The long and short of financing government spending*

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August 22, 2023

Abstract

This paper shows that debt-financed fiscal multipliers vary depending on the maturity of debt issued to finance spending. Utilizing state-dependent SVAR models and local projections for post-war US data, we show that a fiscal expansion financed with short-term debt increases output more than one financed with long-term debt. The reason for this result is that only the former leads to a significant increase in private consumption. We then construct an incomplete markets model in which households invest in long and short assets. Short assets have a lower return (in equilibrium) since they provide liquidity services, households can use them to cover sudden spending shocks. An increase in the supply of these assets through a short-term debt financed government spending shock makes it easier for constrained households to meet their spending needs and therefore crowds in private consumption. We first prove this analytically in a simplified model and then show it in a calibrated standard New Keynesian model. We finally study the optimal policy under a Ramsey planner. The optimizing government faces a trade-off between the hedging value of long-term debt, as its price decreases in response to adverse shocks, and the larger multiplier when it issues short-term debt. We find that the former effect dominates. The optimal policy for the government is to issue a relatively constant amount of short-term debt and finance spending shocks predominantly with long-term debt.

Keywords: Spending multiplier; Fiscal Policy; Debt Maturity, Incomplete Markets, SVAR, Local Projections.
JEL classifications: D52, E31, E43, E62

*We received helpful comments from, Arpad Abraham, Fernando Broner, Harris Dellas, Refet Gürkaynak, Tasos Karantounias, Olivier Loissel, Jean-Baptiste Michau, Ricardo Nunes, Gert Peersman, Ansgar Rannenberg, Kjetil Storesletten, Harald Uhlig, Gianluca Violante, Raf Wouters and seminar participants at the Deutsche Bundesbank, the National Bank of Belgium, at Bristol, Surrey, AUEB, and Crest/Ecole Polytechnique. The views expressed in this document are exclusively the opinion of the authors and do not necessarily represent those of the Bundesbank, the European Central Bank or any other official institution. Oikonomou is grateful to the National Bank of Belgium for funding. We are also thankful to Morteza Ghomi Avili for outstanding research assistance.

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1 Introduction

A considerable literature consisting of both empirical and theoretical contributions has investigated the size of the fiscal multiplier, the increase in the dollar value of aggregate output per additional dollar of spending.[1] This research is of course immensely important since public expenditures, in consumption and investment goods, are a key margin that governments can use to stabilize aggregate economic activity in the face of business cycle shocks.

A recent stream of papers in this literature, conditions the propagation of fiscal shocks on policy variables showing that fiscal multipliers can vary according to the sign of the shock (e.g. Barnichon et al., 2022), to the degree of progressivity of the tax code (Navarro and Ferriere, 2022), the exchange rate regime (e.g. Born, Juessen, and Müller, 2013; Ilzetzki, Mendoza, and Végh, 2013) and according to the type of debt (external vs. internal) that governments issue to finance spending (e.g. Priftis and Zimic, 2021; Broner et al., 2022).

In this paper we advocate that an important and policy relevant determinant of the size of the multiplier is the maturity of debt being issued to finance a spending shock. Employing two widely-used macroeconometric approaches, namely state-dependent SVARs and local projections, we show that when the US government has financed its spending shocks with short maturity debt, then the size of the multiplier has been large, and it exceeded unity. In contrast, when spending was financed with long-term debt, then the fiscal multiplier was lower than one. Accounting for this difference in the output multipliers is the significant difference in the responses of private sector consumption to spending shocks: Financing short-term resulted in a strong crowding in of consumption, whereas long-term financing crowded out consumption.

We then explore a theory that can explain these empirical patterns. At the heart of our model is the notion that short-term bonds function like money, they provide liquidity to the economy which enables agents to reduce idiosyncratic consumption risk. We demonstrate that this mechanism, embedded in an otherwise standard New Keynesian model and calibrated carefully to US data, can explain a large part of the differences in the fiscal multipliers that we find in our empirical exercise. Lastly, we explore the policy implications that we can derive from our theoretical framework, solving for *optimal Ramsey policies* (e.g. Angeletos (2002); Buera and Nicolini (2004); Bhandari, Evans, Golosov, Sargent, et al. (2019); Faraglia, Marcet, Oikonomou, and Scott (2019) among others) to investigate the optimal scale and portfolio composition of government debt.

Our empirical analysis is presented in Section 2 and relies on two complementary methods to show that multipliers indeed depend on the maturity of debt that is issued to finance the spending shocks. Our baseline empirical framework is a proxy-SVAR, in which we identify shocks using the approach of Ramey and Zubairy (2018). Government spending is instrumented with news about military spending. To identify the impact of the maturity choice, we condition on the movements

[1] See Blanchard and Perotti (2002); Hall (2009); Alesina and Ardagna (2010); Mertens and Ravn (2013); Uhlig (2010); Parker (2011); Ramey (2011a,b); Auerbach and Gorodnichenko (2012); Ramey and Zubairy (2018); Barnichon, Debortoli, and Matthes (2022); Priftis and Zimic (2021); Broner, Clancy, Erce, and Martin (2022); Bouakez, Rachedi, and Santoro (2023) for examples of the empirical papers written on this topic. See below for extensive references to the theoretical work in this literature.

of the ratio of short-term to long-term debt in the US. In particular, we extract short-term financed shocks as those occurring in periods in which the ratio of short over long increases; and analogously, long-term financed shocks are those occurring in the periods in which the ratio decreases.

Our second empirical strategy also identifies short and long-term financed shocks through the movements in the ratio of short to long-term debt, but it rather makes use of the local projection method (Jordà, 2005), and more specifically the nonlinear state dependent framework (as in e.g. Auerbach and Gorodnichenko, 2012; Ramey and Zubairy, 2018) continuing to identify fiscal shocks via the news variable.

Our results, using either the proxy-SVAR or the local projections show that short-term financed shocks yield larger fiscal multipliers due to the crowding in of private sector consumption they produce. This finding is robust towards controlling in the VARs for a number of relevant variables, including private sector wages, short and long-term rates (capturing the response of monetary policy and of the term premium to spending shocks), or the debt to GDP ratio. Moreover, our results hold regardless of whether the model is estimated using post 1980s observations (when arguably US monetary policy targeted inflation more actively) or when we use data since the 1960s. Analogously, dropping the Great Recession sample makes little difference for our estimates. We consistently obtain a multiplier that persistently exceeds unity under short-term financing and a much more moderate value when long bonds have been issued to finance spending.

These findings highlight the importance of the choice of debt maturity to finance a spending shock and thus highlight an important role for debt management policy which to our knowledge has been overlooked by the existing literature. In Sections 3 and 4 of the paper we turn to theory in order to investigate a model that can rationalize the empirical findings but also to think of policy going forward, to study how a government facing a portfolio choice between short and long debt may want to exploit the fact that the fiscal multiplier hinges on this choice.

Our model is an incomplete markets economy where households that are heterogeneous in terms of their spending needs, choose to save in a long and a short-term asset. Short-term bonds provide 'liquidity services' enabling households to finance *urgent consumption needs* subject to a 'bonds in advance constraint' that sets the maximum expenditure equal to the real value of the short-term asset. In equilibrium, the return to this asset, is lower (relative to the return of the long-term bond) reflecting the money-like services that short bonds provide to the private sector. The model is otherwise a standard New Keynesian economy, featuring monopolistic competition and sticky prices, and a government that issues debt and levies taxes. Spending is exogenous and is assumed to follow a random process, as is common in many New Keynesian models. Moreover, to keep our modelling as tractable as possible, we abstract from investment (in private and public capital). The empirical analysis of Section 2 did not show a robustly significant effect of maturity on investment; private consumption was clearly the important margin.

In section 3 we investigate the fiscal multipliers in this model. Our baseline is an economy in which monetary policy is set according to a rule targeting inflation and the lagged nominal interest rate and fiscal policy follows an ad hoc rule which adjusts the tax rate to the lagged value of debt. A spending shock which is financed through short-term debt, leads to a multiplier that is considerably above one and to a crowding in of consumption. In contrast, a long-term financed shock predicts a strong crowding out of consumption and a multiplier of around 0.5.

This stark difference between the two modes of financing can be traced to the Euler equation that prices the short-term asset in the model. The supply of short-term debt, appears like a standard demand shock in the Euler equation. When the government increases the quantity of this debt, it engineers a demand expansion. Aggregate consumption increases through two channels: the immediate impact of alleviating the financial friction today, but also through an inter-temporal effect, through inducing households to save less anticipating that future constraints become less likely to bind. In contrast, a long-term financed shock may lead to a lower real value of short bonds in the economy, and thus reverse the effect on consumption. To build this intuition we leverage on a simple version of the model that we can solve analytically.

Though assuming an inertial monetary policy rule magnifies the difference between short and long-term financing of shocks, the difference persists under a standard Taylor rule. To the extent that monetary policy does not forcibly eliminate the demand shock, i.e. through a stochastic intercept that tracks the real rate of interest, we continue finding significant differences between the two modes of financing spending shocks.

These differences persist also in a scenario in which taxes are constant through time and monetary policy responds only weakly to inflation (see e.g. Leeper (1991), passive monetary/ active fiscal regime). In this fiscally dominated equilibrium, the difference in the fiscal multipliers is as large as in our baseline scenario with the inertial rule. Under active fiscal policies, demand shocks do not only impact inflation through the Euler equation but are also filtered through the government budget constraint, adding considerable volatility to macroeconomic variables (e.g. Bianchi and Ilut, 2017).

After establishing that our theory can go a long way towards explaining the empirical evidence, we turn to optimal policy in Section 4. We study how an optimizing government that can set distortionary taxes and the portfolio of short and long bonds would devise its debt issuance policy, taking into account the effect of financing on the fiscal multiplier and hence on its revenue stream. Methodologically, this exercise follows a recent stream of papers studying optimal debt management policies in the canonical real business cycle model, under a Ramsey planner (e.g. Angeletos, 2002; Barnichon et al., 2022; Lustig, Sleet, and Yeltekin, 2008; Debortoli, Nunes, and Yared, 2017; Bhandari et al., 2019; Faraglia, Marcet, and Scott, 2010; Faraglia et al., 2019).

The goal of the government in choosing the optimal portfolio is to smooth tax distortions across time. Financing spending shocks with long-term debt, results in a crowding out of consumption and a drop in long bond prices. A government that issues long debt, can thus benefit from the negative comovement between its outstanding liabilities and its spending needs and smooth distortionary taxes over time (e.g. Angeletos, 2002; Buera and Nicolini, 2004). On the other hand, issuing short-term debt, results in consumption crowding in and may increase prices and the liability of the government, but it also leads to a larger increase in output, which even holding the tax rate constant, can reduce significantly the deficit.

In solving the calibrated model numerically, we find that the optimizing government chooses to issue a positive and stable amount of short-term debt. However, financing spending shocks is done exclusively through long-term debt, the optimal policy takes advantage of the hedging properties of long-term debt, and it does not rely on short-term financing to benefit from the larger multiplier.

This paper is related to several strands of literature. First, from the vast empirical literature estimating the size of the fiscal multiplier, our paper is (methodologically) closely related to Priftis and Zimic (2021) and Broner et al. (2022) who condition the size of the multiplier on the ratio of external vs domestic debt. Specifically, Priftis and Zimic (2021) show that the fiscal multiplier is larger when spending is financed with external debt, using a proxy SVAR where the financing is identified through the contemporaneous movement in the external/domestic ratio. Broner et al. (2022) instead use a local projection method, conditioning the spending shock on the lagged external/domestic ratio. Our empirical exercise draws from these two papers, and therefore our contribution is not on the methodological side. However, investigating the impact of the maturity choice of financing spending shocks is certainly a very relevant question, our findings are particularly relevant for policy.

Second, our empirical finding that the financing of spending shocks with short or long bonds matters for the fiscal multiplier cannot be explained through standard macroeconomic asset pricing models, where bond yields purely reflect intertemporal substitution of consumption. Our theoretical model therefore is inspired by a recent literature in finance and macroeconomics considering models where the relative bond supply, of short or long maturity bonds, affects interest rates (see, e.g. Vayanos and Vila, 2021; Greenwood and Vayanos, 2014; Greenwood, Hanson, and Stein, 2015; Guibaud, Nosbusch, and Vayanos, 2013; Bansal and Coleman, 1996; Chen, Cúrdia, and Ferrero, 2012).

From this line of work our paper is most closely related to Greenwood et al. (2015), who document that short-term US Treasury debt provides liquidity services to the private sector, over and above the services that long bonds may provide. The authors provide empirical evidence for this, and set up a formal model in which short bonds enter into utility giving rise to a money-like demand function for this asset. As Greenwood et al. (2015), we assume that only short bonds provide liquidity, whereas households invest in long-term assets for their return properties. Though Greenwood et al. (2015) set up a 3-period model with exogenous interest rate shocks, we use a fully fledged New Keynesian model with infinitely lived agents and focus on spending shocks.

Our paper is also broadly related to the literature on optimal debt management policy in macroeconomic models with distortionary taxes.[2] The seminal contributions were Angeletos (2002) and Buera and Nicolini (2004) who first pointed out that in the canonical business cycle model, governments ought to save in short-term assets, and focus on issuing long-term debt. In this way, they can fully exploit the negative covariance between long bond prices and deficits and smooth tax distortions over time.

A recent strand of this literature, extends the baseline model with realistic frictions and finds reasons for governments to issue short-term debt. Faraglia et al. (2019) argue that in the presence of financial market frictions and when the payment profiles of long-term bonds are modelled to be close

[2] See, for example, Angeletos (2002); Buera and Nicolini (2004); Nosbusch (2008); Lustig et al. (2008); Faraglia et al. (2010); Faraglia, Marcet, Oikonomou, and Scott (2016); Faraglia et al. (2019); Canzoneri, Collard, Dellas, and Diba (2016); Greenwood et al. (2015); Debortoli et al. (2017); Bhandari et al. (2019); Passadore, Nuno, Bigio, et al. (2017) among others.

to the data analogues, then issuing short-term debt may be useful to smooth taxes. In Debortoli et al. (2017) governments that cannot commit to future policies find it optimal to issue short-term debt, in order to limit the incentive of future governments to distort taxes intertemporally. Finally, Bhandari et al. (2019) show that short bonds are useful to hedge against exogenous shocks to the real rate and avoid tax volatility.

Our paper complements this line of work. In our model, the optimizing government will always want to issue some amount of short-term debt, since short bonds provide valuable liquidity to households. Though this argument is also made in Greenwood et al. (2015), as discussed, theirs is a stylized three period model, whereas ours is an infinite horizon macro model that we can plausibly calibrate to the US data. This enables us to contrast the optimal policy implications of our New Keynesian model with the US historical observations, an exercise that we consider at the end of Section 4. Furthermore, though Greenwood et al. (2015) build a model in which debt management is used by the government to hedge against exogenous fluctuations in the real interest rates, we focus on the case of spending shocks in a model that can rationalize the novel empirical evidence that we provide. Our papers are therefore complementary.

In addition, our paper is closely related to two recent works studying optimal tax and debt issuance policies when government bonds provide liquidity to the private sector. Canzoneri et al. (2016) are interested in characterizing the conditions under which an 'extended Friedman rule' is optimal in this context. Interestingly, they consider the case where government debt can be issued in one liquid and one illiquid asset, like in our paper. Most of their results, however, concern the case where prices are flexible, which makes the Friedman rule optimal.

Angeletos, Collard, and Dellas (2022) investigate a model in which government debt can be issued in one liquid asset, and unravel interesting transitional dynamics from an initial allocation to the optimal policy equilibrium in the steady state. In fact, their model may feature multiple steady states, depending on whether the government desires to satiate the economy with liquidity (that is to completely eliminate the friction facing the private sector) or whether it prefers to limit the supply of debt to extract rents from liquidity provision.

This trade-off is also present in our business cycle model and is extensively discussed in the online appendix accompanying this paper, where we also spell out the numerical approach that we adopt to solve the model. Basically, the system of first order conditions that we need to resolve to find the Ramsey policy equilibrium, gives us multiple stationary points and for this reason we cannot rely fully on global methods that approximate numerically the first order conditions to find the optimum (as in e.g. Faraglia et al., 2019, 2016; Aiyagari, Marcet, Sargent, and Seppälä, 2002). To deal with this issue, we wed the stochastic PEA algorithm of Den Haan and Marcet (1990) with a numerical approximation of the welfare (value) function. The numerical algorithm that we develop in the appendix should be of interest.

Finally, our paper is related to the vast literature that investigates the propagation of fiscal shocks in macroeconomic models (see, for example, Gali, Lopez-Salido, and Valles, 2007; Woodford, 2011; Christiano, Eichenbaum, and Rebelo, 2011; Bilbiie, 2011; Hagedorn, 2018; Hagedorn, Manovskii, and Mitman, 2019; Auclert, Bardóczy, and Rognlie, 2023; Rannenberg, 2021; Bayer, Born, and Luetticke, 2023; Ferriere, Grübener, Navarro, and Vardishvili, 2021).

Closest to ours are papers that study the fiscal multiplier within the context of models in which debt is net wealth; its value exceeds that of tax liabilities. One rapidly growing line of work characterizes the multiplier in quantitatively rich heterogeneous agents models with incomplete financial markets (for example, Bilbiie (2021); Bayer, Born, and Luetticke (2020); Auclert and Rognlie (2020); Hagedorn et al. (2019); Hagedorn (2018); Auclert, Rognlie, and Straub (2023). In these models government debt is valuable to households because it is an asset that can be used to accumulate precautionary savings and buffer consumption against labour income shocks. Another stream of papers takes a shortcut, considering simpler models in which government debt enters in the utility function (as in e.g. Rannenberg, 2021)) or affects consumption through providing liquidity and facilitating transactions (as in e.g. Hagedorn, 2018). The model that we consider here, belongs in the second stream of papers and it can be basically seen as an extension of Hagedorn (2018) to a two asset economy where one of the assets (short debt) provides liquidity.[3]

Related to our paper, Rannenberg (2021) has shown that the fiscal multiplier is higher in a model where government debt is an argument in household utility in an otherwise standard New Keynesian model. Our empirical evidence and theory show that short debt leads to a higher multiplier when households can arbitrage across short and long bonds and the former provide money like services.

2 Empirical Analysis

2.1 Econometric Methodology

In this section we carry out our empirical estimation of the fiscal multiplier and show its dependence on the maturity of debt being issued. We follow two separate approaches: First, we rely on a form of state-dependent estimation applied to an SVAR framework. Second, we use local projections.

2.1.1 Proxy-SVAR

Our benchmark identification approach extends the proxy-SVAR framework with the appealing features of sign restriction methodology. Following Stock and Watson (2012) and Mertens and Ravn (2013), we obtain a proxy for the government spending shock, whose exogenous variation is then included in the VAR system, and which is assumed to be correlated with the structural spending shock but orthogonal to other shocks. Our choice of the proxy follows Ramey and Zubairy (2018), who derive a *defense news* series, based on movements of spending related to political and military events.

Then, to disentangle the debt-maturity financing of the (instrumented) government spending shock, we exploit variation in defense news across different periods based on the ratio of short-term debt to long-term debt. Precisely, we extract a defense news series for periods in which the ratio

[3]Interestingly, some of this recent work (Hagedorn, 2018; Auclert et al., 2023) has shown that the properties of the more complicated heterogeneous agents models regarding the propagation of shocks can be approximated by simpler models with bonds in utility.

increases as a proxy for the short-term financed (STF) spending shock. Conversely, we use the defense news in periods in which the ratio has dropped as a proxy for long-term financing (LTF). Notably, this approach resembles the identification of domestic- and foreign-debt financed spending employed by Priftis and Zimic (2021).

Formally, our objective is to estimate the following system of equations:

$$\mathbf{A}\mathbf{Y}_t = \sum_{i=1}^{p} \mathbf{C}_i \mathbf{Y}_{t-i} + \varepsilon_t \tag{1}$$

where $\mathbf{Y}_t$ is $n \times 1$ vector of endogenous variables in quarter t. $\mathbf{C}_i, i = 1, ..., p$ are $n \times n$ coefficient matrices of the own- and cross-effects of the i^{th} lag of the variables, and ε_t is $n \times 1$ vector of orthogonal i.i.d. shocks with $E[\varepsilon_t] = 0$ and $E\left[\varepsilon_t \varepsilon_t^{'}\right] = I$. $\mathbf{A}$ is $n \times n$, matrix capturing contemporaneous interactions between the elements of $\mathbf{Y}_t$.

An equivalent representation of the above system is:

$$\mathbf{Y}_t = \sum_{i=1}^{p} \delta_i \mathbf{Y}_{t-i} + \mathbf{B}\epsilon_t \tag{2}$$

where $\mathbf{B} = \mathbf{A}^{-1}$, $\delta_i = \mathbf{A}^{-1}\mathbf{C}_i$ and let $\mathbf{u}_t = \mathbf{B}\varepsilon_t$ denote the vector of reduced form residuals. As is well known, the estimate of the covariance matrix of $\mathbf{u}_t$ provides $n(n+1)/2$ independent restrictions, less than the number required for identification of $\mathbf{B}$.

As in Mertens and Ravn (2013) we use covariance restrictions from the proxy of the true (latent) exogenous variable. Let $\widetilde{p}_t$ be a $k \times 1$ vector of proxy variables (defense news) satisfying $E(\widetilde{p}_t) = 0$, that are correlated with the k structural shocks of interest ($\varepsilon_{g,t}$ for government spending) but orthogonal to other shocks ($\varepsilon_{x,t}$ for non-government spending shocks). The proxy variables can be used to identify $\mathbf{B}$ provided the following conditions hold:

$$E\left[\widetilde{p}_t \varepsilon_{g,t}^{'}\right] = \Psi$$

$$E\left[\widetilde{p}_t \varepsilon_{x,t}^{'}\right] = 0$$

where Ψ is non-singular $k \times k$ matrix[4]. Given these conditions hold, we can identify the columns of $\mathbf{B}$, relevant for the innovations in government spending.

In turn, disentangling STF spending shocks from LTF shocks is obtained by defining $\widetilde{p}_t = \begin{bmatrix} \widetilde{p}_{\text{STF},t} \\ \widetilde{p}_{\text{LTF},t} \end{bmatrix}$ with

$$\widetilde{p}_t = \widetilde{p}_{\text{STF},t}, \quad if \quad s_t^{\text{Short/Long}} \quad increases$$

$$\widetilde{p}_t = \widetilde{p}_{\text{LTF},t}, \quad if \quad s_t^{\text{Short/Long}} \quad decreases,$$

and where $s_t^{\text{Short/Long}}$ denotes the ratio of short-term debt to long-term debt.

[4]Obviously, $k = 1$ here since we have one shock to identify and one proxy.

Finally, estimation proceeds following the standard two-step procedure for proxy-SVARs. For each element of $\widetilde{p}_t$ i) we run a two-stage least squares estimation of non-goverrnment spending residuals on the residuals of government spending using $\widetilde{p}_t$ as an instrument, and ii) we impose covariance restrictions to identify the elements in the relevant column of $\mathbf{B}$.

2.1.2 Fiscal multipliers

We calculate the cumulative fiscal multiplier m_{t+s} as

$$m_{t+s} = \frac{\sum_{q=t}^{t+s} \Delta X_q}{\sum_{q=t}^{t+s} \Delta G_q} \left(\frac{\overline{X}}{\overline{G}} \right) \tag{3}$$

which measures the cumulative change of the endogenous variable X per unit of additional government spending G, from the impulse at time t, up to the horizon s.[5] $\left(\frac{\overline{X}}{\overline{G}} \right)$ is the sample average of the endogenous variable over spending.

2.2 Empirical Results

Our benchmark estimates for the effects of government spending shocks are based on a VAR with four variables: $Y_t = [G_t, Y_{t,}, C_t, I_t]$, where G_t are government expenditures, Y_t is real gross domestic product, C_t is private consumption, and I_t is private investment. The sample consists of quarterly observations for the period 1954Q3-2015Q4. [6] The baseline specification estimates the system in (1) in log differences.[7] We employ four lags of the endogenous variables applying the HQ criterion. Along with the median estimates of the impacts of government spending shocks on output, investment and consumption, we report one standard deviation confidence bands using the procedure in Goncalves and Kilian (2004).

2.2.1 Short-term and long-term debt financed government spending shocks

Figures 1 and 2 plot the cumulative impulse responses and the cumulative multipliers of consumption, investment and output, following a 1% government spending shock. The top panels show these objects under STF and LTF separately, and in the bottom panels we plot the response of the differences between the two.[8] Table 1 complements the exposition reporting the point estimates of the cumulative multipliers and the confidence intervals at various horizons.

As it is evident from the figures, financing the spending shock with short-term debt leads to a much stronger reaction of aggregate output. Output increases on impact by more in the STF case (blue dashed line, left panel), and moreover, it continues to increase during the 12 quarters shown in the graph. The difference in terms of the median responses between short and long-term

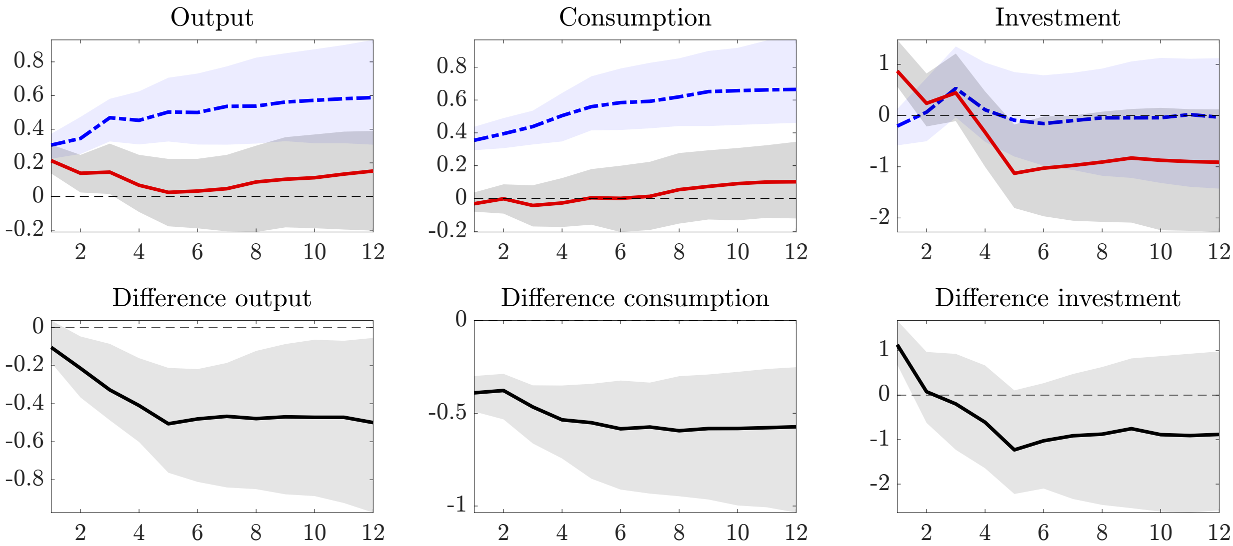
[5] See, for example, Ilzetzki et al. (2013).

[6] Details on data sources and the construction of all variables used in this empirical section are, for brevity, provided in the online appendix.

[7] Running the model in log levels instead of differences gave us very similar results.

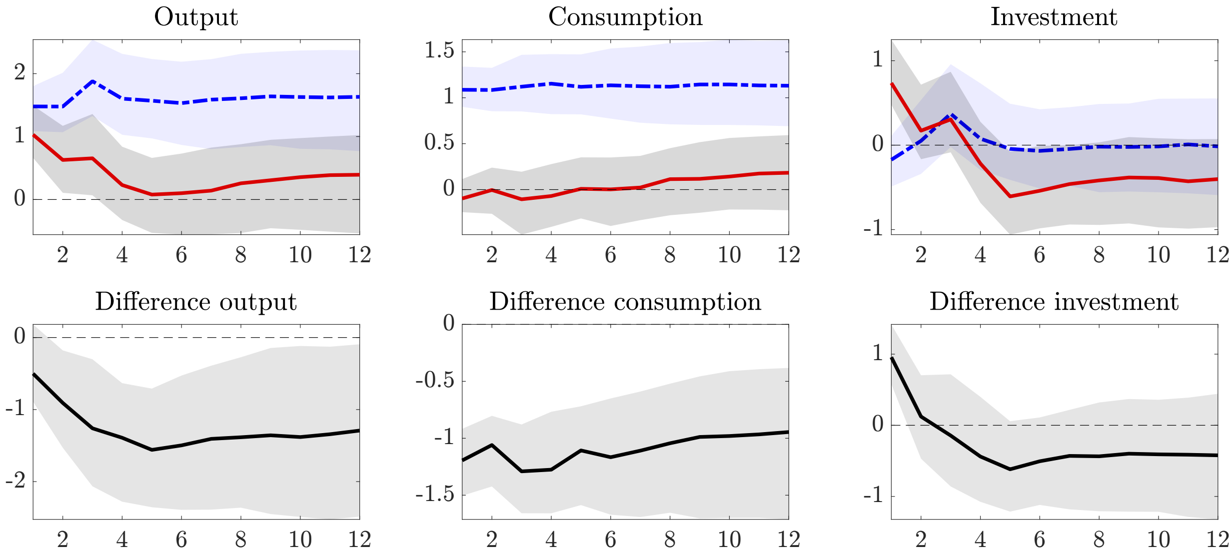
[8] The difference is defined as the LTF responses minus the STF responses. It has been calculated for each draw of the simulated distribution of the models that satisfy the sign restrictions.

Figure 1: Proxy-SVAR: Baseline specification. Cumulative impulse response functions



Notes: Top panel: Impulse response functions following a shock to short-term (blue, dash-dotted) and long-term debt-financed (red, solid) government expenditures. Lines correspond to median responses. Bottom panel: The difference in impulse response function between long-term and short-term debt financed government expenditures. Shaded areas correspond to confidence bands of one standard deviation.

Figure 2: Proxy-SVAR: Baseline specification. Cumulative multipliers



Notes: Top panel: Cumulative multipliers following a shock to short-term (blue, dash-dotted) and long-term debt-financed (red, solid) government expenditures. Cumulative multipliers are calculated as in Equation 3. Lines correspond to median responses. Bottom panel: The difference in cumulative multipliers between long-term and short-term debt financed government expenditures. Shaded areas correspond to confidence bands of one standard deviation.

Table 1: Proxy-SVAR: Baseline specification. Cumulative multipliers

	horizon	"Long-G shock"		"Short-G shock"		difference	
Output							
	1	**1.08**	[0.68 , 1.51]	**1.48**	[1.03 , 1.86]	-0.42	[-1.06 , 0.19]
	4	**0.42**	[-0.38 , 0.99]	**1.85**	[1.23 , 2.51]	-1.44	[-2.70 , -0.62]
	12	**0.55**	[-0.29 , 1.11]	**1.91**	[1.12 , 2.85]	-1.42	[-2.80 , -0.21]
Consumption							
	1	**-0.03**	[-0.28 , 0.16]	**1.16**	[0.96 , 1.40]	-1.21	[-1.55 , -0.89]
	4	**0.00**	[-0.40 , 0.34]	**1.31**	[0.93 , 1.68]	-1.24	[-1.98 , -0.82]
	12	**0.33**	[-0.21 , 0.62]	**1.35**	[0.85 , 1.92]	-1.08	[-2.00 , -0.46]
Investment							
	1	**0.80**	[0.44 , 1.14]	**-0.17**	[-0.55 , 0.17]	0.96	[0.55 , 1.50]
	4	**-0.12**	[-0.68 , 0.41]	**0.17**	[-0.30 , 0.72]	-0.31	[-1.34 , 0.35]
	12	**-0.33**	[-0.82 , 0.14]	**0.15**	[-0.34 , 0.78]	-0.42	[-1.40 , 0.30]

Notes: The table reports cumulative multipliers for output, consumption, and investment at different horizons for short-term debt-financed and long-term debt-financed government spending shocks, as well as the difference in multipliers, defined as Long-Short. Confidence bands of one standard deviation are denoted inside the brackets.

financing (blue and red lines, respectively) grows throughout this horizon and it remains statistically significant.[9]

This difference can be more clearly stated in terms of the implied values of the fiscal multipliers (Figure 2 and Table 1). When spending is financed short-term, the impact multiplier is 1.48 and it remains above 1 after 12 qurters. On the other hand, if the shock is financed with long-term debt, the impact output multiplier is 1.08 but it drops to 0.42 after 3 quarters and becomes statistically insignificant.

The middle and right panels in the Figures and the middle and bottom panels in Table 1, show where the differences in the responses of output to spending derive from. Notice that the differences are clearly driven by the responses of consumption. The short-term debt-financed spending shock produces a crowding in of consumption (the consumption multiplier is 1.16 on impact and remains around that level throughout the horizon). However, when spending is financed with long-term debt, private consumption does not respond. In contrast to consumption, aggregate investment shows no statistically significant response to the spending shock neither under STF or LTF; the difference between the two investment responses is also found to be statistically insignificant.

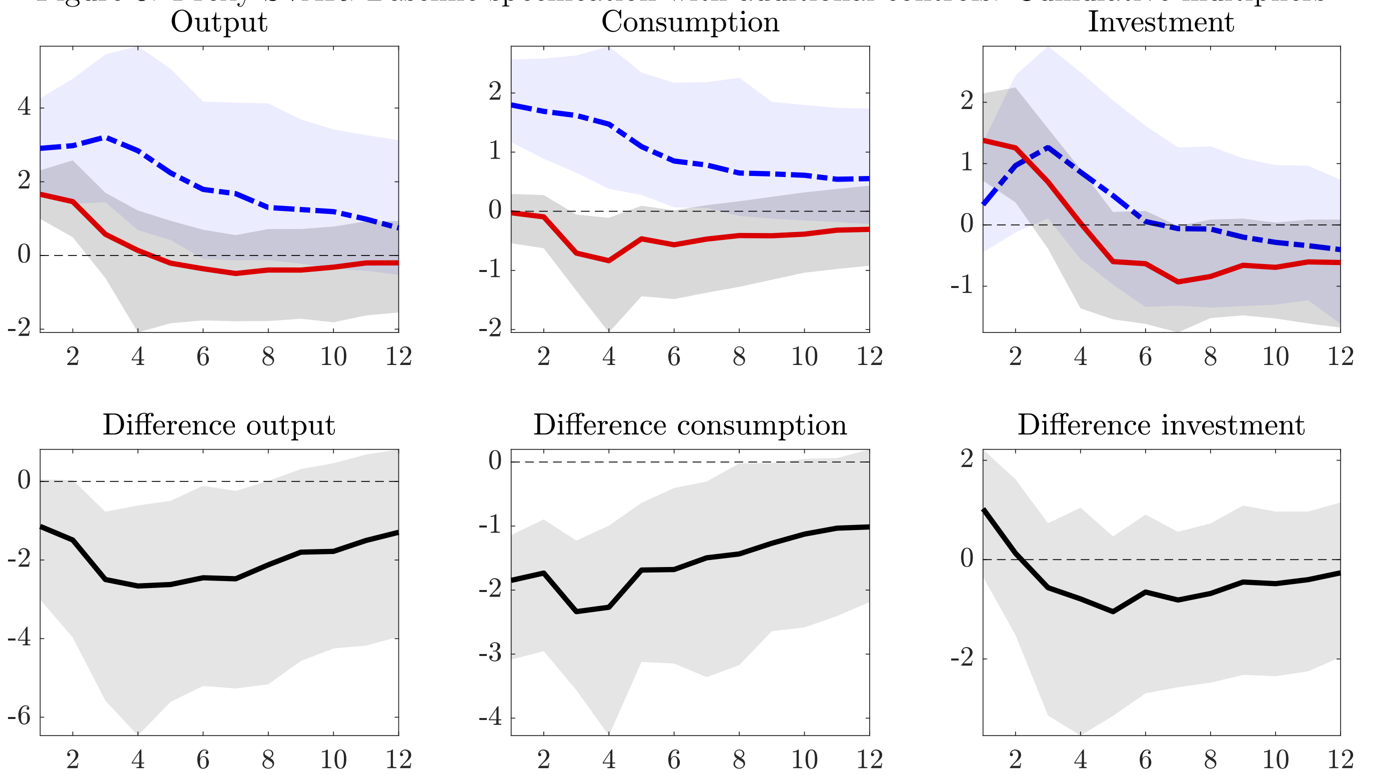
This baseline exercise shows that the way the US government finances its spending, relying on either short-term or long-term debt, exerts an influence on the effects of the shock on the paths of aggregate consumption and output. We next build on this finding, extending our baseline, considering additional controls in estimation and running the model on different subsamples.

[9] In the online appendix we show the paths of spending following STF and LTF shocks. The paths are very similar, both in terms of the magnitude of the responses and their persistence. This indicates that the differential responses on output and consumption that we obtain under STF and LTF shocks are not driven by a different spending process.

2.2.2 Extensions of the empirical model

Adding macroeconomic variables. We first show the robustness of our findings towards including additional macroeconomic variables in the VAR. In particular, we repeat the estimation of system (1) controlling for real wages of the private sector, the yields on short and long-term government debt, the overnight interest rate, and the GDP deflator. We do so to treat possible endogeneity issues that may have contaminated our baseline estimates, using the standard approach of adding variables to the VAR and showing that the results do not change significantly. To motivate the experiments that we conduct in this paragraph let us briefly discuss the types of biases and endogeneity issues that we believe might matter in the context of our exercise.

Figure 3: Proxy-SVAR: Baseline specification with additional controls. Cumulative multipliers



Notes: Top panel: Cumulative multipliers following a shock to short-term (blue, dash-dotted) and long-term debt-financed (red, solid) government expenditures. Cumulative multipliers are calculated as in eq. 3. Lines correspond to median responses. Bottom panel: The difference in cumulative multipliers between long-term and short-term debt financed government expenditures. Shaded areas correspond to confidence bands of one standard deviation. Controls are the term premium, real wages, overnight rate, and the GDP deflator.

First, the endogeneity of the decision of the Treasury to finance with short or long-term debt. It is well known, that debt management decisions are influenced by the interest rate costs of financing. Thus, when faced with a steeply upward sloping yield curve, debt managers are more likely to issue short-term debt, than when the yield curve is downward sloping and long-term debt becomes less costly. Moreover, downward sloping yield curves predict recessions. The lower multipliers for long-term financing could thus be reflecting that the economy is set on a recessionary path.[10] We control

[10] Arguably the opposite could also be true, if fiscal multipliers are higher during economic recessions (see, for example, Auerbach and Gorodnichenko, 2012).

for this possibility by adding the term premium and the short-term rate in our VAR (to capture both the level and the slope of the yield curve).

Second, adding wages as well as interest rates to the VAR enables us to also control for possible differential impacts of the STF and LTF shocks on these variables which may be relevant if the shocks are of a different nature and thus affect the macroeconomy differently. For example, a STF shock may put more upward pressure on wages, when the government is hiring in certain sectors. This could then result in a larger increase in the consumption of hand to mouth households and thus in a stronger effect on aggregate output. Though our shocks have been identified using news about military spending (and both STF and LTF shocks lead to similar cumulative responses of the spending level, see appendix), showing robustness in this regard is useful. Finally, we control for the (endogenous) response of monetary policy through adding the overnight interest rate in the VAR.[11]

Figure 3 shows the cumulative multipliers we obtain when we include all of these variables together in the VAR.[12] As is evident from the Figure, the cumulative output multiplier in the case of short-term financing continues being larger; once again the difference is driven by the differential responses of private sector consumption to the spending shock, under short and long-term financing. Our previous findings thus continue to hold.

Table 2 shows a breakdown of this exercise, reporting the consumption and output multipliers from five separate VARs, when we include one variable at a time. The top panel shows the results from a VAR run with wages as an additional control, then the short-term interest rate is the additional variable in the second panel, the long-term rate in the third panel, the 'yield curve' (short rate and the term premium) in the fourth panel, and lastly, the GDP deflator in the bottom panel. We focus on the consumption and output responses, the multipliers for investment were found insignificant in most of these specifications and we left those outside the table. Moreover, to conserve space, we report the point estimates at horizons of 1, 4 and 12 quarters.

Notice that across all specifications, there are significant differences between STF and LTF, and most notably at 4 or 12 quarters after the shock has hit. Though spending multipliers can be quite large on impact also in the LTF case, i.e. in some of the models we run, very fast, 4 quarters after the shock, they drop significantly. In contrast, the multipliers in the STF remain persistently above 1 throughout the horizon.

[11] In separate experiments in the online appendix we also considered adding taxes in the VAR. Our results did not change.

[12] The term premium has been defined as the difference between the yield of the 10 year Treasury note and the overnight rate. Our results are almost identical when we define the term premium as the difference between the 10 year and the 3 month yields.

Moreover, for brevity, the responses of the interest rates, wages and prices to the spending shock are shown in the online appendix. These responses are (by and large) what we expect them to be and in line with the theoretical model that we develop in Sections 3 and 4 of the paper. For example, a STF shock increases the short-term interest rate and reduces the term premium. In contrast, a LTF shock increases the term premium without affecting the short-term rate. Moreover, the STF shock increases the price level persistently, whereas the effect of the LTF shock on prices is nearly 0. See appendix for further details and discussion.

Table 2: Proxy-SVAR: Baseline specification with additional controls. Impact multipliers

		horizon	"LTF shock"		"STF shock"		difference	
Wages	Y	1	**0.46**	[-0.12 , 0.93]	**1.72**	[0.96 , 2.33]	-1.24	[-2.22 , -0.51]
		4	**-0.64**	[-1.71 , -0.01]	**1.55**	[0.64 , 2.83]	-2.57	[-3.88 , -0.84]
		12	**-0.28**	[-1.30 , 0.58]	**1.47**	[0.50 , 2.65]	-1.95	[-3.23 , -0.44]
	C	1	**-0.31**	[-0.65 , -0.11]	**1.10**	[0.78 , 1.45]	-1.43	[-1.96 , -1.09]
		4	**-0.51**	[-1.11 , -0.18]	**0.88**	[0.37 , 1.56]	-1.53	[-2.33 , -0.82]
		12	**-0.10**	[-0.58 , 0.37]	**0.94**	[0.41 , 1.58]	-1.18	[-1.66 , -0.38]
Short rate	Y	1	**1.32**	[0.86 , 1.58]	**1.72**	[1.20 , 2.22]	-0.48	[-1.12 , 0.18]
		4	**0.59**	[-0.23 , 1.31]	**1.66**	[0.88 , 2.53]	-1.09	[-2.26 , 0.02]
		12	**0.40**	[-0.40 , 1.15]	**1.39**	[0.73 , 2.43]	-1.02	[-2.56 , 0.16]
	C	1	**0.23**	[0.02 , 0.45]	**1.57**	[1.26 , 1.78]	-1.31	[-1.65 , -0.98]
		4	**0.16**	[-0.21 , 0.50]	**1.26**	[0.92 , 1.73]	-1.13	[-1.90 , -0.55]
		12	**0.25**	[-0.17 , 0.65]	**1.06**	[0.61 , 1.70]	-0.86	[-1.78 , -0.17]
Long rate	Y	1	**1.26**	[0.60 , 1.88]	**1.49**	[1.00 , 2.01]	-0.22	[-1.08 , 0.49]
		4	**-0.83**	[-2.71 , 0.37]	**2.11**	[1.38 , 3.32]	-2.95	[-5.30 , -1.72]
		12	**-0.97**	[-2.39 , -0.13]	**2.20**	[1.18 , 3.43]	-3.26	[-5.43 , -1.79]
	C	1	**0.03**	[-0.30 , 0.29]	**1.45**	[1.19 , 1.78]	-1.36	[-1.97 , -1.06]
		4	**-1.10**	[-2.02 , -0.54]	**1.60**	[1.13 , 2.22]	-2.72	[-3.83 , -2.02]
		12	**-0.75**	[-1.42 , -0.25]	**1.58**	[1.00 , 2.34]	-2.37	[-3.63 , -1.54]
Short rate; term premium	Y	1	**1.79**	[1.00 , 2.58]	**1.46**	[0.99 , 1.90]	0.36	[-0.51 , 1.14]
		4	**0.82**	[-0.49 , 1.80]	**1.75**	[0.93 , 2.57]	-1.05	[-2.65 , 0.67]
		12	**0.11**	[-1.16 , 0.96]	**1.71**	[0.99 , 2.52]	-1.57	[-3.73 , -0.59]
	C	1	**0.20**	[-0.08 , 0.52]	**1.51**	[1.28 , 1.82]	-1.38	[-1.71 , -0.92]
		4	**-0.27**	[-1.22 , 0.21]	**1.42**	[1.02 , 1.92]	-1.80	[-2.91 , -1.11]
		12	**-0.11**	[-0.95 , 0.37]	**1.34**	[0.92 , 1.92]	-1.54	[-2.80 , -0.86]
GDP deflator	Y	**1**	**1.12**	[0.78 , 1.54]	**2.35**	[1.84 , 2.89]	-1.08	[-1.88 , -0.51]
		4	**0.24**	[-0.35 , 0.87]	**2.78**	[1.90 , 3.61]	-2.54	[-3.38 , -1.46]
		12	**0.42**	[-0.15 , 1.30]	**2.25**	[1.35 , 3.17]	-1.73	[-3.12 , -0.58]
	C	**1**	**-0.02**	[-0.24 , 0.14]	**1.46**	[1.14 , 1.90]	-1.54	[-1.93 , -1.16]
		4	**-0.00**	[-0.36 , 0.30]	**1.59**	[1.15 , 2.14]	-1.61	[-2.27 , -1.10]
		12	**0.23**	[-0.09 , 0.70]	**1.29**	[0.83 , 2.05]	-1.20	[-2.13 , -0.49]

Notes: The table reports cumulative multipliers for Y and C for short-term and long-term debt-financed government spending shocks, as well as the difference in multipliers, defined as Long-Short, for different proxy-SVAR specifications. Each specification augments the system in 2.2.1 with the variables in the first column. Confidence bands of one standard deviation are denoted inside the brackets.

Additional experiments: High vs. low debt and monetary policy regimes.

We now conduct two additional experiments to further condition our estimates on the macroeconomic policy environment and in particular we focus on the influence of the debt to GDP ratio and of the monetary policy regime.

A well-known feature of US debt management is that the Treasury has typically titled its issuance more towards long-term debt, when the debt to GDP ratio was high (Greenwood et al., 2015).[13] At high debt levels, the response of output to a fiscal shock may be weaker if, for example, the private sector expects that distortionary taxes are more likely to increase significantly, or if high debt implies political controversies about how to manage government liabilities.

To explore whether this is a crucial dimension we re-estimated the baseline system in (1), separately using 'a high debt sample', (that is focusing on periods where the debt to GDP ratio was above the median of the full sample of observations). Our results were unaffected. We continued to find a large difference in the fiscal multipliers of output and consumption in this sub-sample (see online appendix).

Moreover, we also run the model using only observations from the post 1980 period. It has been documented, that US monetary policy did not react strongly to inflation during the 1960s and 1970s but it satisfied the 'Taylor principle' after the early 1980s.[14] We were therefore interested to see whether this change in policy conduct has a bearing on the fiscal multiplier under STF and LTF. The online appendix shows in a graph the results that we obtained from this exercise: The difference across the two cases remains, and the consumption multiplier remains significant only in the STF scenario.

Lastly, we run our sample dropping observations from the financial crisis and the years the Fed kept the short-term nominal interest at its effective lower bound. Again we found no significant change in our estimates when we run the model with this subsample. For brevity, we show these results in the online appendix.[15]

[13]The explanation is that when overall debt rises the refinancing risk increases and debt managers face a trade off between issuing more expensive and less risky debt, long-term, or cheaper and riskier debt, short-term. In general they prefer to issue long-term debt to reduce overall refinancing risks of government portfolios.

[14]See, for example, Bianchi and Ilut (2017) for recent work on this.

[15]It is perhaps necessary to add a couple of lines to discuss what we expect (in theory) the fiscal multipliers to be like, under short-term and long-term financing, in a liquidity trap. As discussed previously, we will attribute the differences in the fiscal multipliers to the money-like properties of short bonds. During a liquidity trap episode, however, the economy is 'satiated' with money (and close substitutes to money) and so we should expect much smaller differences between the STF and LTF multipliers. However, other forces, besides liquidity provision, may give rise to differences in fiscal multipliers, most notably the types of forces that can rationalize why quantitative easing works in a liquidity trap (see below for a brief discussion of the alternative mechanisms).

Unfortunately, the short time span of the liquidity trap episode in the US coupled with our identification assumption for spending shocks, precludes from using the 2008-2015 observations to estimate the differences in fiscal multipliers. We thus consider only what dropping these observations does to our estimates.

2.3 Alternative estimation approaches

2.3.1 State-dependent local projections

We now explore an alternative empirical strategy to investigate the effect of financing on the propagation of spending shocks. In particular, we rely on the local projection method of Jordà (2005) while continuing to identify the spending shock using the news variable. To distinguish between spending shocks financed with short-term debt and shocks financed with long-term debt, we employ a state-dependent specification of the model (as in e.g. Auerbach and Gorodnichenko, 2013; Ramey and Zubairy, 2018).

More specifically, our (non-linear) local projection framework allows for state-dependence estimating a series of regressions of the following form:

$$Y_{t+h} = I_{t-1}\left[a_{A,h} + \beta_{A.h}\varepsilon_t + \psi_{A,h}(L)X_{t-1}\right] + (1 - I_{t-1})\left[a_{B,h} + \beta_{B,h}\varepsilon_t + \psi_{B,h}(L)X_{t-1}\right] + qtrend + u_{t+h}$$

where Y is the variable of interest (e.g., output, consumption, investment), h denotes the horizon over which the effect of the shock is being traced, X is a vector of control variables, $\psi_{A,h}(L)$ is a polynomial in the lag operator, and finally ε is the identified spending shock.[16] Following Ramey and Zubairy (2018), we also include a quadratic trend to control for slow-moving demographics.

The state-dependent regression allows distinguishing between different types of debt financing through variable I. This is an indicator variable of the ratio of short-term over long-term debt. In particular $I_{t-1} = 1$ when the ratio increased between periods $t-2$ and $t-1$, and $I_{t-1} = 0$ otherwise.[17] The coefficients of interest in this local projection model are $\beta_{A.h}$ and $\beta_{B.h}$. These objects measure the impulse response of Y_{t+h} to the spending shock in t under short and long-term financing respectively.[18]

[16] Applying standard criteria we set $\psi_{A,h}(L)$ to have 4 lags. Moreover, we experimented with a variety of specifications of the model in terms of the control variables X. In the results we show here X includes wages and the term spread as well as lags of consumption, output and investment, however, alternative specifications of X (e.g. without wages and/ or interest rates) did not significantly change our findings. Finally, across all specifications, to control for any serial correlation, X also includes lags of the news variable.

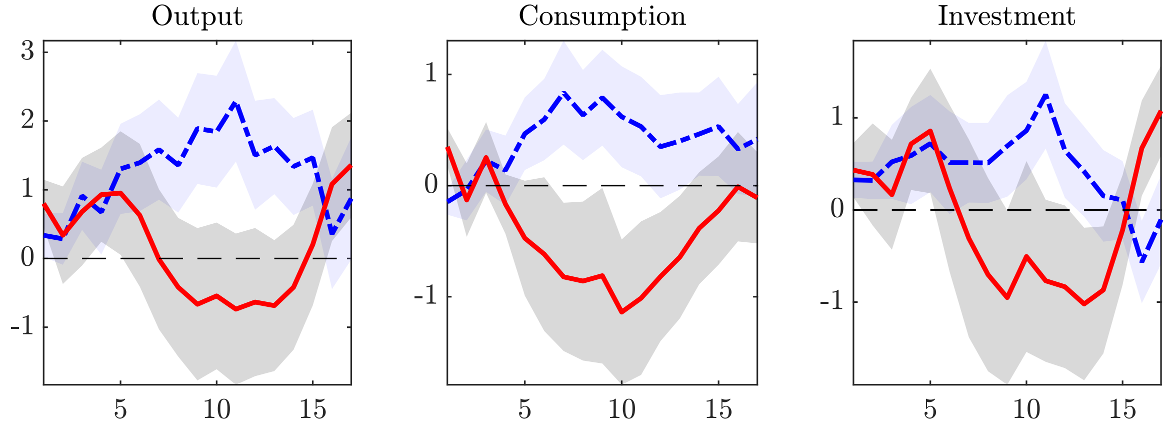
[17] We also experimented with conditioning on average change in the ratio between $t-1$ and $t+1$, as well as $t-1$ and $t+4$ to allow for a better conditioning of medium and long-term effects, which are typically better captured by the method employed here (especially when the news variable is being used). None of these alternative specifications altered significantly our findings and therefore we followed the more standard approach of conditioning on I_{t-1}.

[18] Note that the approach of using local projections to identify differential effects of spending shocks along the maturity financing follows Broner et al. (2022). The differences with that paper are first that Broner et al. (2022) utilize a framework with local projections and interaction terms, whereas we consider a non-linear specification whereby coefficients can vary across financing schemes, and second, Broner et al. (2022) use the lagged stock variable (in their case the ratio of external over total debt) whereas, in keeping with our previous analysis, we defined I based on the change in the ratio of short over long-term debt. We did however, run our non-linear model defining I to be equal to one when the lagged ratio exceeded the median and 0 otherwise and our results went through.

Though relying on the stocks (rather on the contemporaneous movements of the ratio) may be seen as capturing different margins through which debt maturity can influence the size of the fiscal multiplier, for the case of a variable that is as persistent as the share of short-term debt is in US data, outstanding stocks are strongly correlated with new issues. In our sample, the serial autocorrelation of the share of short over long is 0.89.

Note that this is also an important observation for our empirical approach which uses the change in the share. When the share increases, it does so persistently.

Figure 4: State-dependent local projections: Baseline specification. Fiscal multipliers. Defense news shock.



Notes: Fiscal multipliers following a shock to short-term (blue) and long-term debt-financed (red) government expenditures. Lines correspond to median responses. Shaded areas correspond to confidence bands of one standard deviation. The specification includes the following control variables: GDP, private consumption, private investment, wages, long-term rate, and total debt, as well as their lags.

Figure 4 shows the results. Note that the hump-shaped responses of the macro aggregates to the spending shock are to be expected in this local projection method with news shocks. The middle panel of the figure indicates the strong reaction of aggregate consumption under STF. We obtain a statistically significant increase in consumption, a few quarters after the shock has occurred. In contrast, the response of consumption under LTF turns negative and significant suggesting a strong crowding out effect of the shock. These findings are clearly in line with our previous estimates using the proxy SVAR. We thus conclude that our results are robust towards using local projections as an alternative estimation approach of the effect of maturity financing on the fiscal multipliers.

2.3.2 Local projections with the Blanchard-Perotti shocks.

As a final check, we used the local projection framework but instead of identifying spending shocks based on the narrative approach of Ramey and Zubairy (2018) we used the structural VAR approach of Blanchard and Perotti (2002), to identify shocks by including government spending, output and other macroeconomic variables in the VAR, and imposing that the spending shocks only can have a contemporaneous effect on these variables.

For the sake of brevity we show the output of the local projection model in the online appendix. We found again that financing the spending shock short-term gives a statistically significant increase in private sector consumption, especially at longer horizons, whereas the response in the LTF case is insignificant. Remarkably, in this version of our empirical model we find that also private sector investment responds differentially to STF and LTF shocks. For LTF, we find a strong crowding out impact of the shock whereas in the STF case the response of investment is not significant. Put together with our previous findings, these results indicate that consumption is a robust margin to account for the differences in the output multipliers under STF and LTF.

3 A model of short and long-term financing of spending shocks

3.1 Discussion

The empirical analysis showed that the spending multiplier is higher when then government finances its deficit by issuing short-term debt. Before presenting our formal model in the next section, we provide here a general discussion to outline theories that can rationalize this new empirical fact. We then select one of the alternatives and construct a model that is consistent with this fact. In Section 4, we use the theoretical model to talk about optimal debt maturity policy.

The empirical finding that debt maturity influences the spending multiplier cannot be rationalized by a model where bonds of different maturities are only used by investors to substitute consumption inter-temporally in (almost) frictionless financial markets. In standard representative agent models where Ricardian equivalence holds and the yield curve can be derived as a function of consumption growth and inflation, it is well known that consumption and interest rates will depend on the path of spending only, and not on how spending is financed. In this framework, the relative supply of short-term and long-term bonds exerts no influence on yields and therefore no influence on consumption growth or the multiplier.[19]

Departing from this standard framework, adding elements that make relative bond supply matter for allocations is thus key to explaining the fiscal multiplier. Theoretical models in which investors have preferences over particular maturities, where short bonds facilitate transactions and function like money or long-term bonds provide savings to finance retirement, imply non-trivial effects of bond quantities on yields and therefore we need to turn to these theories to interpret the empirical evidence.

Fortunately, the literature is abundant with such models. In an early contribution, Bansal and Coleman (1996) set up a model in which safe and liquid Treasury debt is used by banks to back up checkable deposits accounts. Short-term Treasury bonds fulfill both the safety and liquidity criteria and so banks use these types of bonds. In equilibrium short bond yields line up with the yields of checkable deposits accounts, a property that Bansal and Coleman (1996) exploit to explain observed term and equity premia.

This idea was picked up by Greenwood et al. (2015) who provide empirical evidence and a formal model to validate the view that short bonds have money like attributes and earn a lower return than other assets, including long-term Treasuries, due to their role in backing deposits or collateralizing

[19] See, for example, Greenwood and Vayanos (2014) and the irrelevance of Quantitative Easing in this class of models, shown by, for example, Curdia and Woodford (2011) building on earlier results by Wallace (1981).

and facilitating transactions.[20] In their model, these attributes are formalized through assuming a standard reduced form money like demand for short-term debt: investors hold short-term debt when it affects directly utility and not only for its return properties.[21]

On the other hand, Guibaud et al. (2013) focus on the services provided by long-term bonds to finance retirement. In their overlapping generations model, *bond clienteles* are agents at different stages of the life cycle: The young have a stronger demand for long-term assets that they will use to finance consumption in retirement. When the supply of long-term bonds decreases, long bond yields rise, as they do in the data (see Greenwood and Vayanos, 2010; Guibaud et al., 2013).

In the recent literature on quantitative easing the above features are introduced in the standard New Keynesian framework in a reduced form manner. In these models, bond clienteles are introduced by assuming that certain households have *preferred habitat* over particular maturities (and only trade in those) whilst other households can arbitrage across all maturities subject to portfolio adjustment costs.[22] Obviously, in the context of these linear models (where only first derivatives matter and strict assumptions over functional forms are not needed) assuming a transaction cost for long-term bonds or a money like demand for short bonds is essentially the same. The QE model thus applies the above elements in the standard New Keynesian framework.

Finally, another class of models in which the relative bond supply can impact yields is models of heterogeneous agents and incomplete financial markets (e.g. Huggett (1993); Aiyagari (1994) and the considerable literature that followed these papers). In this framework households value safe and liquid assets when they can be used to build a stock of precautionary savings, a buffer against labour income shocks. Then, assets earn a lower rate of return in equilibrium due to their insurance value and the return varies positively with the supply of assets. Arguably, short-term debt is likely a more useful asset for precautionary savings, than long-term debt is. Households may be reluctant to bear the repricing risk of long-term bonds and in the presence of even mild transaction costs, long bonds will have a lower hedging value against income risk.[23] When short and long bonds are not seen as perfect substitutes by households, their relative supplies will affect the term premium.

The model that we develop below focuses on the money-like services of short-term bonds (as in

[20] See also Gorton and Metrick (2012).

[21] Similar modelling assumptions are made in Canzoneri et al. (2016) who investigate optimal policy in a model with liquid and illiquid government debt, and in Bansal and Shaliastovich (2013).

[22] See, for example, Chen et al. (2012).

[23] An important risk that households have to bear when holding long-term debt is the risk of inflation. A number of papers have explained the term premium in standard representative agent models, relying on the inflation risk channel. See, for example, Piazzesi, Schneider, Benigno, and Campbell (2007); Bansal and Shaliastovich (2013); Rudebusch and Swanson (2012). Though these representative agents models are not likely to generate any effect of the relative bond supply on yield curves, we suspect that heterogeneous agents models with realistic inflation risk can.

Another view for why long-term bonds command a higher rate of return is that is necessary to compensate investors for the lower liquidity of these assets. In an economy with heterogeneous households and idiosyncratic income/consumption risks, the price of long-term bonds will reflect expected portfolio adjustment costs that households will unavoidably bear in order to smooth consumption. Illiquid assets then effectively become risky. (e.g. Huang, 2003; Amihud and Mendelson, 1991).

This class of models, can rationalize non-trivial effects of the relative bond supply on the yield curve. For example, in Amihud and Mendelson (1991) investors facing a high risk of financing consumption, self-select in short bond markets where assets carry lower transaction costs. In contrast, low risk investors, have a preference for less liquid long-term assets. Since bond markets are segmented, a change in the supply of long-term debt (for example) will increase the long-term interest rate, without impinging a significant effect on the short-term rate.

e.g. Greenwood et al., 2015; Bansal and Coleman, 1996). It is an economy where ex ante identical agents solve a standard consumption/savings problem, where savings can be accumulated in a short or a long-term government bond. Ex post, agents become heterogeneous in terms of their spending needs and those with a high desire to consume, can run down their accumulated stock of short bonds to finance consumption. Then, increasing the supply of short bonds provides additional liquidity to the economy exerting a positive effect on private sector consumption. A carefully calibrated version of our model (which matches the empirical evidence of Greenwood et al. (2015)) can explain a great deal of the difference in the fiscal multipliers under STF and LTF.

We close this paragraph by acknowledging that by focusing on the money like attributes of short-term debt, we are leaving out other potentially important elements, along the lines of the theories we discussed in this section. In particular, we abstract from life cycle asset accumulation decisions, however, motivating that long bonds are less liquid would be easy in an OLG model where long-term assets are realistically held in retirement accounts and withdrawals are subject to transaction costs. Moreover, for tractability reasons, we rely on a model where household heterogeneity is only limited (at the start of every period all households are identical). A more realistic account of heterogeneity would imply that households will endogenously self-select in short and long bond markets along their wealth and consumption risk profiles thus adding another plausible mechanism via which long and short term rates do not line up. Moreover, we believe that heterogeneous agents life-cycle models could also potentially explain the empirical evidence we showed in the previous section.[24] Relative to these richer models, the model that we work with in this paper, is more tractable and thus also easier to use to study optimal policy which is our task in Section 4 of the paper.

3.2 The baseline model

We now present our baseline model which can be seen as an extension of the Hagedorn (2018) one liquid asset economy, to two assets (short/long government bonds) where only the short-term bond provides liquidity. We provide a brief description of the model here, focusing on the key equations. Details on derivations are relegated to the online appendix. A more detailed discussion of the frictions and the equilibrium than we offer here, can be found in Hagedorn (2018).

3.2.1 Timing and preferences

The economy is populated by a continuum of infinitely lived, ex-ante identical agents/households. Time is discrete and each period t is divided in two subperiods, t_1, t_2.[25]

[24] Two mechanisms that come to mind, via which STF shocks can lead to larger responses of output in these models are the following: First, with wealth heterogeneity and idiosyncratic consumption risks, if short-term bonds are a better asset to insure against idiosyncratic risks, then increasing their supply will reduce idiosyncratic consumption uncertainty, and exert a positive effect on the level of household consumption. Second, in OLG models with uncertain life spans, households saving in long-term bonds (e.g. for retirement) may anticipate that with positive probability they will not live long enough to get the payoff of their investment. This ought to lead to a more negative consumption response to spending. Verifying whether these channels are important is left to future work.

[25] Technically, t_1 and t_2 need not represent different points in real time; they are simply used to introduce the idea that households can participate in asset markets and make savings decisions (in t_1) before the full vector of state variables has been revealed. In our notation below we very frequently condense t_1 and t_2 into t, we distinguish between

The timing of events is as follows: In subperiod t_1 households make standard consumption/savings/ labour supply choices where savings can be accumulated in short and long-term assets. In subperiod 2, the generic household experiences a shock to preferences which essentially makes her total consumption (and wealth holdings) differ from that of other households. We assume that a higher consumption need in t_2 can be financed by running down the quantity of short-term assets that the household has chosen in t_1. As in Hagedorn (2018) to keep the model tractable we also assume that households are part of a large family pooling together resources and redistributing through transfers, at the end of subperiod 2. At the start of every period all agents in the economy have the same level of wealth and therefore will end up making the same consumption/ portfolio choice decisions.

More specifically, the preferences of household i (when the shocks have been revealed) are:

$$u(C_t^i) + \theta v(c_t^i) - \chi \frac{{h_t}^{i,1+\gamma}}{1+\gamma} \tag{4}$$

where C_t^i (c_t^i) denotes the consumption of i in sub-period t_1 (t_2). $\theta \in [\underline{\theta}, \infty] \sim f_\theta$ is the preference shock, a random variable that affects the relative utility derived from consumption in sub-period 2. Implicitly, a high θ household will face a high urgent expenditure need in t_2 and therefore will desire a high consumption level c^i. We further assume that θ is an i.i.d random variable following a distribution with probability density function f (F denotes the cdf).[26]

Finally, h_t^i denotes hours worked by i. Parameter χ affects the disutility of working and γ is the inverse of the Frisch elasticity of labour supply.

3.2.2 Assets and asset demand

In subperiod t_1 the household solves a portfolio choice problem, choosing the optimal quantity of a short-term (one period) nominal bond and a long-term nominal bond. We denote by $B_{t,S}^i, B_{t,L}^i$ the nominal quantities of the short and long bonds respectively and let $b_{t,S}^i, b_{t,L}^i$ denote the real quantities (scaled by the price level P_t).

Long-term assets, B_L, are perpetuities paying coupons that decay geometrically over time (see, for example, Woodford, 2001). We let δ denote the decay factor, so that a bond pays a stream $1, \delta, \delta^2, ...$ to the investor. The price of the long-term bond in period t is denoted $q_{L,t}$. The ex-post holding period return can be expressed as

$$R_{L,t+1} = \frac{1 + \delta q_{L,t+1}}{q_{L,t}}.$$

Short-term nominal bonds are purchased by households for two reasons: First, for their return (the inverse of the price $q_{S,t}$) and second for providing liquidity to finance consumption in subperiod

t_1 and t_2 whenever it is absolutely necessary.

[26]This assumption will rule out selection effects into different bond market segments (as in e.g. Amihud and Mendelson, 1991), for example when agents that experience a high θ today will likely expect a high θ tomorrow and have a stronger demand for short-term assets. Introducing this element should not be difficult, but for now we leave it to future work.

2. We assume that expenditures c_t^i are subject to the following constraint:

$$c_t^i \leq b_{S,t}^i \tag{5}$$

and therefore a household that desires to finance a high level of expenditures may be constrained by the quantity of short-term bonds it chose in the portfolio.

It is important to note that in subperiod 2 a household has access only to her portfolio to finance c_t^i.[27] However, since as discussed previously, households are part of a family that pools resources when transactions have been carried out, they will have the same level of resources (wealth) at the portfolio choice stage in t_1 and thus will end with the same quantity of short and long-term assets in the portfolio.

3.2.3 Household's problem

We now define formally the household's program. The budget constraint in sub-period 1 is:

$$P_t C_t^i + q_{L,t} B_{L,t}^i + q_{S,t} B_{S,t}^i = P_t(1-\tau_t) w_t h_t^i + (1 + q_{L,t}\delta) B_{L,t-1}^i + B_{S,t-1,2}^i + D_t P_t - T_t P_t - P_t \bar{C}_t^i \tag{6}$$

On the left hand side (LHS) we have the household's choice variables, subperiod 1 consumption C_t^i and the market value of the portfolio $(B_{S,t}^i, B_{L,t}^i)$. The leading term on the right hand side (RHS) represents the household's net wage income $(1-\tau_t)w_t h_t^i$ where w is the real wage rate and τ_t represents a proportional tax levied on labour income. In addition, households can be taxed in a lump sum fashion. T_t denotes lump sum tax.[28]

The terms $(1+q_{L,t}\delta)B_{L,t-1}^i + B_{S,t-1,2}^i$ represent the nominal pay out of long and short-term assets bought by the household in the previous period. Notice that $B_{S,t-1,2}^i$ has a subscript '2' which is used to denote that these are short bonds that remained in the household's portfolio after the transactions at subperiod 2 in period $t-1$ had been realized.

Variable D_t is used to denote income from dividends. Since ours is a New Keynesian model, there is a continuum of monopolistically competitive firms earning profits (see below). Households are the owners of these firms and we assume that each household owns an equal amount of shares as any other household in the economy.[29]

The term $\bar{C}_t^i$ denotes the goods the household expects to sell to other families in sub-period 2. It is important to note that $\bar{C}_t^i$ is not a choice variable for the household, and rather it is used here to

[27] The interpretation of the uninsurability of the expenditure shock, θ, could then be a spatial one. In sub-period 2, family members are spatially separated and so the goods c_t^i have to be obtained from other families in exchange for the liquid asset (the short-term bond), see Hagedorn (2018).

[28] We will use both lump sum and distortionary taxes in the following sections. Lump sum taxes allow us to derive tractable analytical results. Distortionary taxes make the optimal policy program we consider in Section 4 meaningful.

[29] To simplify, we assume (as many papers in the literature do) that shares cannot be traded. This makes stocks a more illiquid asset than bonds.

ensure market clearing in the goods market.[30] It holds that:

$$E_\theta(c_t^i(\theta)) = \bar{C}_t^i, \tag{7}$$

and so the household will enter the next period with short-term bonds equal to

$$B_{S,t,2}^i = E_\theta(B_{S,t}^i - P_t(c_t^i(\theta)) + P_t\bar{C}_t^i, \tag{8}$$

We now express the household's program formally. Optimal choices solve the following value function:

(9)

$$V_t(B_{L,t-1}^i, B_{S,t-1,2}^i, X_t) = \max_{B_{L,t}^i, B_{S,t}^i, C_t^i, c_t^i, h_t^i} \left\{ u(C_t^i) + E_\theta \theta v(c_t^i) - \chi \frac{{h_t^i}^{,1+\gamma}}{1+\gamma} + \beta E_t \left[V_{t+1}(B_{L,t}^i, B_{S,t,2}^i, X_{t+1}) \right] \right\}$$

subject to constraints (6) and (8), the constraint (5) governing consumption in sub-period 2. We use state variable X to denote the vector of aggregate shocks to the economy (to be described later).

Solving the Bellman equation leads to the following optimality conditions (see online appendix): First,

$$u'(C_t^i) = \theta v'(c_t^i) \quad \text{if} \quad \theta < \widetilde{\theta}_t \tag{10a}$$

$$c_t^i = b_{t,S}^i \quad \text{if} \quad \theta \geq \widetilde{\theta}_t \tag{10b}$$

defines the optimal choice of c^i. When the realized value of θ is below the threshold $\widetilde{\theta}_t$ the optimal choice is unconstrained and the household sets $\theta v'(c_t^i) = u'(C_t^i)$. In contrast, if θ exceeds the threshold, then (5) is binding and trivially c^i is equal to $b_{t,S}^i$. Obviously, at the threshold, we have $\widetilde{\theta}_t v'(b_{t,S}^i) = u'(C_t^i)$.

Second, the optimal choice of short-term bonds leads to :

$$q_{t,S} u'(C_t^i) = F(\widetilde{\theta}_t) \beta E_t \frac{u'(C_{t+1}^i)}{\pi_{t+1}} + \int_{\widetilde{\theta}_t}^{\infty} \theta v'(b_{t,S}^i) dF_\theta \tag{11}$$

The interpretation of (11) is the following: At the margin, the household equates the utility cost of saving in the short-term bond, $q_{t,S} u'(C_t^i)$, with the utility benefit of acquiring more of the asset. The benefit has two components: On the one hand, the short-term asset provides liquidity to finance subperiod 2 consumption (this is the term $\int_{\widetilde{\theta}_t}^{\infty} \theta v'(b_{t,S}^i) dF_\theta$). On the other hand, with probability $F(\widetilde{\theta}_t)$, the preference shock is below the threshold value, and short-term bonds will be carried over to the next period. The standard asset pricing formula then applies for this asset which pays $\frac{1}{\pi_{t+1}}$ units of real income in $t+1$.

[30] More specifically, since sub-periods t_1 and t_2 may not represent different points in real time, households cannot distinguish between customers in t_1 and t_2 and how much is sold in either subperiod is basically exogenous to households. For details, see (Hagedorn, 2018).

Third, the price of the long-term bond satisfies a standard Euler equation:

$$q_{t,L}u'(C_t^i) = \beta E_t \frac{u'(C_{t+1}^i)}{\pi_{t+1}}(1 + \delta q_{t+1,L}) \tag{12}$$

Finally, the optimal choice of hours gives the familiar labour supply condition:

$$\chi \frac{h_t^\gamma}{U'(C_t)} = w_t(1 - \tau_t) \tag{13}$$

3.2.4 Production / Government / Resource Constraints

We now describe the production side of the model and the government.

As discussed previously, we assume, in the standard New Keyenesian fashion, that a final good is produced as the aggregate of infinitely many differentiated products. Each of the products is produced under monopolistic competition by a single producer operating a technology that is linear in the labour input:

$$Y_t(j) = H_t(j)$$

The final good is then given by the following Dixit-Stiglitz aggregator

$$Y_t = \left(\int_1^0 Y_t(j)^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}}$$

where η governs the elasticity of substitution across the differentiated goods.

Producers of goods $Y_t(j)$ solve a standard problem, setting the price level to maximize discounted profits subject to the demand curve, and taking as given the costs of hiring labour, w. Moreover, we assume that price setting may involve paying a resource cost as in Rotemberg (1982). In particular,

$$\Omega_t = \frac{\omega}{2} \left(\frac{P_{jt}}{P_{jt-1}} - 1 \right)^2,$$

is the cost that the firm has to bear whenever it changes the price relative to the previous period. Parameter ω governs the degree of price rigidity. A high value for this parameter implies a steep cost of adjusting prices. When $\omega = 0$ prices are perfectly flexible.

Note that the above is a standard set up (see, for example, Schmitt-Grohé and Uribe, 2004) and for brevity we will not define formally the firm's program. In this model, there exists an equilibrium which is symmetric and all firms end up charging the same price and hiring the same units of labour h_t. The model admits the following New Keynesian Phillips curve:

$$\pi_t(\pi_t - 1) = \frac{\eta}{\omega}(\frac{1+\eta}{\eta} - w_t)h_t + \beta E_t \frac{U'(C_{t+1})}{U'(C_t)} \pi_{t+1}(\pi_{t+1} - 1) \tag{14}$$

Let us now turn to fiscal/debt policies in the economy. The government levies taxes and issues debt to finance spending G_t. We assume that G_t is a random variable and the only source of uncertainty in the model. The government issues debt in short and long-term bonds and, as usual, market clearing requires that the total supply of debt by the government is equated with the aggregate demand for the short and long assets by the households.

The government budget constraint can be written as:

$$q_{t,S}B^g_{t,S} + q_{t,L}B^g_{t,L} = B^g_{t-1,S} + B^g_{t-1,L}(1 + \delta q_{t,L}) + P_t(G_t - w_t\tau_t h_t - T_t) \tag{15}$$

where the superscript g is used to denote the supply of bonds by the government. Using market clearing and dropping superscripts (equating demand and supply) we can express the government budget constraint in real terms as:

$$q_{t,S}b_{t,S} + q_{t,L}b_{t,L} = \frac{b_{t-1,S}}{\pi_t} + \frac{b_{t-1,L}}{\pi_t}(1 + \delta q_{t,L}) + G_t - w_t\tau_t h_t - T_t \tag{16}$$

Finally, putting together the household and the government budget constraints we can derive the following economy wide resource constraint:

$$C_t + \int c^i_t(\theta)dF_\theta + G_t + \frac{\omega}{2}(\pi_t - 1)^2 = h_t = Y_t \tag{17}$$

stating that total consumption by the households ($C_t + \int c^i_t(\theta)dF_\theta$) and the government ($G_t$), together with the resource costs of inflation make up for the total output produced in this economy. The latter is obviously equal to hours worked.

3.3 The Fiscal Multiplier in the Linearized Model

We now turn to studying the propagation of spending shocks in our model, and to characterize the spending multiplier under short and long-term financing. To do so, we rely on a log-linear version of the model. In addition, in order to be able to derive analytical results, we assume in this paragraph that taxes are lump sum. Later on, we consider the case of distortionary taxes.

Let us further assume that the period utility functions u, v are both log. In the online appendix we show that the Phillips curve, the resource constraint, the government budget constraint and the two bond pricing equations we previously derived can be written as:

$$\hat{\pi}_t = \frac{1+\eta}{\omega}\overline{h}(\gamma\hat{h}_t + \hat{C}_t) + \beta E_t\hat{\pi}_{t+1} \tag{18}$$

$$\overline{C}\hat{C}_t + \int_0^{\overline{\tilde{\theta}}} \theta dF_\theta \overline{C}\hat{C}_t + \overline{\tilde{\theta}}^2 f_{\overline{\tilde{\theta}}}\overline{C}\hat{\tilde{\theta}}_t + \overline{b}_S(1 - F_{\overline{\tilde{\theta}}})\hat{b}_{t,S} - f_{\overline{\tilde{\theta}}}\overline{\tilde{\theta}}\overline{b}_S\hat{\tilde{\theta}}_t + \overline{G}\hat{G}_t = \overline{Y}\hat{Y}_t \tag{19}$$

(20)

$$\overline{q}_S\overline{b}_S(\hat{q}_{t,S} + \hat{b}_{t,S}) + \overline{q}_L\overline{b}_L(\hat{q}_{t,L} + \hat{b}_{t,L}) = \overline{G}\hat{G}_t - \overline{T}\hat{T}_t + \overline{b}_S(\hat{b}_{t-1,S} - \hat{\pi}_t) + \overline{b}_L(1 + \delta\overline{q}_L)(\hat{b}_{t-1,L} - \hat{\pi}_t) + \delta\overline{q}_L\overline{b}_L\hat{q}_{t,L}$$

(21) $$\frac{\overline{q}_S}{\overline{C}}(\hat{q}_{t,S}-\hat{C}_t) = -F_{\bar{\tilde{\theta}}}\frac{\beta}{\overline{C}}E_t(\hat{C}_{t+1}+\hat{\pi}_{t+1}) + \frac{\beta}{\overline{C}}f_{\bar{\tilde{\theta}}}\bar{\tilde{\theta}}\hat{\tilde{\theta}}_t - \frac{1}{\overline{b}_S}\int_{\bar{\tilde{\theta}}}^{\infty}\theta dF_\theta \hat{b}_{t,S} - \frac{1}{\overline{b}_S}\bar{\tilde{\theta}}^2 f_{\bar{\tilde{\theta}}}\hat{\tilde{\theta}}_t$$

(22) $$\frac{\overline{q}_L}{\overline{C}}(\hat{q}_{t,L}-\hat{C}_t) = -\frac{\beta}{\overline{C}}(1+\delta\overline{q}_L)E_t(\hat{C}_{t+1}+\hat{\pi}_{t+1}) + \frac{\overline{q}_L}{\overline{C}}\delta\overline{q}_L E_t\hat{q}_{t+1,L}$$

where hats denote that variables are expressed in log deviation from their steady state values. $\hat{\tilde{\theta}}_t + \hat{C}_t = \hat{b}_{t,S}$ defines the threshold $\tilde{\theta}_t$ in this log-linear model.

Equations (18) to (22) are sufficient for a competitive equilibrium when we further specify monetary and fiscal policies, setting the path of the short -term nominal interest rate and the tax schedule respectively. We next explore the fiscal multiplier in this model under various specifications of these policies.

3.3.1 Simple analytics

We first show that issuing short-term debt increases the size of the spending multiplier in an analytical version of the model. To show this, we focus on an environment where the Phillips curve, the Euler equation for short-term debt and the resource constraint (equations (18), (19) and (21)) are sufficient to determine the path of output and consumption following a spending shock. In particular, we assume that lump sum taxes are set by the government so that the budget constraint (20) is satisfied. Then, we do not have to keep track of equation (20) and also we can dispense with equation (22), since the price $\hat{q}_{L,t}$ can be set to satisfy this equation given the path of consumption and inflation.

Recall that our empirical analysis had linked the size of the fiscal multiplier to the share of short debt over long-term debt. We assume in this paragraph that the response of the share to the spending shock is of the same sign as the response of $\hat{b}_{t,S}$, the real value of short-term bonds in t.[31] We consider paths $\hat{b}_{t,S} = \varrho\hat{G}_t$ where ϱ is of positive value if the government finances the shock short-term (the share of short bonds then increases) and $\varrho < 0$ when the shock is financed with long-term debt (the short-term share drops).

Consider the Euler equation (21) that prices short-term debt. Substituting in the condition $\hat{\tilde{\theta}}_t = \hat{b}_{t,S} - \hat{C}_t$ and rearranging we get:

(23)
$$\frac{\overline{q}_S}{\overline{C}}\hat{q}_{t,S} + F_{\bar{\tilde{\theta}}}\frac{\beta}{\overline{C}}E_t\hat{\pi}_{t+1} + F_{\bar{\tilde{\theta}}}\frac{\beta}{\overline{C}}\hat{C}_{t+1} = \underbrace{\left(\frac{\overline{q}_S}{\overline{C}} + (1-\beta)\frac{1}{\overline{C}}f_{\bar{\tilde{\theta}}}\bar{\tilde{\theta}}\right)}_{\alpha_1}\hat{C}_t - \underbrace{\left((1-\beta)\frac{1}{\overline{C}}f_{\bar{\tilde{\theta}}}\bar{\tilde{\theta}} + \frac{1}{\overline{b}_S}\int_{\bar{\tilde{\theta}}}^{\infty}\theta dF_\theta\right)}_{\alpha_2}\hat{b}_{t,S}$$

where evidently $\alpha_1, \alpha_2 > 0$.

Let us first assume that monetary policy sets the path of the nominal interest rate so that

[31] This is not a restrictive assumption since we assume that taxes satisfy the government budget for any path of long-term debt after the shock. We can thus always ensure that the share is of the same sign as $\hat{b}_{t,S}$.

$\frac{\overline{q}_S}{\overline{C}}\hat{q}_{t,S} + F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}}E_t\hat{\pi}_{t+1} = 0$. Notice that under this policy, the real rate would be constant if $\frac{\overline{q}_S}{\overline{C}} = F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}}$. This would in turn hold if short-term debt had no liquidity value to finance consumption.[32] In contrast, when short bonds generate liquidity services in subperiod 2, then $\overline{q}_S > \beta > \beta F_{\bar{\bar{\theta}}}$ and the nominal interest rate will not increase proportionally with expected inflation to keep the real interest rate constant.[33]

Under this policy, we can write (23) as:

$$F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}}\hat{C}_{t+1} = \alpha_1\hat{C}_t - \alpha_2\hat{b}_{t,S}$$

which defines a first order difference equation in $\hat{C}$. Since $F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}} < \alpha_1$[34] we can solve forward to obtain:

$$\hat{C}_t = \frac{\alpha_2}{\alpha_1}E_t\sum_{\bar{t}\geq 0}(F_{\bar{\bar{\theta}}}\frac{\beta}{\alpha_1\overline{C}})^{\bar{t}}\hat{b}_{t+\bar{t},S}$$

which expresses consumption in period t as a function of the sequence of real short-term bonds. Using this result, it is simple to characterize the path of $\hat{C}_t$ following a shock to spending when $\hat{b}_{S,t} = \varrho\hat{G}_t$. Let us make the standard assumption, that spending follows a first order auto-regressive process with coefficient ρ_G. Then, considering a positive innovation to spending at date 0 we have that

$$\hat{C}_t = \rho_G^t\frac{\alpha_2}{\alpha_1}\frac{1}{1 - F_{\bar{\bar{\theta}}}\frac{\beta}{\alpha_1\overline{C}}\rho_G}\varrho\hat{G}_0, \qquad t \geq 0$$

Analogously, the response of total consumption (in both subperiods) can be derived as:

$$\hat{TC}_t = \kappa_1\varrho\rho_G^t\hat{G}_0$$

where $\kappa_1 > 0$ is defined in the appendix.

Using these expressions we can derive analytically the fiscal multiplier. Define the impact multiplier as the dollar increase in output for each dollar increase in spending, or $m_0 = \frac{\overline{Y}d\hat{Y}_0}{\overline{G}d\hat{G}_0}$. We have:

$$m_0 = \frac{\overline{Y}d\hat{Y}_0}{\overline{G}d\hat{G}_0} = 1 + \frac{1}{\overline{G}}\left[\frac{\alpha_2}{\alpha_1}\frac{\overline{C}(1 + \int_0^{\bar{\bar{\theta}}}\theta dF_\theta)}{1 - F_{\bar{\bar{\theta}}}\frac{\beta}{\alpha_1\overline{C}}\rho_G} + \overline{b}_S(1 - F_{\bar{\bar{\theta}}})\right]\varrho \tag{24}$$

[32] For a sufficiently large stock of short-term bonds we have that $\overline{q}_S \approx \beta$ and $F_{\bar{\bar{\theta}}} \approx 1$. We then obtain the standard 3 equation NK model in which targeting a constant real interest rate implies no consumption response to the spending shock (Woodford, 2011). Then also $\alpha_2 = 0$.

[33] A way to interpret this condition then is the following: Since $F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}}E_t\hat{\pi}_{t+1}$ is the expected decrease of the real value of short bond holdings for households that retain their stock of short bonds after subperiod 2, monetary policy compensates these households for higher expected inflation. As we will now show, under this policy and if in addition we assume $\hat{b}_{S,t} = 0$, so that the supply of the short-term asset also does not change the payoff of holding the asset, then consumption remains constant through time.

[34] This follows from $F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}} < F_{\bar{\bar{\theta}}}\frac{\beta}{\overline{C}} + \frac{1}{\overline{b}_S}\int_{\bar{\bar{\theta}}}^{\infty}\theta dF_\theta = \frac{\overline{q}_S}{\overline{C}} < \frac{\overline{q}_S}{\overline{C}} + (1-\beta)\frac{1}{\overline{C}}f_{\bar{\bar{\theta}}}\bar{\bar{\theta}} \equiv \alpha_1$.

According to (24) a key parameter determining the size of the multiplier is ϱ. Since the expression contained in the square brackets is positive, when the government finances spending short-term, or $\varrho > 0$, then the multiplier exceeds 1. Otherwise, assuming $\varrho < 0$ yields an impact multiplier that is less than 1.

The expression in the square brackets has two components. The second term, $\bar{b}_S(1 - F_{\bar{\bar{\theta}}})$, measures the immediate effect of relaxing the constraint for households experiencing a high preference shock. The leading term measures the inter-temporal effect of relaxing future constraints on current consumption C. Even if it is not likely that the constraint will bind today, the fact that it may bind in the future generates a strong incentive to accumulate savings. When the relative supply of short-term debt increases ($\varrho > 0$) this incentive becomes weaker.

As is evident from (24) the significance of these margins, and consequently the value of the multiplier, depend (besides on parameter ϱ) on $\alpha_1, \alpha_2, F_{\bar{\bar{\theta}}}$ which influence the elasticity of consumption with respect to $\hat{b}_{S,t}$. The more responsive is total spending to the share $\hat{b}_{S,t}$, the larger is the multiplier.

Our quantitative experiments below will discipline these parameters to match relevant moments from US data. In particular, we will discipline parameter ϱ, measuring the response of the share to the spending shock, using the empirical model of the previous section. Parameters $\alpha_1, \alpha_2, F_{\bar{\bar{\theta}}}$ (their analogues in the calibrated model of the next subsection) will be such that the model produces a realistic response of the term spread to a change in the share of short-term bonds, consistent with the empirical evidence presented in Greenwood et al. (2015). For the moment, our interest is in verifying that the model possesses a mechanism which makes the fiscal multiplier depend on how the government finances spending shocks.

This result can also be obtained under a more plausible specification of monetary policy than what we assumed above. For example, let us consider a simple Taylor rule in which the nominal interest rate responds to inflation:

$$\hat{i}_t = \phi_\pi \hat{\pi}_t$$

To keep the algebra tractable, we need to simplify the shock process. Therefore, we assume that shocks to spending are i.i.d, or $\rho_G = 0$. Then, conjecturing a solution of the form

$$\hat{\pi}_t = \chi_1 \hat{G}_t \qquad \hat{C}_t = \chi_2 \hat{G}_t \qquad \hat{Y}_t = \chi_3 \hat{G}_t$$

for some coefficients χ_1, χ_2, χ_3 which satisfy the three equilibrium conditions (18), (19) and (21), we find

$$m_0 = \alpha_3 \left[1 + \left(\frac{1}{\overline{\overline{G}}} \frac{\alpha_2}{\alpha_1} \frac{\overline{C}\left(1 + \int_0^{\bar{\bar{\theta}}} \theta dF_\theta\right)}{1 + \frac{1+\eta}{\omega} \frac{1}{\alpha_1} \frac{\overline{q}_S}{\overline{\overline{C}}} \phi_\pi} + \bar{b}_S(1 - F_{\bar{\bar{\theta}}}) \right) \varrho \right] \tag{25}$$

where $a_3 = a_3(\phi_\pi) < 1$ decreases in the inflation coefficient ϕ_π (see appendix).

A couple of comments are in order. First, comparing (25) with (24) (the latter when we set

$\rho_G = 0$) it is easy to see that the impact multiplier is now smaller in magnitude. As expected, when monetary policy raises the nominal rate in response to inflation (and therefore also following a positive spending shock which is typically inflationary), then the real interest rate increases, and this suppresses private consumption. In (25) this effect is visible from the leading fraction ($\alpha_3 < 1$) which measures the effect of inflation through the Phillips curve, and the fraction in the square bracket featuring ϕ_π in the denominator, which measures the standard intertemporal substitution effect on consumption. Both fractions decrease in ϕ_π.[35]

Second, parameter ϱ continues being important. We can show that when $\varrho = 0$ (the share remains constant after the shock) then the multiplier falls short of unity (due to the crowding out of consumption). Moreover, it is possible to find sufficiently positive values of ϱ for which the multiplier exceeds 1. In the latter case the crowding out effect of the higher real interest rate on consumption, following the spending shock, is compensated by the crowding in effect deriving from the larger short bond supply.

3.4 A calibrated model

We now calibrate the model to US data to investigate quantitatively how the spending multiplier varies with the financing of the spending shock.

The model horizon is quarterly and so we set $\beta = 0.995$. Moreover, we set $\delta = 0.96$ so that the long-term bond is of (average) maturity equal to 25 quarters. With this value we target an average debt maturity for total debt of roughly 5 years, when we set the share of short over long-term debt to be equal to the mean of our data sample. We also set the steady state ratio of total debt to GDP equal to 60 percent at an annual horizon.

We make the following assumptions about fiscal/monetary policies and the share of short-term debt in the model. First, we assume that taxes follow a feedback rule of the form:

$$\hat{T}_t = \phi_T \hat{D}_{t-1} \tag{26}$$

where $\hat{D}$ denotes the real face value of total debt (both long and short-term bonds).

(26) is a standard rule linking taxes to lagged debt (e.g. Leeper, 1991). In our baseline quantitative experiments below, the parameter ϕ_τ is set equal to 0.01. This value is close to the threshold that defines the determinacy region in the model, when we assume that monetary policy is set according

[35]Note that we did not specify under which condition for ϕ_π the solution to (18), (19) and (21) is a unique stable equilibrium. It is perhaps worth to discuss this briefly.

In this model the usual condition $\phi_\pi > 1$ (i.e. the Taylor principle) does not need to hold for a unique equilibrium. Instead it is sufficient to have $\phi_\pi > \beta \frac{F_{\overline{\theta}}}{\overline{q}_S}$ which, since $\overline{q}_S > \beta$ and $F_{\overline{\theta}} < 1$, defines a threshold value that is strictly less than 1. Intuitively, the Euler equation (21) features 'discounting' and this enables to rule out multiple equlibria even when the Taylor principle does not hold (an analogous property obtains in the HANK model (see, for example, Bilbiie, 2021)).

The reader may also wonder whether the assumption of an exogenous path of real debt, $\hat{b}_{S,t}$, is important for this property. Indeed this is so: Suppose that debt issuance is set according to a rule $\hat{b}_{S,t} + \hat{\pi}_t = \varrho \hat{G}_t$. Then, (for some parameterizations of the model) even setting $\phi_\pi = 0$ could induce determinacy of the equilibrium. The logic follows Hagedorn (2018). In this model, where the real value of debt enters the Euler equation, the price level (and hence also inflation) may be determinate even under a simple interest rate peg.

to an interest rate rule satisfying the Taylor principle. Moreover, it ensures that government debt displays a near unit root, consistent with the US data (Marcet and Scott, 2009).[36]

Second, we assume that monetary policy follows an inertial rule of the form:

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1-\rho_i)\phi_\pi \hat{\pi}_t \tag{27}$$

In our baseline calibration of the model we set $\rho_i = 0.9$ and $\phi_\pi = 1.25$. However, we also experiment with alternative values for these parameters and specifications of the monetary policy rule.

Finally, we assume that the share of short-term over long-term debt follows:

$$\hat{s}_t^{\text{Short/Long}} = \varrho \hat{G}_t \tag{28}$$

We discipline the value of ϱ using the empirical evidence: In the proxy VAR we identified the effects of a spending shock under short-term financing relying on observations where the average increase in $s_t^{\text{Short/Long}}$ is 0.6% and the shock is a 1% increase in government spending. Under long-term financing the share was lower by roughly 0.6% on average. We thus set $\varrho = 0.6$ as our baseline when the government finances short and $\varrho = -0.6$ in the case long-term financing.[37]

We now describe how we chose objects $F_\theta, \overline{\overline{\theta}}, \varrho$ and $\overline{q}_S$. First, given $\overline{q}_L = \frac{\beta}{1-\beta\delta}$ in steady state, we calibrate $\overline{q}_S$ so that the term premium at the annual horizon is equal to 1 percentage point. The quarterly net rate of return on the long-term asset is $\overline{R}_L - 1 = \frac{1+\delta\overline{q}_L}{\overline{q}_L} - 1 = 0.5\%$ and the analogous short-term rate $(\frac{1}{\overline{q}_S})$ equals 0.25%.

Given $\overline{q}_S$, our principle in calibrating the distribution F_θ is the following: We assume that F_θ is log normal which leaves us with two parameters (the mean and the variance) to hit relevant targets. We calibrate the mean so that in steady state, total consumption is 80% of output which we normalize to 1. Government spending then accounts for 20%. The net inflation rate is zero in the deterministic

[36] This is also consistent with the estimates of medium scale DSGE models (see e.g. Bianchi and Ilut (2017) among others.)

[37] $\hat{s}_t^{\text{Short/Long}}$ is defined by taking the log deviation of the ratio of the face value of short-term over long-term debt in the model. The average value of the share is 0.125 in our calibration and in the data. Note however, that since in our model short-term is one quarter debt whereas in the empirical section it is any debt of maturity less than a year, there is a difference between the model and the data. We therefore experimented with an alternative definition of the share.

In particular, consider

$$\widetilde{s}_t^{\text{Short/Long}} = \frac{b_{S,t} + b_{L,t}\frac{1-\delta^4}{1-\delta}}{b_{L,t}\frac{\delta^4}{1-\delta}}$$

to represent the share in levels. $\widetilde{s}_t^{\text{Short/Long}}$ assumes that the face value of all debt of maturity less than a year (including the coupon payments of the long-term bonds) count as short-term debt. In other words, we stripped the coupons of the long-term asset and consider the payments that are of maturity less than 4 quarters as short debt. In log deviations we obtain:

$$\hat{\widetilde{s}}_t^{\text{Short/Long}} = \frac{1}{\overline{\widetilde{s}}^{\text{Short/Long}}} \frac{\overline{b}_S}{\overline{b}_L \frac{\delta^4}{1-\delta}} \left(\hat{b}_{S,t} - \hat{b}_{L,t}\right).$$

In the online appendix we show simulations from this model, showing that our baseline results regarding the fiscal multipliers under STF and LTF do not change and if anything the differences become larger.

steady state.

We then set the variance of F so that our model produces an elasticity of the term premium with respect to the short-term debt to GDP ratio in line with the estimates of Greenwood et al. (2015). This paper reports that an increase of the ratio by 1 percent, reduces the (annualized) spread between T-bills and T-notes/bonds by 16 basis points in the case of 4 week bills and about 8 basis points for 10 week yields. Both are relevant numbers since the data counterpart for b_S is all debt that is of maturity up to one quarter. We target a 2 basis points change in the spread, corresponding to our quarterly model.[38]

Finally, for the remaining model parameters we adopt standard values. ω and η are set to 17.5 and -6 respectively, following Schmitt-Grohé and Uribe (2004). γ_h equals 1 implying a Frisch elasticity of labour supply of the same magnitude. The persistence of the spending shock ρ_G is 0.95. Moreover, as in the previous analytical subsection we continue assuming that utility is log - log.

3.4.1 Baseline experiments

Figure 5 shows the responses of consumption (top plots), output (middle plots) and the cumulative multiplier (bottom) to a shock which increases spending by 1 percent on impact. The blue lines show the responses under short-term financing (STF) whereas the red lines are the analogous objects in the case where the government finances with long-term debt (LTF). Our baseline calibration with an inertial interest rate is shown in the middle column of the figure.

The differences between short and long-term financing are easy to spot in the figure. Financing the deficit short-term, leads to a much stronger output response due to the fact that consumption is crowded in by the shock. In contrast, under long-term financing, consumption drops significantly after the spending shock, and this translates into a weaker response of output. The multiplier under STF is equal to 2 on impact and remains above 1 until roughly period 8 in the graph. Under LTF, the impact multiplier is 0.5 and remains around that level throughout the horizon considered in the plot.

To highlight the key driving forces behind these results let us go back to the Euler equation (23). We can write this equation as

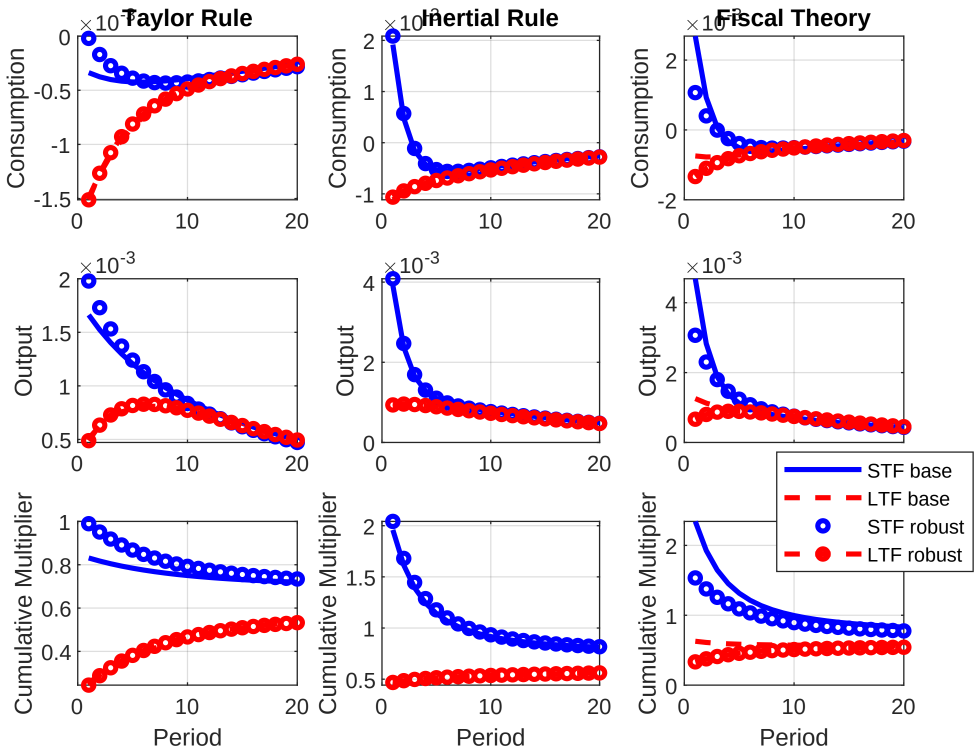
$$\hat{i}_t = F_{\bar{\bar{\theta}}} \frac{\beta}{\overline{q}_S} E_t \hat{\pi}_{t+1} + F_{\bar{\bar{\theta}}} \frac{\beta}{\overline{q}_S} \hat{C}_{t+1} - \frac{\overline{C}\alpha_1}{\overline{q}_S} \hat{C}_t + \frac{\overline{C}\alpha_2}{\overline{q}_S} \hat{b}_{t,S} \tag{29}$$

Note that the crucial element in (29) is the last term on the RHS, $\frac{\overline{C}\alpha_2}{\overline{q}_S} \hat{b}_{t,S}$. This term acts like a standard demand shock to the Euler equation. Under short-term financing, the increase in spending is accompanied by a positive shock ($\hat{b}_{t,S}$ increases), and the opposite could happen under long financing.[39]

[38] To hit this target, we consider a shock to the ratio $\hat{b}_{S,t} - \hat{Y}_t$ using the baseline version of the model. Moreover, for every alternative calibration of the model that consider below, we repeat this exercise and if needed we re-calibrate the distribution F_θ to match the empirical evidence.

[39] In the appendix we show that responses of $\hat{b}_{t,S}$ and $\hat{b}_{t,L}$ to the shocks for this baseline calibration. Indeed the LTF shock leads to a drop in the quantity of real short-term bonds, which can be mainly attributed to higher inflation, when the nominal quantity is roughly constant. Notice however, that even a drop in nominal short-term debt would not be

Figure 5: Responses to a spending shock.



Notes: We plot the paths of consumption, output and the cumulative fiscal multiplier following a shock that increases spending by 1 percent on impact. In the middle panels we show our baseline calibration in which monetary policy sets the nominal interest rate according to $\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)\phi_\pi \hat{\pi}_t$*. The solid (blue) line and the dashed (red) assume* $\phi_\pi = 1.25$ *and* $\rho_i = 0.9$ *(he base calibration of the model). Responses in blue correspond to the case where the government finances with short-term debt. Red colour graphs are for long-term financing. The graphs with circles correspond to an alternative specification of the interest rate rule,* $\phi_\pi = 1$ *and* $\rho_i = 0.9$*. The left panels assume that monetary policy follows a simple inflation targeting rule* $\hat{i}_t = \phi_\pi \hat{\pi}_t$*. The 'base' value is* $\phi_\pi = 1.25$ *and the 'robust' value is* $\phi_\pi = 1$*. Lastly, the right panels correspond to the case of passive monetary policy, that is coefficient* ϕ_π *is strictly below 1. The 'base' is* $\phi_\pi = 0.5$ *and 'robust' corresponds to* $\phi_\pi = 0$*.*

The reaction of monetary policy is key. As with any demand shock, if monetary policy tracks the real interest rate, it can fully eliminate the shock from the Euler equation. This would, however, require that the term $\frac{\overline{C}\alpha_2}{\overline{q}_S}\hat{b}_{t,S}$ enter into the policy rule as a stochastic intercept. But the inertial monetary policy rule in (27) does not feature real interest rate targeting and so the supply of short-term debt has non-trivial effects on the macroeconomy.

It is also evident that parameter ρ_i becomes very important. Smoothing the nominal interest rate is essentially the opposite to tracking real rate fluctuations and a higher coefficient ρ_i will leave extra room for the demand shock to impact the Euler equation amplifying the expansionary effect of the shock on private consumption.[40]

Parameter ϕ_π also exerts an influence. In principle, a stronger reaction of the nominal rate to inflation (a higher inflation coefficient) will mitigate the expansionary effect of increasing the supply of short-term debt.

3.4.2 The effects of varying the monetary policy rule

To dig deeper into how coefficients ρ_i and ϕ_π affect the fiscal multipliers in our model, in the left panels of Figure 5 we show the responses when monetary policy sets interest rates according to a simple Taylor rule, $\hat{i}_t = \phi_\pi \hat{\pi}_t$. The baseline inflation coefficient is 1.25 shown with the solid lines in the figure, whereas the dashed lines consider the case $\phi_\pi = 1$. Notice that we continue finding a substantial difference in the responses of output and consumption across STF and LTF (blue and red plots, respectively). However, now these differences are smaller relative to the middle panels, with the inertial monetary policy rule. Whereas under inertial policies the STF multipliers exceeded unity and consumption was crowded in after the shock, with a simple rule consumption is crowded out and the cumulative multiplier is never above one. Thus, parameter ρ_i exerts a significant influence on the magnitudes of the multipliers, but, qualitatively speaking, the result that short-term and long-term financing induce different responses of aggregate consumption and output to fiscal shocks, is robust to the alternative rules we consider.[41]

The effects of varying parameter ϕ_π are clearly visible in the left panels. Unsurprisingly, a higher inflation coefficient induces a weaker response of output and a smaller fiscal multiplier. Interestingly,

unrealistic. Since short bonds mature after one period, a government that temporarily focuses on issuing long-term debt could see a contraction in the quantity of short bonds outstanding. In the data contractions relative to trend occur frequently.

[40]Simple forward iteration of (29) yields:

$$\hat{C}_t = E_t \sum_{j\geq 0} (\frac{\beta}{\overline{C}\alpha_1} F_{\overline{\overline{\theta}}})^j (-\frac{\overline{q}_S}{\overline{C}\alpha_1}\hat{i}_{t+j} + \frac{\beta}{\overline{C}\alpha_1} F_{\overline{\overline{\theta}}} E_t \hat{\pi}_{t+j+1} + \frac{\overline{C}\alpha_2}{\overline{C}\alpha_1}\hat{b}_{t+j,S})$$

An STF shock will result in a persistent increase of the short bond supply and of inflation. With a smooth path of the interest rates, $\hat{i}_{t+j}$ will not strongly compensate for the increase in the RHS variables and this will result into a stronger reaction of current consumption to the shock.

[41]Obviously, our simplistic framework misses out on ingredients that have been shown to increase fiscal multipliers in the baseline New Keynesian context (e.g. rule of thumb consumers as in Gali et al. (2007), or non-separabilities between consumption and leisure, as in Bilbiie (2011)). Adding these elements to the model would likely increase the STF multiplier above unity. But since our goal here is not to build a quantitative model that can exactly match the data, we leave this to future work.

however, this effect is mainly present in the STF responses, under long-term financing the inflation coefficient seems not to matter much. The reason is that inflation after an LTF shock does not react much, the negative demand impact of reducing the supply of short-term debt compensates for the positive demand impact of the spending shock.[42]

In the online appendix we further extend these results considering different values for coefficients ρ_i, ϕ_π. Moreover, we experiment with monetary policy rules that target the output gap along with inflation and lagged interest rates. The main message is that a significant difference between the fiscal multiplier under STF and under LTF applies also in these cases.

3.4.3 Unbacked fiscal deficits/ Passive monetary policy.

Our baseline model focuses on a scenario in which monetary policy (implicitly) pursues an inflation stabilization goal and fiscal policy ensures the solvency of government debt through taxes. Parameter ϕ_T is large enough so that debt is a mean reverting process even though it displays considerable persistence in our baseline calibration. Assuming higher values of ϕ_T will not change the results we showed previously. However, what may significantly change the model's behavior, is to assume a low enough coefficient ϕ_T so that debt becomes an explosive process. In this case fiscal deficits need to be financed by inflation and it is well understood that monetary policy needs to follow a rule that prescribes a weak response to inflation (e.g. Leeper, 1991). We now explore this scenario. [43]

In particular, we let taxes be constant through time (i.e. $\phi_T = 0$) and also let the nominal interest rate be set according to a rule $\hat{i}_t = \phi_\pi \hat{\pi}_t$ but now coefficient ϕ_π is either 0.5 or 0 ('base' and 'robust' legends respectively). The results are shown in the right panel of Figure 5. Notice that now the spending multipliers are larger (compared with the left panel where we assume an inflation targeting rule with active policy). This is to be expected: In an equilibrium where monetary policy cannot focus fully on stabilizing inflation and has to satisfy debt solvency, inflation will be pinned down by the intertemporal government budget constraint and so a spending shock will not only impact the macroeconomy through the usual channels (the Euler equation and the Phillips curve) but will also be filtered through the consolidated budget. This adds more volatility, macroeconomic variables in this model are more exposed to the fiscal shock (see, for example, Leeper, Traum, and Walker, 2017).[44] The differences in the fiscal multiplier stemming from how the government finances spending are clearly also present in this model.

[42]See online appendix for these responses of inflation.

[43]This is the so called 'passive monetary/active fiscal' policy regime. See e.g. Leeper (1991) and the considerable literature on the fiscal theory of the price level.

[44]An important difference between the STF and LTF shocks concerns how the intertemporal constraint of the government is impacted. Since short debt is 'cheap' in this model (its price reflects the liquidity services) the government extracts profits from liquidity provision (see Angeletos et al., 2022). These rents increase the intertemporal revenues of the government. A STF spending shock, will result in a relatively higher short bond supply and lower rents, reinforcing the drop in the intertemporal surplus of the government. For debt to be stabilized, a larger increase in inflation and output is needed, relative to the case of the LTF shock. See Section C in the online appendix.

3.4.4 Distortionary Taxation

These results continue to hold when we replace the assumption that taxes are lump sum with distortionary taxes levied on labour income at a proportional rate τ. Under distortionary taxation, equations (19), (21) and (22) continue to hold, the only changes to the system of equilibrium conditions concern the government's budget constraint and the Phillips curve. In particular, the government's revenue now becomes

$$\text{Revenue} = \overline{\tau}\overline{Y}\frac{1+\eta}{\eta}\left((1+\gamma_h)\hat{Y}_t + \hat{C}_t + \frac{1}{1-\overline{\tau}}\hat{\tau}_t\right)$$

where $\overline{\tau}$ ($\hat{\tau}_t$) denote the steady state (log-deviation) of the tax rate. Thus, revenue depends also on aggregate output and on consumption, and hence of the path of these variables following a spending shock. Moreover, the Phillips curve now is:

$$\hat{\pi}_t = \frac{1+\eta}{\omega}\overline{Y}(\gamma\hat{Y}_t + \hat{C}_t + \frac{\overline{\tau}}{1-\overline{\tau}}\hat{\tau}_t) + \beta E_t\hat{\pi}_{t+1} \tag{30}$$

and therefore the path of taxes will also influence inflation in this version of the model.

In Figure 6 we repeat the exercises of the previous paragraphs assuming distortionary taxes. As is evident from the figure, the impulse responses and the cumulative multipliers are very close to the the analogous objects in Figure 5. Thus, the main finding of the previous sections, that fiscal mulitpliers differ under STF and LTF carries over the case of distortionary taxes.

Finally, note that this result is important, since in Section 4 we turn to optimal debt maturity policies and we will assume that taxes are distortionary in order to have a meaningful policy problem. There, we will leverage on the property that short-term financing leads to a larger fiscal multiplier with distortionary taxes.

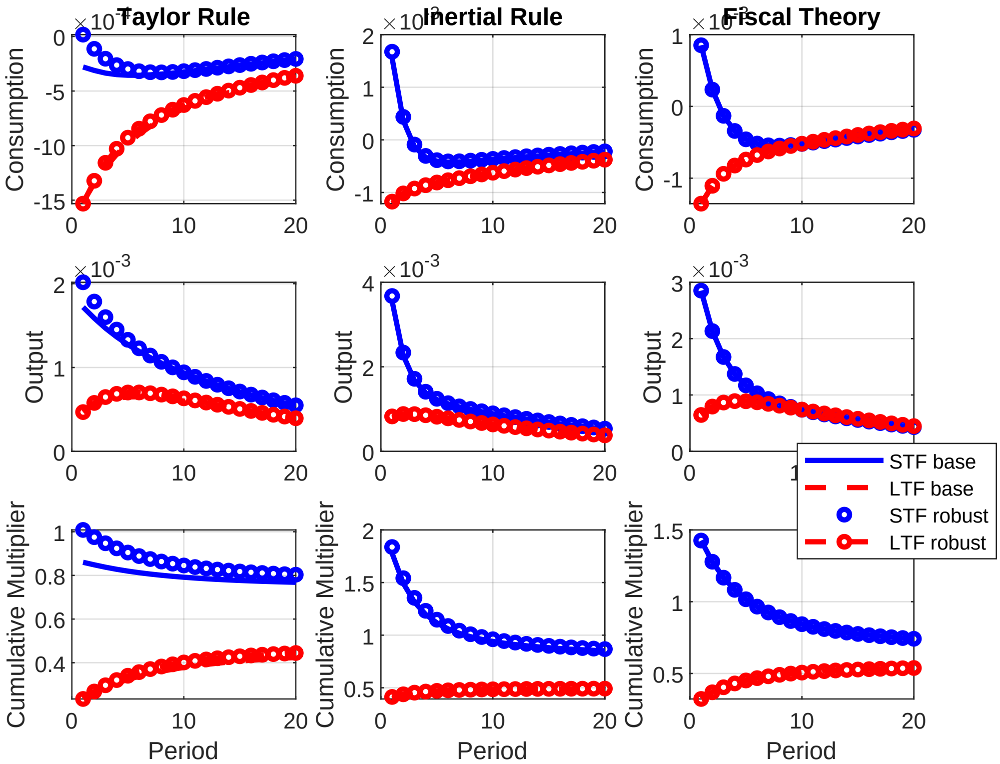
3.4.5 Assuming that long bonds provide partial liquidity services.

Our theoretical model explains the differential effect of financing spending shocks with short and long-term bonds, based on the presumption that short-term bonds provide money like services to the private sector. In our framework households can finance within period idiosyncratic shocks to consumption utility using short-term bonds; long bonds can only be used to transfer resources across periods. The starting point of this analysis has been the recent empirical finance literature (e.g. Greenwood et al., 2015) showing that short-term government debt provides liquidity services over and above the services that may be provided by long-term debt.

We now stress that our results do not hinge on the assumption that short bonds are the only liquid asset in the economy. In the online appendix we experiment with a version of our model in which long bonds provide *partial liquidity*. More specifically, we assume the following constraint applies to the subperiod 2 consumption of households:

$$c^i_t \leq b^i_{S,t} + \kappa b^i_{L,t}$$

Figure 6: Responses to a spending shock: Distortionary taxes



Notes: We plot the paths of consumption, output and the cumulative fiscal multiplier following a shock that increases spending by 1 percent on impact, and assuming distortionary taxation. The calibration of the monetary and fiscal rules corresponding to each of the graphs shown, is discussed in the notes of Figure 5.

where κ is a parameter that governs the liquidity provided by long-term debt.

In calibrating this model we link parameter κ to the term premium. Recall that in our baseline ($\kappa = 0$) the annual term premium is 100 basis points. In the appendix we investigate versions of our model where $\kappa > 0$ and the term premium is 75 bps and 50 bps. In each case, we recalibrate the parameters of F_θ to make our model consistent with the empirical evidence of Greenwood et al. (2015). We continue finding considerable differences in the fiscal multipliers across STF and LTF.

4 Optimal Policy

We have provided evidence that the size of the fiscal multiplier is considerably larger when deficits are financed short-term. In our theoretical work we emphasized that this new empirical fact can be explained by a model in which short-term bonds provide liquidity to finance consumption. We now turn to evaluate the policy implications that we can derive from our theoretical framework. In particular, we ask: Will an optimizing government, facing a random spending sequence, prefer to finance spending shocks with short-term debt due to the larger fiscal multipliers that this entails?

In an economy where issuing debt serves the purpose of smoothing (distortionary) taxes, it may seem that financing short-term entails an advantage for the government: When revenue depends on output, a higher multiplier will translate into lower fiscal deficits in times of high spending needs. This will enable the government to better smooth tax distortions across time.

This argument, however, ignores the potential benefits that can be derived from issuing long-term debt. In canonical macroeconomic models, an increase in the spending level leads to a drop in long bond prices. When consumption is crowded out following a positive shock, the real long term interest rates increase. Thus, a government that issues long-term debt benefits from *fiscal hedging*, from the drop in the real value of its outstanding debt obligations when spending rises. In addition, if inflating away part of the debt is an available option to the government, then long bonds maintain a significant advantage over short-term debt: A mild and persistent increase in the inflation rate, can reduce the real value of long-term debt substantially, thereby stabilizing the government's financing needs.

Angeletos (2002) and Buera and Nicolini (2004) show that the optimal policy under full commitment in the canonical model with distortionary taxation fully exploits the fiscal hedging channel. Optimal debt portfolios feature a large quantity of long-term debt, that can even be several times as large GDP, financed through savings in the short-term asset. Lustig et al. (2008) extend their approach to a New Keyensian economy with both inflation and tax instruments and simple frictions in financial markets that rule out the ability of the government to invest in private assets. They find that it is still optimal for the government to focus on issuing long-term debt.

We follow the trail of these papers and setup an optimal policy program assuming that an optimizing government issues short-term and long-term debt and sets taxes and inflation to maximize household welfare under full commitment. In contrast to the canonical model that has been extensively considered in the literature, here the government faces a non-trivial tradeoff between using long bonds to benefit from fiscal insurance and short bonds to provide liquidity to the economy and to benefit from the larger fiscal multiplier.

Since a complete description of the exercise is quite cumbersome to fit in this final section of our paper, we leave to the appendix the formal and detailed treatment of the optimal policy problem. We provide here a brief account of the setup of the program, as well as a discussion of the policy implications that we derive from the solution.

4.1 The Policy Program

4.1.1 A brief description of the setup

As in the previously mentioned papers, we consider here a Ramsey policy equilibrium in which the benevolent government chooses sequences of prices, taxes, and quantities $\left\{\boldsymbol{\pi}, \boldsymbol{Y}, \boldsymbol{\theta}, \boldsymbol{\tau}, \boldsymbol{q_S}, \boldsymbol{q_L}, \boldsymbol{b_L}, \boldsymbol{b_S}, \widetilde{\boldsymbol{\theta}}, \boldsymbol{C}\right\}$ to maximise household welfare subject to a set of constraints which are sufficient for a competitive equilibrium. In the online appendix, we apply the standard arguments used in the literature to derive this constraint set showing that it comprises of the Phillips curve, the resource constraint, the government budget constraint and the threshold condition $\widetilde{\theta} C_t = b_{S,t}$ (see Proposition 1 in the online appendix). We then derive the objective function of the benevolent government (which is the household expected welfare function when we substitute out sub-period 2 consumption c_θ) and setup a Lagrangian to solve the problem through the first order optimality conditions.

We write succinctly the system of first order conditions together with the constraints defining the competitive equilibrium in the economy, as:

$$E_t \Omega \left(\widetilde{Y}_{t+1}, \widetilde{X}_t, \widetilde{X}_{t-1} \widetilde{Y}_t, \widetilde{\psi}_t, \widetilde{\psi}_{t-1}, \left\{ \underline{M}_j, \overline{M}_j \right\}_{j=S,L} \right) = 0 \tag{31}$$

where $\widetilde{Y}$ condenses variables that may appear in forward expectations in the system of equations; $\widetilde{X}$ are the remaining endogenous variables and the elements of $\widetilde{\psi}$ are the Lagrange multipliers associated with the constraints. Function Ω is nonlinear in these arguments.

Parameters $\underline{M}_S, \overline{M}_S$ and $\underline{M}_L, \overline{M}_L$ are ad hoc debt limits that constrain the size of positions that the government can take in the bond market. More specifically, we wet

$$b_{j,t} \in [\underline{M}_j, \overline{M}_j] \quad \text{for} \quad j = S, L$$

As Aiyagari et al. (2002); Faraglia et al. (2019, 2016), we assume loose upper bounds on short and long-term bonds to ensure that the government does not accumulate debt past the point where it can repay almost surely. Moreover, our baseline calibration of the model (from which we will show the results here) follows Lustig et al. (2008) and Faraglia et al. (2019) who assume lower bounds $\underline{M}_j = 0$, ruling out negative debt.[45]

[45]Clearly given that short bonds enter into the utility function $\underline{M}_S = 0$ will never bind in the simulations of the model. The lower bound constraints are relevant only for long-term bonds. Note that in the appendix we also consider the case where long-term debt can be negative. We show that in this model as in Aiyagari et al. (2002), the government wants to accumulate long-term assets. Thus $b_{L,t}$ becomes negative and in fact it converges (in the

4.1.2 Numerical algorithm

To solve this model we need to approximate the expectations of (the nonlinear functions of) the variables contained in $\widetilde{Y}$. We parameterize these expectations using polynomials of the state variables. Our global solution method is the PEA algorithm of Den Haan and Marcet (1990). However, as we explain in the appendix, ours is not a standard application of optimal debt policy because solving the system of equations (31) can result in multiple stationary points.

The rationale behind this property follows the argument of Angeletos et al. (2022). Generally, two types of optimal policies can emerge from system (31): One in which the short bond supply is limited and the government may benefit from the rents of providing liquidity to the economy which enables to finance deficits at lower cost and second, a solution in which the supply of short bonds is large enough so that the preferences for liquidity are effectively satiated, and our model is then essentially isomorphic to the canonical model of government debt management.

To be able to discern the global optimum from the multiple solutions of system (31) we wed the stochastic PEA algorithm with an approximation of the value function. This numerical procedure is described in detail in the appendix and it should be of interest to some readers.

4.2 Optimal Portfolios

4.2.1 Is it optimal to finance deficits with short-term debt?

We now turn to the analysis of optimal debt policies in the model. Figure 7 shows a 1000 model period simulation of optimal policy. The top left panel displays the quantity of short-term bonds in the model whereas the top right graph shows the market value of the long-term debt issued by the government.

There are a couple noteworthy features. First, note that the short-term issuance is quite stable over time, $b_{S,t}$ fluctuates roughly between 0.24 and 0.26 in the model. Second, the market value of long-term debt displays considerably more volatility, it starts at around 2 (roughly 50 percent of annual GDP) and fluctuates between 1.5 and 4.8. Therefore the long-term debt to GDP ratio in the model can exceed 100 percent. In contrast the analogous short debt to GDP is pretty stable around 7 percent.

It should be evident from these graphs that most of the financing of spending shocks happens through issuing long-term debt. Positive spending shocks lead to significant changes in the quantity of long debt but not in the issuance of the short-term asset.

In the online appendix we show this more explicitly, by looking at the impulse responses of short and long bonds after a positive shock. We find that whereas the quantity of long-term bonds increases, the analogous quantity of short-term debt falls after an increase in spending.

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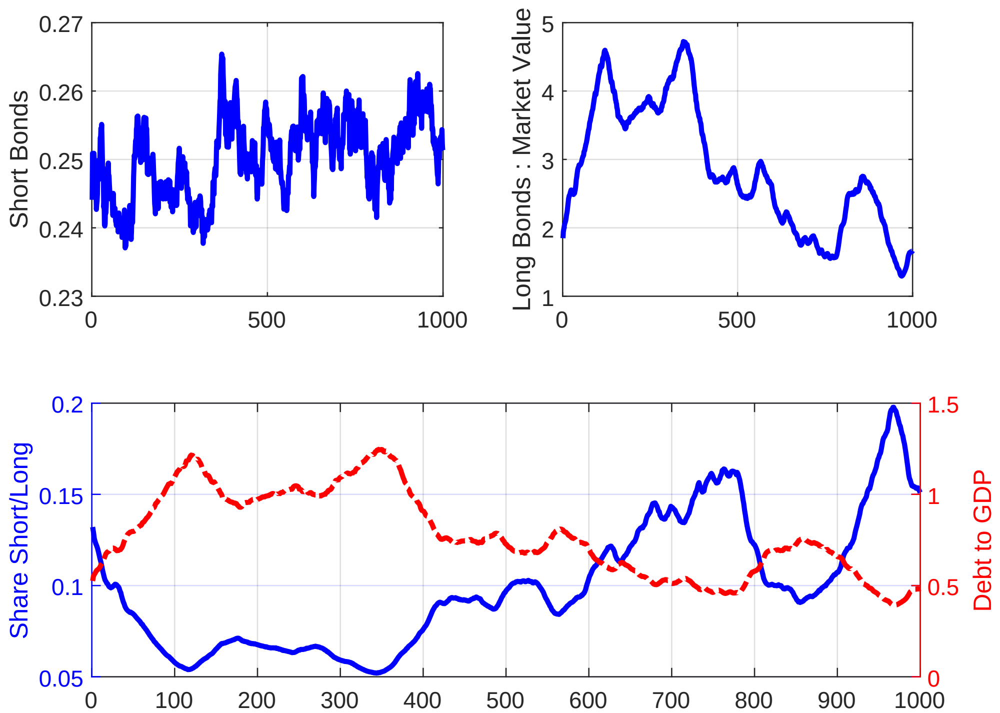
stationary distribution sense) near the lower bound constraint. We can derive interesting insights from this model, but because defining the share of short-term over long-term debt is cumbersome, our preferred calibration is as in Lustig et al. (2008) and Faraglia et al. (2019) the one which rules out negative debt.

Setting $\underline{M}_j = 0$ is justified in the literature by observing that governments are rarely willing to invest in private assets. The rationale is that governments do not want to bear the idiosyncratic risks of possible private sector default. As Lustig et al. (2008) and Faraglia et al. (2019), our aim here is not to provide a microfoundation of this.

Figure 7: Optimal Portfolio Simulation



Notes: We show 1000 periods simulated from the optimal policy model. The top left panel shows the quantity of short-term bonds in the model. The top right panel displays the market value of long-term debt. The bottom panel traces the evolution of the share of short over long and the (annualized) debt to GDP ratio.

Why is this the optimal policy? There are basically two arguments in favor of focusing on long-term bonds to finance spending shocks. First, when the deficit is financed long-term, consumption is crowded out, and long bond prices covary negatively with the deficit. Therefore, a government that has accumulated long-term debt will benefit from fiscal hedging (the drop in the long bond prices when the spending shock hits). In contrast, under short-term financing, consumption is crowded in following the shock. Though this amplifies the effect on output, it increases the market value of long-term debt outstanding, as long bond prices will tend to increase. When faced with this trade-off the optimizing government prefers to issue long term debt.

Second, increasing the quantity of the short-term asset to finance higher spending, implies that the supply of liquidity to the economy increases. Though this can have a positive effect on welfare by alleviating the financing friction for households, it also implies that the government's revenue from liquidity provision is reduced. Lower revenue means higher distortionary taxes are needed to finance debt.[46]

[46] A short bond supply between 0.24 and 0.26 implies, in our calibrated model, that the friction for households is relevant. This is also an important property of the solution which we examine closely in the appendix. In this model, it is generally not optimal to 'satiate' the economy with short bonds, though it may become optimal if the government can accumulate a large stock of long-term assets. In versions of the model where $b_{L,t}$ can become sufficiently negative we find such solutions.

4.2.2 Optimal policy v.s. the US data.

As we have seen, the optimal policy in our model features a positive and stable issuance of short-term bonds. We also saw in the previous section, that financing deficits short-term is not optimal, a property which is clearly at odds with the US data. We now contrast the behavior of the share of short-term over long-term debt in the model and in the data to discern how the difference between optimal policy and actual US policy affects this aggregate.

The bottom panel of Figure 7 shows the share in our simulations, plotted together with the (annual) debt to GDP ratio. As can be seen from the figure, the share of short over long, displays considerable persistence, it fluctuates between 5 percent and 20 percent and covaries negatively with GDP. In our sample in the data (see online appendix for the analogous graph), the share fluctuates between 6 percent and 20 percent and also displays persistence and negative correlation with the debt to GDP ratio.

Table 3 summarizes key moments in the model and in the data. Note that the mean share of short bonds predicted by the model is somewhat lower on average than in the data (first row). The first order autocorrelation coefficient is higher in the model than in the data (0.99 vs 0.89 respectively, second row) and the correlation with GDP is much more negative in the model (final row).

Table 3: Data and model outcomes

	Data	Model
Mean share	0.124	0.099
Auto-correlation	0.89	0.99
Standard deviation	0.024	0.020
Correlation with debt-GDP	−0.43	−0.94

Notes: The first column reports the mean share of short over long, the first order serial autocorrelation coefficient and the standard deviation of the share and the correlation of the share with the debt to GDP ratio in the data. The second column reports the analogous moments in the optimal policy model under 'No Lending'.

5 Conclusion

The empirical evidence presented in this paper demonstrates that the fiscal multiplier, the increase in aggregate output per additional dollar spent by the US government, is higher when short-term debt is issued by the US Treasury. We provide a theoretical explanation for this phenomenon by incorporating financial market frictions into a model, where short-term bonds serve as a source of liquidity, enabling ex post heterogeneous households to finance a higher consumption stream. Our modeling approach aligns with a growing body of literature that emphasizes the influence of bond supply on the yield curve.

Using the model, we analyze the interplay between debt financing and monetary/fiscal policies to determine the magnitude of the output response to a spending shock. Subsequently, we investigate optimal policy choices to understand how a government aiming to optimize its portfolio allocation of short and long-term debt may capitalize on the fact that short-term financing leads to larger fiscal multipliers. Our findings reveal that an optimizing government issues a consistent and positive amount of short-term debt, financing spending shocks mainly with long-term bonds. We attribute this behavior to the fiscal hedging value associated with long-term bonds, enabling the government to smooth taxes over time.

While our tractable model offers valuable insights, there are several fruitful extensions that warrant consideration. Notably, our model abstracts from several layers of heterogeneity, particularly in terms of age and wealth. We acknowledge that quantitatively rich models of heterogeneous agents, in which households possess strong incentives to accumulate wealth in short-term assets for precautionary savings and long-term assets for retirement financing, could also serve as a valuable laboratory for studying the propagation of spending shocks under various maturity financing arrangements. Such models would endogenously lead to segmented bond markets and non-trivial selection effects when agents that prefer to invest in short term assets differ in age and wealth than long horizon investors who prefer to hold long-term debt. Such selection effects could be important for the fiscal multipliers.

However, solving large-scale models incorporating heterogeneous agents, particularly when long-term bonds are realistically risky assets or entail transaction costs within retirement accounts is not a straightforward task. Utilizing such models to study optimal policy choices is also far from trivial. The tractable model we employed in this paper allows us to derive valuable insights into the optimal maturity financing of spending shocks.

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