university of groningen / faculty of economics and business

2022008-EEF

Monetary Financing Does Not Produce Miraculous Fiscal Multipliers

August 2022

Christiaan van der Kwaak

SOM is the research institute of the Faculty of Economics & Business at the University of Groningen. SOM has seven programmes:
- Accounting
- Economics, Econometrics and Finance
- Global Economics & Management
- Innovation & Organization
- Marketing
- Operations Management & Operations Research
- Organizational Behaviour

Research Institute SOM
Faculty of Economics & Business
University of Groningen

Visiting address:
Nettelbosje 2
9747 AE Groningen
The Netherlands

Postal address:
P.O. Box 800
9700 AV   Groningen
The Netherlands

T +31 50 363 9090/7068/3815

www.rug.nl/feb/research

Monetary Financing Does Not Produce Miraculous Fiscal Multipliers

Christiaan van der Kwaak
University of Groningen, Faculty of Economics and Business, Department of Economics, Econometrics and Finance
c.g.f.van.der.kwaak@rug.nl

Monetary financing does not produce miraculous fiscal multipliers*

Christiaan van der Kwaak†

August 8, 2022

Abstract

In the standard New Keynesian model, a money-financed fiscal stimulus is much more effective in expanding output than a debt-financed stimulus. However, a key assumption is that the monetary base does not pay interest. In line with current central bank practices, I introduce interest-paying reserves into the monetary base, which allows the central bank to simultaneously control the size of its balance sheet *and* the short-term policy rate. In that case, money-financed fiscal stimuli are hardly more effective than debt-financed stimuli. Even worse, money-financed fiscal stimuli become *less* effective than debt-financed stimuli when all privately-held government bonds are held by balance-sheet-constrained financial intermediaries.

Keywords: Monetary Policy; Fiscal Policy; Fiscal multipliers; Monetary financing

JEL: E32, E52, E62, E63

*I am grateful to Nuno Palma for comments and suggestions. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Declarations of interest: none.

†Affiliation: Rijksuniversiteit Groningen. Address: Nettelbosje 2, 9747 AE Groningen. Email address: c.g.f.van.der.kwaak@rug.nl. Telephone: +31(0)50 363 3760.

1 Introduction

The monetary financing of fiscal stimuli came roaring back into the policy debate at the beginning of the corona crisis in early 2020. Advocates at the time argued that the massive increase in government deficits, necessary to cushen the pandemic's economic impact, should be monetized to prevent a massive increase in debt-GDP ratios (Buiter and Kapoor, 2020; Galí, 2020a; De Grauwe and Diessner, 2020).[1] According to the New Keynesian model, such money-financed fiscal stimuli would not only have prevented the massive increases in debt-GDP ratios that would eventually materialize, but would also have been (much) more effective in expanding economic output (Galí, 2020b): by expanding the money supply (to finance the additional deficits), the interest rate on government debt must fall for households to be willing to hold larger money balances in equilibrium. A lower interest rate, in turn, induces households to expand consumption, which further increases aggregate demand and output. This contrasts with a debt-financed fiscal stimulus, for which interest rates increase.

A key modeling assumption in Galí (2020b), however, is that the monetary base does not pay interest. As a result, the central bank can either control the nominal interest rate or the nominal money supply, but not both. This contrasts, however, with the way monetary policy has been conducted by many central banks since the Great Financial Crisis of 2007-2009, where the central bank simultaneously controls the short-term nominal interest rate *and* the size of its balance sheet. This is possible because the central bank not only finances itself through non-interest-paying money, but also through interest-paying reserves held by the commercial banking system.[2] The economic relevance of these reserves is illus-

[1] The Federal Reserve (Fed) and the European Central Bank (ECB) acquired substantial amounts of government bonds in response to the outbreak of the pandemic. De Grauwe and Diessner (2020) points out that these bond holdings did not prevent government debt levels from increasing, and should therefore be viewed as dealing with liquidity problems that governments face in bond markets rather than as monetized deficits. For example, the Fed motivated its decision to resume asset purchases in the following way: "To support the smooth functioning of markets for Treasury securities and agency mortgage-backed securities that are central to the flow of credit to households and businesses, over coming months the Committee will increase its holdings of Treasury securities by at least $500 billion and its holdings of agency mortgage-backed securities by at least $200 billion.", see https://www.federalreserve.gov/newsevents/pressreleases/monetary20200315a.htm.

[2] The ECB has been paying interest on commercial bank reserves ever since its inception in

trated by Figure 1, which shows the monetary base of the Federal Reserve. From this figure, we clearly see that the unconventional montary policies of the Federal Reserve since 2008 have predominantly been financed through an expansion of interest-paying reserves while non-interest-paying money ("currency") shows no substantial deviation from trend.[3]

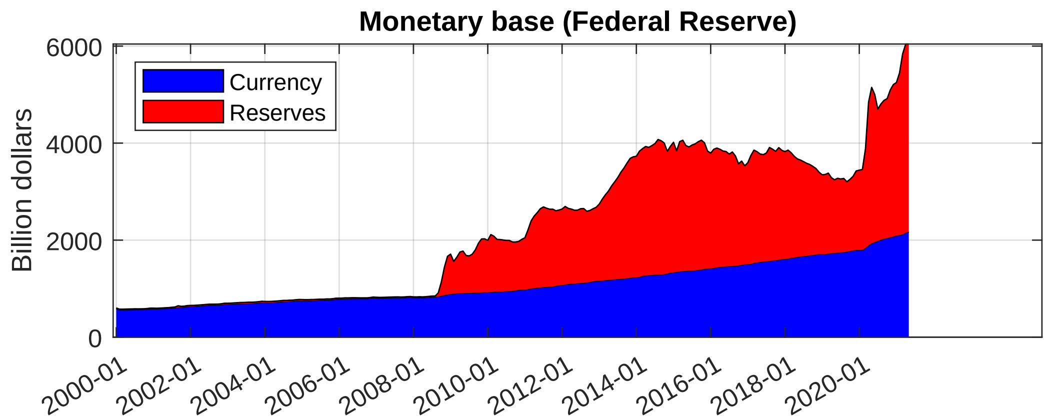


Figure 1: The monetary base of the Federal Reserve, which consist of non-interest-paying money ("currency") and interest-paying reserves. *Source:* FRED database.

Therefore, I introduce interest-paying reserves into the standard New Keynesian model of Galí (2020b), and investigate how the effectiveness of money-financed fiscal stimuli is affected by the inclusion of these reserves. Doing so is important, as these reserves allow the central bank to retain control over the nominal interest rate on reserves *and* the size of the monetary base (Benigno and Nisticò, 2020; Benigno and Benigno, 2021; Diba and Loisel, 2021). My contribution is that I show that money-financed fiscal stimuli are in this case barely more effective in expanding

January 1999. The Federal Reserve did not pay interest on reserves prior to October 2008, a policy that coincides with the way monetary policy is modeled in Galí (2020b). The Federal Reserve started to pay interest on reserves in order for commercial banks to be willing to absorb the large amount of freshly created reserves in unconventional monetary policies, while simultaenously being able to control the Federal Funds rate: "The payment of interest on excess reserves will permit the Federal Reserve to expand its balance sheet as necessary to provide the liquidity necessary to support financial stability while implementing the monetary policy that is appropriate in light of the System's macroeconomic objectives of maximum employment and price stability." *Source:* https://www.federalreserve.gov/newsevents/pressreleases/monetary20081006a.htm.

[3]The equivalent figure for the European Central Bank shows a similar development regarding the creation of interest-bearing reserves.

economic activity than debt-financed stimuli. A second contribution is that I show that money-financed stimuli can even be *less* effective than debt-financed stimuli when all privately-held government bonds are held by balance-sheet-constrained financial intermediaries, which is at odds with most of the literature on money-financed stimuli.

Specifically, I start from the standard New Keynesian model without physical capital as described in Galí (2020b), and extend this model in three directions. First, I explicitly model the central bank balance sheet, which features government bonds on the asset side. In addition to the non-interest-paying money that already features in Galí (2020b), the liabilities side of the balance sheet also features interest-paying reserves and central bank net worth (Hall and Reis, 2015; Benigno and Nisticò, 2020). The monetary base thus consists of interest-paying reserves and non-interest-paying money, with its composition endogenously determined in equilibrium (Benigno and Nisticò, 2020). A fiscal stimulus is money-financed if the central bank buys the additional bonds that are issued by the fiscal authority, and permanently retains them on its balance sheet (Buiter, 2014).[4] Therefore, a money-financed stimulus implies a permanent expansion of the monetary base (in nominal terms), with the composition of the expansion endogenously determined in equilibrium between interest-paying reserves and non-interest-paying money. The central bank sets the nominal interest rate on reserves following a standard active Taylor rule, both under a money-financed stimulus and a debt-financed stimulus. The central bank keeps its net worth constant by transferring all profits (and losses) to the fiscal authority in the form of dividends. Just as in Galí (2020b), I investigate two types of fiscal stimuli, namely a decrease in lump sum taxes and an increase in government spending.

A second extension is that I introduce financial intermediaries into the model. These are financed by net worth and household deposits, which are used to acquire government bonds and central bank reserves. These intermediaries are subject to an incentive compatibility constraint as in Gertler and Kiyotaki (2010); Gertler and

[4]Buiter (2014) points out that central banks cannot openly act as 'fiscal principals' in most contemporary advanced economies, and can therefore not make transfer payments or pay overt subsidies to the fiscal authority. Therefore, I model a money-financed stimulus as a stimulus for which the government bonds issued by the fiscal authority are acquired by the central bank, which retains these indefinitely on its balance sheet, see page 32-33 of Buiter (2014).

Karadi (2011), which prevents intermediaries from perfectly elastically expanding their bond holdings when this constraint is binding. However, I assume that central bank reserves directly relax this incentive compatibility constraint (Gertler and Kiyotaki, 2010).[5] This assumption ensures that central bank reserves have a key property of money, namely that the return on it is dominated by the return on all other financial assets, and strictly dominated when the incentive compatibility constraint is binding (Buiter, 2014).

A third extension is that i) government bonds have a flexible maturity structure as in Woodford (1998, 2001), and ii) that privately-held government bonds are held by financial intermediaries and households, as this composition will turn out to play a key role for the effectiveness of money-financed fiscal stimuli.

The key result of the paper is that money-financed fiscal stimuli are hardly more effective in stimulating economic activity when the central bank simultaneously controls the short-term nominal interest rate *and* the size of its balance sheet. In fact, they are equally effective when intermediaries' incentive compatibility constraint is not binding, in which case the return on bonds and reserves are equal: the fact that the central bank still controls the nominal interest rate on reserves implies that the central bank's policy rate is the same as under a debt-financed stimulus. Therefore, households' consumption-savings decision is unaffected, and aggregate demand is the same as under a debt-financed stimulus. With the policy rate the same, households' demand for non-interest-paying money balances is the same as under a debt-financed stimulus, which implies that a money-financed stimulus is entirely financed by an expansion of interest-paying reserves. But since the return on bonds and reserves is the same, central bank dividends are the same as under a debt-financed stimulus, and the expected present value of future lump sum taxes is the same. With no change in households' life-time income, the cumulative multiplier for both a money- and debt-financed stimulus is the same, which sharply contrasts with Galí (2020b), where the multiplier substantially increases under a money-financed stimulus.

Money-financed fiscal stimuli become slightly more effective than debt-financed

[5] In Gertler and Kiyotaki (2010), the central bank funds that relax the incentive compatibility constraint are a liability from the persepctive of financial intermediaries, while the central bank reserves in my model are an asset from the perspective of financial intermediaries.

stimuli when financial intermediaries' incentive compatibility constraint is binding. In that case, intermediaries can no longer perfectly elastically expand their bond holdings, as a result of which the return on bonds is higher than the return on reserves, and Ricardian equivalence is broken. As a result, central bank profits increase, everything else equal, when the central bank finances the stimulus by buying the additional government bonds. The resulting higher central bank dividends, in turn, decrease the expected present value of future lump sum taxes, which leads to higher life-time incomes for households. However, the resulting expansion in aggregate demand under a money-financed stimulus leads to higher interest rates on reserves and deposits, which induces a relative shift from consumption to savings. In addition, a higher interest rate on deposits reduces households' demand for non-interest-paying money balances, as a result of which the money-financed stimulus is entirely financed through the creation of additional reserves. Furthermore, a higher interest rate on reserves also decreases central bank profits and dividends, everything else equal. These feedback effects via the interest rate on reserves ensure that households' life-time incomes under a money-financed stimulus hardly increase in equilibrium (with respect to a debt-financed stimulus), as the difference in the multiplier of a money-financed and debt-financed stimulus is less than 0.01 percentage points in the case of a binding incentive compatibility constraint, both for a tax cut and an increase in government spending. This sharply contrasts with Galí (2020b), who finds money-financed spending multipliers that are larger than one, and a difference with the debt-financed multiplier of more than 0.50 percentage points.

The feedback effect via the policy rate ensures that this result is robust when switching from short-term government debt to long-term government debt, although the cumulative fiscal multiplier under a money-financed stimulus is now 0.08 percentage points higher than under a debt-financed stimulus. In the latter case, higher debt issue to finance the fiscal stimulus leads to capital losses on intermediaries' existing bond holdings, as a result of which their net worth decreases. When intermediaries' incentive compatibility constraint is binding, a lower net worth leads to a further decrease in bond prices (van der Kwaak and van Wijnbergen, 2017), and an increase in funding costs for the fiscal authority, which increases the expected present discounted value of current and future lump sum taxes. Under a money-financed stimulus, the additional bonds (that finance the stimulus) are acquired by an unconstrained central bank, as a result of which bond prices increase with respect to a debt-financed stimulus (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011, 2013). Therefore, the fiscal authority's funding costs decrease with respect to a debt-financed stimulus.

Finally, I show that there are situations in which the money-financed multiplier is lower than the debt-financed multiplier. The reason is that there is a second, negative effect from an expansion in central bank reserves: the fact that these reserves directly relax intermediaries' incentive compatibility constraint implies that the interest rate on reserves is below that on deposits. Therefore, an expansion in reserves reduces intermediaries' net worth, which tightens intermediaries' incentive compatibility constraint, everything else equal. However, this second effect only dominates the first when intermediaries hold all government bonds that are not held by the central bank, which is unlikely to be the case in reality.[6] In that case, the balance sheet capacity that is freed up by the central bank buying the additional bonds (instead of intermediaries) is relatively small as a fraction of total bonds held by intermediaries, as a result of which the positive effect on bond prices from money-financed stimuli is relatively small.

Literature review

Galí (2020b) provides an elaborate review of the literature on money-financed fiscal stimuli, among which Buiter (2014), who analytically shows that a money-financed stimulus is always and everywhere expansionary. While I also find that money-financed stimuli are expansionary in most cases, I show that it is possible that they are less effective than debt-financed stimuli. The difference arises from the fact that the monetary base is held by unconstrained households in Buiter (2014), while reserves in my model are held by balance-sheet-constrained financial

[6] Only commercial banks can directly hold central bank reserves, while insurance companies and pension funds cannot. Therefore, my financial intermediaries would only capture the commercial banks, whereas insurance companies and pension funds would be captured by households' holdings of government bonds. Since insurance companies and pension funds hold a substantial fraction of all government bonds on their balance sheets, it is unlikely that the negative effect from an expansion in central bank reserves under a money-financed stimulus will dominate the positive effects in reality.

intermediaries. This allows for the possibility of an increase in the fiscal authority's funding costs when the negative effect from an expansion in central bank reserves (which decreases intermediaries' net worth, everything else equal) dominates the positive effects on bond prices from an unconstrained central bank acquiring the additional bonds from the stimulus.

My paper is for two reasons related to the literature on financial frictions (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011, 2013). First, I also employ the Gertler and Kiyotaki (2010); Gertler and Karadi (2011) incentive compatibility constraint. Second, these papers look at the effectiveness of asset purchases by the central bank. A key difference is that my intermediaries do not lend to the real economy, while the primary impact of asset purchase programs in Gertler and Kiyotaki (2010); Gertler and Karadi (2011), and Gertler and Karadi (2013) is to expand lending to the real economy. A second difference is that these papers do not look at fiscal stimuli, and solely focus on the impact of unconventional monetary policies in isolation. A third, and key difference is that intermediaries' incentive compatibility constraint is directly relaxed by central bank reserves in my model, which is absent in Gertler and Karadi (2011) and Gertler and Karadi (2013). Therefore, asset purchases only have positive effects on financial intermediaries in Gertler and Karadi (2011), and Gertler and Karadi (2013), while the losses from holding central bank reserves negatively affect intermediaries in my setup, everything else equal.

An additional reason that links my paper with that of Gertler and Kiyotaki (2010) is that Gertler and Kiyotaki (2010) also features a model version where central bank loans to intermediaries directly relax intermediaries' incentive compatibility constraints, which is similar to central bank reserves directly relaxing the incentive compatibility constraint in my model.[7] However, Gertler and Kiyotaki (2010) look at the policy of central bank lending to financial intermediaries in isolation, whereas in my model central bank reserves relax intermediaries' incentive compatibility constraint while simultaneously featuring bond purchases by the central bank under a money-financed stimulus.

[7] In Gertler and Kiyotaki (2010), central bank loans are a liability from the persepctive of financial intermediaries, while central bank reserves in my model are an asset from the perspective of financial intermediaries.

My paper is also related to the literature that studies the impact of fiscal stimuli. This literature normally focuses on the impact of expansions in government spending, as Ricardian equivalence typically prevents a decrease in lump sum taxes to have real effects. The multiplier from a change in government spending is below or close to unity in standard RBC or New Keynesian models. Woodford (2011) also investigates the size of the multiplier, and analyzes the interaction with monetary policy. Ramey (2011) and Ramey (2019) survey the theoretical and empirical literature on the spending multiplier, while Ramey (2019) also looks at tax change multipliers. While the spending multiplier is normally below unity, it increases above unity in the presence of hand-to-mouth consumers (Galí et al., 2007), when the utility function is non-separable between consumption and labor supply (Bilbiie, 2011), when the economy is at the Zero Lower Bound (ZLB) (Christiano et al., 2011; Eggertsson, 2011), when the policy regime features an active fiscal policy and a passive monetary policy (Davig and Leeper, 2011), and when stimuli are financed by non-interest-paying money (Galí, 2020b).

van der Kwaak and van Wijnbergen (2017) also looks at the size of the debt-financed spending multiplier, and does so in an environment where financial intermediaries are subject to the Gertler and Kiyotaki (2010); Gertler and Karadi (2011) incentive compatibility constraint and hold substantial amounts of government debt that is subject to default risk. van der Kwaak and van Wijnbergen (2017) shows that extending the maturity of government bonds reduces the spending multiplier, as such a maturity extension amplifies the crowding out of private investment found in Corsetti et al. (2013) and Kirchner and Wijnbergen (2016): the initial drop in bond prices from extra debt issue by the sovereign leads to capital losses on intermediaries' existing bond holdings, as a result of which their net worth decreases. Lower net worth, in turn, tightens the incentive compatibility constraint as a result of which interest rates on private credit increase. In addition, bond prices further decrease, thereby imposing a second round of capital losses on existing bond holdings, which leads to a second round of interest rate increases on private credit. Like in van der Kwaak and van Wijnbergen (2017), the debt-financed multiplier also decreases in my paper when extending the maturity of government debt. However, the decrease in the multiplier is substantially smaller than in van der Kwaak and van Wijnbergen (2017), as my intermediaries do not provide credit to the real economy. A second difference is that van der Kwaak and van Wijnbergen (2017) does not consider money-financed stimuli, which increase bond prices with respect to debt-financed stimuli, as a result of which the negative amplification cycle between capital losses on bonds and intermediaries' net worth is eliminated.

My paper is also related to the literature that separately models the central bank balance sheet and the budget constraint of the fiscal authority. With the separation of the two constraints, the transfer policy between the central bank and the fiscal authority can influence equilibrium inflation. For example, Sims (2003, 2004) and Del Negro and Sims (2015) argue that the central bank might not be able to control inflation in the absence of support from the fiscal authority, as the central bank could become insolvent if it were to commit to a certain Taylor rule. Reis (2013, 2015) investigate under what circumstances a central bank can become insolvent, which is defined as an exploding path of central bank reserves, and highlight the crucial role of the central bank's dividend rule. Hall and Reis (2015) investigate the implications for central bank solvency of new style central banking, under which the central bank buys risky assets. Benigno and Nisticò (2020) investigate under what circumstances unconventional open-market operations by the central bank are non-neutral, and find that this crucially depends on the tax policy of the fiscal authority and the remittance policy of the central bank. My paper does not feature central bank insolvency, as the central bank's remittance policy and fiscal supoort in case of losses ensure that central bank net worth is constant in real terms period by period. In addition, the tax policy is such that it guarantees intertemporal solvency of the government budget constraint by following a rule in the spirit of Bohn (1998). Instead, the real effects from money-financed stimuli arise in my model because Ricardian equivalence is broken when financial intermediaries' incentive compatibility constraint becomes binding.

My paper is also related to the literature in which the policy rate does not coincide with the nominal interest rate that households face when deciding how much to save and how much to spend (Benigno and Benigno, 2021; Diba and Loisel, 2021; Piazzesi et al., 2021). In Benigno and Benigno (2021), the distinction between the policy rate and the nominal interest rate households face arises because of a reserve-requirement that forces intermediaries to (partially) collateralize deposits with central bank reserves. In Diba and Loisel (2021), central bank reserves allow commercial banks to expand lending to the real economy, as a result of which reserves reduce firms' borrowing costs. Therefore, both Benigno and Benigno (2021) and Diba and Loisel (2021) feature an interest rate on reserves that is below the interest rate that determines households' consumption-savings decision. Another similarity with my model is that the central bank simultaneously controls the interest rate on reserves and the size of the monetary base. However, my model differs in three dimensions. First, in my model there is no lending by financial intermediaries to the real economy. Second, the mechanism through which the interest rate on reserves ends up being below that on deposits is different in my model, as reserves directly relax intermediaries' incentive compatibility, a constraint that is absent in Benigno and Benigno (2021) and Diba and Loisel (2021). Finally, the focus of my paper is on the effectiveness of fiscal stimuli.

Next, I will describe the baseline model version in Section 2, and describe the accompanying calibration of the model in Section 3. The results are explained in Section 4, whereas Section 5 discusses the results and several robustness checks. Finally, Section 6 concludes.

2 Model

2.1 The Government

2.1.1 Fiscal Authority

The fiscal authority raises revenue from lump sum taxes $P_t\tau_t$, nominal central bank dividends D_t^{cb}, and issuance of government bonds $q_t^b B_t$, where q_t^b denotes the bond price, B_t the stock of nominal government debt, and P_t the price level of final goods. These government bonds have a flexible maturity structure as in Woodford (1998, 2001).[8] A bond acquired in period $t-1$ pays a nominal coupon x_c in period t, which exponentially declines afterwards at rate $1-\rho$: the coupon equals $(1-\rho)\,x_c$ in period $t+1$, $(1-\rho)^2\,x_c$ in period $t+2$, etc. As a result, the price of a bond issued in period $t-1$ is traded at a price $(1-\rho)\,q_t^b$ in period t,

[8] The average duration of the bonds is given by: $\frac{\sum_{j=1}^{\infty} j\beta^{j-1}(1-\rho)^{j-1}x_c}{\sum_{j=1}^{\infty}\beta^{j-1}(1-\rho)^{j-1}x_c} = \frac{1}{1-\beta(1-\rho)}$.

where q_t^b is the price of a bond issued in period t. Therefore, the nominal return $r_t^{n,b}$ in period t on a bond acquired in period $t-1$ is equal to:

$$1 + r_t^{n,b} = \frac{x_c + (1-\rho)\, q_t^b}{q_{t-1}^b}. \tag{1}$$

In that case, the real return r_t^b on bonds is given by:

$$1 + r_t^b = \frac{x_c + (1-\rho)\, q_t^b}{\pi_t q_{t-1}^b} = \frac{1 + r_t^{n,b}}{\pi_t}, \tag{2}$$

where $\pi_t \equiv P_t/P_{t-1}$ denotes the gross inflation rate of final goods. The revenues of the fiscal authority raises are used to finance outstanding nominal liabilities on bonds $\left(1 + r_t^{n,b}\right) q_{t-1}^b B_{t-1}$, and government purchases $P_t g_t$. Therefore, the nominal government budget constraint is equal to:

$$q_t^b B_t + P_t \tau_t + D_t^{cb} = P_t g_t + \left(1 + r_t^{n,b}\right) q_{t-1}^b B_{t-1},$$

Division by the price level of the final good P_t delivers the government budget constraint in real terms:

$$q_t^b b_t + \tau_t + d_t^{cb} = g_t + \left(1 + r_t^b\right) q_{t-1}^b b_{t-1}, \tag{3}$$

where variable $x_t \equiv X_t/P_t$. Government purchases g_t are given by:

$$\log\left(g_t/\bar{g}\right) = \rho_g \log\left(g_{t-1}/\bar{g}\right) + \varepsilon_{g,t}, \tag{4}$$

where $\bar{g}$ denotes steady state government spending. Finally, lump sum taxes τ_t follow a process that guarantees solvency of the intertemporal government budget constraint (Bohn, 1998):

$$\tau_t = \bar{\tau} + \psi_b \left(b_{t-1} - \bar{b}\right) - \kappa_\tau \tilde{\tau}_t, \tag{5}$$

where $\tilde{\tau}_t$ is given by:

$$\tilde{\tau}_t = \rho_\tau \tilde{\tau}_{t-1} + \varepsilon_{\tau,t}. \tag{6}$$

2.1.2 Central Bank

The central bank acquires nominal government bonds $S_t^{b,cb}$ at a price q_t^b, which are financed by nominal central bank net worth N_t^{cb}, non-interest-paying nominal money M_t^C, and interest-paying nominal reserves M_t^R:

$$P_t^{cb} \equiv q_t^b S_t^{b,cb} = N_t^{cb} + M_t^C + M_t^R,$$

where P_t^{cb} denotes nominal central bank assets. Division by the price level of the final good P_t gives the central bank balance sheet constraint in real terms:

$$p_t^{cb} \equiv q_t^b s_t^{b,cb} = n_t^{cb} + m_t^C + m_t^R, \tag{7}$$

In line with reality, the central bank has full control over the size of its balance sheet, which I assume to be equal to previous period nominal assets in normal times: $P_t^{cb} = P_{t-1}^{cb}$. Therefore, central bank assets in terms of the price level are equal to $p_t^{cb} = p_{t-1}^{cb}/\pi_t$. However, the central bank has the possibility to finance additional government purchases or a tax cut in case of a fiscal stimulus. It does so by buying the bonds that are issued to finance the additional purchases $g_t - \bar{g}$ or $\tilde{\tau}_t$. I assume that these additional bonds are permanently retained on the central bank's balance sheet (in nominal terms). Therefore, central bank assets (in terms of the price level of final goods P_t) are given by:

$$p_t^{cb} = \frac{p_{t-1}^{cb}}{\pi_t} + \kappa_g \left(g_t - \bar{g}\right) + \kappa_\tau \tilde{\tau}_t. \tag{8}$$

Therefore, an expansion in government spending is debt-financed when $\kappa_g = 0$, and it is money-financed when $\kappa_g = 1$. Similarly, a tax cut is debt-financed when $\kappa_\tau = 0$, and money-financed when $\kappa_\tau = 1$.[9] I assume that the central bank ensures

[9] In most contemporary advanced economies, central banks cannot openly act as fiscal principals (Buiter, 2014). This implies that the central bank can not make transfer payments or pay overt subsidies to the fiscal authority. Therefore, the only way to money-finance a fiscal stimulus is to acquire the additional government bonds from the stimulus, and permanently retain them on the central bank's balance sheet sheet, see Buiter (2014) page 32-33.

that its net worth in real terms n_t^{cb} remains constant across time:

$$n_t^{cb} = \bar{n}^{cb}. \tag{9}$$

The central bank achieves a constant net worth by paying out dividends to the fiscal authority. Before explaining how central bank dividends are determined, let me observe that by controlling the size of its balance sheet p_t^{cb} and the amount of central bank net worth n_t^{cb}, the central bank also controls the monetary base $m_t^B \equiv m_t^C + m_t^R$. Observe, however, that the central bank has no control over the composition between non-interest-paying money m_t^C and interest-paying reserves m_t^R. Instead, these are endogenously determined by the demand for money from households and the demand for reserves from financial intermediaries to be defined below. However, since central bank net worth is constant in real terms, a money-financed fiscal stimulus will entirely financed through an expansion of the monetary base m_t^B.

The central bank pays the nominal interest rate $r_t^{n,r}$ on reserves. This nominal interest rate is given by the maximum of the interest rate $r_t^{n,T}$ prescribed by the Taylor-rule and zero (in case of a negative Taylor rule):

$$r_t^{n,r} = \max\left\{0, r_t^{n,T}\right\}, \tag{10}$$

where $r_t^{n,T}$ is given by:

$$r_t^{n,T} = \bar{r}^{n,T} + \kappa_\pi \left(\pi_t - \bar{\pi}\right) + \kappa_y \log\left(y_t/y_{t-1}\right). \tag{11}$$

The relation between the nominal interest rate on reserves $r_{t-1}^{n,r}$ and the real return on reserves ex post r_t^r is given by:

$$1 + r_t^r = \frac{1 + r_{t-1}^{n,r}}{\pi_t}, \tag{12}$$

Next, I define the central bank's nominal net worth before dividend payments N_t^{cb*}, which is equal to the return on its assets minus the return on its liabilities:

$$N_t^{cb*} = \left(1 + r_t^{n,b}\right) q_{t-1}^b S_{t-1}^{b,cb} - \left(1 + r_{t-1}^{n,r}\right) M_{t-1}^R - M_{t-1}^C.$$

Division by the price level of the final good P_t gives the central bank's net worth before dividend payments in real terms:

$$n_t^{cb*} = \left(1 + r_t^b\right) q_{t-1}^b s_{t-1}^{b,cb} - \left(1 + r_t^r\right) m_{t-1}^R - \frac{m_{t-1}^C}{\pi_t}. \tag{13}$$

Given the expression for the central bank's net worth before dividend payments (13), we can infer that central bank net worth after dividend payments n_t^{cb} is equal to its steady state value $\bar{n}^{cb}$ when real dividend payments d_t^{cb} are equal to the central bank's net real profits (Hall and Reis, 2015):

$$d_t^{cb} \equiv n_t^{cb,*} - \bar{n}^{cb} \quad = \quad \left(r_t^b - r_t^r\right) p_{t-1}^{b,cb} + \frac{r_{t-1}^{n,r} m_{t-1}^C}{\pi_t} + r_t^r \bar{n}^{cb}, \tag{14}$$

where I susbtituted equation (13) and the balance sheet constraint of the central bank (7) to eliminate m_t^R. Hence, we see from equation (14) that an expansion of the size of the central bank's balance sheet p_{t-1}^{cb} will increase central bank dividends as along as $r_t^b > r_t^r$. I will prove in Section 2.3 that the expected value of this return difference will always be larger than or equal to zero in my model, i.e. $r_t^b \geq r_t^r$.

2.2 Households

There is a continuum of households $j \in [0, 1]$ that aim to maximize the sum of current and discounted future utility:

$$E_t \left\{ \sum_{s=0}^{\infty} \beta^s \xi_{t+s} \left[\frac{c_{j,t+s}^{1-\sigma_c} - 1}{1 - \sigma_c} - \chi_h \frac{h_{j,t+s}^{1+\varphi}}{1+\varphi} + \chi_m \frac{\left(m_{jt+s}^C\right)^{1-\rho_m} - 1}{1 - \rho_m} \right] \right\}$$

where $c_{j,t}$ denotes consumption, $h_{j,t}$ labor supply, $m_{j,t}^C$ households' holdings of non-interest-paying money balances (in terms of the price level P_t), and ξ_t denotes a preference shock. Households obtain income from providing labor $h_{j,t}$ at a nominal wage rate W_t, repayment of nominal government bonds $S_{j,t-1}^{b,h}$ with net nominal return $r_t^{n,b}$, repayment of nominal deposits $D_{j,t-1}$ with net nominal interest rate $r_{t-1}^{n,d}$, non-interest-paying nominal money $M_{j,t}^C$, and nominal profits $\Omega_{j,t}$ from the firms they own. Household income is spent on consumption $c_{j,t}$ which is acquired at the price level P_t of the final good, lump sum taxes $P_t \tau_{j,t}$, nominal government bonds $S_{j,t}^{b,h}$, nominal deposits $D_{j,t}$, non-interest paying nominal money $M_{j,t}^{C}$, and adjustment costs from bond holdings $P_t \frac{1}{2}\kappa_b \left(\frac{S_{j,t}^{b,h}}{P_t} - \hat{s}_{b,h}\right)^2$. This gives rise to the following budget constraint:

$$\begin{aligned} P_t c_{j,t} \quad &+ \quad P_t \tau_{j,t} + q_t^b S_{j,t}^{b,h} + D_{j,t} + M_{j,t}^C + P_t \frac{1}{2}\kappa_b \left(\frac{S_{j,t}^{b,h}}{P_t} - \hat{s}_{b,h}\right)^2 = W_t h_{j,t} \\ &+ \quad \left(1 + r_t^{n,b}\right) q_{t-1}^b S_{j,t-1}^{b,h} + \left(1 + r_{t-1}^{n,d}\right) D_{j,t-1} + M_{j,t-1}^C + \Omega_{j,t}. \end{aligned} \tag{15}$$

Division by the price level P_t results in the budget constraint in real terms:

$$\begin{aligned} c_{j,t} + \tau_{j,t} + q_t^b s_{j,t}^{b,h} + d_{j,t} + m_{j,t}^C + \frac{1}{2}\kappa_b \left(s_{j,t}^{b,h} - \hat{s}_{b,h}\right)^2 \quad &= \quad w_t h_{j,t} + \left(1 + r_t^b\right) q_{t-1}^b s_{j,t-1}^{b,h} \\ &+ \quad \left(1 + r_t^d\right) d_{j,t-1} + \frac{m_{j,t-1}^C}{\pi_t} + \omega_{j,t}, \end{aligned} \tag{16}$$

where the net real return on deposits r_t^d is given by:

$$1 + r_t^d = \frac{1 + r_{t-1}^{n,d}}{\pi_t}, \tag{17}$$

The resulting first order conditions are standard, and can be found in Appendix A.1. Observe, however, that the policy rate of the central bank (10) does not show up in households' optimization problem. Therefore, the central bank cannot directly influence households' consumption-savings decision (Benigno and Benigno, 2021).

2.3 Financial intermediaries

Financial intermediaries are financed by net worth $n_{j,t}$ and deposits $d_{j,t}$, which finance central bank reserves $m_{j,t}^R$ and (long-term) government bonds $s_{j,t}^{b,f}$ that are acquired at price q_t^b. The balance sheet is therefore given by:

$$q_t^b s_{j,t}^{b,f} + m_{j,t}^R = n_{j,t} + d_{j,t}. \tag{18}$$

Government bonds acquired in period $t-1$ pay a net real return r_t^b in period t, reserves pay a net real return r_t^r, while deposits pay a net real return r_t^d. Net worth in period t is therefore given by:

$$n_{j,t} = \left(1 + r_t^b\right) q_{t-1}^b s_{j,t-1}^{b,f} + \left(1 + r_t^r\right) m_{j,t-1}^R - \left(1 + r_t^d\right) d_{j,t-1}. \tag{19}$$

At the beginning of period $t+1$, there is an exogenous probability $1-\sigma$ that intermediary j will have to exit the financial sector, in which case intermediary's net worth is paid out to households as dividends (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011). Therefore, the continuation value $V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right)$ of intermediary j is given by:

$$V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) = E_t\left\{\beta\Lambda_{t,t+1}\left[\left(1-\sigma\right) n_{j,t+1} + \sigma V\left(s_{j,t}^{b,f}, m_{j,t}^R, d_{j,t}\right)\right]\right\}, \tag{20}$$

Following Gertler and Kiyotaki (2010); Gertler and Karadi (2011), financial intermediaries are subject to an incentive compatibility constraint, which implies that intermediaries' continuation value must in equilibrium be larger or equal to the funds that can be diverted by intermediaries:

$$V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) \geq \lambda_b q_t^b s_{j,t}^{b,f} - \lambda_m m_{j,t}^R. \tag{21}$$

The first term on the right hand side of the constraint is familiar from Gertler and Kiyotaki (2010); Gertler and Karadi (2011), and denotes the effective funds that can be diverted by bankers. The second term implies that central bank reserves alleviate the incentive compatibility constraint, everything else equal (Gertler and Kiyotaki, 2010), which can be motivated in the following way.[10] Since the central bank can fully monitor the reserves, these reserves cannot be diverted by intermediaries and can therefore be used to reimburse depositors in case the intermediary decides to divert assets. Therefore, the larger intermediaries' reserve balances, the more likely it becomes that depositors can be fully repaid in case of diversion.

[10] In Gertler and Kiyotaki (2010), discount window lending by the central bank to financial intermediaires directly relaxes intermediaires' incentive compatibility constraint. Central bank funding in Gertler and Kiyotaki (2010), however, is a liability from the perspective of financial intermediaires, whereas my central bank reserves are an asset from the perspective of financial intermediaries.

Financial intermediaries are interested in maximizing the continuation value (20), subject to the balance sheet constraint (18), the law of motion for net worth (19), and the incentive compatibility constraint (21). I show in Appendix A.2 that the first order conditions for bonds, reserves, and deposits, respectively, are given by:

$$E_t\left\{\beta\Lambda_{t,t+1}\left[1-\sigma+\sigma\chi_{t+1}\right]\left(r^b_{t+1}-r^d_{t+1}\right)\right\} = \lambda_b\left(\frac{\mu_t}{1+\mu_t}\right), \tag{22}$$

$$E_t\left\{\beta\Lambda_{t,t+1}\left[1-\sigma+\sigma\chi_{t+1}\right]\left(r^d_{t+1}-r^r_{t+1}\right)\right\} = \lambda_m\left(\frac{\mu_t}{1+\mu_t}\right), \tag{23}$$

$$E_t\left\{\beta\Lambda_{t,t+1}\left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r^d_{t+1}\right)\right\} = \frac{\chi_t}{1+\mu_t}, \tag{24}$$

where χ_t denotes the Lagrangian multiplier on intermediary j's balance sheet constraint (18) while μ_t denotes the Lagrangian multiplier on the incentive compatibility constraint (21). The first order conditions for bonds (22) and deposits (24) are relatively standard and can be found in Gertler and Karadi (2011, 2013).

The first order condition for reserves (23), however, is not standard and therefore requires more explanation. We can infer from the left hand side of the equation that the return on reserves will be below that on deposits if the incentive compatibility constraint is binding ($\mu_t > 0$), and therefore the interest rate set by the central bank does not coincide with that faced by households (Benigno and Benigno, 2021). As a result of this return difference, an additional unit of reserves decreases intermediaries' expected net worth, as it is financed by an additional unit of deposits at the margin. However, intermediaries are willing to incur losses on these reserves, as they alleviate the incentive compatibility constraint (21).

Also observe that the return on reserves is dominated (in expectation) by the return on government bonds. To see this, observe from the first order condition for government bonds (22) that the return on deposits is dominated by the return on bonds. Since the return on reserves is dominated by the return on deposits, we can immediately conclude that the return on reserves is dominated by the return on bonds. Therefore, reserves in my model capture an essential property of money according to Buiter (2014), namely that intermediaries are willing to hold reserves even if the return on them is dominated by other non-monetary assets.

A final observation is that a binding incentive compatibility constraint is a situation in which an expansion of the central bank balance sheet (by acquiring additional government bonds) increases (expected) central bank dividends, see equation (14), since the (expected) return from an additional unit of bonds is above the return on an additional unit of reserves.

Next, I show in Appendix A.2 that financial intermediaries' incentive compatibility constraint (21) can be rewritten with the help of first order conditions (22) - (24) in the following way:

$$\chi_t n_{j,t} = \lambda_b q_t^b s_{j,t}^{b,f} - \lambda_m m_{j,t}^R. \tag{25}$$

As is well known from Gertler and Kiyotaki (2010); Gertler and Karadi (2011), this implies that the size of intermediaries' bond holdings are limited by the amount of net worth.

At the beginning of period t, a fraction $1-\sigma$ of bankers has to leave the financial sector, and is replaced by a member from the same family (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011). Each new banker receives a starting net worth, which is equal to $\chi_b n_{t-1}$ after aggregation. Therefore, the law of motion for aggregate net worth given by:

$$n_t = \sigma \left[\left(1 + r_t^b\right) q_{t-1}^b s_{t-1}^{b,f} + \left(1 + r_t^r\right) m_{t-1}^R - \left(1 + r_t^d\right) d_{t-1} \right] + \chi_b n_{t-1}, \tag{26}$$

2.4 Production sector

The production sector is modeled as in Galí (2020b), who employs a standard New Keynesian production structure with price-stickiness a la **?**. In this model, intermediate goods producers operate using a production function that is concave in labor:

$$y_{i,t} = z_t h_{i,t}^{1-\alpha}, \tag{27}$$

where z_t denotes productivity, which follows a lognormal AR(1) process. Intermediate goods producers sell their goods to retail goods producers at a relative price ζ_t (expressed in terms of the price P_t of the final good), and hire labor in a perfectly competitive labor market at a nominal wage rate W_t. Therefore, the first order condition for labor is given by:

$$w_t = (1-\alpha)\,\zeta_t z_t h_{i,t}^{-\alpha}, \tag{28}$$

where $w \equiv W_t/P_t$.

Retail goods producer $f \in [0,1]$ acquires intermediate goods, which it transforms into a unique retail good $y_{f,t}$ using a one-for-one production technology $y_{f,t} = y_{i,t}$. Retail good f is a unique product, which provides retail goods producer f with a monopoly position, and therefore with the power to set the price $P_{f,t}$ for retail good f. However, since final goods producers purchase from all retail goods producers using a CES production function, retail goods producers operate under monopolistic competition. Therefore, they maximize expected discounted future profits, subject to the demand curve $y_{f,t} = (P_{f,t}/P_t)^{-\epsilon}\,y_t$, where y_t is aggregate demand for final goods, and ϵ the constant elasticity of substitution between two retail goods. Following **?**, however, each retail goods producers faces an exogenous probability ψ_p that he or she will not be able to change the price of retail goods next period.

Final goods producers operate in a perfectly competitive market. Therefore, they take prices of retail goods and final goods as given, as well as aggregate demand for final goods. As a result, each final good producer only has to choose how many retail goods $y_{f,t}$ to purchase from each retail goods producer.

2.5 Market clearing & equilibrium

The market for government bonds clears when the supply of bonds b_t is equal to the demand by financial intermediaries $s_t^{b,f}$, households $s_t^{b,h}$, and the central bank $s_t^{b,cb}$:

$$b_t = s_t^{b,f} + s_t^{b,h} + s_t^{b,cb}. \tag{29}$$

The aggregate resource constraint is given by:

$$y_t = c_t + g_t, \tag{30}$$

A definition of the resulting equilibrium can be found in the Appendix A.6.

3 Calibration

I solve the model using a first order perturbation around the steady state using the Dynare software (Adjemian et al., 2011). The calibration largely follows Galí (2020b), with the calibration targets displayed in Table 1. I set households' relative risk aversion $\sigma_c = 1$, and follow Galí (2020b) for the subjective discount factor β, the invere Frisch elasticity φ, and the semi-elasticity of demand η. As Galí (2020b) does not report steady state labor supply, I set it equal to 1/3. I also have to choose a value for κ_b, the coefficient in front of households' quadratic adjustment costs, which I set equal to 0.001, implying that households' marginal costs from changing bond holdings is relatively small. Galí (2020b) has no adjustment costs from bond holdings, but households are the only agents holding government debt in his model, while in my model bonds are also held by financial intermediaries and the central bank. Therefore, I need adjustment costs in order to pin down households' holdings of government bonds in equilibrium. However, since Galí (2020b) has no adjustment costs, I assume that households' adjustment costs are small on the margin. Subsequently, I adjust the parameter $\hat{s}_{b,h}$ such that households hold 80% of government bonds in steady state, which implies that 20% of bonds are held by financial intermediaries and the central bank, as the central bank and commercial banks with central bank reserves typically hold a minority of outstanding government bonds. I will investigate in Section 4.4 the case where all government debt is held by financial intermediaries and the central bank.

I set the average number of periods during which bankers operate equal to six years or 24 quarters, which implies that the probability σ of bankers continuing to operate is equal to 0.9583, a value in line with Gertler and Kiyotaki (2010); Gertler and Karadi (2011); Gertler and Kiyotaki (2015). I set the steady state spread between the return on bonds and deposits equal to 25 quarterly basis points, or 100 annual basis points following Gertler and Karadi (2011). I define what I call the 'adjusted' leverage ratio $\phi_t^{adj} \equiv \left(q_t^b s_{j,t}^{b,f} - \left(\frac{\lambda_m}{\lambda_b}\right) m_{j,t}^R \right) / n_{j,t}$, and set this adjusted leverage ratio equal to $\bar{\phi}^{adj} = 5$ in the steady state, which is in between the leverage ratio of four found in Gertler and Kiyotaki (2010); Gertler and Karadi (2011) and six in Gertler and Karadi (2013). Finally, I assume that the 'relaxation' rate λ_m at which an additional euro of reserves relaxes intermediaries' incentive compatibility constraint (25) is half the effective diversion rate λ_b at which intermediaries can effectively divert government bonds. I will perform a robustness check in Appendix C, where I employ alternative values for λ_m/λ_b.

I follow Galí (2020b) in setting the labor share $1-\alpha$, the Calvo probability of changing prices ψ_p, and the elasticity of substitution ϵ_p between different retail goods producers. I also adopt the value for steady state government debt as a fraction of steady state output, and the feedback ψ_b from the level of government debt on lump sum taxes in equation (5). In the baseline calibration I assume that government debt is short-term, which I capture by setting $\rho = 1$ and the coupon payment $x_c = 1$ in equation (2). In later sections I will consider long-term debt, for which I will set $\rho = 1/20$, and set the coupon payment $x_c = 0.01$, because ψ_b would have to increase to a number close to one for $x_c = 1$. I deviate from Galí (2020b) by setting steady state government spending over steady state output equal to $\bar{g}/\bar{y} = 0.2$, which is in line with the average amount of government spending in most advanced economies.

Just as in Galí (2020b), I assume that net inflation is equal to zero in the steady state, or equivalently that gross inflation is equal to $\bar{\pi} = 1$. Galí (2020b) allows the nominal interest rate to adjust such that $\pi_t = 1$ in every period under a debt-financed stimulus. In my model, I am not only capable of setting $\pi_t = 1$ under a debt-financed stimulus, but unlike Galí (2020b) I can also set $\pi_t = 1$ under a money-financed stimulus. In the main text, however, I employ a Taylor-rule (11) in determining the nominal interest rate on reserves (10). The inflation and output feedback parameters are set at values conventional in the New Keynesian literature, as well as the interest smoothing parameter ρ_r and the standard deviation of the monetary policy shock σ_r, which is set to 25 basis points. I discuss in Section 5 how the results are affected by implementing $\pi_t = 1$.

Galí (2020b) assumes that non-interest-paying money balances are equal to 1/3 of steady state consumption. My monteary base, however, not only consists of non-interest-paying money, but also of interest-paying reserves. Therefore, I set steady state central bank assets $\bar{p}^{cb}$ (as a fraction of quarterly output $\bar{y}$) equal to 1/3 of steady state consumption $\bar{c}$ as a fraction of quarterly output $\bar{y}$. Therefore, I have that $\bar{p}^{cb}/\bar{y} = 1/3\left(1 - \frac{\bar{g}}{\bar{y}}\right)$. In line with reality, the central bank has a positive net worth $\bar{n}^{cb}$, which I set equal to 1% of total central bank assets. Finally, I set steady state non-interest-paying money $\bar{m}^C$ equal to 10% of quarterly steady state output $\bar{y}$, which results in steady state interest-paying reserves being equal to 1.63 times non-interest-paying money balances. Such a number seems reasonable given the Federal Reserve monetary base in Figure 1, but I check in Section 5 and Appendix A.8 that my results are not driven by this particular choice.

The calibration of the autoregressive process for government spending follows Galí (2020b), while the calibration for the preference shock ξ_t ensures that the preference shock pushes the economy for several periods to the Zero Lower Bound (ZLB).

An overview with the calibration targets can be found in Table 1, while an overview with the resulting deep parameter values can be found in Appendix A.7.

4 Results

In this section I follow Galí (2020b) and investigate the macroeconomic impact of fiscal stimuli, which consist of cuts in lump sum taxes $\tilde{\tau}_t$ and increases in government spending g_t. I distinguish between a debt-financed stimulus for which $\kappa_\tau = 0$ and $\kappa_g = 0$ in equation (8), and a money-financed stimulus for which $\kappa_\tau = 1$ (tax cut) or $\kappa_g = 1$ (government spending).

4.1 Impact of a money-financed stimulus in normal times

I start by comparing a debt-financed and money-financed fiscal stimulus in nornal times, which I define as times in which intermediaries' incentive compatibility constraint (25) is not binding, i.e. $\mu_t = 0$. In that case, we see from the first order condition for reserves (23) that the return on reserves will be equal to that on deposits. We also see from the first order condition for government bonds (22) that the return on bonds is equal to the return on deposits. Therefore, we can conclude that the return on bonds will be equal to the return on reserves in equilibrium.

I follow Galí (2020b) and report the results of a fiscal stimulus that consists of decreasing the level of lump sum taxes (6) by 1% of steady state output on impact in Figure 2, and an increase in government spending (4) by 1% of steady

Parameter	Value	Definition
Households		
β	0.995	Discount rate
σ_c	1	Coefficient of relative risk-aversion
$\bar{h}$	1/3	Steady state labor supply
φ	5	Inverse Frisch elasticity
η	7	Semi-elasticity of money demand
κ_b	0.001	Coefficient HHs adjustment costs bond holdings
$\bar{s}^{b,h}/\bar{b}$	0.8	Steady state bond holdings HHs over total bonds
Financial intermediaries		
T	24	Average number of periods that banks operate
$E\left[\bar{r}^b - \bar{r}^d\right]$	0.0025	Spread between bonds and deposits
$\bar{\phi}^{adj}$	5	Adjusted leverage ratio
λ_m/λ_b	0.5	Relaxation rate reserves over diversion rate bonds
Goods producers		
α	0.25	1 - labor share
ψ_p	3/4	Probability of changing prices
ϵ_p	9	Elasticity of substitution
Fiscal policy		
$\bar{g}/\bar{y}$	0.2	Steady state gov't spending over GDP
$\bar{b}/\bar{y}$	2.4	60% of annual GDP
ψ_b	0.020	Tax feedback parameter from government debt
x_c	1	Coupon payment bonds
ρ	1	Maturity parameter bonds
Monetary policy		
$\bar{\pi}$	1	Steady state gross inflation rate
κ_π	1.500	Inflation feedback on nominal interest rate
κ_y	0.125	Output feedback on nominal interest rate
ρ_r	0.8	Interest rate smoothing parameter
$\bar{p}^{cb}/\bar{y}$	$1/3\left(1-\frac{\bar{g}}{\bar{y}}\right)$	Steady state CB assets over GDP
$\bar{n}^{cb}/\bar{p}^{cb}$	0.01	Steady state CB net worth over assets
$\bar{m}^C/\bar{y}$	0.1	Steady state non-interest-paying money over GDP
Autoregressive processes		
ρ_ξ	0.9	AR(1) parameter preference shock
ρ_g	0.5	AR(1) parameter government spending shock
σ_ξ	0.05	Standard deviation preference shock
σ_g	0.05	Standard deviation gov't spending shock
σ_r	0.0025	Standard deviation interest rate shock

Table 1: Calibration targets.

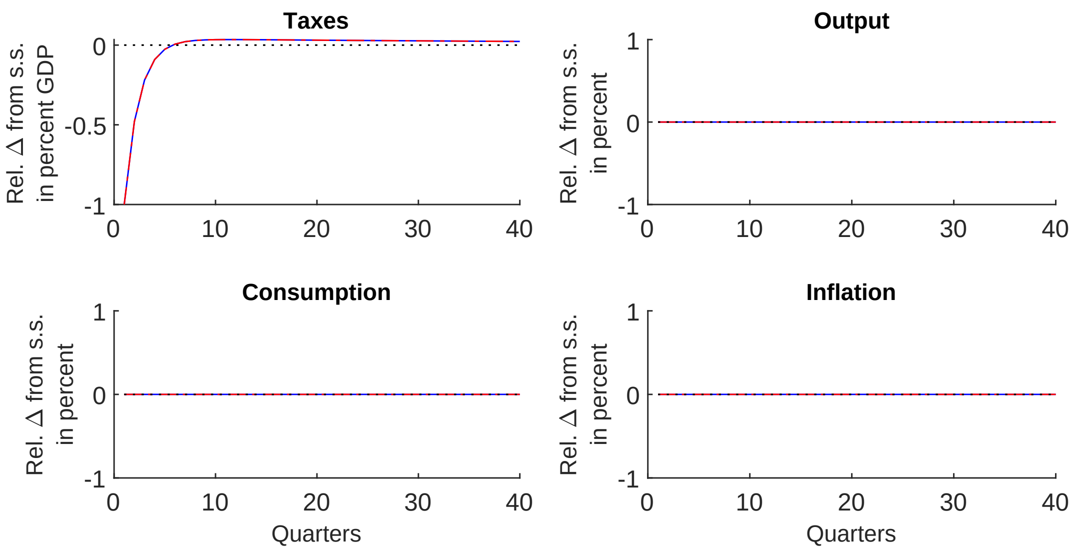
state output on impact in Figure 3. The blue, solid simulations correspond to a debt-financed stimulus, which is in both figures implemented by setting $\kappa_\tau = 0$ and $\kappa_g = 0$ in equation (8). The red, slotted simulations correspond to a money-financed stimulus, which is implemented in Figure 2 by setting $\kappa_\tau = 1$ and $\kappa_g = 0$, and in Figure 3 by setting $\kappa_\tau = 0$ and $\kappa_g = 1$.

In both figures we see that output, consumption, inflation, central bank dividends, and the nominal interest rate on reserves under a money-financed stimulus are exactly the same as under a debt-financed stimulus. The key difference is the fact that central bank assets permanently expand by 7% of steady state assets under a money-financed stimulus.

The intuition behind these results is the following: both under a debt-financed and a money-financed stimulus, the nominal interest rate on reserves is determined via an active Taylor rule (10), which in turn depends on inflation and output growth. Since the nominal interest rate on reserves is equal to that on deposits, households' savings decisions are unaffected by switching from a debt-financed stimulus to a money-financed stimulus. Therefore, households' demand for non-interest-paying money is the same under both stimuli, which implies that the money-financed fiscal stimulus is entirely financed through the creation of additional interest-paying reserves. Since the return on government bonds is equal to the return on reserves, the money-financed stimulus does not increase central bank dividends, see equation (14), as a result of which there is no effect on the net present value of future lump sum taxes (with respect to a debt-financed stimulus). Therefore, households' lifetime income is the same under a money-financed and a debt-financed stimulus, as a result of which the impact from a money-financed fiscal stimulus is zero (relative to a debt-financed stimulus).

These results form a striking contrast with Galí (2020b), who finds that a money-financed stimulus is much more effective in expanding output than a debt-financed stimulus. The results in Galí (2020b), however, are driven by the fact that the central bank only issues non-interest-paying money, whereas my monetary base consists of both non-interest-paying money as well as interest-paying reserves, which is in line with monetary policy operations since the Great Financial Crisis, see Figure 1. Therefore, the central bank in Galí (2020b) can either control the (non-interest-paying) money supply or the nominal interest rate, but not both.

Debt-financing vs. money-financing: tax cut, $\mu_t = 0$



(a)

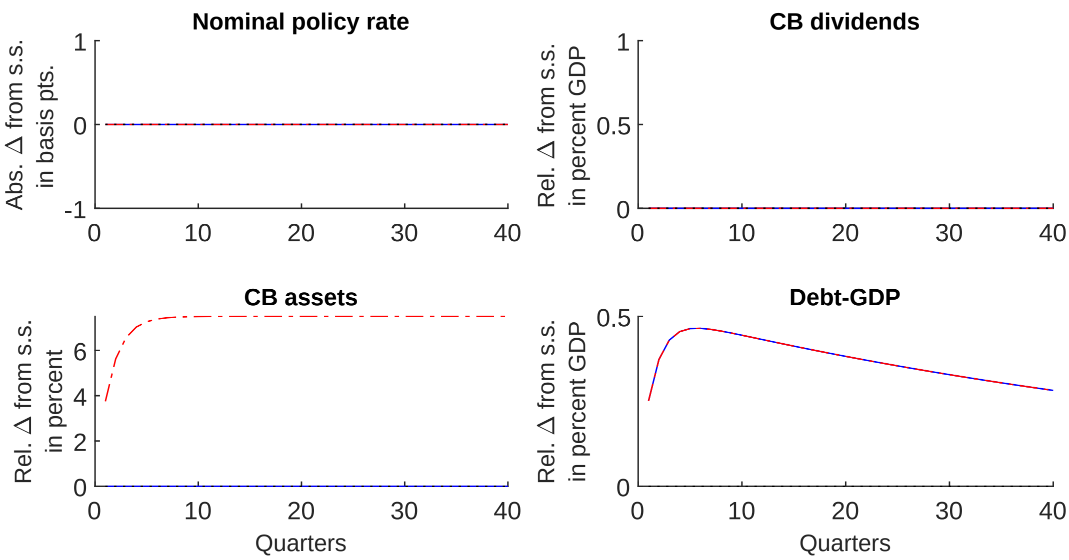
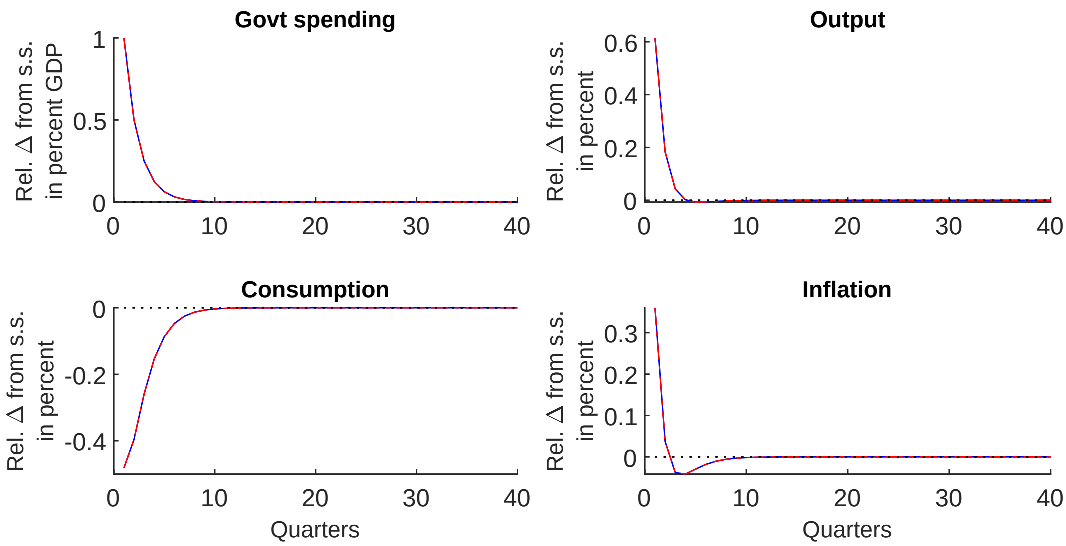


Figure 2: Impulse response functions for a tax cut shock of 1% of steady state output in normal times ($\mu_t = 0$). The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

Debt-financing vs. money-financing: government spending, $\mu_t = 0$



(a)

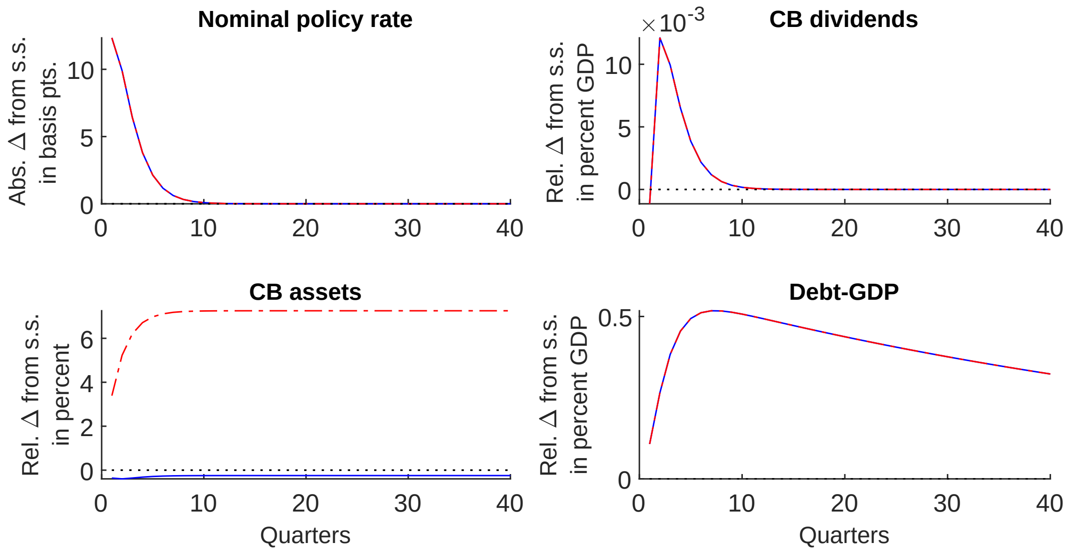


Figure 3: Impulse response functions for a government spending shock of 1% of steady state output in normal times ($\mu_t = 0$). The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

In that case, financing a fiscal stimulus by expanding the money supply implies that the nominal interest rate has to decrease to induce households to hold larger money balances in equilibrium. A lower nominal interest rate, in turn, expands consumption, as a result of which output increases (relative to a debt-financed stimulus, for which the nominal interest increases). This contrasts with my model, where the central bank simultaneously controls the nominal interest rate as well as the size of its balance sheet, which allows the central bank to control the nominal interest rate even in case of a money-financed government spending stimulus.

However, since the return on bonds and reserves are the same when intermediaries' incentive compatibility constraint (25) is not binding, my money-financed stimulus is effectively a debt-financed stimulus. Therefore, I will investigate in the next sections how my results change when the return on reserves is below that on government bonds, which happens when intermediaries' incentive compatibility constraint (25) is binding.

4.2 Impact of a money-financed stimulus in financial crises

Within my model, the return on reserves will be below that on bonds when financial intermediaries' incentive compatibility constraint (25) is binding ($\mu_t > 0$), which can be interpreted as times of financial crises (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011): we see from the first order condition for government bonds (22) that the return on bonds will be larger than the return on deposits, while we see from first order condition (23) that the return on reserves will be below that on deposits. As a consequence, the return on bonds will be above that on reserves. In such an environment, we see from equation (14) that switching from debt-financing to money-financing increases central bank dividends to the fiscal authority, which reduces the expected present discounted value of current and future taxes, everything else equal. Therefore, households' lifetime incomes increase, everything else equal, and a money-financed stimulus might be more effective than a debt-financed stimulus in financial crisis times. I will now investigate whether this is actually the case.

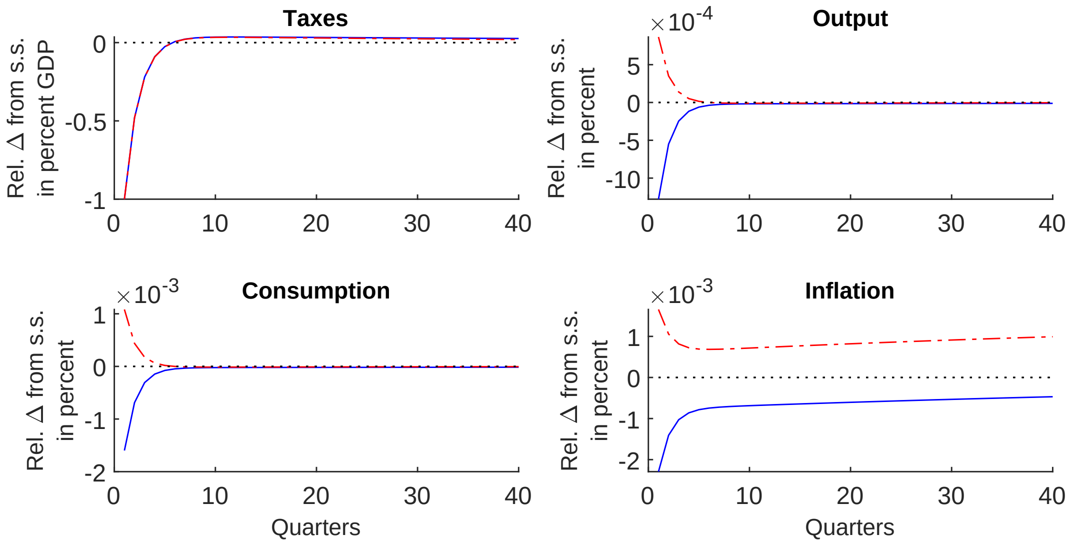
To do so, I first investigate in Figure 4 the results from the same tax cut as in Figure 2, but now intermediaries' incentive compatibility constraint (25) is binding. Again, the blue, solid line denotes a debt-financed tax cut ($\kappa_\tau = \kappa_g = 0$), whereas the red, slotted line denotes a money-financed tax cut ($\kappa_\tau = 1$ and $\kappa_g = 0$). Whereas a debt-financed tax cut has zero effect in Figure 2 and in Galí (2020b), we see that it negatively affects output and consumption in financial crisis times, although the effects are quantitatively small. Similarly to Galí (2020b), a money-financed tax cut has an expansionary effect, but the effects are an order of magnitude smaller.

Let me first discuss why a debt-financed tax cut has a negative effect in Figure 4: the decrease in taxes increases the supply of government bonds issued by the fiscal authority. Since intermediaries are balance-sheet-constrained (because of the binding incentive compatibility constraint (25)), they cannot perfectly elastically expand their holdings of government bonds, as a result of which Ricardian equivalence is broken. Therefore, in order for intermediaries to be willing to hold (some of) the additional bonds in equilibrium, the bond price must decrease relative to the case where the incentive compatibility constraint is not binding. As a result, the fiscal authority has to issue more bonds to finance a given sequence of expenditures, which raises the expected present discounted value of current and future lump sum taxes. Therefore, households' lifetime income decreases, as a result of which consumption decreases. Lower aggregate demand, in turn decreases inflation, as a result of which the nominal interest rate on reserves decreases.

Things are different when the tax cut is money-financed, because the expansion in central bank assets increases central bank dividends, which everything else equal decreases the expected present discounted value of current and future taxes. As a result, households' lifetime income increases, and aggregate demand expands. Consumption, output, and inflation increase as a consequence, which leads to higher interest rates on reserves and deposits.

Observe, however, that the quantitative effects are small: output increases by less than 0.001% on impact for a money-financed tax cut, which sharply contrasts with Galí (2020b), where a money-financed tax cut expands output by approximately 0.5% on impact. Whereas the ineffectiveness of a money-financed stimulus (relative to a debt-financed stimulus) in the previous section could be attributed to the fact that central bank dividends were the same as under a debt-financed stimulus, this is no longer the case in the current section, since the return on

Debt-financing vs. money-financing: tax cut



(a)

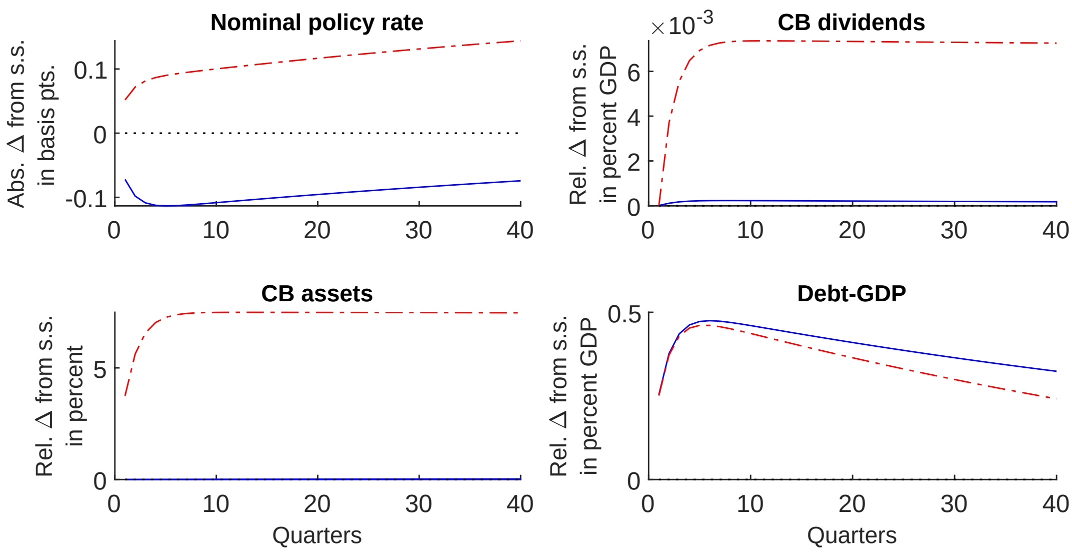


Figure 4: Impulse response functions for a tax cut shock of 1% of steady state output. The tax cut is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

reserves is below that on government bonds.

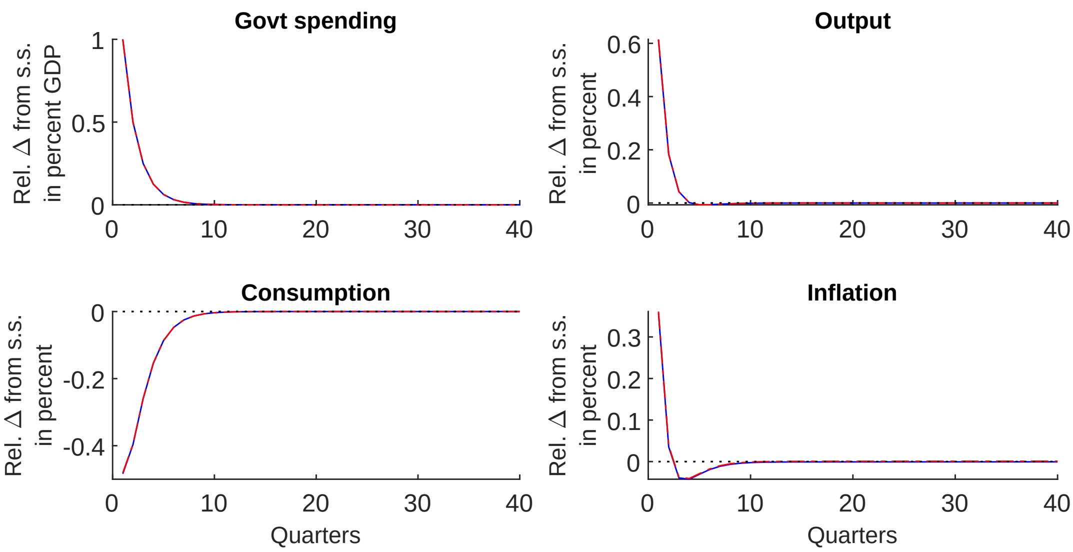
The difference with Galí (2020b) is that the central bank still controls the nominal interest rate on reserves. As a result, the extra demand resulting from a higher life-time income increases inflation. In response, the central bank raises interest rates with respect to a debt-financed stimulus, which induces households to reduce consumption, everything else equal. This is different in Galí (2020b), where the nominal interest rate decreases to ensure that households are willing to hold larger money balances in equilibrium. The resulting drop in interest rates expands consumption and output.

Higher interest rates also explain why central bank dividends increase by less than 0.01% of output for a money-financed stimulus (with respect to a debt-financed stimulus). First, the higher nominal interest rate decreases households' holdings of non-interest-paying money. Therefore, the tax cut is entirely financed by interest-paying reserves, whereas the Galí (2020b) tax cut is financed by non-interest-paying money (which substantially increases central bank dividends everything else equal). Second, the nominal interest rate on reserves increases with respect to the debt-financed stimulus, which also decreases central bank dividends, everything else equal.

Next, I report in Figure 5 the results of the same spending stimulus as in Figure 3, with the difference that intermediaries' incentive compatibility constraint (25) is binding. At first sight, it seems as if the effect of a money-financed stimulus is exactly the same as that of a debt-financed stimulus. Closer inspection, however, shows that there is a miniscule expansion in consumption and output. The mechanism behind the negligible expansion in consumption and output (with respect to a debt-financed stimulus) is the same as for the tax cut in Figure 4: because the central bank still controls the nominal interest rate on reserves, an increase in households' life-time income from a money-financed stimulus increases interest rates, whereas they decrease in Galí (2020b). And just as for a money-financed tax cut, the increase in households' life-time income (relative to a debt-financed spending stimulus) is much smaller, because the money-financed stimulus is financed by interest-paying reserves rather than non-interest-paying money in Galí (2020b).

Finally, I quantify the impact of the different fiscal stimuli by calculating the

Debt-financing vs. money-financing: government spending



(a)

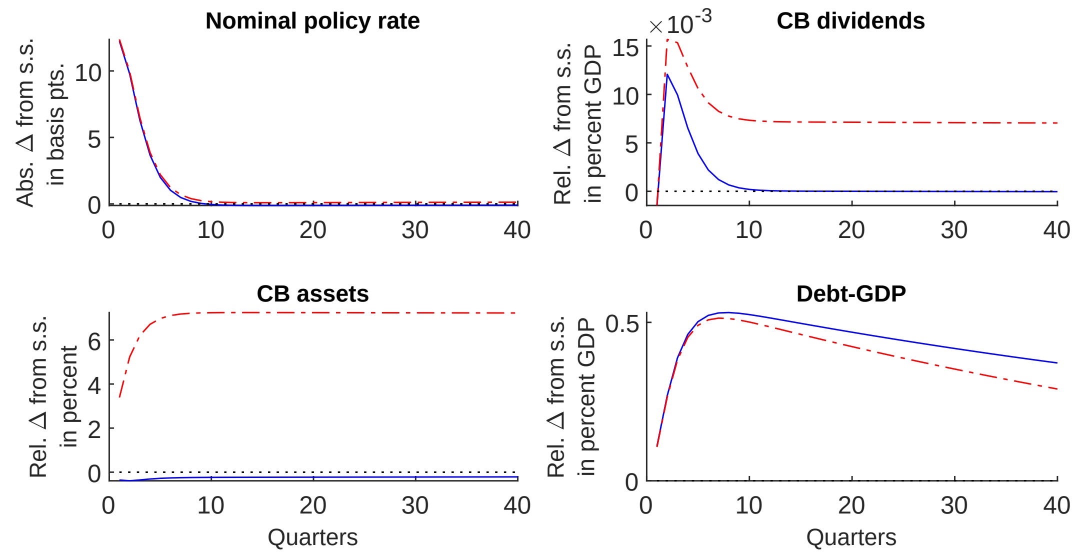


Figure 5: Impulse response functions for a government spending shock of 1% of steady state output in financial crisis times ($\mu_t > 0$). The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

cumulative fiscal multiplier μ using the same formula as in Galí (2020b):

$$\mu = \frac{\sum_{s=0}^{\infty} (y_{t+s} - \bar{y})}{\sum_{s=0}^{\infty} (x_{t+s} - \bar{x})}, \tag{31}$$

where $x \in \{g, \tilde{\tau}\}$, and g and $\tilde{\tau}_t$, respectively, are given by equation (4) and (6), respectively. The results are reported in Table 2.

The table confirms the results from the previous and the current section. First, we see that the multiplier for money-financed and debt-financed fiscal stimuli are equal when the incentive compatibility constraint (25) is not binding, and the interest rate on reserves is equal to that on bonds. Second, we see that the debt-financed multiplier decreases when the incentive compatibility constraint (25) is binding (with respect to the case where it is not binding), whereas the money-financed multiplier increases. Third, we see that the difference between the money-financed multiplier and the debt-financed multiplier is 0.0066 percentage points (= 0.0048 - - 0.0018) for a tax cut and 0.0065 percentage points (= 0.4133 - 0.4068) for a spending stimulus when the incentive compatibility constraint (25) is binding. This further shows that money-financed stimuli are hardly more effective than debt-financed stimuli when the central bank controls the nominal interest on reserves under a money-financed stimulus.

	Tax cut (D)	Tax cut (M)	Spending (D)	Spending (M)
Normal times	0	0	0.4091	0.4091
Fin. crisis	-0.0018	0.0048	0.4068	0.4133
Fin. crisis, LT debt	-0.0299	0.0499	0.3752	0.4550
Fin. crisis, LT debt, $s_t^{b,h} = 0$	-0.0846	-0.1236	0.2625	0.2235

Table 2: Table displaying the discounted cumulative dynamic multiplier (31) over the first 1,000 quarters for listed scenarios under a fiscal stimulus. (D) refers to a debt-financed stimulus, whereas (M) refers to a money-financed stimulus. 'LT' refers to long-term government debt. Finally, the incentive compatibility constraint (25) does not bind in normal times, while it is binding in financial crisis times.

4.3 Extension with long-term government debt

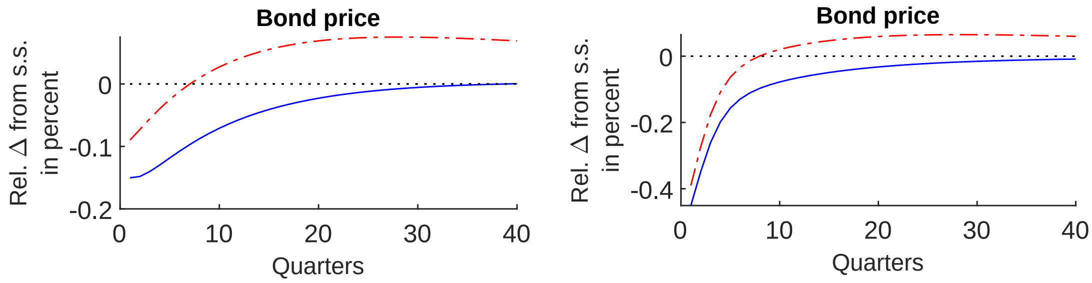
The previous section showed that even when the interest rate on reserves is below that on government bonds, money-financed fiscal stimuli are hardly more effective in expanding consumption and output than debt-financed stimuli. However, it is known from the Gertler and Kiyotaki (2010); Gertler and Karadi (2011) framework employed in this paper, that capital gains and losses on financial assets can be amplified when financial intermediaries' incentive compatibility constraint (25) is binding. Such capital gains and losses, in turn, have the potential to affect the effectiveness of fiscal stimuli: van der Kwaak and van Wijnbergen (2017), for example, show that an extension of the effective maturity of government debt causes the initial decrease in the price of government bonds to be amplified, thereby leading to even higher bond yields that further reduce the effectiveness of spending stimuli. However, such capital gains and losses were not possible in the previous sections, where the maturity of government debt was one period.

Therefore, I investigate in this section how the fiscal multiplier is affected by increasing the duration of government debt. Specifically, I set $\rho = 1/20$ and $x_c = 0.01$, see Section 3. The results can be found in Table 2, and the accompanying simulations in Appendix C.

We can draw three conclusions from Table 2. First, we see that extending the maturity of government bonds decreases the cumulative multiplier for debt-financed fiscal stimuli. Specifically, the multiplier for a debt-financed tax cut decreases from -0.0018 when government debt is short-term to -0.0299 when debt is long-term. Similarly, the multiplier for a debt-financed spending stimulus decreases from 0.4068 when government debt is short-term to 0.3752 when debt is long-term. As already alluded to above, this result is explained by an amplification of capital losses on government bonds, the possibility of which opens up when extending the maturity of government debt (van der Kwaak and van Wijnbergen, 2017): the initial decrease in the bond price as a result of the additional debt issue decreases the market value of intermediaries' existing bond holdings, which reduces intermediaries' net worth. Lower net worth, in turn, tightens intermediaries' incentive compatibility constraint (25), as a result of which bond prices decrease further. Therefore, net worth decreases even further, a second round effect that is absent when government debt is short-term. As a result, the government has to issue more debt with respect to the case where government debt is short-term, which increases the present discounted value of future taxes. In response, households decrease consumption with respect to the case with short-term debt, and output decreases as a result.

A second conclusion is that extending the duration of government bonds increases the cumulative multiplier for money-financed fiscal stimuli, where the multiplier for a money-financed tax cut increases from 0.0048 when government debt is short-term to 0.0499 when debt is long-term. Similarly, the multiplier for a money-financed spending stimulus increases from 0.4133 when government debt is short-term to 0.4550 when debt is long-term. The intuition behind this result is also driven by bond prices, see Figure 6: just as for the case of short-term debt, we have that bond prices increase, everything else equal, when the additional government bonds that finance the stimulus are acquired by an unconstrained central bank, a key mechanism behind the effectiveness of asset purchase programs (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011, 2013). Extending the duration of government debt amplifies the resulting capital gains on government bonds, as higher bond prices increase intermediaries' net worth, which in turn expands their capacity to hold additional government bonds. As a result, bond prices increase further, which leads to further increases in intermediaries' net worth, an effect that is absent when government debt is short-term.

Therefore, the capital losses on bonds under a debt-financed stimulus, and the capital gains under a money-financed stimulus increase the difference between the cumulative multiplier of money- and debt-financed fiscal stimuli when government debt is long-term to 0.0798 percentage points (=0.0499 - - 0.0299) for a tax cut, and to 0.0798 percentage points (=0.4550 - 0.3752) for a spending stimulus. These differences are larger than for the case of short-term debt, where the difference was 0.0066 percentage points for a tax cut, and 0.0065 percentage points for a spending stimulus. However, despite the fact that the difference between the multiplier under money-financed and debt-financed stimuli increases, it remains small with respect to Galí (2020b), where the difference is approximately 0.50 percentage points for a tax cut, and 0.85 percentage points for a spending stimulus. Therefore, it remains the case that whether or not the central bank controls the



(a) (b)

Figure 6: The left figure displays the impulse response function for the bond price in response to a tax cut shock of 1% of steady state output. The right figure displays the impulse response function to a government spending shock of 1% of steady state output. The fiscal stimuli are debt-financed for the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$.

nominal interest rate on reserves is crucial for the effectiveness of money-financed fiscal stimuli, even in the presence of long-term government debt.

4.4 Is a money-financed stimulus always more effective than a debt-financed stimulus?

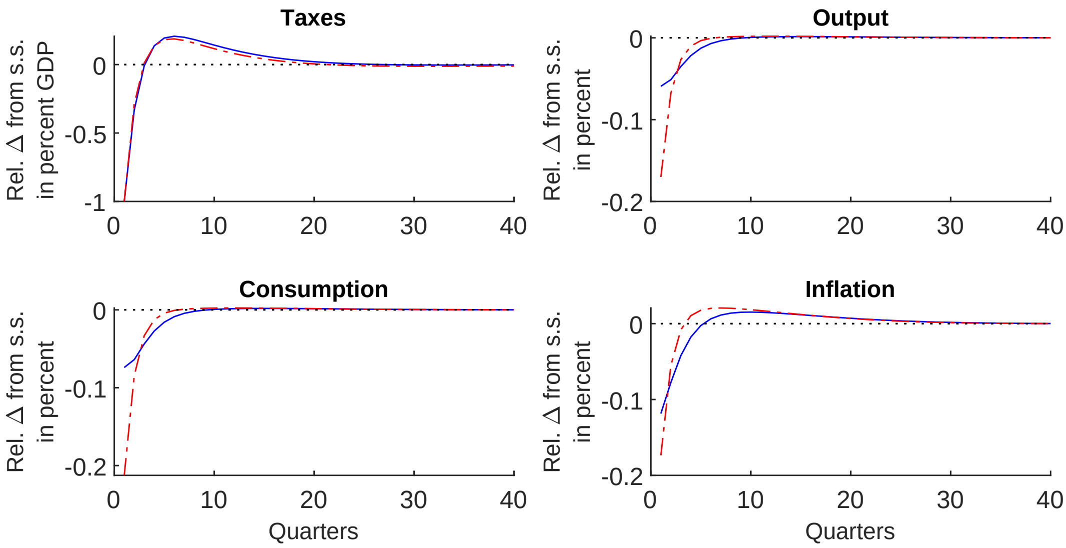
In the simulations thus far, we have seen that money-financed fiscal stimuli are always more effective than debt-financed fiscal stimuli. However, we can see from the first order condition for reserves (23) that the return on reserves will be below that on deposits when $\lambda_m > 0$ and intermediaries' incentive compatibility constraint (25) binds. In that case, financial intermediaries incur losses from holding central bank reserves, a feature which I explained more elaborately in Section 2.3. Therefore, money-financed fiscal stimuli negatively affect the net worth of balance-sheet-constrained financial intermediaries, everything else equal, because the accompanying expansion of central bank reserves increases intermediaries' losses from holding these reserves. Lower net worth, in turn, tightens intermediaries' incentive compatibility constraint (25), which leads to lower bond prices and higher bond yields, everything else equal. Therefore, this negative effect has the potential to offset the positive effect on bond prices from the unconstrained central bank financing the fiscal stimulus, a mechanism that was stressed in previous sections. As a result, there could be circumstances where a money-financed fiscal stimulus is less effective than a debt-financed stimulus.

We can see from the last row of Table 2, and from Figures 7 and 8 that this is the case when households have no access to the market for government bonds, and financial intermediaries have all privately-held government bonds on their balance sheet. Like the previous section, government debt is still long-term. Specifically, we see from Table 2 that the tax cut multiplier decreases from -0.0846 for a debt-financed stimulus to -0.1236 for a money-financed stimulus, which implies a decrease by 0.0390. Similarly, the spending multiplier decreases by 0.0390 from 0.2625 for a debt-financed stimulus to 0.2235 for a money-financed stimulus.

We see from Figures 7 and 8 that this is indeed caused by the fact that the bond price decreases by more on impact for a money-financed stimulus than for a debt-financed stimulus. The reason why the negative effect (from intermediaries holding more reserves) dominates is that when intermediaries already have large holdings of government bonds on their balance sheet, the central bank buying the additional bonds that are issued by the fiscal authority frees up relatively little balance sheet capacity, and therefore the positive effect on the bond price is relatively small. This is different from the situation in the previous sections, where households hold the majority of government debt. In that case, the additional balance sheet capacity that is freed up by the central bank buying the newly issued bonds from the stimulus is substantially larger as a fraction of intermediaries' existing holdings of government bonds, and therefore the positive effect on bond prices dominates the negative effect from intermediaries having to hold more reserves in equilibrium.

In addition to higher bond yields with respect to a debt-financed stimulus, the tightening of the incentive compatibility constraint under a money-financed stimulus also increases the spread between the interest rate on reserves and deposits, see the first order condition for reserves (23). As a result, we see from Figures 7 and 8 that the nominal interest rate on deposits under a money-financed fiscal stimulus is substantially higher than under a debt-financed stimulus, which leads to a shift from consumption to saving, everything else equal. As a result, we see that consumption under a money-financed stimulus is substantially below that under a debt-financed stimulus on impact, which leads to a drop in output with

Debt-financing vs. money-financing: tax cut, long-term bonds, $s_t^{b,h} = 0$



(a)

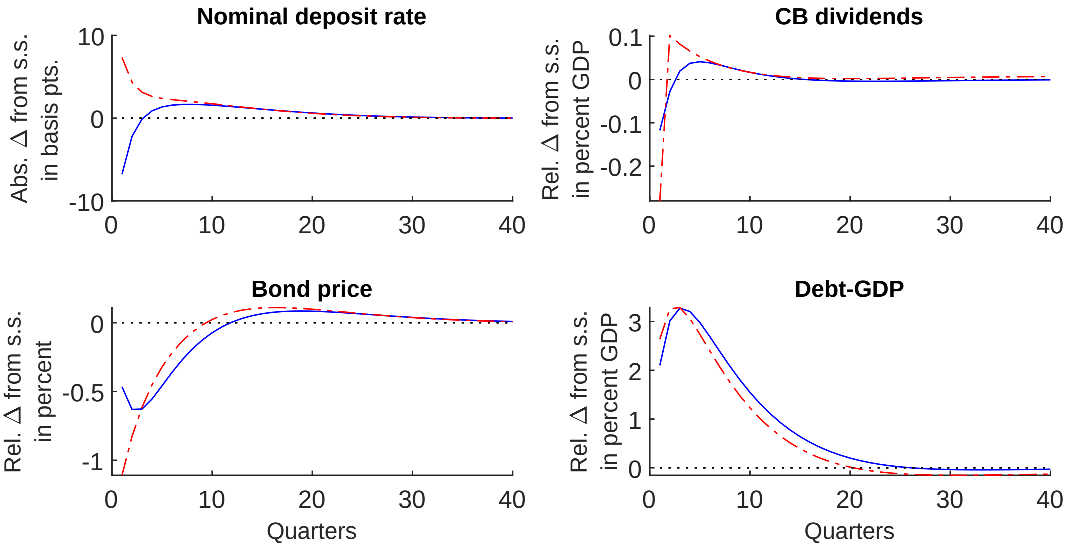
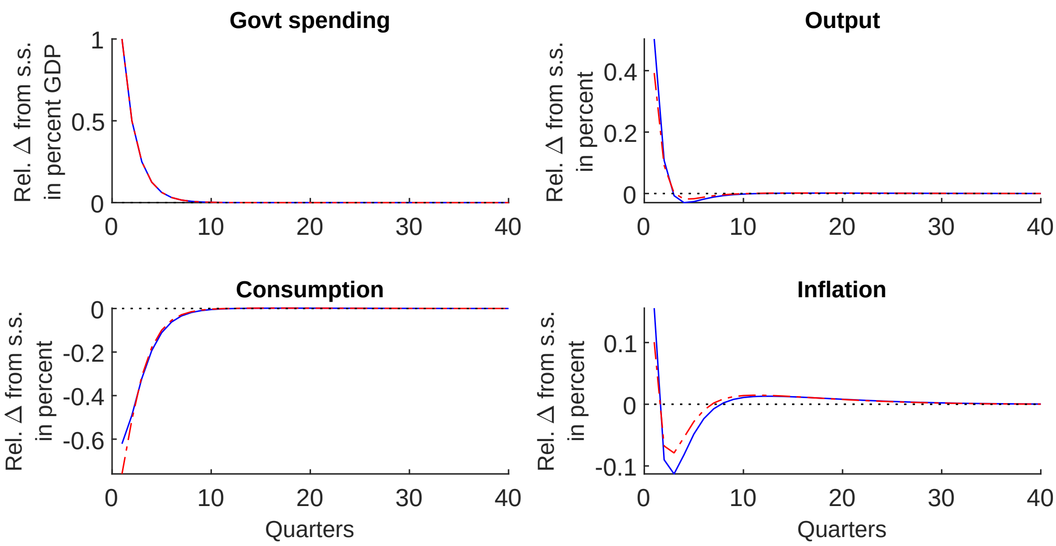


Figure 7: Impulse response functions for a tax cut shock of 1% of steady state output. The tax cut is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$. Households do not hold government bonds, i.e. $s_t^{b,h} = 0$.

Debt-financing vs. money-financing: government spending, long-term bonds, $s_t^{b,h} = 0$



(a)

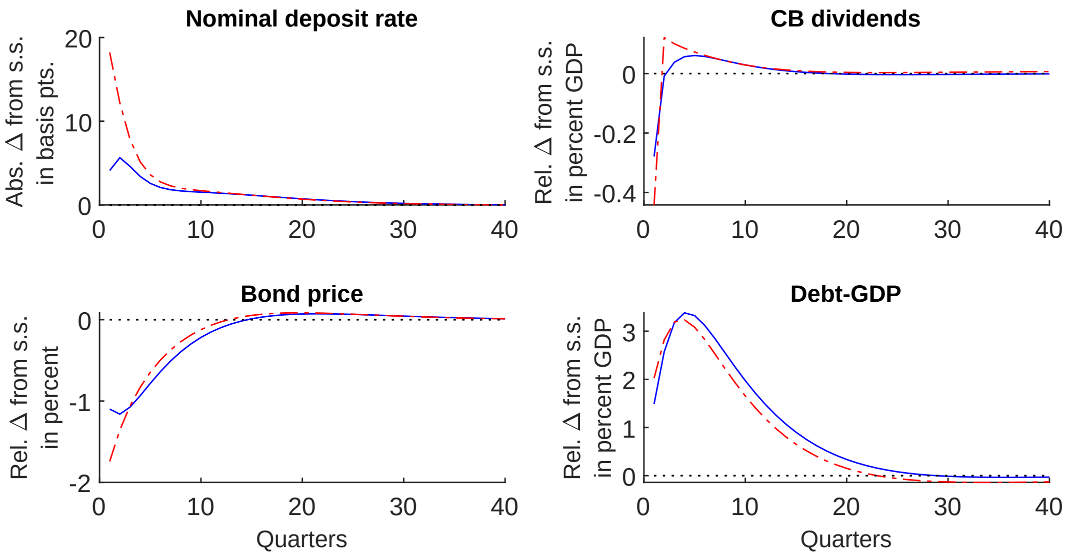


Figure 8: Impulse response functions for a government spending shock of 1% of steady state output in financial crisis times ($\mu_t > 0$). The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$. Households do not hold government bonds, i.e. $s_t^{b,h} = 0$.

respect to a debt-financed stimulus.

In reality, however, it is unlikely that a money-financed stimulus will have a negative impact with respect to debt-financed stimuli, as the commercial banks that hold central bank reserves typically only hold a minor fraction of the total stock of outstanding government debt.

5 Discussion & robustness checks

In this section, I discuss several robustness checks.

First, I build a model version where the central bank balance sheet and the budget constraint of the fiscal authority are consolidated to check that the explicit modeling of the separate budget constraints does not affect my results, see Appendix B.1 for the results.

Second, I introduce sovereign default risk into the model with long-term government debt in Appendix B.2, with the accompanying simulations in Appendix C. I assume that the probability of default increases in the stock of privately-held government bonds. In that case, letting the central bank acquire the additional bonds from the fiscal stimulus prevents the stock of privately-held government bonds from increasing. Therefore, the probability of default under a money-financed stimulus is below that under a debt-financed stimulus, which increases capital gains on intermediaries' existing bond holdings everything else equal (with respect to a debt-financed stimulus). Although I find that the multiplier of money-financed stimuli increases with respect to the case without sovereign risk, the quantitative effect is relatively small: the money-financed multiplier of a tax cut increases from 0.0499 to 0.0742 in the presence of sovereign default risk, while the spending multiplier increases from 0.4550 to 0.4791 in the presence of sovereign default risk. Therefore, the introduction of sovereign default risk does not change my conclusions qualitatively.

Third, I perform a robustness check in Appendix A.8 by changing the steady state ratio of non-interest-paying money over output. I find that my results are qualitatively and quantitatively very similar.

Fourth, I investigate the extent to which the result from Section 4.4 that a money-financed fiscal stimulus can be less effective than a debt-financed stimulus depends on the value of λ_m, the parameter that determines by how much central bank reserves relax intermediaries' incentive compatbility constraint (25). I find that this result is robust for all values of $\lambda_m > 0$ (assuming that government debt is long-term and exclusively held by financial intermediaries and the central bank). I also find that the difference between the debt-financed multiplier and money-financed multiplier increases with λ_m, see Appendix C.

Next, I redo a couple of robustness checks that were performed by Galí (2020b). First, I calculate the cumulative fiscal multiplier for different degrees of price-stickiness ψ_p, see Appendix C. I find that the cumulative multiplier of a money-financed tax stimulus increases with ψ_p, which is in line with Galí (2020b), while that of a debt-financed stimulus decreases with ψ_p. The cumulative spending multiplier increases with ψ_p for both money- and debt-financed stimuli. However, the difference between money- and debt-financed fiscal stimuli remains less than 0.03 percentage points for both types of fiscal stimuli when government debt is short-term. This difference increases to approximately 0.40 percentage points for $\psi_p = 0.9$ when government debt is long-term. However, the spending multiplier of a money-financed stimulus does not get above 1, while the tax multiplier remains below 0.3. These results sharply contrast with Galí (2020b), where the cumulative multiplier of a money-financed spending stimulus reaches a value above 1.5 for $\psi_p = 0.9$, and the multiplier of a money-financed tax cut reaches a value close to 1 for $\psi_p = 0.9$. Therefore, the conclusion that money-financed fiscal stimuli become less effective when the central bank retains control of the nominal interest rate on reserves carries over for high degrees of price-stickiness.

Furthermore, my result that money-financed fiscal stimuli are hardly more effective than debt-financed stimuli becomes even stronger when I follow the monetary policy rule under a debt-financed stimulus in Galí (2020b), which is to set the nominal interest rate such that inflation is always at target ($\pi_t = 1$, pure inflation-targeting). In that case, Galí (2020b) finds that the multiplier of a debt-financed stimulus no longer changes with the degree of price-stickiness, a result that carries over to my model. Unlike Galí (2020b), however, the central bank in my model can also be a pure-inflation targeter when the fiscal stimulus is money-financed. In that case, I find that the cumulative multiplier of a money-financed fiscal stimulus is exactly equal to that of a debt-financed stimulus, and does not depend on the degree of price-stickiness, see also Appendix C for the accompanying simulations. Therefore, following the monetary policy rule employed by Galí (2020b) strengthens my conclusions regarding the relative ineffectiveness of money-financed fiscal stimuli (with respect to debt-financed stimuli).

Finally, I perform a robustness check where I follow Galí (2020b) and introduce a negative preference shock that temporarily lands the economy at the Zero Lower Bound (ZLB), and investigate the response to a fiscal stimulus at the ZLB, see Appendix C for the accompanying simulations. I find that my result regarding the limited expansionary impact of a money-financed stimulus (with respect to a debt-financed stimulus) carries over to this particular situation. This is not particularly surprising: Galí (2020b) already finds that money-financed fiscal stimuli become less effective in an environment where the ZLB is binding, as in that case interest rates under a money-financed stimulus can no longer decrease with respect to those under a debt-financed stimulus, which is the key driver behind the main results in Galí (2020b).

6 Conclusion

The standard New Keynesian model shows that money-financed fiscal stimuli are more effective in expanding output than debt-financed stimuli (Galí, 2020b). In this paper, I show that this result is driven by the assumption that the entire monetary base consists of non-interest-paying money, in which case the central bank can either control the nominal money supply or the short-term nominal interest rate, but not both. Therefore, expanding the money supply to finance a fiscal stimulus requires interest rates to fall, as a result of which households increase consumption. This contrasts with a debt-financed stimulus, for which interest rates increase, and consumption decreases.

In reality, however, central banks can simultaneously control the short-term nominal interest rate as well as the size of the monetary base. Central banks are capable of doing so because the monetary base not only consists of non-interest-paying money, but also of interest-paying reserves that are held by the commercial banking system. Therefore, I introduce such interest-paying reserves into the Galí (2020b) framework. These reserves are held by financial intermediaries which are subject to an incentive compatibility constraint as in Gertler and Kiyotaki (2010); Gertler and Karadi (2011). Importantly, central bank reserves directly relax intermediaries' incentive compatibility constraint (Gertler and Kiyotaki, 2010).

I show that money-financed fiscal stimuli are hardly more effective than debt-financed stimuli in such a framework, despite the fact that the funding costs of reserves are below that of bonds. The reason is twofold. First, since the central bank still controls the nominal interest rate, the monetary base can be expanded without having to decrease the interest rate. In fact, the policy rate *increases* in equilibrium in response to the higher aggregate demand resulting from higher lifetime incomes of households. Higher interest rates, in turn, induce a relative shift from consumption to saving, and therefore mitigate the expansionary effect from higher aggregate demand. In addition, higher interest rates also reduce households' demand for non-interest-paying money balances. Therefore, the money-financed stimulus is entirely financed through an expansion of interest-paying reserves. Together with the higher interest rate on reserves (with respect to debt-financed stimuli), central bank dividends increase by less, as a result of which the expansion in households' lifetime incomes is mitigated.

I also show that the above result is not affected when extending the maturity of government debt. However, I do show that money-financed stimuli can be *less* effective than debt-financed stimuli when all privately-held government bonds are held by balance-sheet-constrained financial intermediaries. As a result of the fact that reserves directly relax intermediaries' incentive compatibility constraint, the return on them is below that on deposits. Therefore, an expansion of reserves under a money-financed stimulus increases intermediaries' losses on these reserves, which tightens intermediaries' incentive compatibility constraint, everything else equal. When intermediaries hold all privately-held government bonds, the additional balance sheet capacity that is freed up by the central bank buying the additional bonds is relatively small. Therefore, the positive impact on bond prices is relatively small, and is trumped by the negative effect from higher losses on reserves, as a result of which money-financed stimuli become less effective than debt-financed stimuli. In reality, however, the commercial banks that have a reserve account at the central bank hold a minority of all privately-held government bonds. Therefore, it is unlikely that money-financed stimuli will be less effective than debt-financed stimuli in reality.

References

Adjemian, S., Bastani, H., Juillard, M., Karamé, F., Maih, J., Mihoubi, F., Perendia, G., Pfeifer, J., Ratto, M., Villemot, S., 2011. Dynare: Reference Manual Version 4. Dynare Working Papers 1. CEPREMAP.

Benigno, G., Benigno, P., 2021. Interest, Reserves, and Prices. Staff Reports 971. Federal Reserve Bank of New York. URL: https://ideas.repec.org/p/fip/fednsr/92400.html.

Benigno, P., Nisticò, S., 2020. Non-neutrality of Open-Market Operations. American Economic Journal: Macroeconomics 12, 175–226. URL: https://ideas.repec.org/a/aea/aejmac/v12y2020i3p175-226.html, doi:10.1257/mac.20180030.

Bilbiie, F.O., 2011. Nonseparable Preferences, Frisch Labor Supply, and the Consumption Multiplier of Government Spending: One Solution to a Fiscal Policy Puzzle. Journal of Money, Credit and Banking 43, 221–251. URL: https://ideas.repec.org/a/wly/jmoncb/v43y2011i1p221-251.html, doi:10.1111/j.1538-4616.2010.

Bohn, H., 1998. The behavior of U.S. public debt and deficits. The Quarterly Journal of Economics 113, 949–963.

Buiter, W.H., 2014. The simple analytics of helicopter money: Why it works - always. Economics - The Open-Access, Open-Assessment E-Journal (2007-2020) 8, 1–51. URL: https://ideas.repec.org/a/zbw/ifweej/201428.html, doi:10.5018/economics-ejourna.

Buiter, W.H., Kapoor, S., 2020. To fight the COVID pandemic, policymakers must move fast and break taboos. Voxeu.org URL: https://voxeu.org/article/fight-covid-pandemic-policymakers-must-move-fast-and-break-taboos.

Christiano, L., Eichenbaum, M., Rebelo, S., 2011. When Is the Government Spending Multiplier Large? Journal of Political Economy 119, 78–121. URL: `https://ideas.repec.org/a/ucp/jpolec/doi10.1086-659312.html`, doi:`10.1086/659312`.

Corsetti, G., Kuester, K., Meier, A., Müller, G.J., 2013. Sovereign Risk, Fiscal Policy, and Macroeconomic Stability. Economic Journal 0, F99–F132. URL: `https://ideas.repec.org/a/ecj/econjl/vy2013ipf99-f132.html`.

Davig, T., Leeper, E.M., 2011. Monetary-fiscal policy interactions and fiscal stimulus. European Economic Review 55, 211–227. URL: `https://ideas.repec.org/a/eee/eecrev/v55y2011i2p211-227.html`.

De Grauwe, P., Diessner, S., 2020. What price to pay for monetary financing of budget deficits in the euro area. Voxeu.org URL: `https://voxeu.org/article/what-price-pay-monetary-financing-budget-deficits-euro-area`.

Del Negro, M., Sims, C.A., 2015. When does a central banks balance sheet require fiscal support? Journal of Monetary Economics 73, 1–19. URL: `https://ideas.repec.org/a/eee/moneco/v73y2015icp1-19.html`, doi:`10.1016/j.jmoneco.2015.05`.

Diba, B., Loisel, O., 2021. Pegging the interest rate on bank reserves: A resolution of New Keynesian puzzles and paradoxes. Journal of Monetary Economics 118, 230–244. URL: `https://ideas.repec.org/a/eee/moneco/v118y2021icp230-244.html`, doi:`10.1016/j.jmoneco.2020.10`.

Eggertsson, G.B., 2011. What Fiscal Policy is Effective at Zero Interest Rates?, in: NBER Macroeconomics Annual 2010, Volume 25. National Bureau of Economic Research, Inc. NBER Chapters, pp. 59–112. URL: `https://ideas.repec.org/h/nbr/nberch/12027.html`.

Galí, J., 2020a. Helicopter money: The time is now. Voxeu.org URL: `https://voxeu.org/article/helicopter-money-time-now`.

Galí, J., 2020b. The effects of a money-financed fiscal stimulus. Journal of Monetary Economics 115, 1–19. URL: https://ideas.repec.org/a/eee/moneco/v115y2020icp1-19.html, doi:10.1016/j.jmoneco.2019.08.

Galí, J., López-Salido, J.D., Vallés, J., 2007. Understanding the Effects of Government Spending on Consumption. Journal of the European Economic Association 5, 227–270. URL: https://ideas.repec.org/a/tpr/jeurec/v5y2007i1p227-270.html.

Gertler, M., Karadi, P., 2011. A model of unconventional monetary policy. Journal of Monetary Economics 58, 17–34.

Gertler, M., Karadi, P., 2013. QE 1 vs. 2 vs. 3. . . : a framework for analyzing large-scale asset purchases as a monetary policy tool. International Journal of Central Banking 9, 5–53.

Gertler, M., Kiyotaki, N., 2010. Financial intermediation and credit policy in business cycle analysis, in: Friedman, B.M., Woodford, M. (Eds.), Handbook of Monetary Economics. Elsevier. volume 3. chapter 11, pp. 547–599.

Gertler, M., Kiyotaki, N., 2015. Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy. American Economic Review 105, 2011–2043. URL: https://ideas.repec.org/a/aea/aecrev/v105y2015i7p2011-43.html.

Hall, R.E., Reis, R., 2015. Maintaining Central-Bank Financial Stability under New-Style Central Banking. NBER Working Papers 21173. National Bureau of Economic Research, Inc. URL: https://ideas.repec.org/p/nbr/nberwo/21173.html.

Kirchner, M., Wijnbergen, S.v., 2016. Fiscal deficits, financial fragility, and the effectiveness of government policies. Journal of Monetary Economics 80, 51–68. URL: https://ideas.repec.org/a/eee/moneco/v80y2016icp51-68.html, doi:10.1016/j.jmoneco.2016.04.

van der Kwaak, C., van Wijnbergen, S., 2017. Financial Fragility and the Keynesian Multiplier. CEPR Discussion Papers 12394. C.E.P.R. Discussion Papers. URL: https://ideas.repec.org/p/cpr/ceprdp/12394.html.

Piazzesi, M., Rogers, C., Schneider, M., 2021. Money and Banking in the New Keynesian Model. Technical Report.

Ramey, V.A., 2011. Can Government Purchases Stimulate the Economy? Journal of Economic Literature 49, 673–685. URL: https://ideas.repec.org/a/aea/jeclit/v49y2011i3p673-85.html.

Ramey, V.A., 2019. Ten Years after the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research? Journal of Economic Perspectives 33, 89–114. URL: https://ideas.repec.org/a/aea/jecper/v33y2019i2p89-114.html.

Reis, R., 2013. The Mystique Surrounding the Central Bank's Balance Sheet, Applied to the European Crisis. American Economic Review 103, 135–140. URL: https://ideas.repec.org/a/aea/aecrev/v103y2013i3p135-40.html.

Reis, R., 2015. Comment on: "when does a central bank's balance sheet require fiscal support?" by Marco Del Negro and Christopher A. Sims 73, 20–25. URL: https://www.sciencedirect.com/science/article/pii/S0304393215000628.

Schabert, A., van Wijnbergen, S.J.G., 2014. Sovereign Default and the Stability of Inflation-Targeting Regimes. IMF Economic Review 62, 261–287.

Sims, C.A., 2003. Fiscal Aspects of Central Bank Independence. Technical Report.

Sims, C.A., 2004. Limits to Inflation Targeting, in: The Inflation-Targeting Debate. National Bureau of Economic Research, Inc. NBER Chapters, pp. 283–299. URL: https://ideas.repec.org/h/nbr/nberch/9562.html.

Woodford, M., 1998. Public debt and the price level. unpublished manuscript Columbia University.

Woodford, M., 2001. Fiscal requirements for price stability. Journal of Money, Credit and Banking 33, 669–728.

Woodford, M., 2011. Simple Analytics of the Government Expenditure Multiplier. American Economic Journal: Macroeconomics 3, 1–35. URL: https://ideas.repec.org/a/aea/aejmac/v3y2011i1p1-35.html.

Appendix "Monetary financing does not produce miraculous fiscal multipliers"

A Model equations

A.1 Households

The Lagrangian of households is given by:

$$\begin{aligned}
\mathcal{L} &= E_t\left\{\sum_{s=0}^{\infty}\beta^s\xi_{t+s}\left[\frac{c_{j,t+s}^{1-\sigma_c}-1}{1-\sigma_c}-\chi_h\frac{h_{j,t+s}^{1+\varphi}}{1+\varphi}+\chi_m\frac{\left(m_{jt+s}^C\right)^{1-\rho_m}-1}{1-\rho_m}\right]\right\} \\
&+ E_t\left\{\sum_{s=0}^{\infty}\beta^s\lambda_{t+s}\left[w_{t+s}h_{t+s}+\left(\frac{1+r_{t+s}^{n,b}}{\pi_{t+s}}\right)q_{t-1+s}^b s_{t-1+s}^{b,h}+\left(\frac{1+r_{t-1+s}^{n,d}}{\pi_{t+s}}\right)d_{t-1+s}\right.\right. \\
&+ \left.\left.\frac{m_{t-1+s}^C}{\pi_{t+s}}+\omega_{t+s}-c_{t+s}-\tau_{t+s}-q_{t+s}^b s_{t+s}^{b,h}-d_{t+s}-m_{t+s}^C-\frac{1}{2}\kappa_b\left(s_{t+s}^{b,h}-\hat{s}_{b,h}\right)^2\right]\right\}.
\end{aligned}$$

The resulting first order conditions are given by:

$$\begin{aligned}
c_t &: \xi_t c_{j,t+s}^{-\sigma_c}=\lambda_t, && (32)\\
h_t &: \xi_t\chi_h h_{j,t+s}^{\varphi}=\lambda_t w_t, && (33)\\
s_t^{b,h} &: E_t\left\{\beta\Lambda_{t,t+1}\left[\frac{\left(\frac{1+r_{t+1}^{n,b}}{\pi_{t+1}}\right)q_t^b}{q_t^b+\kappa_b\left(s_t^{b,h}-\hat{s}_{b,h}\right)}\right]\right\}=1, && (34)\\
d_t &: E_t\left[\beta\Lambda_{t,t+1}\left(\frac{1+r_t^{n,d}}{\pi_{t+1}}\right)\right]=1, && (35)\\
m_t^C &: \frac{\xi_t\chi_m\left(m_{jt+s}^C\right)^{-\rho_m}}{\lambda_t}+E_t\left[\beta\Lambda_{t,t+1}\left(\frac{1}{\pi_{t+1}}\right)\right]=1, && (36)
\end{aligned}$$

where $\Lambda_{t,t+s}\equiv\lambda_{t+s}/\lambda_t$.

A.2 Financial intermediaries

I described in the main text that the maximization problem of financial intermediaries is given by intermediaries' continuation value (20), subject to the balance sheet constraint (18), the law of motion for net worth (19), and the incentive compatibility constraint (21):

$$\max_{\left\{s^{b,f}_{j,t}, m^R_{j,t}, d_{j,t}\right\}} \quad V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right)$$

$$\text{s.t.}$$

$$\begin{aligned} V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right) &= E_t\left\{\beta\Lambda_{t,t+1}\left[(1-\sigma)\,n_{j,t+1} + \sigma V\left(s^{b,f}_{j,t}, m^R_{j,t}, d_{j,t}\right)\right]\right\}, \\ q^b_t s^{b,f}_{j,t} + m^R_{j,t} &= n_{j,t} + d_{j,t}, \\ n_{j,t} &= \left(1+r^b_t\right) q^b_{t-1} s^{b,f}_{j,t-1} + \left(1+r^r_t\right) m^R_{j,t-1} - \left(1+r^d_t\right) d_{j,t-1}, \\ V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right) &\geq \lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}. \end{aligned}$$

After elimination of $V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right)$ using equation (20), and net worth using the law of motion for net worth (19), I construct the Lagrangian:

$$\begin{aligned} \mathcal{L} &= (1+\mu_t)\,E_t\Bigg(\beta\Lambda_{t,t+1}\Bigg\{(1-\sigma)\left[\left(1+r^b_{t+1}\right) q^b_t s^{b,f}_{j,t} + \left(1+r^r_{t+1}\right) m^R_{j,t}\right. \\ &- \left.\left(1+r^d_{t+1}\right) d_{j,t}\right] + \sigma V\left(s^{b,f}_{j,t}, m^R_{j,t}, d_{j,t}\right)\Bigg\}\Bigg) \\ &- \mu_t\left(\lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}\right) \\ &+ \chi_t\left[\left(1+r^b_t\right) q^b_{t-1} s^{b,f}_{j,t-1} + \left(1+r^r_t\right) m^R_{j,t-1} - \left(1+r^d_t\right) d_{j,t-1} + d_{j,t} - q^b_t s^{b,f}_{j,t} - m^R_{j,t}\right], \end{aligned}$$

where μ_t denotes the Lagrangian multiplier on intermediaries' incentive compatibility constraint (21), and χ_t the Lagrangian multiplier on the balance sheet constraint (18). The first order condtions are then given by:

$$
\begin{aligned}
s_{j,t}^{b,f} \quad &: \quad (1+\mu_t)\, E_t \left\{ \beta \Lambda_{t,t+1} \left[(1-\sigma)\left(1+r_{t+1}^{b}\right) q_t^b + \sigma \frac{\partial V\left(s_{j,t}^{b,f}, m_{j,t}^{R}, d_{j,t}\right)}{\partial s_{j,t}^{b,f}} \right] \right\} \\
&- \quad \lambda_b \mu_t q_t^b - \chi_t q_t^b = 0, \qquad (37) \\
m_{j,t}^{R} \quad &: \quad (1+\mu_t)\, E_t \left\{ \beta \Lambda_{t,t+1} \left[(1-\sigma)\left(1+r_{t+1}^{r}\right) + \sigma \frac{\partial V\left(s_{j,t}^{b,f}, m_{j,t}^{R}, d_{j,t}\right)}{\partial m_{j,t}^{R}} \right] \right\} \\
&+ \quad \lambda_m \mu_t - \chi_t = 0, \qquad (38) \\
d_{j,t} \quad &: \quad (1+\mu_t)\, E_t \left\{ \beta \Lambda_{t,t+1} \left[-(1-\sigma)\left(1+r_{t+1}^{d}\right) + \sigma \frac{\partial V\left(s_{j,t}^{b,f}, m_{j,t}^{R}, d_{j,t}\right)}{\partial d_{j,t}} \right] \right\} + \chi_t = 0, \\
& \qquad (39)
\end{aligned}
$$

Employing the envelope theorem, I find that:

$$
\begin{aligned}
\frac{\partial V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^{R}, d_{j,t-1}\right)}{\partial s_{j,t-1}^{b,f}} &= \chi_t \left(1+r_t^b\right) q_{t-1}^b, \\
\frac{\partial V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^{R}, d_{j,t-1}\right)}{\partial m_{j,t-1}^{R}} &= \chi_t \left(1+r_t^r\right), \\
\frac{\partial V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^{R}, d_{j,t-1}\right)}{\partial d_{j,t-1}} &= -\chi_t \left(1+r_t^d\right).
\end{aligned}
$$

Iterating one period forward, and substituting into the first order conditions (37) - (39) gives the following first order conditions:

$$
\begin{aligned}
s_{j,t}^{b,f} \quad &: \quad E_t \left\{ \beta \Lambda_{t,t+1} \left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r_{t+1}^{b}\right) \right\} = \frac{\chi_t}{1+\mu_t} + \lambda_b \frac{\mu_t}{1+\mu_t}, \qquad (40) \\
m_{j,t}^{R} \quad &: \quad E_t \left\{ \beta \Lambda_{t,t+1} \left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r_{t+1}^{r}\right) \right\} = \frac{\chi_t}{1+\mu_t} - \lambda_m \frac{\mu_t}{1+\mu_t}, \qquad (41) \\
d_{j,t} \quad &: \quad E_t \left\{ \beta \Lambda_{t,t+1} \left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r_{t+1}^{d}\right) \right\} = \frac{\chi_t}{1+\mu_t}. \qquad (42)
\end{aligned}
$$

Now I assume a particular functional form for the value function (20), and later check whether my guess is correct:

$$V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right) = \eta^b_t q^b_t s^{b,f}_{j,t} + \eta^R_t m^R_{j,t} - \eta^d_t d_{j,t}, \tag{43}$$

where η^b_t, η^R_t, and η^d_t are given by:

$$\eta^b_t \equiv E_t\left\{\beta\Lambda_{t,t+1}\left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r^b_{t+1}\right)\right\}, \tag{44}$$

$$\eta^R_t \equiv E_t\left\{\beta\Lambda_{t,t+1}\left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r^r_{t+1}\right)\right\}, \tag{45}$$

$$\eta^d_t \equiv E_t\left\{\beta\Lambda_{t,t+1}\left[1-\sigma+\sigma\chi_{t+1}\right]\left(1+r^d_{t+1}\right)\right\}. \tag{46}$$

Substitution of the first order conditions (40) - (42) allow me to rewrite the value function in the following way (43):

$$\begin{aligned} V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right) &= \left[\frac{\chi_t}{1+\mu_t} + \lambda_b\frac{\mu_t}{1+\mu_t}\right] q^b_t s^{b,f}_{j,t} + \left[\frac{\chi_t}{1+\mu_t} - \lambda_m\frac{\mu_t}{1+\mu_t}\right] m^R_{j,t} - \frac{\chi_t}{1+\mu_t} d_{j,t} \\ &= \frac{\chi_t}{1+\mu_t}\left(q^b_t s^{b,f}_{j,t} + m^R_{j,t} - d_{j,t}\right) + \frac{\mu_t}{1+\mu_t}\left(\lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}\right) \\ &= \frac{\chi_t}{1+\mu_t} n_{j,t} + \frac{\mu_t}{1+\mu_t}\left(\lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}\right), \end{aligned} \tag{47}$$

where I used intermediaries' balance sheet constraint (18). Next, I distinguish two cases. In the first, the incentive compatibility constraint (21) is not binding, in which case $\mu_t = 0$. In that case, intermediaries' continuation value is equal to $V\left(s^{b,f}_{j,t-1}, m^R_{j,t-1}, d_{j,t-1}\right) = \chi_t n_{j,t}$. In the second case, constraint (21) is binding. In that case I can rewrite it with the help of expression (47) in the following way:

$$\frac{\chi_t}{1+\mu_t} n_{j,t} + \frac{\mu_t}{1+\mu_t}\left(\lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}\right) = \lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}.$$

I can rewrite this in the following way:

$$\frac{\chi_t}{1+\mu_t} n_{j,t} = \left(1 - \frac{\mu_t}{1+\mu_t}\right)\left(\lambda_b q^b_t s^{b,f}_{j,t} - \lambda_m m^R_{j,t}\right),$$

which delivers the following expression after further rewriting:

$$\chi_t n_{j,t} = \lambda_b q_t^b s_{j,t}^{b,f} - \lambda_m m_{j,t}^R. \tag{48}$$

Next, I use this equation to replace $\lambda_b q_t^b s_{j,t}^{b,f} - \lambda_m m_{j,t}^R$ in expression (47) to obtain:

$$V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) = \frac{\chi_t}{1+\mu_t} n_{j,t} + \frac{\mu_t}{1+\mu_t} \chi_t n_{j,t} = \chi_t n_{j,t}. \tag{49}$$

Hence we see that the value function of financial intermediary j is equal to $V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) = \chi_t n_{j,t}$, irrespective of whether the incentive compatibility constraint (21) is binding or not. Now that I have solved for the value function, I check whether my initial guess for the value function (43) is correct by substituting $V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) = \chi_t n_{j,t}$ into the right hand side of expression (20):

$$V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) = E_t \left\{\beta \Lambda_{t,t+1} \left[1 - \sigma + \sigma \chi_{t+1}\right] n_{j,t+1}\right\}.$$

Substitution of equation (19) allows me to rewrite this expression as:

$$\begin{aligned} V\left(s_{j,t-1}^{b,f}, m_{j,t-1}^R, d_{j,t-1}\right) &= E_t \left\{\beta \Lambda_{t,t+1} \left[1 - \sigma + \sigma \chi_{t+1}\right] \left(1 + r_{t+1}^b\right)\right\} q_t^b s_{j,t}^{b,f} \\ &+ E_t \left\{\beta \Lambda_{t,t+1} \left[1 - \sigma + \sigma \chi_{t+1}\right] \left(1 + r_{t+1}^r\right)\right\} m_{j,t}^R \\ &- E_t \left\{\beta \Lambda_{t,t+1} \left[1 - \sigma + \sigma \chi_{t+1}\right] \left(1 + r_{t+1}^d\right)\right\} d_{j,t} \\ &= \eta_t^b q_t^b s_{j,t}^{b,f} + \eta_t^R m_{j,t}^R - \eta_t^d d_{j,t}. \end{aligned}$$

Thereby I confirm that the initial guess (43) was correct.

A.3 Production sector

A.3.1 Final goods producers

Final goods producers acquire retail goods $y_{f,t}$ from a continuum of retail goods producers $f \in [0, 1]$, and convert these into final goods using a standard constant elasticity of substitution (CES) function:

$$y_t = \left[\int_0^1 y_{f,t}^{(\epsilon-1)/\epsilon} \right]^{\epsilon/(\epsilon-1)} . \tag{50}$$

Final goods producers operate in a perfectly competitive market. Therefore, they take the price P_t at which they sell final goods as given, as well as aggregate demand for final goods y_t, and the price $P_{f,t}$ at which retail goods producers sell to final goods producers. Final goods producers aim to maximize period t profits by choosing how many retail goods $y_{f,t}$ from each retail good producer $f \in [0, 1]$:

$$\max_{y_{f,t}} \quad P_t y_t - \int_0^1 P_{f,t} y_{f,t} df, \tag{51}$$

subject to their production technology (50). This results in the standard demand equation for retail good $y_{f,t}$:

$$y_{f,t} = \left(\frac{P_{f,t}}{P_t} \right)^{-\epsilon} y_t. \tag{52}$$

Substitution of the demand function (52) into final goods producers' production technology (50) gives the familiar expression for the price level of final goods:

$$P_t^{1-\epsilon} = \int_0^1 P_{f,t}^{1-\epsilon} df. \tag{53}$$

A.3.2 Retail goods producers

There is a continuum of retail goods prodcuers $f \in [0, 1]$ who acquire intermediate goods at a relative price ζ_t in terms of the price level of final goods, and convert these intermediate goods one-for-one into retail goods, i.e. $y_{f,t} = y_{i,t}$. Retail goods producers produce a unqiue retail good, therefore they are monopolists in the market for retail good f. However, since final goods producers have a constant elasticity of substitution between two retail goods, see equation (50), retail goods producers operate in an environment of monopolistic competition. Because they are monopolists, however, they have the power to set the price $P_{f,t}$, after which they supply the amount demanded by final goods producers. Their goal is to maximize the sum of expected, discounted future profits. However, following **?**, there is a probability ψ_p each period that they will not be allowed to change prices. Therefore, their optimization problem is given by:

$$\max_{P_{f,t}} \quad E_t \left\{ \sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \psi_p^s \left[\left(\frac{P_{f,t}}{P_{t+s}} - \zeta_{t+s} \right) y_{f,t+s} \right] \right\},$$

subject to the demand schedule (52), and where $\beta^s \Lambda_{t,t+s} \equiv \beta^s \lambda_{t+s} / \lambda_t$ denotes households' stochastic discount factor, as households are the ultimate owners of all firms in the economy. Substitution of the demand schedule (52) allows us to rewrite the problem in the following way:

$$\max_{P_{f,t}} \quad E_t \left\{ \sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \psi_p^s \left[\left(\frac{P_{f,t}}{P_{t+s}} \right)^{1-\epsilon} y_{t+s} - \zeta_{t+s} \left(\frac{P_{f,t}}{P_{t+s}} \right)^{-\epsilon} y_{t+s} \right] \right\}.$$

Taking the first derivative with respect to $P_{f,t}$, and denoting the optimal chosen price P_t^{new}, we get the following first order condition:

$$(\epsilon - 1)\, E_t \left[\sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \psi_p^s \left(\frac{P_t^{new}}{P_{t+s}} \right)^{1-\epsilon} \frac{y_{t+s}}{P_t^{new}} \right] = \epsilon E_t \left[\sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \psi_p^s \zeta_{t+s} \left(\frac{P_t^{new}}{P_{t+s}} \right)^{-\epsilon} \frac{y_{t+s}}{P_t^{new}} \right],$$

which we can rewrite in the following way:

$$\frac{P_t^{new}}{P_t} (\epsilon - 1)\, E_t \left[\sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \psi_p^s \left(\frac{P_t}{P_{t+s}} \right)^{1-\epsilon} y_{t+s} \right] = \epsilon E_t \left[\sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \psi_p^s \zeta_{t+s} \left(\frac{P_t}{P_{t+s}} \right)^{-\epsilon} y_{t+s} \right].$$

Next, we write this as:

$$\frac{P_t^{new}}{P_t} = \left(\frac{\epsilon}{\epsilon - 1} \right) \frac{E_t \left[\sum_{s=0}^{\infty} (\beta \psi_p)^s \Lambda_{t,t+s} \zeta_{t+s} \left(\prod_{k=1}^{k=s} \pi_{t+k} \right)^{\epsilon} y_{t+s} \right]}{E_t \left[\sum_{s=0}^{\infty} (\beta \psi_p)^s \Lambda_{t,t+s} \left(\prod_{k=1}^{k=s} \pi_{t+k} \right)^{\epsilon - 1} y_{t+s} \right]} \tag{54}$$

Defining $\pi_t^{new} \equiv P_t^{new}/P_t$, we can rewrite the above first order condition in its final form:

$$\begin{aligned}
\pi_t^{new} &= \left(\frac{\epsilon}{\epsilon-1}\right)\frac{\Xi_{1,t}}{\Xi_{2,t}}, && (55)\\
\Xi_{1,t} &= \lambda_t\zeta_t y_t + E_t\left(\beta\psi_p\pi_{t+1}^{\epsilon}\Xi_{1,t+1}\right), && (56)\\
\Xi_{2,t} &= \lambda_t y_t + E_t\left(\beta\psi_p\pi_{t+1}^{\epsilon-1}\Xi_{2,t+1}\right). && (57)
\end{aligned}$$

Now that we have found an expression for the newly chosen price by retail goods producers, we calculate the price level of the final good P_t using equation (53):

$$P_t^{1-\epsilon} = (1-\psi_p)\left(P_t^{new}\right)^{1-\epsilon} + \psi_p(1-\psi_p)\left(P_{t-1}^{new}\right)^{1-\epsilon} + \psi_p^2(1-\psi_p)\left(P_{t-2}^{new}\right)^{1-\epsilon} + ... \quad (58)$$

Iterating one period back, and multiplying the left and right hand side with ψ_p gives the following expression:

$$\psi_p P_{t-1}^{1-\epsilon} = \psi_p(1-\psi_p)\left(P_{t-1}^{new}\right)^{1-\epsilon} + \psi_p^2(1-\psi_p)\left(P_{t-2}^{new}\right)^{1-\epsilon} + \psi_p^3(1-\psi_p)\left(P_{t-3}^{new}\right)^{1-\epsilon} + ...$$

Looking at the above expression, we see that the right hand side coincides with the right hand side of equation (58), except for the first term. Therefore, we can write equation (58) in the following way:

$$P_t^{1-\epsilon} = (1-\psi_p)\left(P_t^{new}\right)^{1-\epsilon} + \psi_p P_{t-1}^{1-\epsilon}. \quad (59)$$

Division of the left and right hand side of the above expression by $P_t^{1-\epsilon}$ allows us to obtain the following equation:

$$1 = (1-\psi_p)\left(\pi_t^{new}\right)^{1-\epsilon} + \psi_p\pi_t^{\epsilon-1}. \quad (60)$$

Finally, price dispersion $\mathcal{D}_{p,t} \equiv \int_0^1 \left(\frac{P_{f,t}}{P_t}\right)^{-\epsilon} df$ is equal to:

$$\mathcal{D}_{p,t} = (1-\psi_p)\left(\frac{P_t^{new}}{P_t}\right)^{-\epsilon} + \psi_p(1-\psi_p)\left(\frac{P_{t-1}^{new}}{P_t}\right)^{-\epsilon} + \psi_p^2(1-\psi_p)\left(\frac{P_{t-2}^{new}}{P_t}\right)^{-\epsilon} + ... \quad (61)$$

Iterating back one period, and multiplyingleft and right hand side by $\psi_p \left(\frac{P_{t-1}}{P_t}\right)^{-\epsilon}$ gives the following equation:

$$\psi_p \left(\frac{P_{t-1}}{P_t}\right)^{-\epsilon} \mathcal{D}_{p,t-1} = \psi_p \left(1-\psi_p\right) \left(\frac{P_{t-1}^{new}}{P_t}\right)^{-\epsilon} + \psi_p^2 \left(1-\psi_p\right) \left(\frac{P_{t-2}^{new}}{P_t}\right)^{-\epsilon} + ...$$

We see from theright hand side of the above expression that it coincides with the right hand side of equation (61), except for the first term. Therefore, we can write equation (61) as:

$$\mathcal{D}_{p,t} = \left(1-\psi_p\right) \left(\frac{P_t^{new}}{P_t}\right)^{-\epsilon} + \psi_p \left(\frac{P_{t-1}}{P_t}\right)^{-\epsilon} \mathcal{D}_{p,t-1}, \tag{62}$$

which we can further rewrite using $\pi_t^{new} \equiv P_t^{new}/P_t$ and $\pi_t \equiv P_t/P_{t-1}$ in the following way:

$$\mathcal{D}_{p,t} = \left(1-\psi_p\right) \left(\pi_t^{new}\right)^{-\epsilon} + \psi_p \pi_t^{\epsilon} \mathcal{D}_{p,t-1}, \tag{63}$$

A.4 Aggregation

A.4.1 Financial intermediaries

Intermediaries' balance sheet constraint (18) is linear in quantities, as a result of which aggregation is straightforward:

$$q_t^b s_t^{b,f} + m_t^R = n_t + d_t. \tag{64}$$

Since the shadow value χ_t of intermediaries' incentive compatibility constraint (25) is not firm-specific, the aggregation over this constraint is also straightforward, and results in:

$$\chi_t n_t = \lambda_b q_t^b s_t^{b,f} - \lambda_m m_t^R. \tag{65}$$

A.4.2 Production sector

We start by observing from intermediate goods producers' first order conditions for labor demand (28) that each intermediate goods producer will choose the same amount of labor in equilibrium, i.e. $h_{i,t} = h_t$. Therefore, we can write the first order condition for the wage rate using aggregate labor h_t:

$$w_t = (1 - \alpha)\, \zeta_t z_t h_t^{-\alpha}, \tag{66}$$

The knowledge that $h_{i,t} = h_t$ allows us to integrate over the right hand side of equation (27):

$$\int_0^1 z_t h_{i,t}^{1-\alpha} di = z_t h_t^{1-\alpha} \int_0^1 di = z_t h_t^{1-\alpha}.$$

Next, we integrate over the left hand side of equation (27), where we remember that $y_{i,t} = y_{f,t} = \left(\frac{P_{f,t}}{P_t}\right)^{-\epsilon} y_t$ via equation (52), and that the measure of intermediate goods producers is equal to the measure of retail goods producers, and equal to one:

$$\int_0^1 y_{i,t} di = \int_0^1 y_{f,t} df = y_t \int_0^1 \left(\frac{P_{f,t}}{P_t}\right)^{-\epsilon} df = \mathcal{D}_{p,t} y_t.$$

These results allow us to obtain the aggregated version of equation (27), which is given by:

$$\mathcal{D}_{p,t} y_t = z_t h_t^{1-\alpha}. \tag{67}$$

A.5 Exogenous processes

Productivity z_t and the demand shock ξ_t are given by:

$$\log(z_t) = \rho_z \log(z_{t-1}) + \varepsilon_{z,t}, \tag{68}$$

$$\log(\xi_t) = \rho_\xi \log(\xi_{t-1}) + \varepsilon_{\xi,t}, \tag{69}$$

A.6 Equilibrium Conditions

Let $\{m_{t-1}^C, s_{t-1}^{b,h}, d_{t-1}, s_{t-1}^{b,f}, m_{t-1}^R, n_{t-1}, b_{t-1}, \tilde{\tau}_{t-1}, p_{t-1}^{cb}, s_{t-1}^{b,cb}, r_{t-1}^n, r_{t-1}^{n,d}, \mathcal{D}_{p,t-1}\}$ be the endogenous state-variables, while $\{z_t, \xi_t, g_t\}$ be the exogenous state-variables. A recursive competitive equilibrium is a sequence of quantities and prices $\{c_t, \lambda_t, h_t, m_t^C, s_t^{b,h}, \chi_t, \mu_t, s_t^{b,f}, m_t^R, n_t, d_t, q_t^b, r_t^b, r_t^r, r_t^d, w_t, \zeta_t, \pi_t, \pi_t^{new}, \Xi_{1,t}, \Xi_{2,t}, \mathcal{D}_{p,t}, y_t, b_t, g_t, \tau_t, \tilde{\tau}_t, p_t^{cb}, s_t^{b,cb}, n_t^{cb}, n_t^{cb*}, d_t^{cb}, r_t^{n,r}, r_t^{n,T}, r_t^{n,d}, r_t^{n,b}\}$, and exogenous shocks $\{z_t, \xi_t\}$ such that:

1. Households optimize taking prices as given: (32) - (36).

2. Financial intermediaries optimize taking prices as given: intermediaries' balance sheet constraint (64), the first order conditions for bonds, reserves, and deposits (22) - (24), intermediaries' incentive compatibility constraint (65), and the aggregate law of motion for net worth (26).

3. Intermediate goods producers optimize taking prices as given, from which we can find the wage rate (66), and the aggregate supply relation (67).

4. Domestic retail goods producers that are allowed to choose prices optimize taking the input price ζ_t as given: (55) - (57), (60), and (63).

5. The bond market clears: (29).

6. The market for final goods clears: (30).

7. The fiscal variables evolve according to: (1) - (6).

8. The monetary variables evolve according to: the central bank's balance sheet constraint (7), the evolution of central bank assets (8), the ex post dividend amount of central bank net worth (9), the ex ante amount of central bank net worth (13), central bank dividends (14), the nominal interest rate on reserves (10), and the Taylor rule (11).

9. The relation between the ex post real interest rate and the nominal interest rate on reserves (12) and deposits (17) hold.

10. Exogenous processes evolve according to (68) - (69).

A.7 Calibration

The numerical values of the deep parameters of the model can be found in Table 3.

A.8 Robustness checks

In this section, I investigate the robustness of my results under an alternative calibration target for the steady state ratio of non-interest-paying money. Table

Parameter	Value	Definition
Households		
β	0.995	Discount rate
σ_c	1	Coefficient of relative risk-aversion
χ_h	607.5	Coefficient in front of disutility labor supply
φ	5	Inverse Frisch elasticity
χ_m	$3.5665 \cdot 10^{-41}$	Coefficient in front of utility from money
ρ_m	28.4286	Inverse elasticity from money balances
κ_b	0.001	Coefficient HHs adjustment costs bond holdings
$\hat{s}_{b,h}$	-1.6203	Reference level adjustment costs HH bonds
Financial intermediaries		
σ	0.9583	Probability of intermediaries continuing to operate
λ_b	0.2836	Diversion rate government bonds
λ_m	0.1418	Relaxation rate central bank reserves
χ_b	0.0249	Fraction of old net worth for new bankers
Goods producers		
α	0.25	1 - labor share
ψ_p	3/4	Probability of changing prices
ϵ_p	9	Elasticity of substitution retail goods
Fiscal policy		
ψ_b	0.020	Tax feedback parameter from government debt
x_c	1	Coupon payment bonds
ρ	1	Maturity parameter bonds
Monetary policy		
$\bar{\pi}$	1	Steady state gross inflation rate
κ_π	1.500	Inflation feedback on nominal interest rate
κ_y	0.125	Output feedback on nominal interest rate
ρ_r	0.8	Interest rate smoothing parameter
$\bar{n}^{cb}$	0.0012	Steady state CB net worth
Autoregressive processes		
ρ_ξ	0.9	Preference shock AR(1) parameter
ρ_g	0.5	Government spending AR(1) parameter
σ_ξ	0.05	Standard deviation preference shock
σ_g	0.05	Standard deviation gov't spending shock
σ_r	0.0025	Standard deviation interest rate shock

Table 3: Parameter values for the baseline version of the model.

4 displays the case where I increase $\bar{m}^C/\bar{y}$ from 0.1 in the baseline version of the model to 0.2.

	Tax cut (D)	Tax cut (M)	Spending (D)	Spending (M)
Normal times	0	0	0.4091	0.4091
Fin. crisis	-0.0018	0.0045	0.4069	0.4132
Fin. crisis, LT debt	-0.0284	0.0432	0.3782	0.4498
Fin. crisis, LT debt, $s_t^{b,h} = 0$	-0.0824	-0.1137	0.2697	0.2384

Table 4: Table displaying the discounted cumulative dynamic multiplier (31) over the first 1,000 quarters for listed scenarios under a fiscal stimulus during a financial crisis with $\bar{m}^C/\bar{y} = 0.2$. (D) refers to a debt-financed fiscal stimulus, whereas (M) refers to a money-financed stimulus. Finally, LT refers to long-term government debt.

B Alternative model versions

B.1 Consolidated balance sheet fiscal authority and central bank

In this model version, I consolidate the budget constraints of the fiscal authority and the central bank. Just as in the main text, interest-paying reserves are financed by financial intermediaries. Let me start by rewriting the consolidated government budget constraint (29) in the following way:

$$b_t = s_t^{b,p} + s_t^{b,cb}. \tag{70}$$

where $s_t^{b,p} \equiv s_t^{b,f} + s_t^{b,h}$ denotes government bonds held by the private sector. Next, I substitute the above expression into the government budget constraint (3), after which I substitute equation (14) and equation (13), and iterate the resulting expression forward:

$$q_{t-1}^b s_{t-1}^{b,p} + p_{t-1}^{cb} = \sum_{j=0}^{\infty} \prod_{i=0}^{j} \left(\frac{1}{1 + r_{t+i}^b} \right) \left(\tau_{t+j} - g_{t+j} + d_{t+j}^{cb} \right), \tag{71}$$

assuming that the transversality condition of the government budget constraint holds.

The consolidated government budget constraint is obtained when consolidating the budget constraints of the fiscal authority and the central bank. To do so, I start by substituting central bank dividends (14) and the market clearing condition for government bonds (70) into the budget constraint of the fiscal authority (3):

$$\begin{aligned} & q_t^b \left(s_t^{b,p} + s_t^{b,cb} \right) + \tau_t + \left(1 + r_t^b\right) q_{t-1}^b s_{t-1}^{b,cb} - \left(\frac{1 + r_{t-1}^{n,r}}{\pi_t} \right) m_{t-1}^R - \frac{m_{t-1}^C}{\pi_t} - \bar{n}^{cb} \\ = \; & g_t + \left(1 + r_t^b\right) q_{t-1}^b \left(s_{t-1}^{b,p} + s_{t-1}^{b,cb} \right). \end{aligned}$$

Substitution of the central bank's balance sheet constraint (7) allows me to eliminate $q_t^b s_t^{b,cb}$, and I can write the consolidated government budget constraint as:

$$q_t^b s_t^{b,p} + m_t^R + m_t^C + \tau_t = g_t + \left(1 + r_t^b\right) q_{t-1}^b s_{t-1}^{b,p} + \left(1 + r_t^r\right) m_{t-1}^R + \frac{m_{t-1}^C}{\pi_t}. \tag{72}$$

Hence, we see from the consolidated government budget constraint that switching from debt-financing to money-financing will reduce the consolidated government's funding costs when the return on reserves r_t^r is below the return on bonds r_t^b, thereby reducing the present discounted value of current and future lump sum taxes.

Now that we have arrived at the consolidated government budget constraint (72), we no longer need the government budget constraint (3) from the main text, In addition, we no longer need the central bank's balance sheet constraint (7), which implies that we also no longer need the evolution of central bank assets (8). In addition, we no longer need central bank's ex ante net worth (13), or central bank's ex post net worth (9) or central bank dividends (14).

As a result of the consolidation, I need to write the market clearing condition for government bonds as:

$$b_t = s_t^{b,p}, \tag{73}$$

where $s_t^{b,p}$ denotes government bonds held by the private sector:

$$s_t^{b,p} = s_t^{b,f} + s_t^{b,h}. \tag{74}$$

In addition, we have to introduce a new variable m_t^B, which I will refer to as the monetary base, and is given by:

$$m_t^B = m_t^R + m_t^C. \tag{75}$$

In addition, I need to define a law of motion for the newly defined monetary base. Just as for the law of motion for central bank assets (8) in the main text, I assume that the monetary base is constant in nominal terms in the absence of money-financed stimuli, and that money-financed stimuli permanently expand the monetary base in nominal terms. Therefore, the law of motion for the monetary base is given by:

$$m_t^B = \frac{m_{t-1}^B}{\pi_t} + \kappa_g\left(g_t - \bar{g}\right) + \kappa_\tau \tilde{\tau}_t. \tag{76}$$

Equilibrium definition

Let $\{m_{t-1}^C, s_{t-1}^{b,h}, d_{t-1}, s_{t-1}^{b,f}, m_{t-1}^R, n_{t-1}, b_{t-1}, \tilde{\tau}_{t-1}, r_{t-1}^n, r_{t-1}^{n,d}, \mathcal{D}_{p,t-1}\}$ be the endogenous state-variables, while $\{z_t, \xi_t, g_t\}$ be the exogenous state-variables. A recursive competitive equilibrium is a sequence of quantities and prices $\{c_t, \lambda_t, h_t, m_t^C, s_t^{b,h}, \chi_t, \mu_t, s_t^{b,f}, m_t^R, n_t, d_t, q_t^b, r_t^b, r_t^r, r_t^d, w_t, \zeta_t, \pi_t, \pi_t^{new}, \Xi_{1,t}, \Xi_{2,t}, \mathcal{D}_{p,t}, y_t, b_t, g_t, \tau_t, \tilde{\tau}_t, r_t^{n,r}, r_t^{n,T}, r_t^{n,d}, r_t^{n,b}, s_t^{b,p}, m_t^B\}$, and exogenous shocks $\{z_t, \xi_t\}$ such that:

1. Households optimize taking prices as given: (32) - (36).

2. Financial intermediaries optimize taking prices as given: intermediaries' balance sheet constraint (64), the first order conditions for bonds, reserves, and deposits (22) - (24), intermediaries' incentive compatibility constraint (65), and the aggregate law of motion for net worth (26).

3. Intermediate goods producers optimize taking prices as given, from which we can find the wage rate (66), and the aggregate supply relation (67).

4. Domestic retail goods producers that are allowed to choose prices optimize taking the input price ζ_t as given: (55) - (57), (60), and (63).

5. The bond market clears: (73)- (74).

6. The market for final goods clears: (30).

7. The monetary and fiscal variables evolve according to: (1) - (2), (4) - (6), (72), (75) - (76), and (10) - (11).

8. The relation between the ex post real interest rate and the nominal interest rate on reserves (12) and deposits (17) hold.

9. Exogenous processes evolve according to (68) - (69).

B.1.1 Results

	Tax cut (D)	Tax cut (M)	Spending (D)	Spending (M)
Normal times	0	0	0.4091	0.4091
Fin. crisis	-0.0018	0.0014	0.4069	0.4100

Table 5: Table displaying the discounted cumulative dynamic multiplier (31) over the first 1,000 quarters for listed scenarios under a government spending shock during a financial crisis. (D) refers to a debt-financed fiscal stimulus, whereas (M) refers to a money-financed stimulus. Finally, LT refers to long-term government debt.

B.2 Sovereign default risk

B.2.1 Model adjustments

While the above description applies to the case where sovereign default risk is absent, I now introduce the possibility of the sovereign (partially) defaulting on its liabilities. To do so, I follow Corsetti et al. (2013) and Schabert and van Wijnbergen (2014) by assuming the existence of a stochastic, maximum level of taxation, the realization of which is drawn from a distribution that is known to agents. Therefore, at the beginning of period t there is a probability p_t^{def} that the sovereign will default:

$$p_t^{def} = F_\beta \left(\frac{s_t^{b,p}}{4y_t} \frac{1}{\bar{b}_{max}}, \alpha_b, \beta_b \right), \tag{77}$$

where F_β denotes the cumulative density function of a generalized beta-distribution with parameters α_b, β_b, and $\bar{b}_{max}$ following Corsetti et al. (2013).[11] Endogenous variables that affect the probability of default are $s_t^{b,p}$, which denotes the stock of government bonds held by the private sector, and output y_t.[12]

In case the level of taxes τ_t required to service outstanding liabilities is above the stochastic maximum level of taxation, a haircut ϑ_t is imposed upon outstanding liabilities. Therefore, outstanding liabilities after the haircut are equal to $(1-\vartheta_t)\left(1+r_t^b\right)q_{t-1}^b b_{t-1}$. The haircut ϑ_t itself depends on the realization of the draw for the fiscal limit, and is given by:

$$\vartheta_t = \begin{cases} \vartheta_{def} & \text{with probability } p_t^{def}; \\ 0 & \text{with probability } 1-p_t^{def}. \end{cases} \tag{78}$$

The gains from the partial default are equal to $\tilde{\tau}_t^{tr} = \vartheta_t\left(1+r_t^b\right)q_{t-1}^b b_{t-1}$, and are effectively transferred to households by reducing their lump sum taxes from τ_t to $\tilde{\tau}_t = \tau_t - \tilde{\tau}_t^{tr}$. In that case, the ex post default budget constraint of the government is given by:

$$q_t^b b_t + \tilde{\tau}_t + d_t^{cb} = g_t + (1-\vartheta_t)\left(1+r_t^b\right)q_{t-1}^b b_{t-1}, \tag{79}$$

Substitution of $\tilde{\tau}_t = \tau_t - \vartheta_t\left(1+r_t^b\right)q_{t-1}^b b_{t-1}$ shows that the ex post default budget constraint is the same as the budget constraint in case of no default(3).

Impact of a sovereign default on the holders of government bonds

I assume that in case of sovereign default, a haircut is only imposed on privately-held government bonds, i.e., the central bank is exempted from incurring a haircut.

[11] Note that $\bar{b}_{max}$ does not refer to a maximum level of debt, but is a parameter of the default function. There is only a maximum level of taxation in both Corsetti et al. (2013) and Schabert and van Wijnbergen (2014), while there is no limit on the amount of debt the government can issue. One interpretation of $\bar{b}_{max}$ is to think of it as the maximum level of debt in the Maastricht Treaty, which prescribes that government debt should not be above 60% of GDP. In reality, Eurozone governments are not constrained in issuing more debt than this, as many Eurozone countries have debt levels above 100%.

[12] We assume that the probability of default is increasing in the stock of debt held by private investors rather than the total stock of government debt. Everything else equal, this makes a money-financed stimulus more effective than a debt-financed stimulus, as the stock of privately held government bonds will increase less under a money-financed stimulus than under a debt-financed stimulus.

However, financial intermediaries and housholds will take into account the possibility of a sovereign default, as a result of which their first order condition for government bonds, equations (22) and (34), respectively, feature the the probability of default p_t^{def} and the haircut ϑ_{def}. Specifically, the first order condition for intermediaries' holdings of government bonds in the presence of sovereign risk is given by:

$$E_t \left\{ \beta \Lambda_{t,t+1} \left[1 - \sigma + \sigma \chi_{t+1}\right] \left[\left(1 - p_{t+1}^{def} \vartheta_{def}\right) \left(1 + r_{t+1}^b\right) - \left(1 + r_{t+1}^d\right) \right] \right\} = \lambda_b \left(\frac{\mu_t}{1 + \mu_t} \right), \tag{80}$$

The first order condition for households' holdings of government bonds in the presence of sovereign default risk is now given by:

$$E_t \left\{ \beta \Lambda_{t,t+1} \left[\frac{\left(1 - p_{t+1}^{def} \vartheta_{def}\right) \left(1 + r_{t+1}^b\right) q_t^b}{q_t^b + \kappa_b \left(s_t^{b,h} - \hat{s}_{b,h}\right)} \right] \right\} = 1, \tag{81}$$

Following van der Kwaak and van Wijnbergen (2017), I assume that households recapitalize their financial intermediaries. However, financial intermediaries do not anticipate this recapitalization, which is why they price in the risk of sovereign default. However, the recapitalization ensures that the aggregate law of motion for intermediaries' net worth is unaffected by a default by the government. Therefore, the law of motion is given by equation (26), see van der Kwaak and van Wijnbergen (2017) for details.

Equilibrium definition

The definition of the equilibrium is the same as in Appendix A.6, except that there is an additional variable p_t^{def}, which results in an additional equation, which is given by equation (77). Furhtermore, the first order conditions for intermediaries' and households' choice of government bonds, equations (22) and (34), respectively, are replaced by the first order conditions (80) and (81).

Let $\{m_{t-1}^C, s_{t-1}^{b,h}, d_{t-1}, s_{t-1}^{b,f}, m_{t-1}^R, n_{t-1}, b_{t-1}, \tilde{\tau}_{t-1}, p_{t-1}^{cb}, s_{t-1}^{b,cb}, r_{t-1}^n, r_{t-1}^{n,d}, \mathcal{D}_{p,t-1}\}$ be the endogenous state-variables, while $\{z_t, \xi_t, g_t\}$ be the exogenous state-variables. A recursive competitive equilibrium is a sequence of quantities and prices $\{c_t, \lambda_t, h_t, m_t^C, s_t^{b,h},$

$\chi_t, \mu_t, s_t^{b,f}, m_t^R, n_t, d_t, q_t^b, r_t^b, r_t^r, r_t^d, w_t, \zeta_t, \pi_t, \pi_t^{new}, \Xi_{1,t}, \Xi_{2,t}, \mathcal{D}_{p,t}, y_t, b_t, g_t, \tau_t, \tilde{\tau}_t, p_t^{cb}, s_t^{b,cb}, n_t^{cb}, n_t^{cb*}, d_t^{cb}, r_t^{n,r}, r_t^{n,T}, r_t^{n,d}, r_t^{n,b}, p_t^{def}\}$, and exogenous shocks $\{z_t, \xi_t\}$ such that:

1. Households optimize taking prices as given: (32) - (33), (35) - (36), and the new first order condition for government bonds (81).

2. Financial intermediaries optimize taking prices as given: intermediaries' balance sheet constraint (64), the first order conditions for reserves, and deposits (23) - (24), intermediaries' incentive compatibility constraint (65), the aggregate law of motion for net worth (26), and the new first order condition for government bonds (80).

3. Intermediate goods producers optimize taking prices as given, from which we can find the wage rate (66), and the aggregate supply relation (67).

4. Domestic retail goods producers that are allowed to choose prices optimize taking the input price ζ_t as given: (55) - (57), (60), and (63).

5. The bond market clears: (29).

6. The market for final goods clears: (30).

7. The fiscal variables evolve according to: (1) - (6).

8. The probability of default is given: (77).

9. The monetary variables evolve according to: the central bank's balance sheet constraint (7), the evolution of central bank assets (8), the ex post dividend amount of central bank net worth (9), the ex ante amount of central bank net worth (13), central bank dividends (14), the nominal interest rate on reserves (10), and the Taylor rule (11).

10. The relation between the ex post real interest rate and the nominal interest rate on reserves (12) and deposits (17) hold.

11. Exogenous processes evolve according to (68) - (69).

B.2.2 Results

Below, I reproduce the results from Table 2 of the main text in Table 6, and add an additional row with the results from the inclusion of sovereign default risk. The accompanying simulations for the model version with sovereign default risk can be found in Appendix C in Figures 11 and 12.

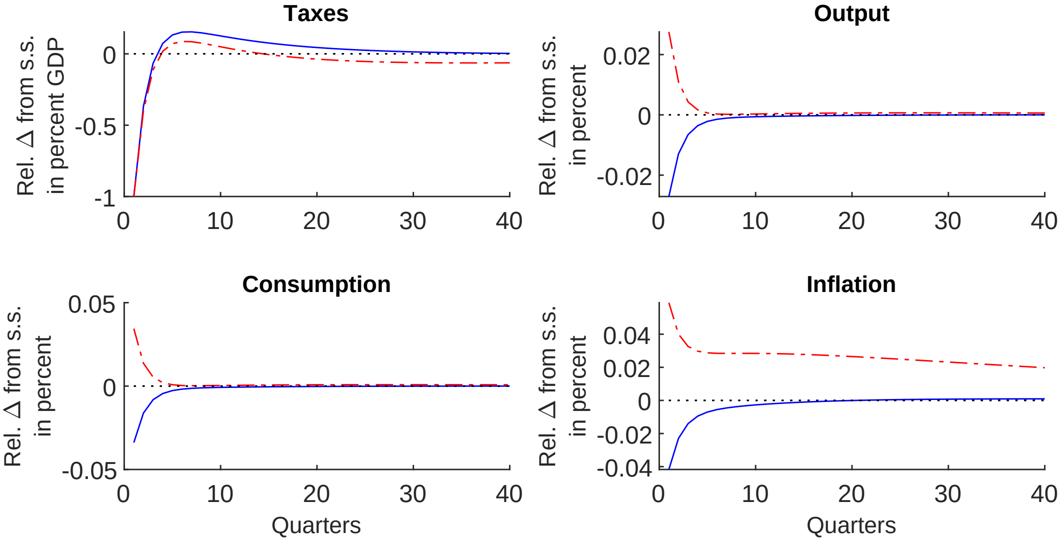
	Tax cut (D)	Tax cut (M)	Spending (D)	Spending (M)
Normal times	0	0	0.4091	0.4091
Fin. crisis	-0.0018	0.0048	0.4068	0.4133
Fin. crisis, LT debt	-0.0299	0.0499	0.3752	0.4550
Fin. crisis, LT debt, $s_t^{b,h} = 0$	-0.0846	-0.1236	0.2625	0.2235
Fin. crisis, LT debt, sov. risk	-0.0346	0.0742	0.3703	0.4791

Table 6: Table displaying the discounted cumulative dynamic multiplier (31) over the first 1,000 quarters for listed scenarios under a fiscal stimulus during a financial crisis. (D) refers to a debt-financed fiscal stimulus, whereas (M) refers to a money-financed stimulus. Finally, LT refers to long-term government debt.

C Additional figures

In the simulations below, I follow Galí (2020b), and replace the rule for the nominal interest rate (10) by imposing that the central bank always ensures that inflation is equal to steady state inflation, i.e. $\pi_t = 1$.

Debt-financing vs. money-financing: tax cut, long-term bonds



(a)

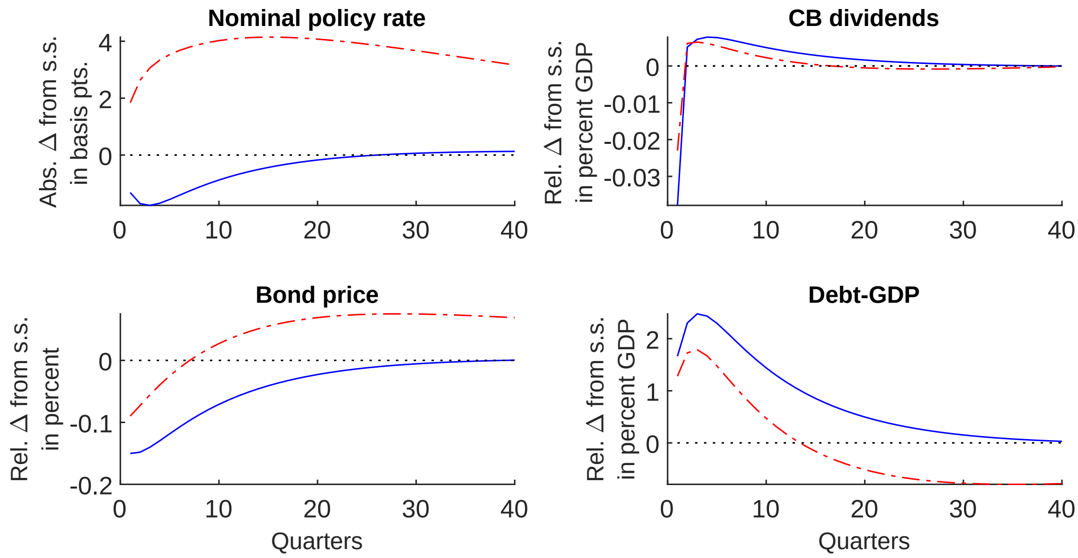
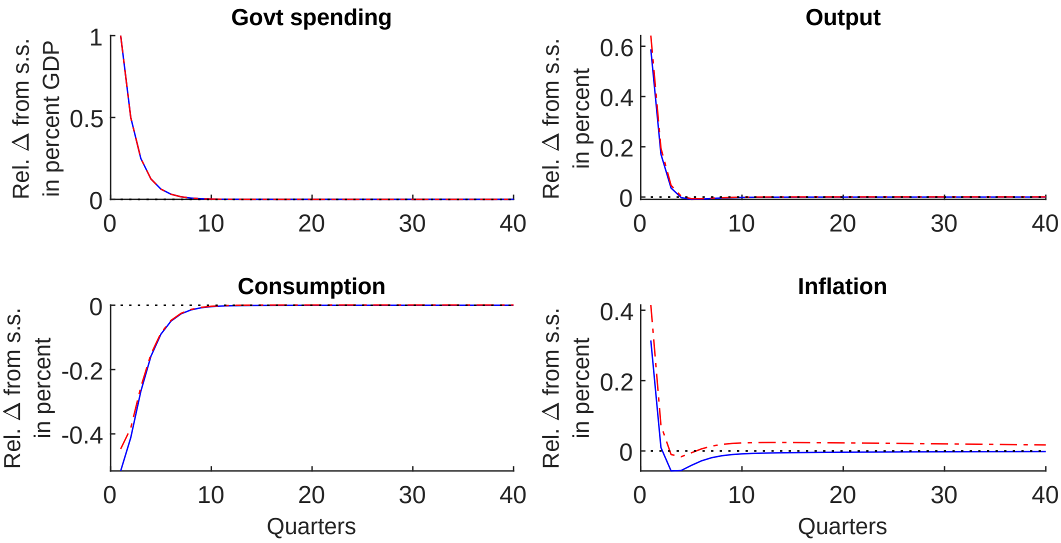


Figure 9: Impulse response functions for a tax cut shock of 1% of steady state output. The tax cut is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$.

Debt-financing vs. money-financing: government spending, long-term bonds



(a)

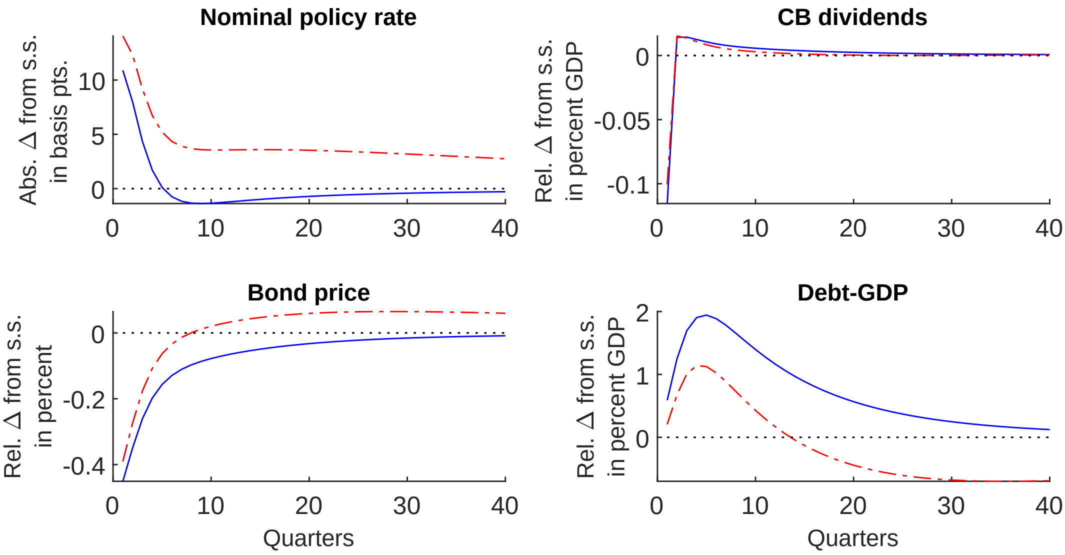
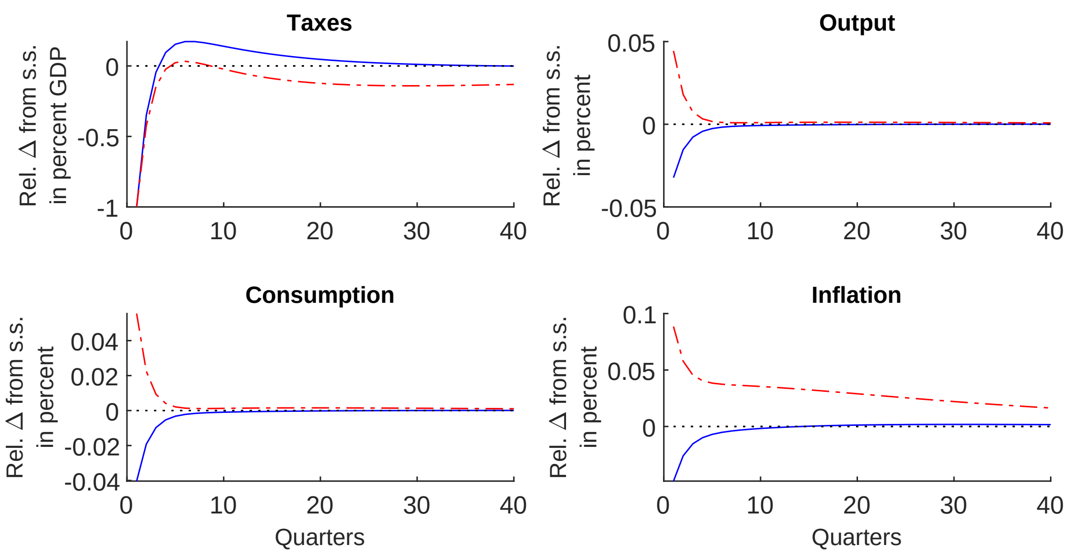


Figure 10: Impulse response functions for a government spending shock of 1% of steady state output in financial crisis times ($\mu_t > 0$). The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$

Debt-financing vs. money-financing: tax cut, long-term bonds, sovereign default risk



(a)

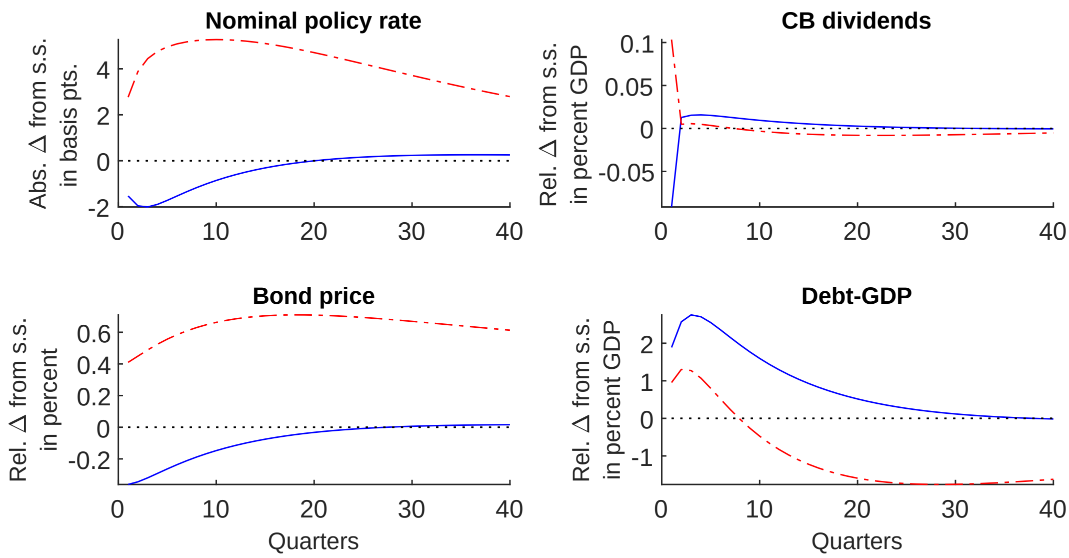
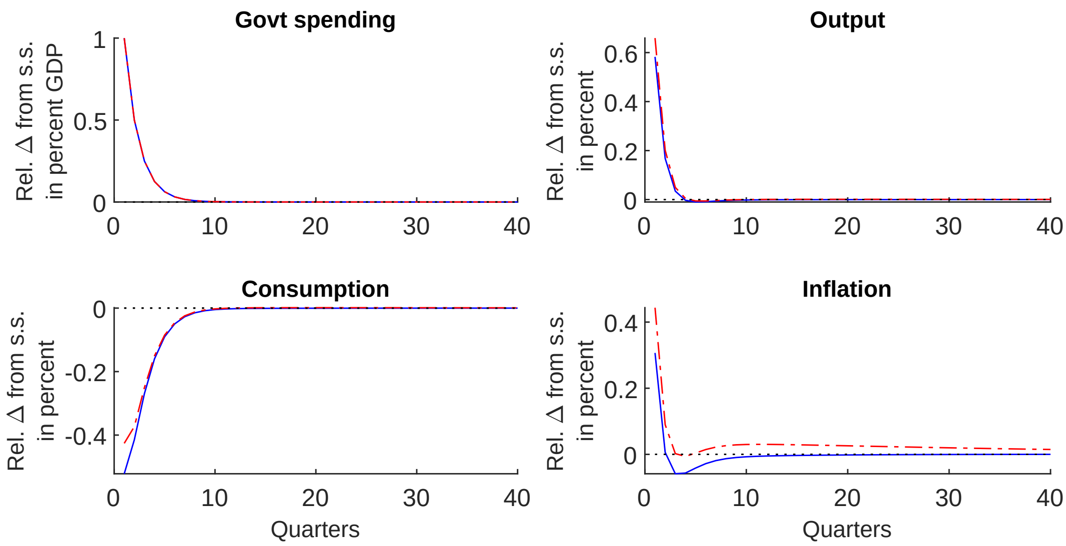


Figure 11: Impulse response functions for a tax cut shock of 1% of steady state output. The tax cut is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$. Government bonds are subject to sovereign default risk.

Debt-financing vs. money-financing: government spending, long-term bonds, sovereign default risk



(a)

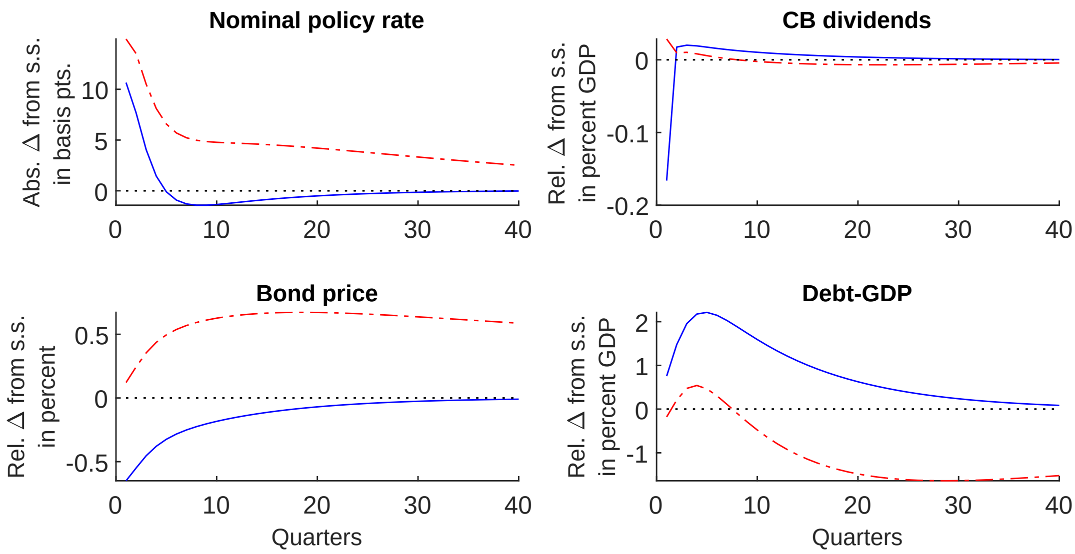
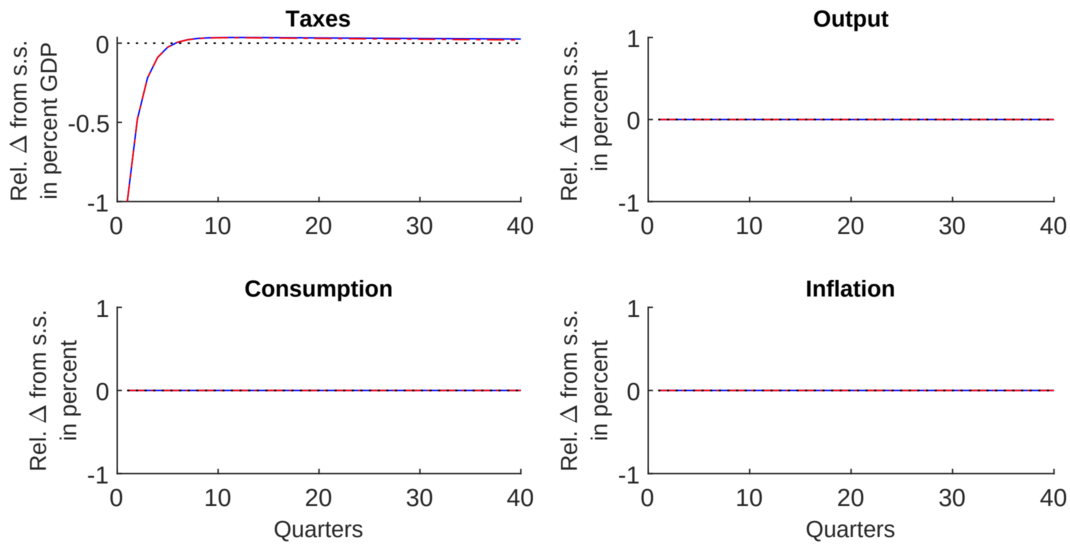


Figure 12: Impulse response functions for a government spending shock of 1% of steady state output in financial crisis times ($\mu_t > 0$). The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output. Government debt is long-term by setting $\rho = 1/20$ and $x_c = 0.01$. Government bonds are subject to sovereign default risk.

Debt-financing vs. money-financing: tax-cut $\pi_t = 1$



(a)

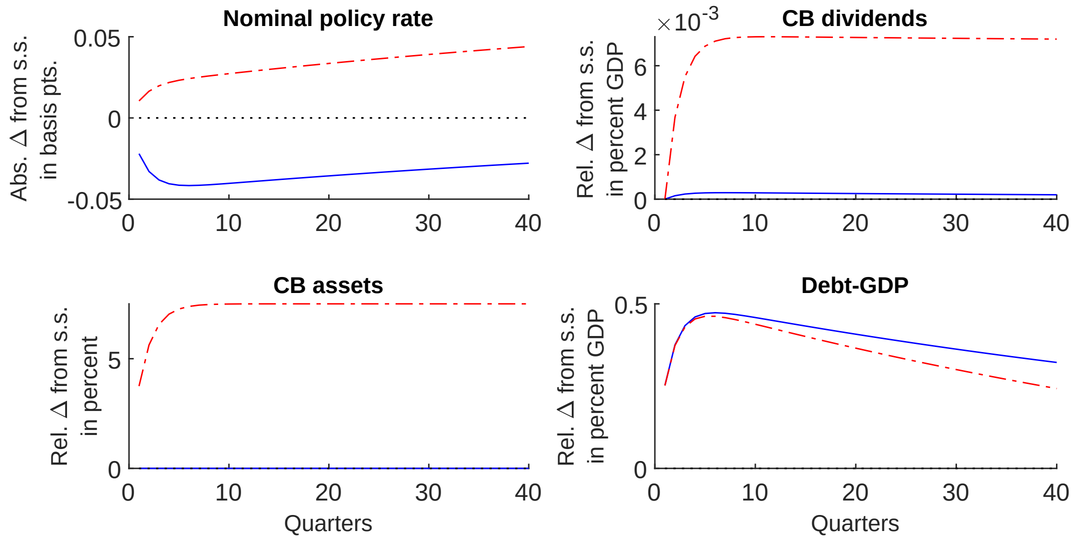
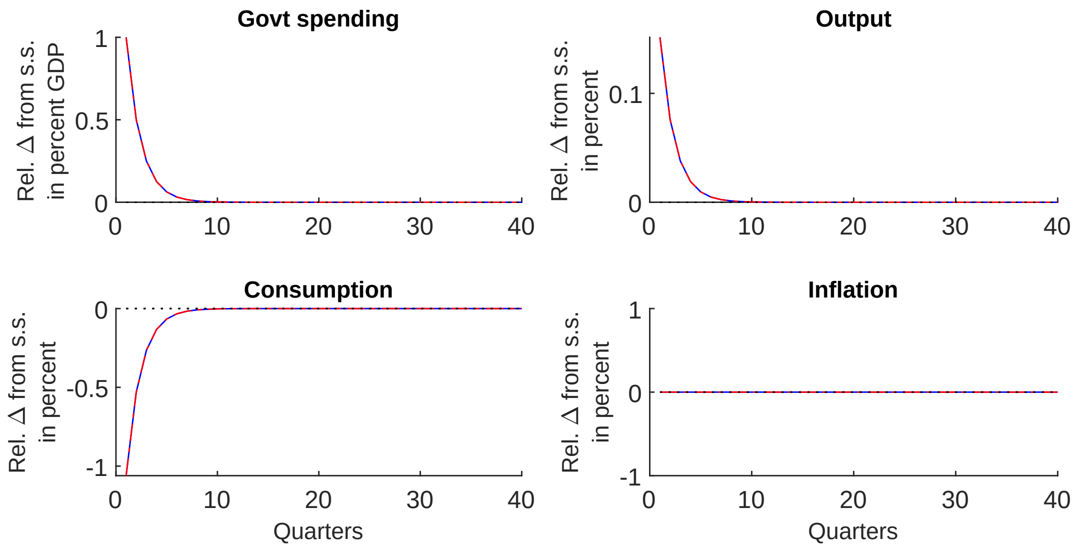


Figure 13: Impulse response functions for a tax cut shock of 1% of steady state output. The tax cut is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

Debt-financing vs. money-financing: government spending, $\pi_t = 1$



(a)

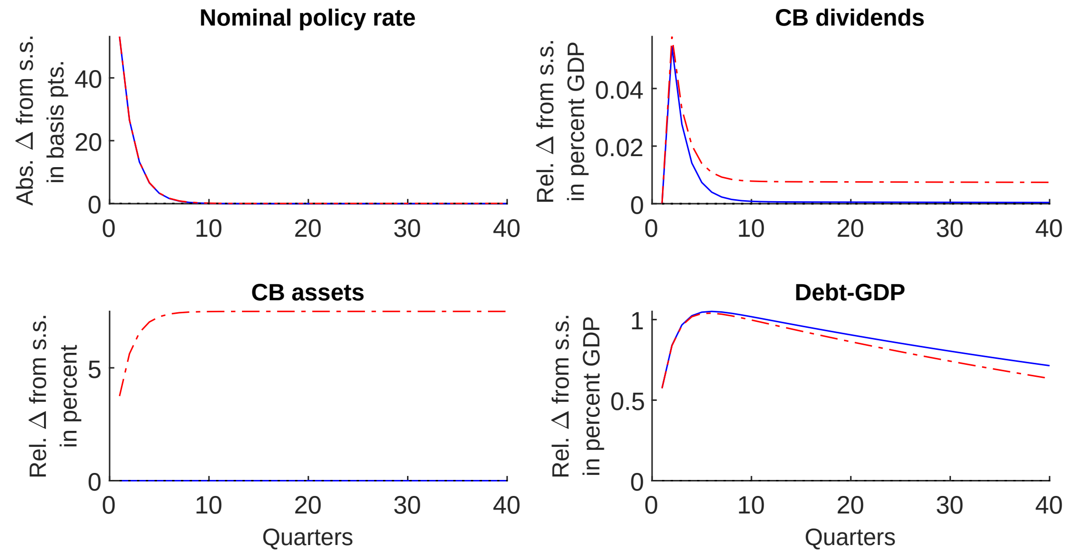


Figure 14: Impulse response functions for a government spending shock of 1% of steady state output. The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

Debt-financing vs. money-financing: fiscal multpliers

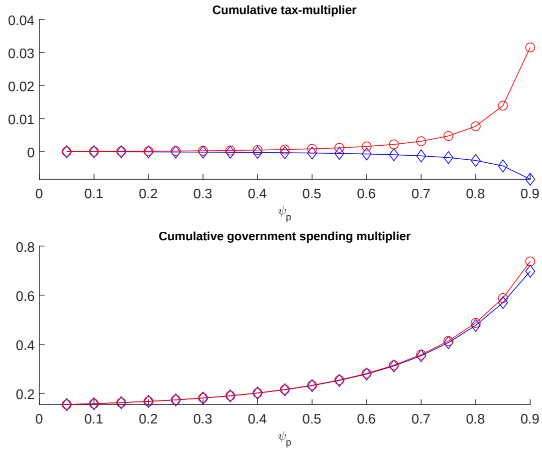


Figure 15: Multipliers: the role of price-stickiness. The figure displays the dynamic multipliers according to formula (31) in response to a tax cut of 1% of steady state output (top), and an increase in government spending of 1% of steady state output (bottom) as a function of the degree of price-stickiness ψ_p. The blue diamonds correspond to a debt-financing regime, while the red circles correspond to a money-financing regime.

C.1 The Zero Lower Bound (ZLB)

	Tax cut (D)	Tax cut (M)	Spending (D)	Spending (M)
ZLB: Fin. crisis	-0.0228	0.0192	0.6422	0.6641

Table 7: Table displaying the discounted cumulative dynamic multiplier (31) over the first 1,000 quarters for listed scenarios under a government spending shock during a financial crisis, where the economy is pushed to the ZLB as a result of a negative preference shock of 6%. (D) refers to a debt-financed fiscal stimulus, whereas (M) refers to a money-financed stimulus. Finally, LT refers to long-term government debt.

Debt-financing vs. money-financing: fiscal multpliers

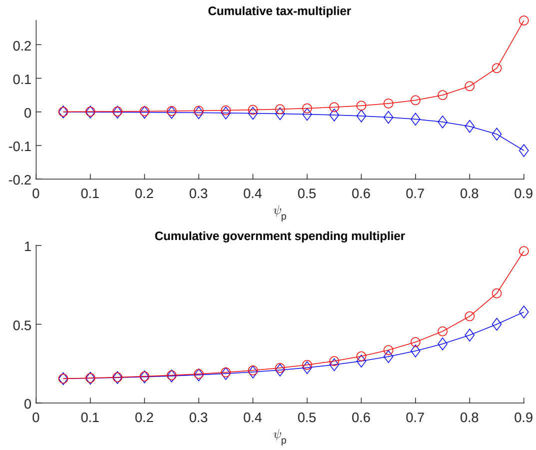


Figure 16: Multipliers: the role of price-stickiness. The figure displays the dynamic multipliers according to formula (31) in response to a tax cut of 1% of steady state output (top), and an increase in government spending of 1% of steady state output (bottom) as a function of the degree of price-stickiness ψ_p. The maturity of government debt is 20 quarters by setting $\rho = 1/20$, while the interest payment $x_c = 0.01$. The blue diamonds correspond to a debt-financing stimuli, while the red circles correspond to a money-financing stimuli.

Debt-financing vs. money-financing: fiscal multpliers

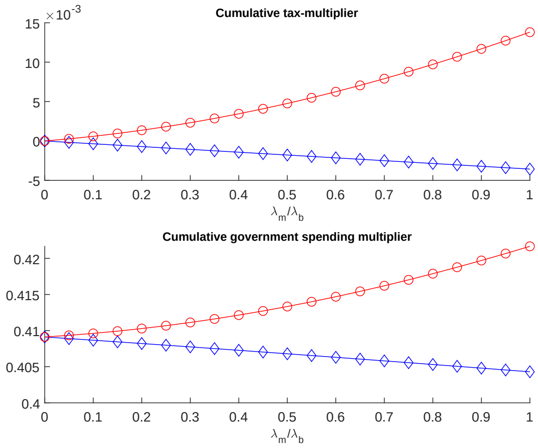


Figure 17: Multipliers: the role of λ_m. The figure displays the dynamic multipliers according to formula (31) in response to a tax cut of 1% of steady state output (top), and an increase in government spending of 1% of steady state output (bottom) as a function of the ratio of λ_m over λ_b. The blue diamonds correspond to a debt-financing regime, while the red circles correspond to a money-financing regime.

Debt-financing vs. money-financing: fiscal multpliers

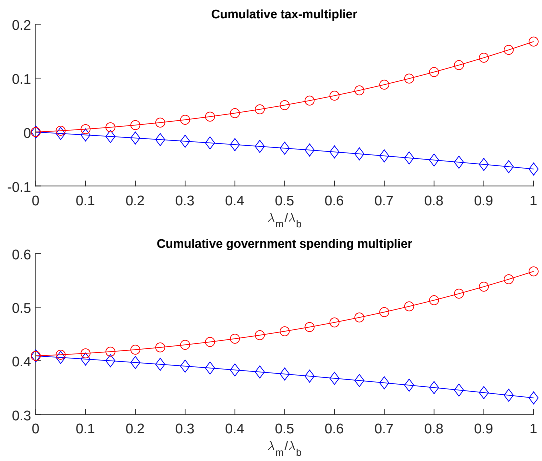


Figure 18: Multipliers: the role of λ_m. The figure displays the dynamic multipliers according to formula (31) in response to a tax cut of 1% of steady state output (top), and an increase in government spending of 1% of steady state output (bottom) as a function of the ratio of λ_m over λ_b. The maturity of government debt is 20 quarters by setting $\rho = 1/20$, while the interest payment $x_c = 0.01$. The blue diamonds correspond to a debt-financing regime, while the red circles correspond to a money-financing regime.

Debt-financing vs. money-financing: fiscal multpliers

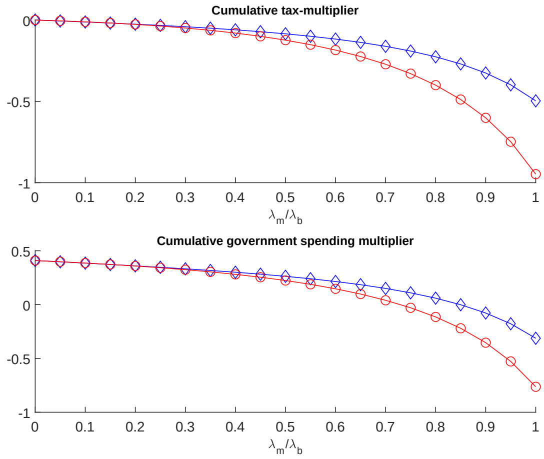
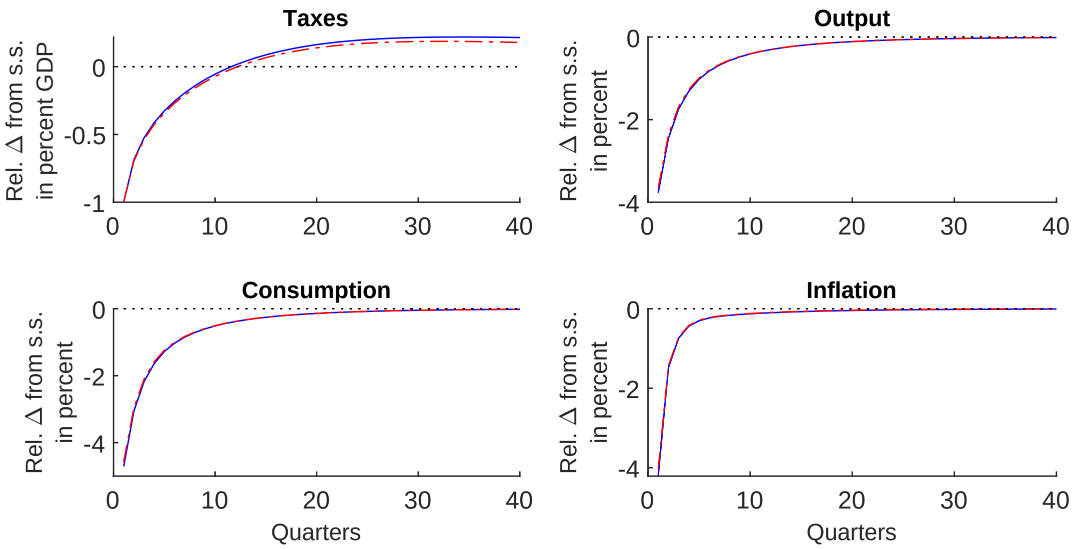


Figure 19: Multipliers: the role of λ_m for the model version where all government debt is held by financial intermediaries, i.e. $s_t^{b,h} = 0$. The figure displays the dynamic multipliers according to formula (31) in response to a tax cut of 1% of steady state output (top), and an increase in government spending of 1% of steady state output (bottom) as a function of the ratio of λ_m over λ_b. The maturity of government debt is 20 quarters by setting $\rho = 1/20$, while the interest payment $x_c = 0.01$. The blue diamonds correspond to a debt-financing regime, while the red circles correspond to a money-financing regime.

Debt-financing vs. money-financing: tax-cut, ZLB



(a)

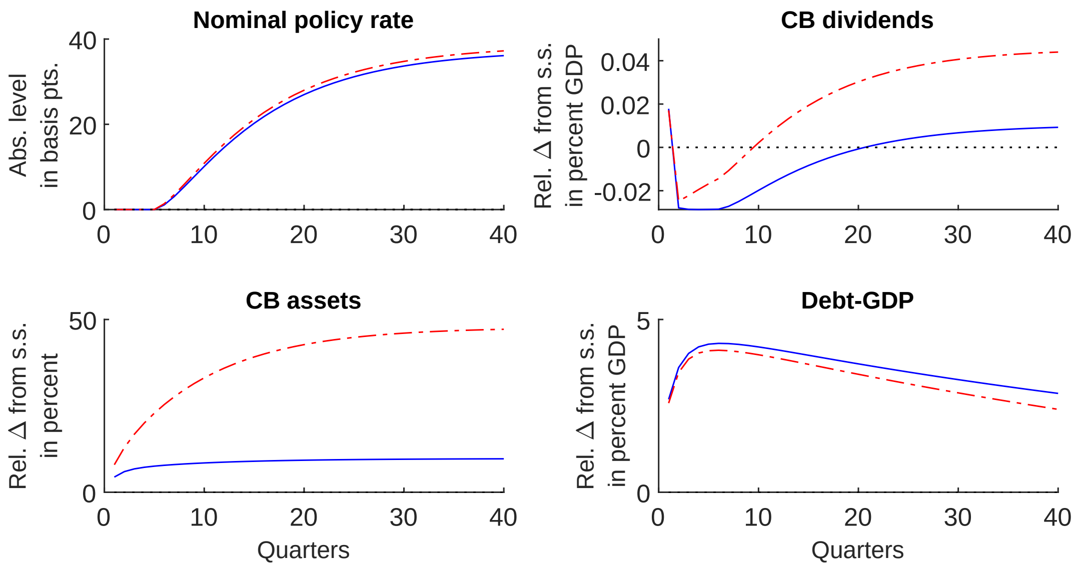
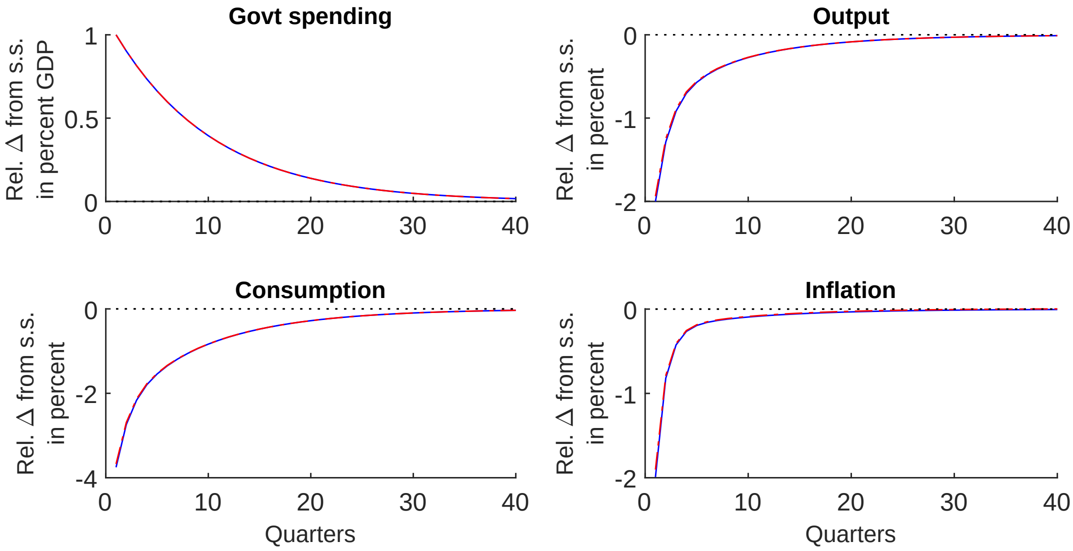


Figure 20: Impulse response functions for a decrease in taxes by 1% of steady state output on impact in response to a negative preference shock of 6% that brings the nominal interest rate on reserves to the ZLB. The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

Debt-financing vs. money-financing: government spending, ZLB



(a)

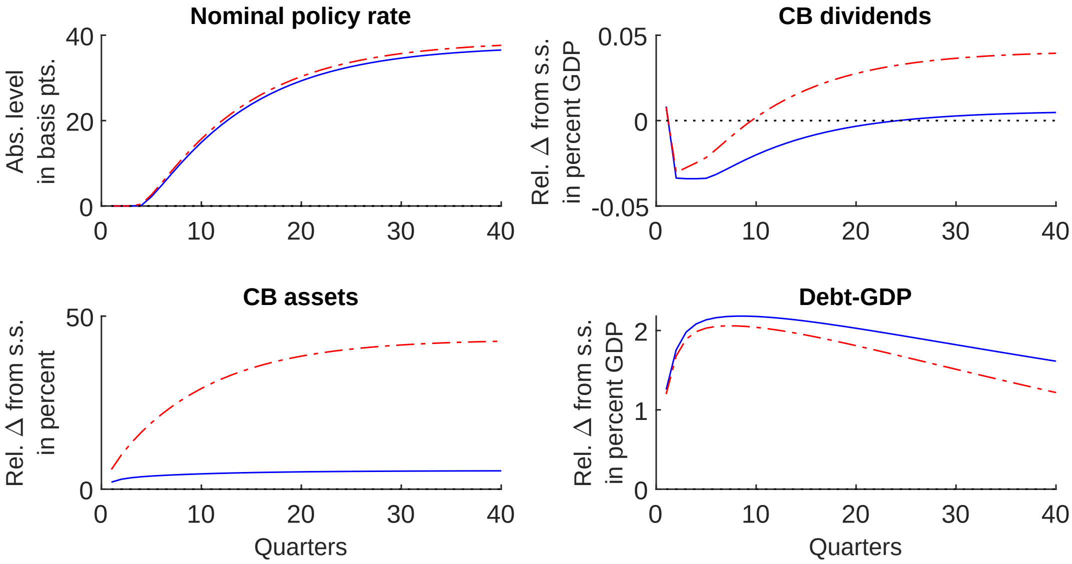


Figure 21: Impulse response functions for an increase in government spending by 1% of steady state output on impact in response to a negative preference shock of 6% that brings the nominal interest rate on reserves to the ZLB. The additional spending is debt-financed in the blue-solid impulse response functions, and money-financed for the red, slotted impulse response functions. The debt-to-GDP ratio denotes the deviation of government debt b_t from steady state, and is expressed as a percentage of annual output.

university of groningen

faculty of economics and business

List of research reports

17001-EEF: Trinks, A., B. Scholtens, M. Mulder, and L. Dam, Divesting Fossil Fuels: The Implications for Investment Portfolios

17002-EEF: Angelini, V., and J.O. Mierau, Late-life Health Effects of Teenage Motherhood

17003-EEF: Jong-A-Pin, R., M. Laméris, and H. Garretsen, Political Preferences of (Un)happy Voters: Evidence Based on New Ideological Measures

17004-EEF: Jiang, X., N. Hermes, and A. Meesters, Financial Liberalization, the Institutional Environment and Bank Efficiency

17005-EEF: Kwaak, C. van der, Financial Fragility and Unconventional Central Bank Lending Operations

17006-EEF: Postelnicu, L. and N. Hermes, The Economic Value of Social Capital

17007-EEF: Ommeren, B.J.F. van, M.A. Allers, and M.H. Vellekoop, Choosing the Optimal Moment to Arrange a Loan

17008-EEF: Bekker, P.A., and K.E. Bouwman, A Unified Approach to Dynamic Mean-Variance Analysis in Discrete and Continuous Time

17009-EEF: Bekker, P.A., Interpretable Parsimonious Arbitrage-free Modeling of the Yield Curve

17010-GEM: Schasfoort, J., A. Godin, D. Bezemer, A. Caiani, and S. Kinsella, Monetary Policy Transmission in a Macroeconomic Agent-Based Model

17011-I&O: Bogt, H. ter, Accountability, Transparency and Control of Outsourced Public Sector Activities

17012-GEM: Bezemer, D., A. Samarina, and L. Zhang, The Shift in Bank Credit Allocation: New Data and New Findings

17013-EEF: Boer, W.I.J. de, R.H. Koning, and J.O. Mierau, Ex-ante and Ex-post Willingness-to-pay for Hosting a Major Cycling Event

17014-OPERA: Laan, N. van der, W. Romeijnders, and M.H. van der Vlerk, Higher-order Total Variation Bounds for Expectations of Periodic Functions and Simple Integer Recourse Approximations

17015-GEM: Oosterhaven, J., Key Sector Analysis: A Note on the Other Side of the Coin

17016-EEF: Romensen, G.J., A.R. Soetevent: Tailored Feedback and Worker Green Behavior: Field Evidence from Bus Drivers

17017-EEF: Trinks, A., G. Ibikunle, M. Mulder, and B. Scholtens, Greenhouse Gas Emissions Intensity and the Cost of Capital

17018-GEM: Qian, X. and A. Steiner, The Reinforcement Effect of International Reserves for Financial Stability

17019-GEM/EEF: Klasing, M.J. and P. Milionis, The International Epidemiological Transition and the Education Gender Gap

2018001-EEF: Keller, J.T., G.H. Kuper, and M. Mulder, Mergers of Gas Markets Areas and Competition amongst Transmission System Operators: Evidence on Booking Behaviour in the German Markets

2018002-EEF: Soetevent, A.R. and S. Adikyan, The Impact of Short-Term Goals on Long-Term Objectives: Evidence from Running Data

2018003-MARK: Gijsenberg, M.J. and P.C. Verhoef, Moving Forward: The Role of Marketing in Fostering Public Transport Usage

2018004-MARK: Gijsenberg, M.J. and V.R. Nijs, Advertising Timing: In-Phase or Out-of-Phase with Competitors?

2018005-EEF: Hulshof, D., C. Jepma, and M. Mulder, Performance of Markets for European Renewable Energy Certificates

2018006-EEF: Fosgaard, T.R., and A.R. Soetevent, Promises Undone: How Committed Pledges Impact Donations to Charity

2018007-EEF: Durán, N. and J.P. Elhorst, A Spatio-temporal-similarity and Common Factor Approach of Individual Housing Prices: The Impact of Many Small Earthquakes in the North of Netherlands

2018008-EEF: Hermes, N., and M. Hudon, Determinants of the Performance of Microfinance Institutions: A Systematic Review

2018009-EEF: Katz, M., and C. van der Kwaak, The Macroeconomic Effectiveness of Bank Bail-ins

2018010-OPERA: Prak, D., R.H. Teunter, M.Z. Babai, A.A. Syntetos, and J.E. Boylan, Forecasting and Inventory Control with Compound Poisson Demand Using Periodic Demand Data

2018011-EEF: Brock, B. de, Converting a Non-trivial Use Case into an SSD: An Exercise

2018012-EEF: Harvey, L.A., J.O. Mierau, and J. Rockey, Inequality in an Equal Society

2018013-OPERA: Romeijnders, W., and N. van der Laan, Inexact cutting planes for two-stage mixed-integer stochastic programs

2018014-EEF: Green, C.P., and S. Homroy, Bringing Connections Onboard: The Value of Political Influence

2018015-OPERA: Laan, N. van der, and W. Romeijnders, Generalized aplha-approximations for two-stage mixed-integer recourse models

2018016-GEM: Rozite, K., Financial and Real Integration between Mexico and the United States

2019001-EEF: Lugalla, I.M., J. Jacobs, and W. Westerman, Drivers of Women Entrepreneurs in Tourism in Tanzania: Capital, Goal Setting and Business Growth

2019002-EEF: Brock, E.O. de, On Incremental and Agile Development of (Information) Systems

2019003-OPERA: Laan, N. van der, R.H. Teunter, W. Romeijnders, and O.A. Kilic, The Data-driven Newsvendor Problem: Achieving On-target Service Levels.

2019004-EEF: Dijk, H., and J. Mierau, Mental Health over the Life Course: Evidence for a U-Shape?

2019005-EEF: Freriks, R.D., and J.O. Mierau, Heterogeneous Effects of School Resources on Child Mental Health Development: Evidence from the Netherlands.

2019006-OPERA: Broek, M.A.J. uit het, R.H. Teunter, B. de Jonge, J. Veldman, Joint Condition-based Maintenance and Condition-based Production Optimization.

2019007-OPERA: Broek, M.A.J. uit het, R.H. Teunter, B. de Jonge, J. Veldman, Joint Condition-based Maintenance and Load-sharing Optimization for Multi-unit Systems with Economic Dependency

2019008-EEF: Keller, J.T. G.H. Kuper, and M. Mulder, Competition under Regulation: Do Regulated Gas Transmission System Operators in Merged Markets Compete on Network Tariffs?

2019009-EEF: Hulshof, D. and M. Mulder, Renewable Energy Use as Environmental CSR Behavior and the Impact on Firm Profit

2019010-EEF: Boot, T., Confidence Regions for Averaging Estimators
2020001-OPERA: Foreest, N.D. van, and J. Wijngaard. On Proportionally Fair Solutions for the Divorced-Parents Problem

2020002-EEF: Niccodemi, G., R. Alessie, V. Angelini, J. Mierau, and T. Wansbeek. Refining Clustered Standard Errors with Few Clusters

2020003-I&O: Bogt, H. ter, Performance and other Accounting Information in the Public Sector: A Prominent Role in the Politicians' Control Tasks?

2020004-I&O: Fisch, C., M. Wyrwich, T.L. Nguyen, and J.H. Block, Historical Institutional Differences and Entrepreneurship: The Case of Socialist Legacy in Vietnam

2020005-I&O: Fritsch, M. and M. Wyrwich. Is Innovation (Increasingly) Concentrated in Large Cities? An Internatinal Comparison

2020006-GEM: Oosterhaven, J., Decomposing Economic Growth Decompositions.

2020007-I&O: Fritsch, M., M. Obschonka, F. Wahl, and M. Wyrwich. The Deep Imprint of Roman Sandals: Evidence of Long-lasting Effects of Roman Rule on Personality, Economic Performance, and Well-Being in Germany

2020008-EEF: Heijnen, P., On the Computation of Equilibrium in Discontinuous Economic Games

2020009-EEF: Romensen, G.J. and A.R. Soetevent, Improving Worker Productivity Through Tailored Performance Feedback: Field Experimental Evidence from Bus Drivers

2020010-EEF: Rao, Z., M. Groneck, and R. Alessie, Should I Stay or Should I Go? Intergenerational Transfers and Residential Choice. Evidence from China

2020011-EEF: Kwaak, C. van der, Unintended Consequences of Central Bank Lending in Financial Crises

2020012-EEF: Soetevent, A.R., Determinants choice set variation in demand estimation – with an application to the electric vehicle public charging market

2020013-EEF: Kwaak, C. van der, Old-Keynesianism in the New Keynesian model

2020014-EEF: Plaat, m. van der, Loan Sales and the Tyranny of Distance in U.S. Residential Mortgage Lending

2020015-I&O: Fritsch, M., and M. Wyrwich, Initial Conditions and Regional Performance in the Aftermath of Disruptive Shocks: The Case of East Germany after Socialism

2020016-OPERA: Laan, N. van der, and W. Romeijnders, A Converging Benders' Decomposition Algorithm for Two-stage Mixed-integer Recourse Models

2021001-OPERA: Baardman, L., K.J. Roodbergen, H.J. Carlo, and A.H. Schrotenboer, A Special Case of the Multiple Traveling Salesmen Problem in End-of-aisle Picking Systems

2021002-EEF: Wiese, R., and S. Eriksen, Willingness to Pay for Improved Public Education and Public Health Systems: The Role of Income Mobility Prospects.

2021003-EEF: Keller, J.T., G.H. Kuper, and M. Mulder, Challenging Natural Monopolies: Assessing Market Power of Gas Transmission System Operators for Cross-Border Capacity

2021004-EEF: Li, X., and M. Mulder, Value of Power-to-Gas as a Flexibililty Option in Integrated Electricity and Hydrogen Markets
2021005-GEM: Rozite, K., J.P.A.M. Jacobs, and D.J. Bezemer, Investor Sentiment and Business Investment

2021006-EEF: Spierdijk, L., and T. Wansbeek, Differencing as a Consistency Test for the Within Estimator

2021007-EEF: Katz, M., and C. van der Kwaak, To Bail-in or to Bailout: that's the (Macro) Question

2021008-EEF: Haan, M.A., N.E. Stoffers, and G.T.J. Zwart, Choosing Your Battles: Endogenous Multihoming and Platform Competition

2021009-I&O: Greve, M., M. Fritsch, and M. Wyrwich, Long-Term Decline of Regions and the Rise of Populism: The Case of Germany

2021010-MARK: Hirche, C.F., T.H.A. Bijmolt, and M.J. Gijsenberg, When Offline Stores Reduce Online Returns

2021011-MARK: Hirche, C.F., M.J. Gijsenberg, and T.H.A. Bijmolt, Promoting Product Returns: Effects of Price Reductions on Customer Return Behavior

2021012-MARK: Hirche, C.F., M.J. Gijsenberg, and T.H.A. Bijmolt, Asking Less, Getting More? The Influence of Fixed-Fee and Threshold-Based Free Shipping on Online Orders and Returns

2021013-I&O: Sorgner, A., and M. Wyrwich, Calling Baumol: What Telephones Can Tell Us about the Allocation of Entrepreneurial Talent in the Face of Radical Institutional Changes

2021014-I&O: Slavtchev, V., and M. Wywich, TV and Entrepreneurship

2021015-EEF: Kate, F. ten, M.J. Klasing, and P. Milionis, Diversity, Identity and Tax Morale

2021016-EEF: Bergemann, A., and R.T. Riphahn, Maternal Employment Effects of Paid Parental Leave

2021017-GEM: Abolhassani, M., Productivity Spillovers of Multinational Enterprises through Worker Mobility: New Evidence for the Netherlands

2021018-GEM: Abolhassani, M., Productivity Spillovers of Superior Firms through Worker Mobility

2022001-GEM: Oosterhaven, J., A Price Reinterpretation of the Leontief Quantity Model

2022002-EEF: Ghaemi, S, X. Li, and M. Mulder, Economic Value of Flexibility Provided by Power to gas Conversion Systems in Low-voltage Distribution Grids

2022003-OB: Meer, P.H. van der, Are All Self-employed Happy?

2022004-EEF: Perey, P., and M. Mulder, International Competitiveness of Low-carbon Hydrogen Supply to the North-west European Market

2022005-OPERA: Kasper, A., M. Land, and R. Teunter, University of Groningen, Faculty of Economics and Business, Department of Operations.

2022006-I&O: Fritsch, M., and M. Wyrwich, Entrepreneurship in the Long-run: Empirical Evidence and Historical Mechanisms.

2022007-EEF: Treurniet, M., and R. Lensink, Belief-based Poverty Traps and the Effects of Material and Psychological Development Interventions.

2022008-EEF: Kwaak, Christiaan van der, Monetary Financing Does Not Produce Miraculous Fiscal Multipliers www.rug.nl/feb