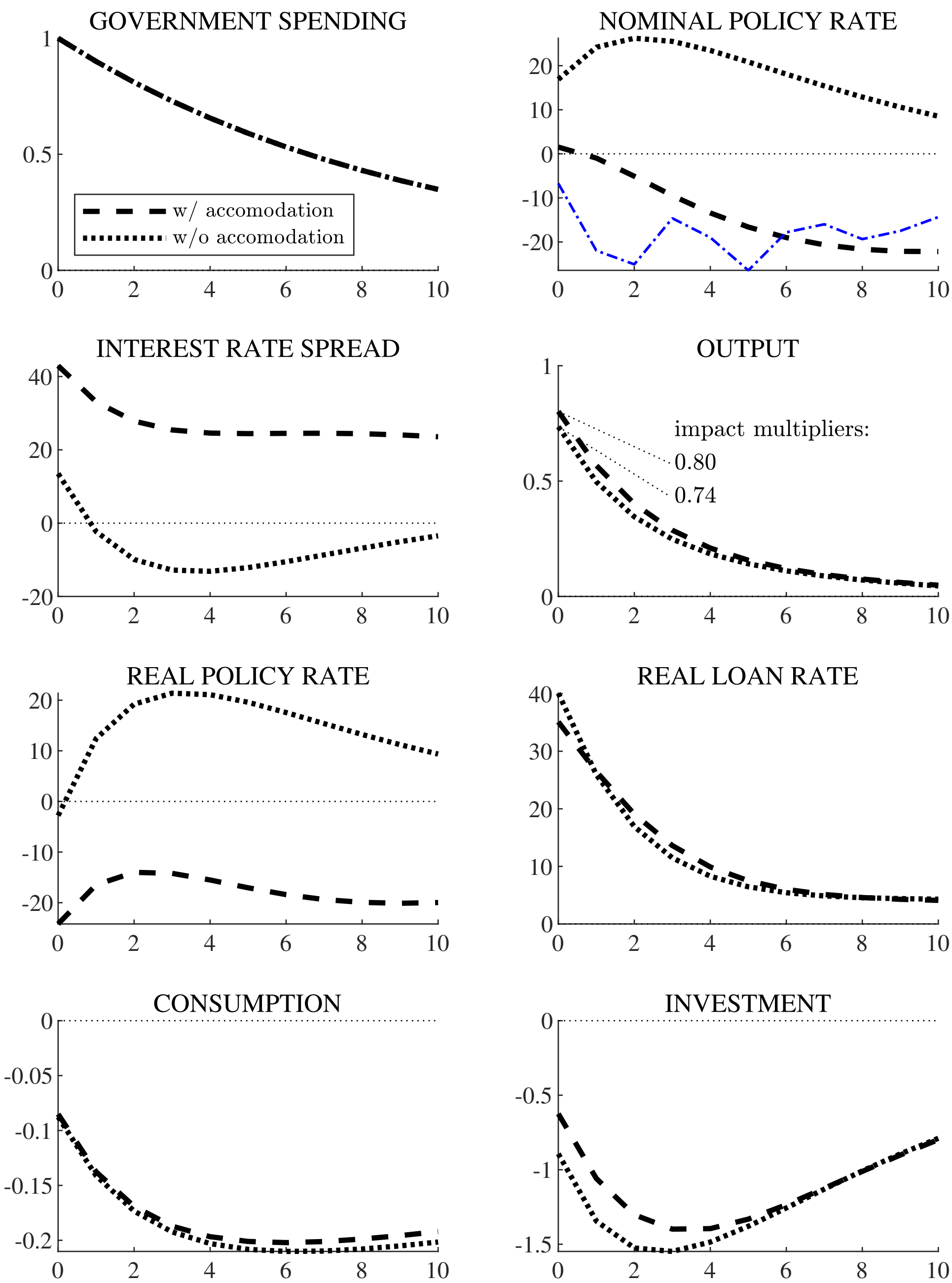
Figure 4 shows impulse responses to a government spending shock that amounts to one percent of GDP as in the empirical analysis in Figure 1. We distinguish between two scenarios regarding the response of monetary policy to this impulse. In the first scenario (dotted lines), the monetary policy rate follows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

Consider first the case of an increasing policy rate (dotted lines). The figure shows 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 74 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 monetary policy rule induces the policy rate to fall by up to 20 bps, which is similar to the (untargeted) empirical response of the T-bill rate from Figure 2, represented by the blue dashed-dotted line in the upper-right panel of Figure 4. In isolation, a lower policy rate stimulates private

[17] “Occbin” solves dynamic models with occasionally binding constraints using a first-order perturbation approach. It handles occasionally binding constraints as different regimes of the same model to obtain a piecewise linear solution.

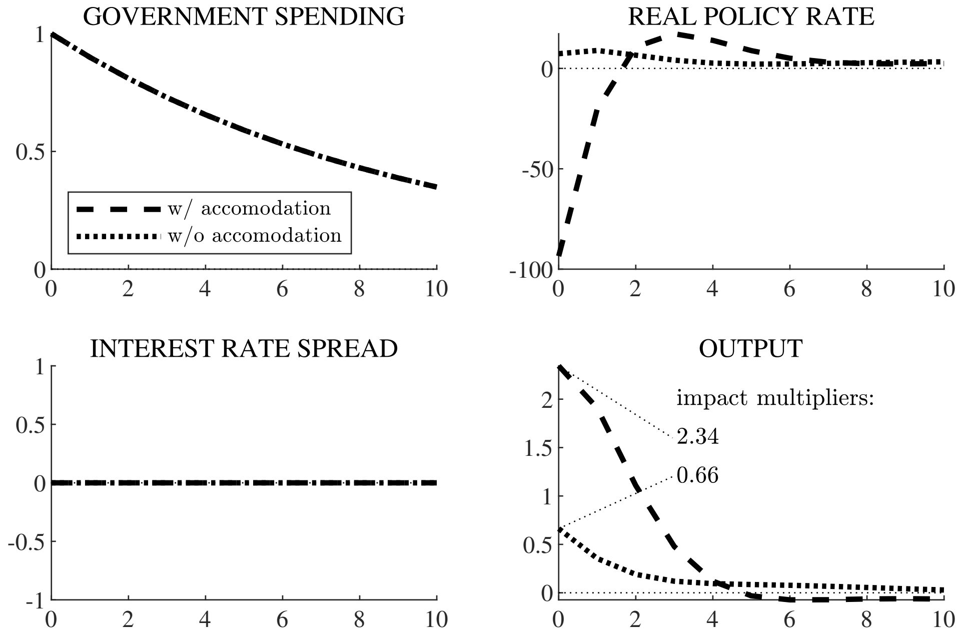
Figure 4: Responses to spending expansion with and without monetary accommodation - model with liquidity premium.



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 annualized basis points. Thin dashed-dotted line in upper-right panel shows empirical response of the T-bill rate, see Figure 2.

consumption and, consequently, private demand is crowded out by somewhat less than in the first scenario. Hence, in this scenario, the output multiplier is slightly larger and the rise in the liquidity premium is more pronounced. Quantitatively, monetary accommodation raises the multiplier to 0.8 and the liquidity premium rises by around

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 annualized basis points.

25 bps in the medium run, which is slightly stronger than the 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 a similar amount, this increases the spending multiplier by only about 8% (from 0.74 to 0.80). 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 direction of the policy rate response is reversed. Our model thus helps understand why empirically estimated fiscal multipliers are moderate even when monetary policy is found to accommodate spending expansions.

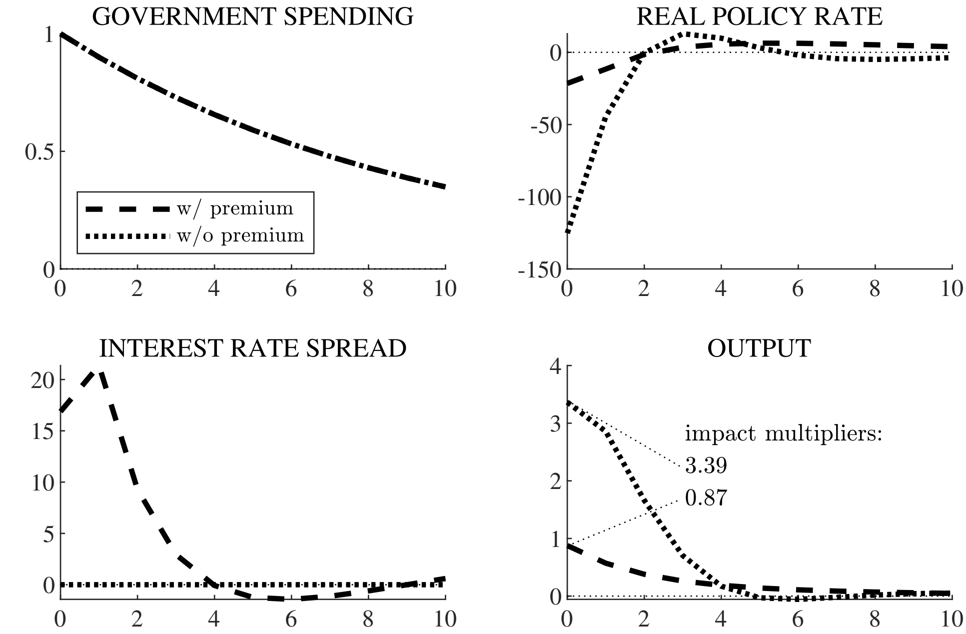
Figure 5 illustrates the strong role monetary policy plays for the fiscal multiplier in a model version that corresponds to a simple single-interest-rate model, which stands in sharp contrast to the previous results. In the figure, we repeat the experiments shown in Figure 4 but, here, we perform them in an otherwise identically calibrated model version where the money supply constraint 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 3.5, from 0.66 to 2.34. This is the case 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, σ, 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 higher willingness to substitute consumption intertemporally, $\sigma = 1$, rates on ineligible assets and hence the liquidity premium rise less strongly, while the fiscal multiplier increases to a value of 1.01. 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 then increases to a value of 1.20. These results show that our main findings are robust, while our model is not restricted to multipliers below 1. Yet, the resulting multipliers remain far from the levels which a model without liquidity premium would predict in presence of monetary accommodation.

Our conclusions are also robust to accounting for a delayed peak in government spending, similar to the pattern shown in Figure 1 (see Figure 12 in Appendix C.2). The model with the liquidity premium displays an increase in the interest rate spread by about 25 bps in the medium run, 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 over 3.

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

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 ξ_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 anualized basis points.

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 differs across specifications, it remains moderate also under monetary accommodation for all parameter variations.

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 23) without a fiscal feedback, $\rho_g = 0$, facilitating comparisons to related studies. At the ZLB, the real monetary policy rate tends to fall in response to a fiscal shock due to an increase in inflation. To induce a binding ZLB, we consider a discount factor shock ξ_t that causes the economy to reach the ZLB in the impact period and to remain there for two further periods. The preference shock causes output and inflation to fall such that the central bank lowers the policy rate until the ZLB is reached. In this scenario, 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.

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 0.87. Overall, the impulse responses from the model with the liquidity premium are similar to 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 3.39.

Thus, the monetary policy stance is far less crucial for the size of the fiscal multiplier when liquidity premia are taken into account than when 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 an endogenous 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 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], Personal Consumption Expenditures [PCE], Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], 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-month, 1-year, and 10-year Refcorp spreads as the differences between the constant maturity 3-month, 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-month 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-month 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

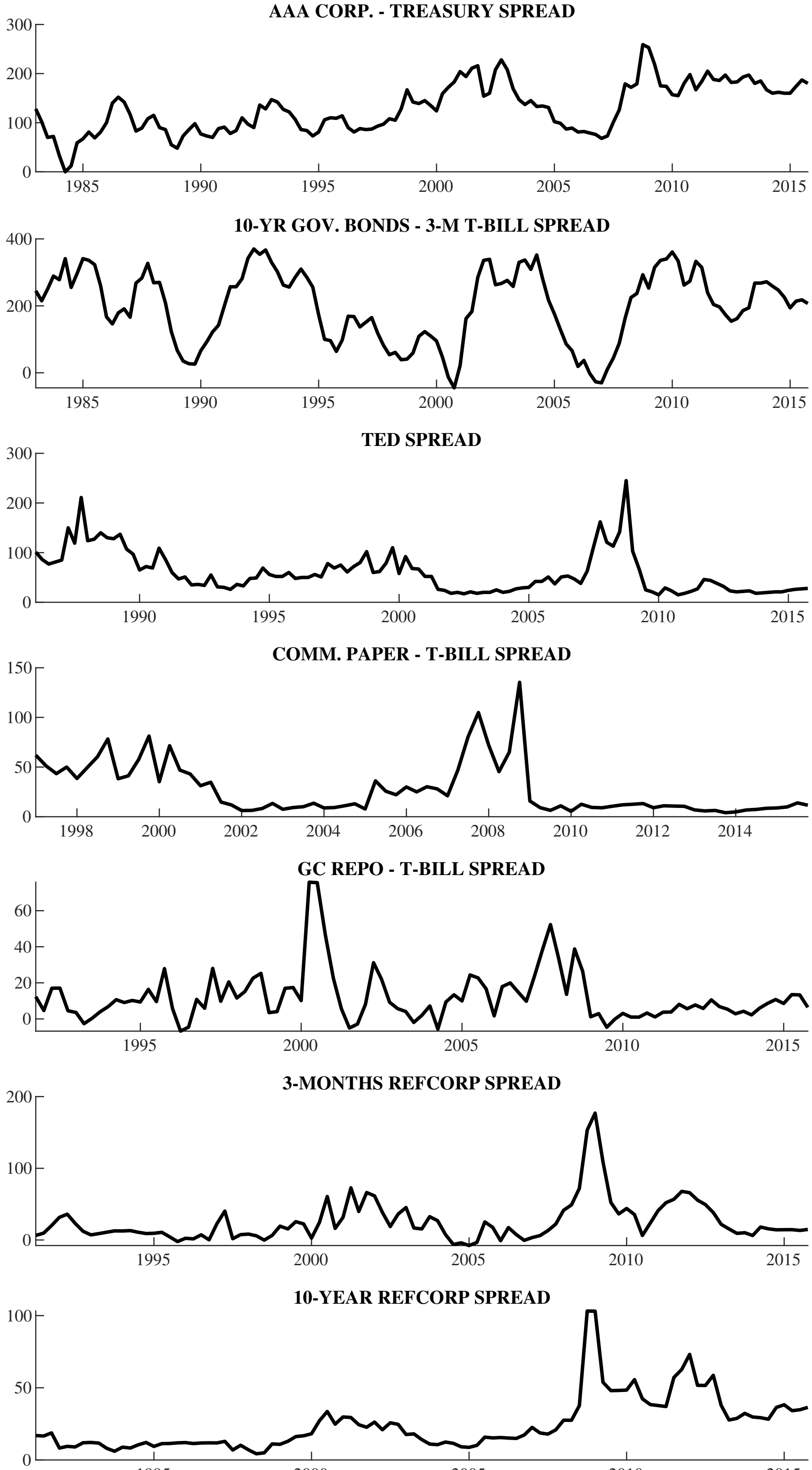
We construct the common liquidity factor (clf) following Del Negro et al. (2017). We estimate a principal-component model with one component based on different liquidity spreads. Based on the estimated model, we project the observed liquidity spreads on a common liquidity factor, thereby reducing the 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

Table 2: 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
π_{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-month T-bills	DGS10–TB3MS
Figure 3:		
$R^{Libor3} - R^{T-bill3}$	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-month 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
c	log real consumption p.c.	log(PCE/(GDPDEF×CNP16OV))
π	CPI inflation	4 * (log(CPIAUCSL(+1))-log(CPIAUCSL)) * 100
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. (+1) indicates a one-quarter lead.

Figure 7: Time series of interest rate spreads analyzed in Section 3.2.



Notes: Spreads shown in basis points.

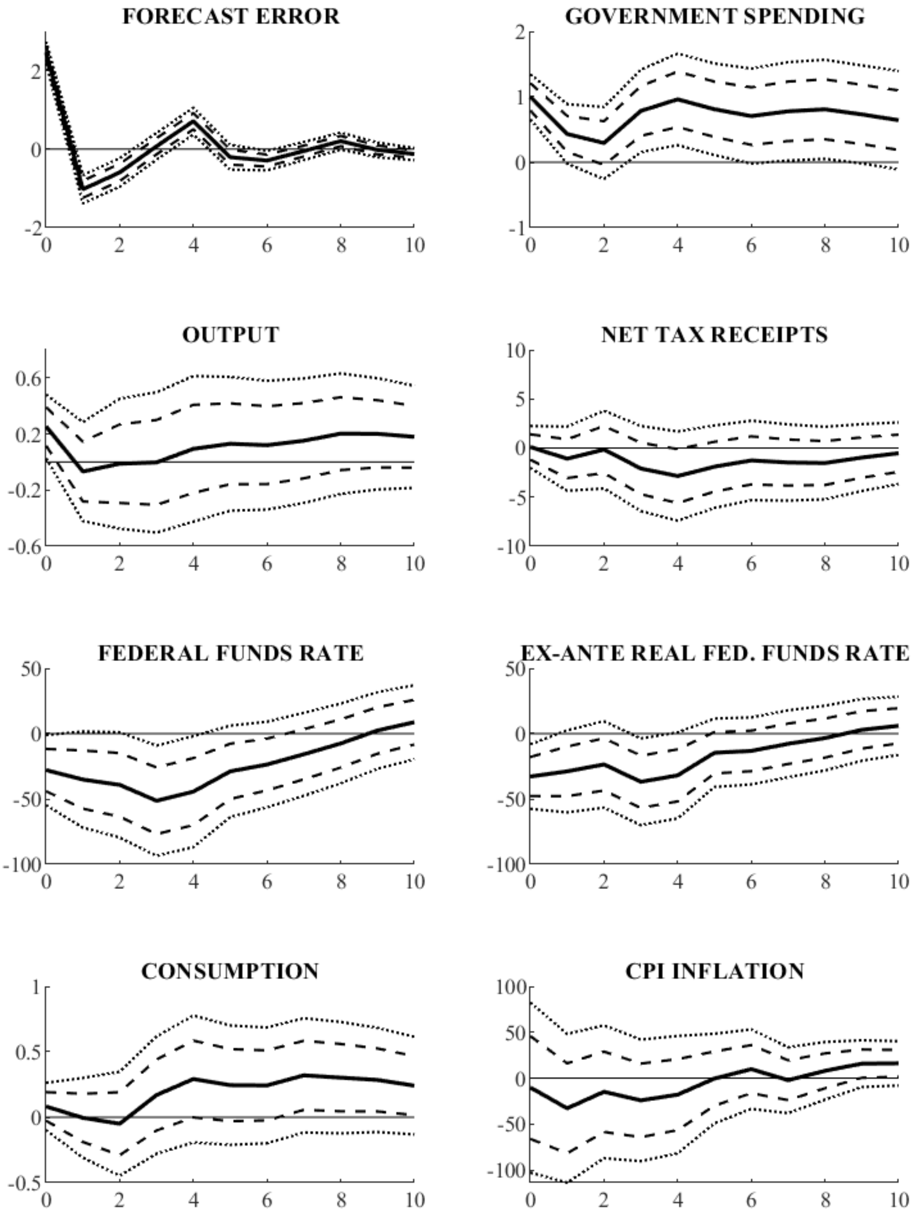
common factor are the differences 1) between the 3-month commercial papers rate and 3-month T-bill rate, 2) between the 3-month GC repo rate and the 3-month T-bill rate, 3) between the 3-month LIBOR and the 3-month T-bill rate, 4) between the 10-year Aaa corporate bonds rate and the 10-year treasury bond rate with 10-year maturity, 5) between the 3-month Refcorp rate and 3-month 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. The sample period for the principal-component model starts in 1983Q1 (the sample contains at least two liquidity spreads per quarter).

A.3 Baseline VAR results for sample period 1979.IV to 2015.IV

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. Figure XII in Ramey (2011) shows a very similar output response as documented in our Figure 8. 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 final three panels of Figure 8 show responses of additional variables. 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. Consumption and inflation respond insignificantly.

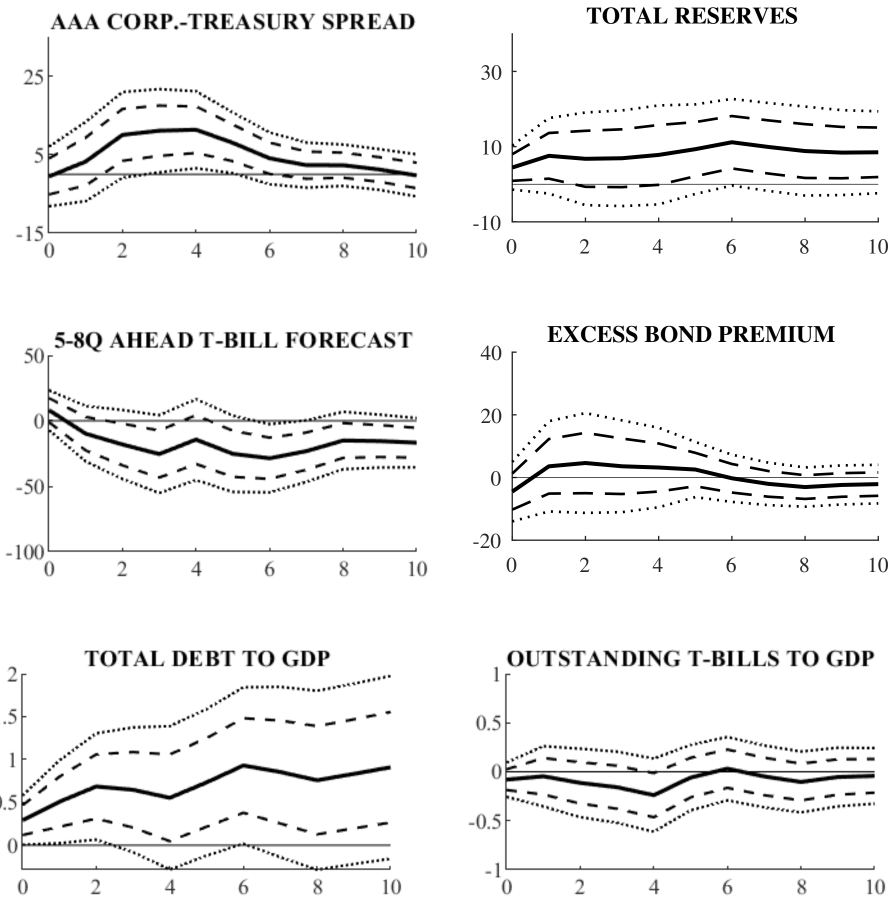
Figure 8: Responses to government spending shocks identified through forecast errors.



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. Right panel in third row: real federal funds rate replaces nominal federal funds rate in VAR. Bottom row: Consumption and inflation, respectively, added to the set of variables. 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.4 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.

A.5 Estimation of monetary policy rule

We follow Clarida et al. (2000) in estimating a forward-looking monetary policy rule, extended by a direct feedback effect to government spending. Specifically, consider the monetary reaction function for the nominal federal funds rate R_t^m

$$R_t^m = \rho_R R_{t-1}^m + (1-\rho_R) \begin{bmatrix} R^m + \rho_\pi \left(E_t\left(\pi_{t+1}-\pi\right)\right) + \rho_y \left(E_t\left(\check{y}_{t+1}-\check{y}\right)\right) \\ +\rho_g \left(E_t\left(g_{t+1}-g\right)\right) + \varrho_t \end{bmatrix},$$

where π_t is inflation, $\check{y}_t = y_t/\tilde{y}_t$ is the output gap with y_t and $\tilde{y}_t$ denoting actual and potential output, respectively, and g_t is government spending. Variables without time index are steady-state values. As is standard, the policy rule accounts for adjustment of the federal funds rate to inflation and the output gap, with sensitivities ρ_π and ρ_y, respectively, and we allow for partial adjustment of the federal funds rate to its target value captured by ρ_R. ϱ_t is a mean-zero exogenous interest rate shock. The non-standard element is the direct response to government spending, captured by ρ_g.

As in Clarida et al. (2000), the estimation approach follows from the rewritten reaction function

$$R_t^m = \rho_R R_{t-1}^m + (1-\rho_R) \begin{bmatrix} R^m - \pi - (\rho_\pi - 1)\pi + \rho_g g \\ +\rho_\pi\left(\pi_{t+1}-\pi\right) + \rho_y\left(\check{y}_{t+1}-\check{y}\right) + \rho_g\left(g_{t+1}-g\right) + \xi_{t+1} \end{bmatrix},$$

where ξ_{t+1} comprises a linear combination of forecast errors and is thus orthogonal to any variable in the information set at time t.

Let z_t denote a vector of instruments known when R_t^m is set. The parameter vector $(\rho_R, \rho_\pi, \rho_y, \rho_g)$ can then be estimated using the moment conditions

$$E\left(\begin{bmatrix} R_t^m - \big\{(1-\rho_R)\big(R^m - \pi - (\rho_\pi - 1)\pi + \rho_g g \\ +\rho_\pi\left(\pi_{t+1}-\pi\right) + \rho_y\left(\check{y}_{t+1}-\check{y}\right) + \rho_g\left(g_{t+1}-g\right)\big) + \rho_R R_{t-1}^m\big\} \end{bmatrix} z_t \right) = 0.$$

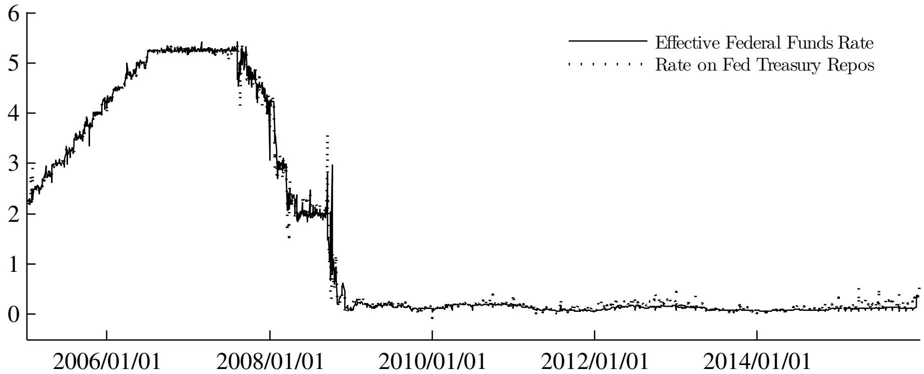
We use an optimal weighting matrix that accounts for arbitrary forms of serial correlation and impose the additional restrictions that the steady-state values for the federal funds rate, the inflation rate, and government spending, R^m, π, $\check{y}$, and g, correspond to the observed sample averages of the respective variables. The instruments we use are, following Clarida et al. (2000), four lags each of the federal funds rate, inflation, the output gap, commodity price inflation, and M2 growth. We augment this set of instruments by four lags of the government spending variable. Our measure of inflation is the (quarter-to-quarter) rate of change of the GDP deflator and for the output gap, we use the CBO series from FRED. The federal funds rate is measured in percentage points per quarter. The government spending variable is defined as in our forecast error VAR (log real government consumption and investment per capita).

For the estimation, we use the same sample period as in our forecast error VAR, 1979.IV-2015.IV, which is effectively an extended post-Volcker period compared to the estimation sample considered in Clarida et al. (2000). For completeness, we checked that we obtain very similar estimation results as reported in Clarida et al. (2000) when estimating a standard Taylor rule without a feedback to government spending for their sample period 1979.III-1996.IV.

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 $\beta E_t\pi_{t+1}^{-1}\left(\lambda_{t+1}+\psi_{t+1}\right) = \lambda_t$, which can – by using condition (7) – be combined to the following expression for the multiplier of the money supply constraint (1),

$$\eta_t = \left(R_t^{IS}/R_t^m\right) - 1. \tag{24}$$

Combining $\beta E_t\pi_{t+1}^{-1}\left(\lambda_{t+1}+\psi_{t+1}\right) = \lambda_t$ 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*

$$c_t = m_t + m_t^R,\ \text{if}\ \ \psi_t = u_{c,t}\left(1-1/R_t^{IS}\right) > 0, \tag{25}$$
$$\text{or}\ c_t \le m_t + m_t^R,\ \text{if}\ \ \psi_t = u_{c,t}\left(1-1/R_t^{IS}\right) = 0,$$
$$b_{t-1}/\left(R_t^m\pi_t\right) = m_t - m_{t-1}\pi_t^{-1} + m_t^R,\ \text{if}\ \ \eta_t = \left(R_t^{IS}/R_t^m\right) - 1 > 0, \tag{26}$$
$$\text{or}\ b_{t-1}/\left(R_t^m\pi_t\right) \ge m_t - m_{t-1}\pi_t^{-1} + m_t^R,\ \text{if}\ \ \eta_t = \left(R_t^{IS}/R_t^m\right) - 1 = 0,$$
$$m_t^R = \Omega m_t, \tag{27}$$
$$b_t = b_t^T - m_t, \tag{28}$$
$$b_t^T = \Gamma b_{t-1}^T/\pi_t, \tag{29}$$
$$\theta n_t^{\sigma_n} = u_{c,t}w_t/R_t^{IS}, \tag{30}$$
$$1/R_t^{IS} = \beta E_t\left[u_{c,t+1}/\left(u_{c,t}\pi_{t+1}\right)\right], \tag{31}$$
$$w_t = mc_t, \tag{32}$$
$$\lambda_t = \beta E_t\left[u_{c,t+1}/\pi_{t+1}\right], \tag{33}$$
$$Z_{1,t} = \lambda_t y_t mc_t + \phi\beta E_t\pi_{t+1}^{\varepsilon}Z_{1,t+1}, \tag{34}$$
$$Z_{2,t} = \lambda_t y_t + \phi\beta E_t\pi_{t+1}^{\varepsilon-1}Z_{2,t+1}, \tag{35}$$
$$Z_t = \left[\varepsilon/\left(\varepsilon-1\right)\right]Z_{1,t}/Z_{2,t}, \tag{36}$$
$$1 = (1-\phi)Z_t^{1-\varepsilon} + \phi\pi_t^{\varepsilon-1}, \tag{37}$$
$$s_t = (1-\phi)Z_t^{-\varepsilon} + \phi s_{t-1}\pi_t^{\varepsilon}, \tag{38}$$
$$y_t = n_t/s_t, \tag{39}$$
$$y_t = c_t + g_t, \tag{40}$$

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

$B^T_{-1} > 0$, *and* $s_{-1} \geq 1$.

Given a rational expectations equilibrium as summarized in Definition 1, the equilibrium sequences $\{R_t,\ R^D_t,\ R^q_{t+1},\ R^L_t = R^A_t\}_{t=0}^{\infty}$ can be residually determined: The T-bill rate R_t closely 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 $\varkappa_t + 1 = R^m_t\,(\eta_t+1)$,

$$R_t = E_t[u_{c,t+1}\pi^{-1}_{t+1}]/[E_t\left(R^m_{t+1}\right)^{-1} u_{c,t+1}\pi^{-1}_{t+1}]. \tag{41}$$

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

$$(1/R^{L,A}_t)\cdot E_t[u_{c,t+1}/\pi_{t+1}] = E_t[\left(1/R^{IS}_{t+1}\right)\cdot u_{c,t+1}/\pi_{t+1}]. \tag{42}$$

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

If the money supply constraint (1) is not binding, which is the case if $R^m_t = R^{IS}_t$ (see 24), 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* $\{c_t,\ y_t,\ n_t,\ w_t,\ \lambda_t,\ mc_t,\ Z_{1,t},\ Z_{2,t},\ Z_t,\ s_t,\ \pi_t,\ R^{IS}_t\}_{t=0}^{\infty}$ *satisfying* $R^{IS}_t = R^m_t$, *(30)-(40), the transversality condition, a monetary policy* $\{R^m_t \geq 1\}_{t=0}^{\infty}$, $\pi \geq \beta$, *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 $R^m_t = R^{IS}_t$, i.e., (17), (18), and (15), which can by substituting out $\widehat{R}^{IS}_t$ be summarized as

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

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \delta_c\widehat{c}_t + \delta_g\widehat{g}_t + \chi\rho_\pi\widehat{\pi}_t, \tag{44}$$

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 (43) and (44), leads to the following two conditions in γ_π 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 real 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 real 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 real 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*

$$\rho_\pi < [(1+\beta)\chi^{-1} + 1 - \sigma]/\sigma. \tag{45}$$

Proof. The model given in Definition 3 for the version with $R_t^m < R_t^{IS}$, i.e., (16)-(15), is simplified by substituting out $\widehat{R}_t^{IS}$ and $\widehat{R}_t^m$:

$$\delta_1 E_t\widehat{\pi}_{t+1} + \delta_3\widehat{b}_t + \delta_2\widehat{c}_t = \widehat{\pi}_t - \delta_g\widehat{g}_t, \tag{46}$$

$$\widehat{c}_t = \widehat{b}_{t-1} - (1+\rho_\pi)\widehat{\pi}_t - \rho_g\widehat{g}_t, \tag{47}$$

and (19), 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 (19), (46), and (47) by eliminating $\widehat{c}_t$

with (47) in (46) and then $\widehat{b}_{t-1}$ with (19). 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

$$\mathbf{A} = \begin{pmatrix} \delta_1 & \delta_3 + \delta_2 \\ 0 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 + \delta_2 \rho_\pi & 0 \\ -1 & 1 \end{pmatrix} \tag{48}$$

is given by $F(X) = X^2 - \frac{\delta_1 + \delta_2 + \delta_3 + \rho_\pi \delta_2 + 1}{\delta_1} X + \frac{\rho_\pi \delta_2 + 1}{\delta_1}$. Given that there is one backward-looking variable and one forward-looking variable, stability and uniqueness require $F(X)$ to be characterized by one stable and one unstable root. At $X = 0$, the sign of $F(X)$ equals the sign of δ_1, $F(0) = (\rho_\pi \delta_2 + 1)/\delta_1$, while $F(X)$ exhibits the opposite sign at $X = 1 : F(1) = -\frac{1}{\delta_1}(\delta_2 + \delta_3)$. Consider first the case where $\delta_1 = \beta + \chi(1-\sigma) - \chi\sigma\rho_\pi > 0$. Given that $\sigma \geq 1$ and $\beta < 1$, we know that δ_1 is then strictly smaller than one. Hence, $F(1) < 0$ and $F(0) > 1$, which implies that exactly one root is unstable and the stable root is strictly positive. Now consider the second case where $\delta_1 = \beta + \chi(1-\sigma) - \chi\sigma\rho_\pi < 0 \Leftrightarrow \rho_\pi > \frac{\beta + \chi(1-\sigma)}{\chi\sigma}$, such that $F(1) > 0$ and $F(0) < 0$. We then know that there is at least one stable root between zero and one. To establish a condition which ensures that there is exactly one stable root, we further use $F(-1) = [2(1+\delta_1) + \delta_3 + (2\rho_\pi + 1)\delta_2]/\delta_1$. Rewriting the numerator with $\delta_1 = \beta + \chi(1-\sigma) - \chi\sigma\rho_\pi$, $\delta_2 = \chi\sigma_n c_y$ and $\delta_3 = \chi\sigma$, the condition

$$2(1 + \beta + \chi(1-\sigma) - \chi\sigma\rho_\pi) + \chi\sigma + (2\rho_\pi + 1)\chi\sigma_n c_y > 0 \tag{49}$$

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 (49) holds, if but not only if

$$\rho_\pi \leq \frac{1+\beta}{\chi\sigma} + \frac{1-\sigma}{\sigma}, \tag{50}$$

where the RHS of (50) is strictly larger than $\frac{\beta + \chi(1-\sigma)}{\chi\sigma}$. Hence, (50) is sufficient for local equilibrium determinacy, which establishes the claim made in the lemma. ■

Condition (45) 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). The parameter ρ_g does not affect determinacy since g_t is exogenous. It should further be noted that the sufficient condition (45) is far from being restrictive for a broad range of reasonable parameter values.

Proof of Proposition 2. Consider the set of equilibrium conditions (19), (46), and (47). We aim at identifying the impact responses to fiscal policy shocks. For this, we assume that (50) is satisfied, which ensures existence and uniqueness of a locally stable solution. We then apply the following solution form for the system (19), (46), and (47):

$$\widehat{\pi}_t = \gamma_{\pi b}\widehat{b}_{t-1} + \gamma_{\pi g}\widehat{g}_t, \tag{51}$$

$$\widehat{b}_t = \gamma_b\widehat{b}_{t-1} + \gamma_{bg}\widehat{g}_t, \tag{52}$$

$$\widehat{c}_t = \gamma_{cb}\widehat{b}_{t-1} + \gamma_{cg}\widehat{g}_t. \tag{53}$$

Substituting out the endogenous variables in (19), (46), and (47) with the generic solutions in (51)-(53), leads to the following conditions for $\gamma_{\pi b}$, γ_{cb}, $\gamma_{\pi b}$, γ_{cg}, $\gamma_{\pi g}$, and γ_{bg} :

$$\gamma_{\pi b} = \delta_1\gamma_{\pi b}\gamma_b + \delta_3\gamma_b + \delta_2\gamma_{cb},\ 1 = (1+\rho_\pi)\gamma_{\pi b} + \gamma_{cb},\ 1 = \gamma_b + \gamma_{\pi b}, \tag{54}$$

$$-\delta_2\gamma_{cg} = (\delta_1\gamma_{\pi b} + \delta_3)\gamma_{bg} - \gamma_{\pi g} + \delta_g,\ -\gamma_{cg} = (1+\rho_\pi)\gamma_{\pi g} + \rho_g,\ \gamma_{bg} = -\gamma_{\pi g}, \tag{55}$$

Using the three conditions in (54) and substituting out $\gamma_{\pi b}$ with $\gamma_{\pi b} = 1 - \gamma_b$, gives $0 = (\delta_1\gamma_b - 1)(1-\gamma_b) + \delta_3\gamma_b + \delta_2\gamma_{cb}$, $1 = (1+\rho_\pi)(1-\gamma_b) + \gamma_{cb}$, and eliminating γ_{cb}, leads to $0 = (\delta_1\gamma_b - 1)(1-\gamma_b) + \delta_3\gamma_b + \delta_2(1-(1+\rho_\pi)(1-\gamma_b))$, which is a quadratic equation in γ_b,

$$\gamma_b^2 - (\delta_1 + \delta_3 + \delta_2(\rho_\pi + 1) + 1)\gamma_b\delta_1^{-1} + (\rho_\pi\delta_2 + 1)\delta_1^{-1} = 0. \tag{56}$$

Note that the polynomial in (56) is the characteristic polynomial of $\mathbf{A}$ (see 48). Hence, under (50) 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 (55). The latter imply that the impact responses of inflation and consumption are related by $-\gamma_{cg} = (1+\rho_\pi)\gamma_{\pi g} + \rho_g$. Eliminating γ_{bg} with $\gamma_{bg} = -\gamma_{\pi g}$ and $\gamma_{\pi g}$ with $-\delta_2\gamma_{cg} = -(\delta_1\gamma_{\pi b} + \delta_3)\gamma_{\pi g} - \gamma_{\pi g} + \delta_g$, gives

$$\gamma_{cg} = -\frac{(1+\rho_\pi)\delta_g + (\delta_1\gamma_{\pi b} + \delta_3 + 1)\rho_g}{(\delta_1\gamma_{\pi b} + \delta_3 + 1) + \delta_2(1+\rho_\pi)}. \tag{57}$$

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 (57) can be rewritten, such that

$$\gamma_{cg} = -\frac{(1+\rho_\pi)\chi\sigma_n g_y + \Gamma_1\rho_g}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}, \tag{58}$$

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

$$\rho_g > -(1+\rho_\pi)\chi\sigma_n g_y/\Gamma_1. \tag{59}$$

The solution coefficient (58) 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 iff $\rho_g < 1 + (c_y - g_y)\chi\sigma_n(1+\rho_\pi)\Gamma_1^{-1}$. Using $\gamma_{\pi g} = -\frac{\gamma_{cg}+\rho_g}{(1+\rho_\pi)}$ and (58), the inflation response is given by

$$\gamma_{\pi g} = \frac{(g_y - \rho_g c_y)\chi\sigma_n}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}, \tag{60}$$

implying that $\gamma_{\pi g} > 0$, iff $\rho_g < g_y/c_y$. Using (60), 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 iff

$$\rho_g < -\rho_\pi\frac{g_y\chi\sigma_n}{\chi\sigma_n c_y + \Gamma_1} \le 0. \tag{61}$$

Using the equilibrium condition (17) and $\partial\widehat{R}_t^m/\partial\widehat{g}_t$, the response of the spread can be written as

$$\frac{\partial(\widehat{R}_t^{IS} - \widehat{R}_t^m)}{\partial\widehat{g}_t} = \sigma\frac{\partial E_t\widehat{c}_{t+1}}{\partial\widehat{g}_t} - \sigma\frac{\partial\widehat{c}_t}{\partial\widehat{g}_t} + \frac{\partial\widehat{\pi}_{t+1}}{\partial\widehat{g}_t} - \frac{\partial\widehat{R}_t^m}{\partial\widehat{g}_t}$$

$$= \frac{\begin{array}{c}((\sigma - 1 + \sigma(1-\gamma_b))\rho_\pi + (\sigma-1)(1-\gamma_b))g_y\chi\sigma_n \\ +((\sigma-1)(\chi\sigma_n c_y\gamma_b + \beta(1-\gamma_b) + \chi(\sigma\gamma_b + 1 - \gamma_b) + 1) - \sigma\chi\rho_\pi(1-\gamma_b)(\sigma - 1 + \sigma_n c_y))\rho_g\end{array}}{\Gamma_1 + \chi\sigma_n c_y(1+\rho_\pi)}$$

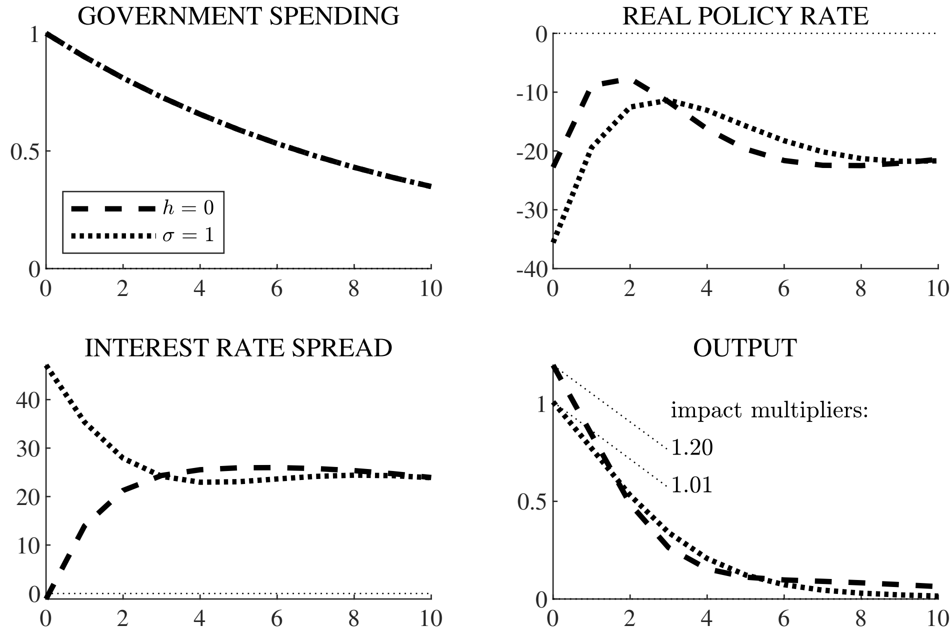
Defining $\Gamma_2 = \sigma\chi(1-\gamma_b)(\sigma - 1 + \sigma_n c_y) > 0$ and $\Gamma_3 = (\sigma-1)(\chi\sigma_n c_y\gamma_b + \beta(1-\gamma_b) + \chi(\sigma\gamma_b + 1 - \gamma_b) + 1) > 0$, the spread response is strictly positive, $\partial(\widehat{R}_t^{IS} - \widehat{R}_t^m)/\partial\widehat{g}_t > 0$ if

$$(\rho_\pi\Gamma_2 - \Gamma_3)\rho_g < ((\sigma - 1 + \sigma(1-\gamma_b))\rho_\pi + (\sigma-1)(1-\gamma_b))g_y\chi\sigma_n$$

which establishes the claims made in the proposition. ■

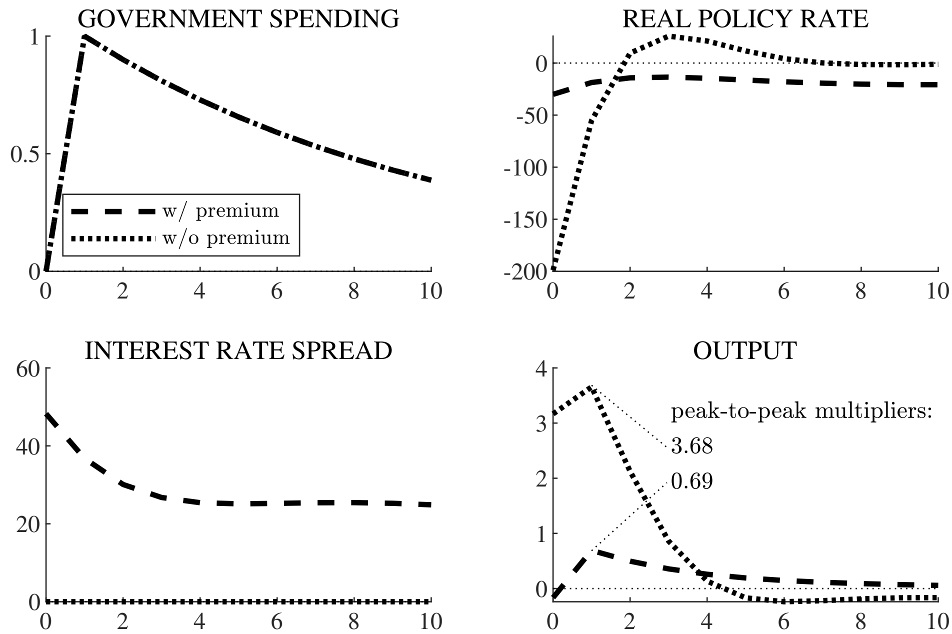
C.2 Sensitivity analysis

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



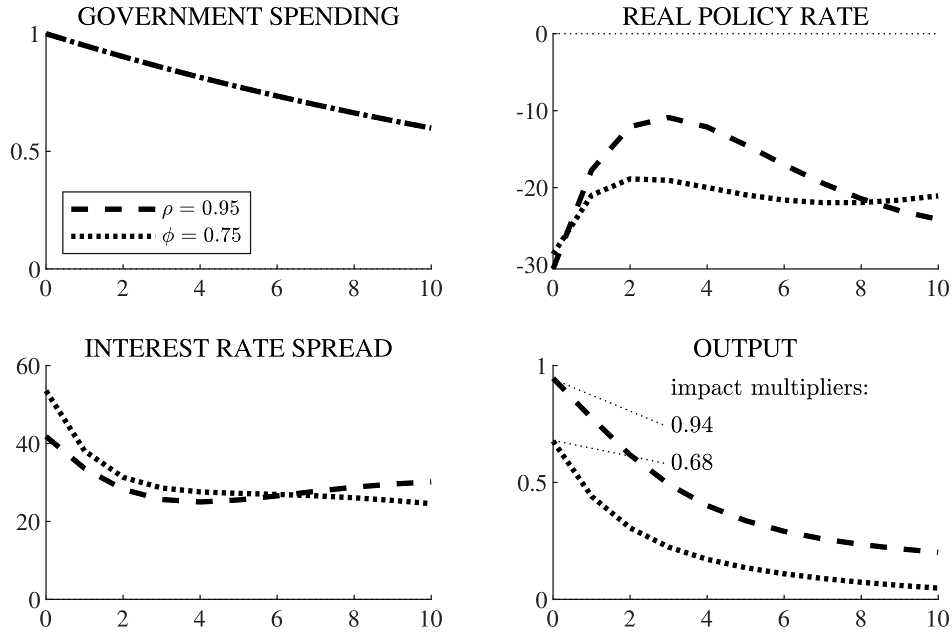
Notes: Responses of g_t and y_t in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in annualized basis points.

Figure 12: Responses to hump-shaped spending expansion.



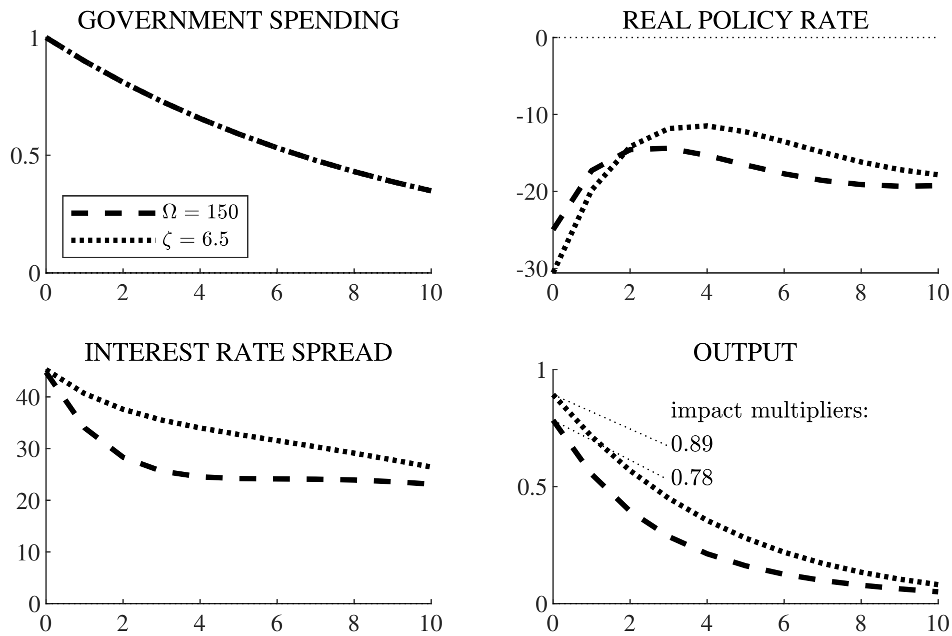
Notes: Responses of g_t and y_t in percent of steady-state GDP. Responses of $R_t^m/E_t\pi_{t+1}$ and $R_t^L - R_t^m$ in annualized basis points.

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 annualized 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 annualized basis points.