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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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A convenient truth: The convenience yield, low interest rates and implications for fiscal policy*

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Abstract

Some countries currently face historically low interest rates on government debt due to a positive 'convenience yield' arising from an excess demand for safe and liquid assets. This low interest rate environment has raised interest in the role of fiscal stabilization policy. We study the convenience yield and its implications for fiscal policy in a New Keynesian model where households derive utility from government bonds. We find that the convenience yield expands the set of sustainable fiscal policies and renders countercyclical fiscal policy successful in stabilizing business cycle fluctuations. Conveniently, fiscal policies that stabilize output rather than debt are feasible, welfare enhancing and can even reduce the risk of exploding debt dynamics if the convenience yield is positive.

JEL Classification: E32, E62, E63

Keywords: convenience yield, low interest rate, fiscal policy, debt sustainability

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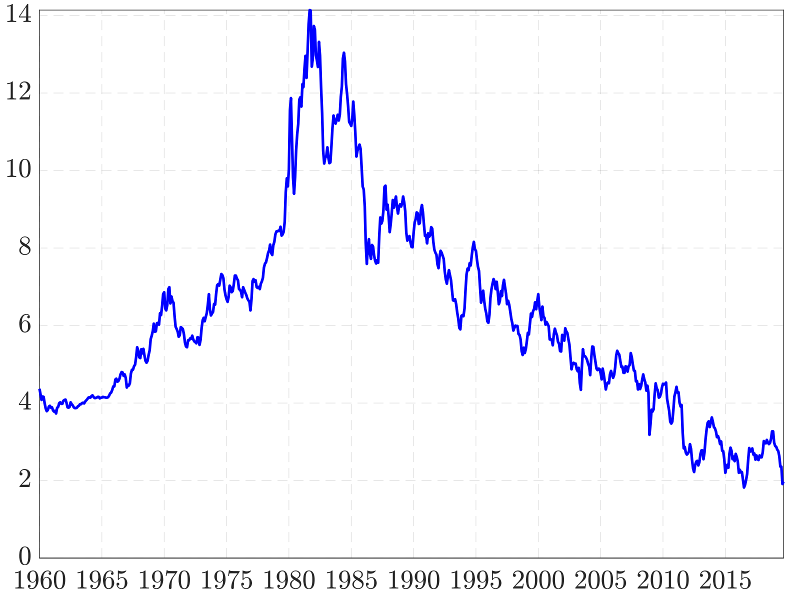
1 Introduction

With much of the advanced world currently facing historically low and downward-trending interest rates, central banks increasingly run out of ammunition to further provide economic stimulus if need be. Consequently, some policymakers have called out on fiscal policy to support monetary policy in stabilizing economic conditions (e.g. Carney, 2019; Draghi, 2019). Although the COVID-19 pandemic will leave many countries heavily indebted, some governments can still borrow at very low (and even negative) rates, suggesting that deficit-financed fiscal expansions come cheap and would not necessarily put public finances on an unsustainable path. Figure 1, for instance, shows that nominal long-maturity interest rates on US Treasuries are near their lowest level since the 1960s. While this can partly be explained by the accommodative monetary policy pursued by the Federal Reserve in the past decade, the figure shows that Treasury yields have been trending downwards much longer, potentially reflecting a persistent rise in the demand for safe and liquid assets. Indeed, the seminal study by Krishnamurthy and Vissing-Jorgensen (2012) shows that US Treasuries are valued more than other assets of similar maturity, due to their unique safety and liquidity attributes. The resulting price differential gives rise to a so-called *convenience yield*. For a given supply of Treasuries, an increase in the desire to hold safe and liquid assets then drives up the price of Treasuries and raises this convenience yield. It is likely that in times of financial stress, when many investors flee to safety, the convenience yield is particularly high, and thus public borrowing costs conveniently low.

In this paper, we study fiscal policy in times when interest rates are low due to a positive convenience yield on government bonds. We first provide some empirical evidence that support our conjecture that the convenience yield on US Treasuries is especially high during financial crises. We then examine what a positive convenience yield implies for (1) the requirements for fiscal policy to guarantee non-explosive debt dynamics and (2) the stabilizing properties and welfare consequences of fiscal stabilization policy. To this end, we employ a New Keynesian model in which households derive utility from holding government bonds

Figure 1: Nominal long-maturity yield on US Treasuries (%)



Source: Federal Reserve Board.

(as in Krishnamurthy and Vissing-Jorgensen, 2012, among others). The latter captures the motives for accumulating assets beyond reasons related to the pecuniary return on those assets and intertemporal consumption smoothing, and thereby generates a wedge between the household's discount factor and the market interest rate, i.e. the convenience yield.

We show that a positive convenience yield loosens the stability requirements for fiscal policy by reducing the government's debt-servicing costs and thereby lowering the long-run growth rate of debt. In fact, for a sufficiently high convenience yield, debt sustainability is guaranteed even if the government does not adjust its primary budget balance in response to changes in outstanding debt. This goes against the more commonly viewed prerequisite for fiscal policy that has the government offset debt increases through appropriate budgetary consolidations. In our model, setting primary balances independently from the level of debt outstanding does not necessarily threaten debt sustainability. A positive convenience yield also changes the necessary requirements for fiscal and monetary policy coordination to deliver a determinate and stable equilibrium, in a way that depends on the cyclical stance of fiscal policy. When fiscal policy is counter-cyclical, meaning that the government raises (reduces) its primary balance endogenously in response to an expansion (contraction) in output, the likelihood of obtaining a stable and unique equilibrium increases, provided that monetary policy satisfies the Taylor Principle (i.e. is 'active' according to the language of Leeper, 1991). Moreover, the less actively the central bank targets inflation, the weaker are the minimum required debt stabilization efforts for fiscal policy, provided the government adopts a counter-cyclical fiscal stance. Hence, we find that, when interest rates are low and monetary policy is likely to be constrained by the effective lower bound (ELB), counter-cyclical fiscal policies are feasible and even reduce the risk of explosive debt dynamics. Pro-cyclical fiscal policies, on the other hand, complicate the task of ensuring debt sustainability.

Furthermore, counter-cyclical fiscal policies are found to successfully stabilize the business cycle and improve welfare, but only in the presence of a positive convenience yield—if the convenience yield were zero, counter-cyclically adjusting the primary balance in response to changes in economic conditions would offer no stability gains due to Ricardian equivalence. We show that if an economy experiences a demand-driven economic boom, a counter-cyclical fiscal response triggers an increase in the primary balance which, in turn, leads to a reduction in the amount of government debt outstanding. Because this leads to an increase in the marginal utility of holding government bonds, households are prompted to accumulate more bonds and reduce consumption, which partly offsets the initial surge in economic activity. Hence the convenience yield establishes a positive link between consumption and government debt, thereby breaking Ricardian equivalence and rendering fiscal policy better capable of stabilizing the economy. The more the government uses its fiscal tools to stabilize government debt, the less scope remains to limit the variability in output, which implies a trade-off between stabilizing output and stabilizing debt. However, the greater is the convenience yield, the more favorable this trade-off becomes, meaning that fluctuations in output can be reduced for any given variability in government debt. Moreover, using a utility-based welfare criterion, we show that a fiscal policy mix that has the government respond weakly to changes in government debt and strongly to fluctuations in output delivers the largest gains to household welfare.

Combined, our results provide clear-cut recommendations for the design of fiscal policy in countries that experience very low interest rates due to an exceptionally high demand for their government debt. Particularly, these countries are to shift their fiscal efforts away from debt stabilization and towards output stabilization. The latter can be achieved by promoting strong counter-cyclical fiscal policies and enhancing automatic stabilizers. Our findings imply that, during an economic downturn, countries will benefit from a government flooding the market with bonds as this provokes the desire to consume. The convenience yield renders such counter-cyclical policies stabilizing, welfare enhancing and sustainable. In fact, the convenient truth is that such policies actually reduce the risk of exploding debt dynamics, exactly in times when the potency of monetary policy is limited.

Our paper is related to a growing literature on the role of fiscal policy and public debt in times of low interest rates, a topic recently rekindled by the global secular decline in real interest rates and the corresponding challenges it poses to monetary policy. Blanchard (2019), for instance, argues that if the safe interest rate (i.e. the rate on government bonds) lies below the growth rate of the economy, fiscal policies that involve debt rollovers without future tax hikes may be feasible, to the extent the safe rate is expected to remain low. This is consistent with our finding of feasible active fiscal policies in the presence of a sufficiently high convenience yield that suppresses public borrowing costs. According to Blanchard, a negative interest rate-growth differential has been the norm rather than the exception in US history.[1] Because such conditions impose limits on the potency of monetary policy (due to the presence of the ELB, see Kiley and Roberts, 2017), Blanchard and Summers (2017) argue that fiscal authorities should carry a larger share of the brunt of economic stabilization while reducing efforts to stabilize debt, which is consistent with our findings on the optimal fiscal policy mix. Auerbach and Gorodnichenko (2017) provide empirical support for this rationale

[1] See also Mehrotra (2017) who studies the interest rate-growth differential for a group of advanced economies since 1870.

by showing that fiscal stimulus may not necessarily threaten, but could actually improve, debt sustainability when economic activity is weak and interest rates are low. De Grauwe et al. (2019) use a behavioral macroeconomic model to study fiscal policy in regimes with either high or low interest rates. Similar to our results on the trade-off between stabilizing output and government debt, they find this trade-off to be more favorable in the low interest rate regime. With regards the role of counter-cyclical fiscal policy, Eichenbaum (2019) suggests to assign a greater role for automatic fiscal stabilizers in times when interest rates are low and monetary policy is constrained by the ELB, during which automatic stabilizers are especially potent (see also Christiano et al., 2016).[2] Relatedly, Feldstein (2002) argues that, when interest rates are low, discretionary fiscal policy can have stimulative effects by providing the right (tax) incentives to increase private spending. These recommendations echo those stemming from our welfare analysis that strongly favors enhanced counter-cyclical fiscal policies when interest rates are low.

Relative to the aforementioned contributions, our paper differs by highlighting that the feasibility and efficacy of fiscal policy hinge, not only on *whether* interest rates are low, but also on *why* interest rates are low. Specifically, our analysis shows that if a strong demand for government bonds keeps interest rates low, a positive link between consumption and government debt arises which can be exploited to boost the fiscal benefits of low interest rates. It is this positive consumption-debt link that strengthens the stabilizing effects of counter-cyclical fiscal policy.[3]

The convenience yield on government bonds further plays an important role in contemporary discussions on secular stagnation (e.g. Caballero et al., 2015; Eggertsson et al., 2016). Del Negro et al. (2017b) and Gerali and Neri (2018), for instance, claim that the rising

[2]Suggestions to strengthen automatic stabilization in times when economic performance is weak are offered by Blinder (2016), among others.

[3]Bohn (1999) also stresses the importance of the underlying forces that keep real returns on government bonds low for the welfare consequences of budget deficits. In particular, he shows that budget deficits are benign (and can even improve welfare) if interest rates are low because government bonds offer superior advantages over other assets, whereas deficits may be welfare reducing if low interest rates are driven by risk aversion.

trend in the convenience yield has been one of the key forces behind the secular decline in the natural rate of interest in the US and the euro area, respectively. This has prompted academics to examine to what extent fiscal policy can remedy such secular developments. Eggertsson et al. (2019) and Rachel and Summers (2019), for example, show how increases in government debt in an overlapping generations model can lead to a rise in the natural rate of interest, thereby helping to avoid secular stagnation. Cuba-Borda and Singh (2018) study secular stagnation and permanently negative natural interest rates in a model featuring government bonds in the utility function of the household. They find that, in a secular stagnation steady state, increased government spending is successful in reducing unemployment, yet is contractionary in an expectations-driven liquidity trap, again underscoring the importance of the sources behind low interest rates. Finally, the convenience yield has been studied in Del Negro et al. (2017a), who show that liquidity shocks that raise the convenience yield can explain a significant share of the drop in output and inflation during the 2008 financial crisis.[4]

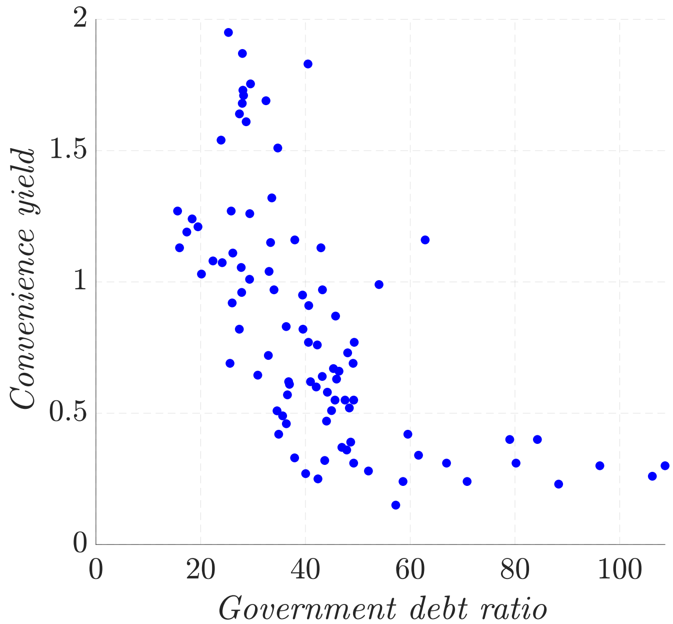
The rest of the paper is organized as follows. In Section 2, we provide suggestive evidence that the convenience yield on US Treasury bonds is more elevated in times of financial stress. Section 3 describes the New Keynesian model and the calibration of the parameters. The implications of the convenience yield for the stability requirements of fiscal policy are studied in Section 4. The implications for the stabilizing properties and welfare consequences of fiscal stabilization policy are discussed in Section 5. Finally, Section 6 concludes.

2 The convenience yield in good and bad times

In this section, we document two stylized facts regarding the convenience yield on US Treasuries. The first is borrowed from Krishnamurthy and Vissing-Jorgensen (2012, hereafter KVJ) who show that the convenience yield is negatively related to the supply of govern-

[4]In their model, the convenience yield arises due to the assumption that government bonds provide superior liquidity services over private paper. Liquidity provision by government bonds also features in Calvo and Végh (1995) and Canzoneri et al. (2008).

Figure 2: The convenience yield vs government debt ratio in the US, 1919-2010 (%)



Notes: The convenience yield is measured as in KVJ, i.e. as the percentage spread between Moody's Aaa-rated long-maturity corporate bond yield and the yield on long-maturity Treasury bonds, both taken from the FRED Economic Database. The series for the government debt ratio are taken from Henning Bohn's website. For more information about data construction and sources, we refer the reader to KVJ.

ment bonds (as a share of GDP). We replicate this observation in Figure 2. As in KVJ, we measure the convenience yield by the percentage difference between Moody's Aaa-rated long-maturity corporate bond yield and the yield on long-maturity Treasury bonds.[5] We then plot this series, which runs from 1919 to 2010, against the government debt ratio. The negative relationship between the two variables can be interpreted as a demand function for Treasuries: a lower supply of Treasuries will, for a given demand, result in a higher bond price and, thereby, a higher convenience yield.

Figure 2 further shows that the relationship between the convenience yield and government debt is non-linear, with the slope being relatively steep when the debt ratio is low and almost flat at high debt ratios. This observation suggests that the demand for Treasuries is state dependent, which brings us to a second stylized fact that we wish to highlight: the

[5]The rationale behind this measure is that long-maturity Aaa corporate bonds and Treasury bonds are both very safe and liquid assets, implying that differences in their corresponding yield are likely to capture the 'convenience' value of holding Treasuries.

convenience yield rises in times of financial stress. In fact, van Binsbergen et al. (2019) show that the convenience yield on Treasuries quadrupled during the financial crisis. Similarly, Paret and Weber (2019) find that German Bunds also carry a convenience yield which tends to rise when risk aversion (proxied by bond market volatility) increases. Here, we provide additional suggestive evidence for the state-dependence of the convenience yield. We do so by estimating the following two-state Markov-Switching model for the convenience yield, which we denote by cy_t:

$$cy_t = c\left(\mathcal{S}_t\right) + \delta\left(\mathcal{S}_t\right)\log\left(\frac{b_t}{y_t}\right) + e_t, \tag{1}$$

where b_t/y_t is the government debt ratio and $e_t \sim \mathcal{N}\left(0, \sigma^2\left(\mathcal{S}_t\right)\right)$ the residual. The intercept, $c\left(\mathcal{S}_t\right)$, and slope, $\delta\left(\mathcal{S}_t\right)$, as well as the residual variance, $\sigma^2\left(\mathcal{S}_t\right)$, may have different values across two regimes, labeled $\mathcal{S}_t = \{1, 2\}$. The constant transition probability matrix, $\mathbb{P}$, that governs the transitions between these two regimes is given by

$$\mathbb{P} = \begin{bmatrix} p_1 & 1-p_1 \\ 1-p_2 & p_2 \end{bmatrix}, \tag{2}$$

where $p_i \in [0, 1]$ denotes the probability of staying in regime $i = \{1, 2\}$ conditional on being in regime i. We estimate the model (1) using Maximum Likelihood.

The estimation results are displayed in Table 1. The first and second columns show the estimated parameters corresponding to Regime 1 and Regime 2, respectively. Although the estimated slope is significantly negative in both regimes, the results suggest there being two distinct regimes with Regime 2 featuring a slope that is about 1.5 times bigger than in Regime 1. A similar conclusion can be drawn for the intercept, implying that, on average, the convenience yield is much larger in Regime 2 than in Regime 1. The results therefore imply that a move from Regime 1 to Regime 2 results in a higher and more sensitive convenience yield, which can be interpreted as an upward shift of the demand schedule for Treasuries.

Consistent with the findings of van Binsbergen et al. (2019) and Paret and Weber (2019),

Table 1: Markov-Switching model for the US convenience yield

Dependent variable: convenience yield, cy_t	**Regime 1**	**Regime 2**
Log of government debt ratio, $\log(b_t/y_t)$	-0.59***	-0.94***
	(0.07)	(0.28)
Intercept, c	2.84***	4.70***
	(0.26)	(1.01)
Residual variance, σ^2	0.03***	0.08**
	(0.01)	(0.04)
Probability of staying in Regime i, p_i	0.89	0.72
Expected duration of Regime i (years)	8.66	3.57
No. of observations: 92		

Notes: The two-state Markov Switching model (1) is estimated using Maximum Likelihood. Standard errors in parentheses. Estimates significant at 1% (***), 5% (**) en 10% (*).

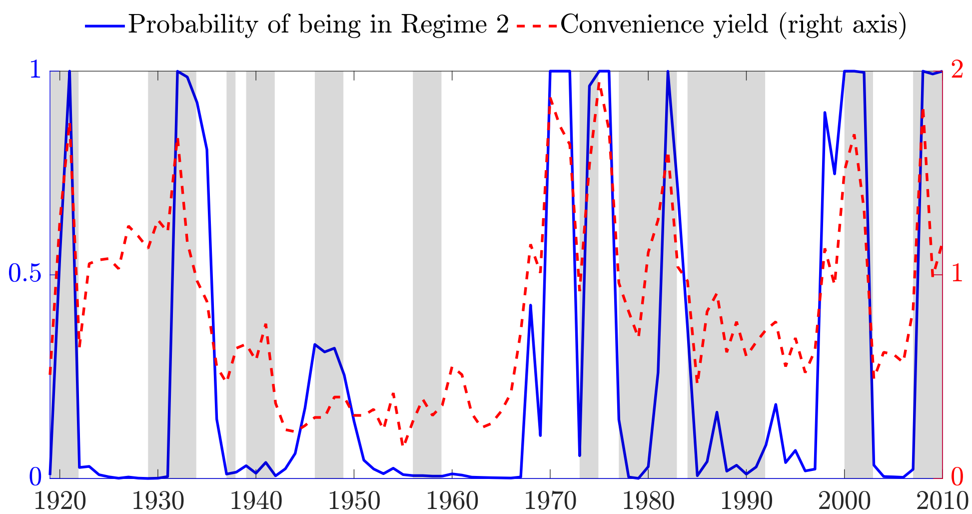
we find that Regime 2 corresponds to periods characterized by high levels of financial distress. This can be seen in Figure 3, which plots the filtered probability of being in Regime 2 (i.e. $\Pr(\mathcal{S}_t = 2)$, shown by the solid line), along with the convenience yield (dashed line) and shaded regions that indicate episodes during which the US experienced banking crises and stock market crashes according to the dates obtained by Reinhart and Rogoff (2011). Both the convenience yield and the probability of being in Regime 2 are especially high during these episodes, which likely reflects that financial stress prompts investors to flee to safety and raise their demand for safe and liquid assets, such as Treasuries, thereby pushing up the convenience yield. This further suggests that in times of financial crises, when deficit-financed fiscal expansions are particularly welcome to prevent a full-blown economic crisis, public borrowing costs are kept low by an elevated convenience yield.

The following theoretical sections of this paper are devoted to better understand the implications for fiscal policy when the economy enters such a regime characterized by a high convenience yield.

3 A New Keynesian model with bonds in the utility

We make use of a relatively standard New Keynesian model with optimizing households, a fiscal and monetary authority, monopolistic firms and staggered price setting. In this section,

Figure 3: The high convenience yield regime and financial crises in the US



Notes: Regime 1 (2) is associated with a relatively low (high) intercept and low (high) convenience yield elasticity, see Table 1. Shaded areas refer to dates of US banking crises and stock market crashes as identified by Reinhart and Rogoff (2011).

we provide a description of the main building blocks of the model.

3.1 Household preferences

In each period t, a representative, infinitely-lived household chooses how much to consume, c_t, how much labor to supply, n_t, and how many real government bonds, b_t, to hold. Household utility is increasing in consumption and decreasing in the amount of hours worked. In addition, the household derives utility from holding government bonds, as in KVJ, Fisher (2015) and Anzoategui et al. (2019), among others. Specifically, we assume that the expected lifetime utility of the household is expressed as follows:

$$E_t \sum_{k=0}^{\infty} \beta^k z_{D,t+k} \left(\frac{c_{t+k}^{1-\sigma}}{1-\sigma} - \frac{n_{t+k}^{1+\varphi}}{1+\varphi} + \chi \frac{b_{t+k}^{1-\sigma_b}}{1-\sigma_b} \right), \tag{3}$$

where $\beta \in (0,1)$ denotes the household's discount factor, $\sigma > 1$ the risk aversion coefficient, $\varphi > 0$ the inverse Frisch elasticity of labor supply and $z_{D,t}$ a preference (or demand) shock that evolves according to the following stationary AR(1) process:

$$\ln z_{D,t} = \rho_D \ln z_{D,t-1} + \varepsilon_{D,t}, \tag{4}$$

with $\rho_D \in [0, 1]$ and $\varepsilon_{D,t} \sim \mathcal{N}(0, \sigma_D^2)$.[6]

The inclusion of government bonds (or other assets that contribute to the accumulation of wealth more generally) in the utility function has recently become more popular in the macroeconomics literature. Michaillat and Saez (2019), Rannenberg (2019) and Rannenberg (2020), for instance, enter bonds in the utility function to study the effects of forward guidance and government spending shocks at the ELB, which more standard New Keynesian models find to be implausibly large. On the other hand, the utility provision of wealth is featured in Saez and Stantcheva (2018) to examine the implications for optimal capital taxation, and in Kumhof et al. (2015) to match the profiles of the income distribution in the US. Kaplan and Violante (2018) discuss how introducing bonds in the utility function in representative agent New Keynesian (RANK) models is a reduced-form way of capturing the precautionary savings motives present in heterogeneous agent New Keynesian (HANK) models with uninsurable idiosyncratic income risk. This also allows one to use RANK models to study negative natural interest rates and secular stagnation, as in Cuba-Borda and Singh (2018) and Michau (2018). Apart from the precautionary savings motive, a preference to accumulate wealth may stem from many other sources, such as the social status and moral prestige associated with wealth (Smith, 1822) or 'capitalist spirit'-type preferences (Weber, 1958; Caroll, 2000). Here, we follow the interpretation of KVJ and Fisher (2015), who state that agents wish to hold government bonds because they offer superior safety and liquidity compared to alternative assets of similar maturity. Nevertheless, what matters for our purposes is that, regardless of its source, there exists an excessive demand for government

[6] We keep the asset market deliberately simple, with the household investing only in government bonds, such that the model is sufficiently tractable to provide analytical results. Nevertheless, our main results go through in a more elaborate model featuring alternative assets, provided these are not considered perfect substitutes to government bonds.

bonds such that the corresponding yield is below the risk-free interest rate. As in KVJ, we refer to the resulting wedge as the 'convenience yield'.

The two key parameters of interest are those that govern the shape of the demand schedule for government bonds and, implicitly, the size of the convenience yield. These are $\sigma_b \geq 0$, which determines the curvature of the demand schedule and thus the sensitivity of the convenience yield to changes in the supply of outstanding government bonds[7], and $\chi \geq 0$, which pins down the intercept of the demand schedule and thereby also the long-run level of the convenience yield. In what follows, we shall refer to the model as the 'baseline model' when the convenience yield is zero (i.e. when $\chi = 0$). Our objective is then to analyze how the behavior of the model differs from the baseline model when the convenience yield is positive (with $\chi > 0$) and what the corresponding implications are for the stabilizing properties of fiscal policy. One can interpret a sudden exogenous change in χ as a (flight-to-safety or flight-to-quality) shock that raises the demand for government bond holdings which, as we have shown in Section 2, is most likely to occur in times of financial stress.

The household pays a lump-sum tax τ_t to the government, receives a real wage w_t for each unit of labor supplied to firms and earns a nominal gross return of R_t on its holdings of government bonds. When $\tau_t < 0$, the tax should be interpreted as a lump-sum subsidy or transfer provided to the household. The period budget constraint of the household can thus be expressed as

$$c_t + b_t + \tau_t = w_t n_t + \frac{R_{t-1}}{\pi_t} b_{t-1} + \mathcal{P}_t, \tag{5}$$

where π_t denotes gross price inflation and $\mathcal{P}_t$ refers to firm profits which are distributed as lump-sum dividends to the household who is the owner of the firm. Maximizing (3) subject to (5) and the transversality condition $\lim_{K\to\infty} \prod_{j=0}^{K-1} R_{t+j}^{-1} \pi_{t+j+1} b_{t+K} = 0$ yields the following

[7] As explained by Kaplan and Violante (2018), the curvature parameter σ_b also determines the consumption response to income and interest rates, and thereby the marginal propensity to consume.

first-order conditions that pin down optimal consumption and labor supply:

$$1 = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}} \right] + z_{D,t}\theta_t, \tag{6}$$

$$w_t = \frac{z_{D,t} n_t^{\varphi}}{\lambda_t}, \tag{7}$$

where λ_t denotes the marginal utility of consumption and

$$\theta_t \equiv \chi \frac{b_t^{-\sigma_b}}{\lambda_t}, \tag{8}$$

is our definition of the convenience yield. In line with Figure 2, the convenience yield is a decreasing and convex function of the supply of government bonds outstanding.

Let R_t^* be the CCAPM interest rate on a hypothetical risk-free bond, b_t^*, that does not provide utility, satisfying

$$\frac{1}{R_t^*} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \right] \equiv \mathcal{Q}_{t,t+1}, \tag{9}$$

where $\mathcal{Q}_{t,t+1}$ is the pricing kernel for nominal payoffs in period $t+1$. Ignoring demand shocks, we can then express the government bond spread as

$$\frac{R_t}{R_t^*} = 1 - \theta_t. \tag{10}$$

For $\chi > 0$, the convenience yield drives a wedge between the government bond rate and the return on b_t^*. Hence, for a positive convenience yield, the government can borrow at a rate that is below the risk-free rate. This also holds in steady state. Assuming zero steady-state inflation, i.e. $\pi = 1$, it follows that $\beta R = 1 - \theta$. For $\chi > 0$, $\beta R < 1$, i.e. the government bond rate is lower than the household's discount rate.[8]

[8] A similar example is used in Canzoneri et al. (2008) to explain that government bonds will be held at a lower rate than the risk-free rate if they provide transaction services.

3.2 Public sector

A fiscal authority (or 'government') issues one-period government bonds and levies lump-sum taxes (net of transfers), τ_t, to cover gross interest payments on outstanding debt and an exogenous stream of government consumption expenditures, g_t. The period budget constraint of the government can thus be expressed as

$$b_t + \tau_t = \frac{R_{t-1}}{\pi_t} b_{t-1} + g_t. \tag{11}$$

For simplicity, we assume that government consumption remains constant, i.e. $g_t = g$ for all t. Taxes are adjusted to stabilize government debt according to a standard fiscal response function. To study the implications of the convenience yield for fiscal stabilization policy, we augment this fiscal response function with an endogenous stabilization component:

$$\tau_t - \tau = \gamma_b \left(b_{t-1} - b\right) + \gamma_y \left(y_t - y\right), \tag{12}$$

where y_t denotes aggregate output. $\gamma_b \geq 0$ measures the aggressiveness with which the fiscal authority pursues its debt target. Following the terminology from Leeper (1991), we say that fiscal policy is 'passive' when $\gamma_b > 1/\beta - 1$ and 'active' otherwise. Note from (6) that $1/\beta - 1$ is the steady-state real interest rate in the baseline model with a zero convenience yield ($\theta = 0$). The parameter γ_y determines the cyclical stance of fiscal policy: when $\gamma_y > 0$ (< 0), fiscal policy is referred to as 'counter-cyclical' ('pro-cyclical'). When $\gamma_y = 0$, we say that fiscal policy is 'a-cyclical'.[9] Much of the analysis that follows focuses on the interaction between the fiscal policy parameters γ_b and γ_y, and the steady-sate convenience yield, θ.

The monetary authority (or 'central bank') sets the interest rate, R_t, to stabilize inflation,

[9] By having taxes respond contemporaneously to changes in output (when $\gamma_y \neq 0$), we capture both the automatic stabilization component of fiscal policy hard-wired into the economy's tax system and discretionary changes in fiscal policy. With regards to the latter, it might be more realistic to have taxes respond with a lag as it may take time for the government to implement discretionary fiscal policy. All our results go through if we were to take such implementation lags into account. However, we chose to work with the contemporaneous fiscal response function to avoid having to deal with another state variable.

π_t, according to the following feedback rule:

$$\frac{R_t}{R} = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}, \tag{13}$$

where ϕ_π measures how actively the central bank targets inflation. Again, we follow Leeper (1991)'s terminology and say that monetary policy is 'active' if $\phi_\pi > 1$ and 'passive' otherwise.

3.3 Production, price setting and market clearing

Differentiated goods, $y_t(i)$, are produced by monopolistically competitive firms, indexed by $i \in [0, 1]$, using the following production function:

$$y_t(i) = n_t(i), \tag{14}$$

with $n_t(i)$ firm-specific labor demand. Each firm faces a downward-sloping demand schedule and sets its price, $P_t(i)$, at a markup over marginal costs, $mc_t(i)$. Furthermore, firms face a Calvo-type price-setting constraint, which prohibits a constant, yet random, fraction of firms, $\theta_p \in (0, 1)$, from adjusting their prices in a given period. Subject to (14), the demand schedule $y_t(i) = (P_t(i)/P_t)^{-\epsilon} y_t$, with $\epsilon > 1$ the elasticity of substitution between goods, the optimal labor demand condition $w_t = mc_t$, and taking into account the probability of non-price adjustment, the firm chooses the optimal price $\overline{P}_t$ to maximize future expected profits. This results in the following optimal price-setting condition:

$$\overline{P}_t = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{k=0}^{\infty} (\theta_p \beta)^k \lambda_{t+k} y_{t+k} P_{t+k}^{\epsilon} mc_{t+k}}{E_t \sum_{k=0}^{\infty} (\theta_p \beta)^k \lambda_{t+k} y_{t+k} P_{t+k}^{\epsilon-1}}. \tag{15}$$

Finally, the economy's resource constraint is given by $y_t = c_t + g$, while labor market clearing implies $y_t = n_t \mathcal{D}_t^{-1}$, where $\mathcal{D}_t$ is a measure of price dispersion.

Table 2: Benchmark calibration

Parameter	Description	Value
σ_b	Curvature of utility for government bonds	$[0, 2.5]$
χ	Utility weight of government bonds	$[0, 1.7]$
β	Household discount factor	0.9926
σ	Elasticity of intertemporal substitution	2
φ	Inverse Frisch elasticity of labor supply	3
ϕ_π	Monetary policy response to inflation	1.5
ϵ	Elasticity of substitution between intermediate goods	11
θ_p	Probability of non-price adjustment	0.75
ρ_D	Persistence of the demand shock	0.9
c/y	Steady-state consumption ratio	0.6
b/y	Steady-state debt ratio (annualized)	0.4

3.4 Calibration

The calibration of the model parameters is based on a quarterly frequency for t. For many of the structural parameters, we use commonly used values found in the literature. The steady-state values for the consumption and government debt ratios are chosen to match their empirical counterparts for the US. Monetary policy is assumed to be active and we set $\phi_\pi = 1.5$—in some cases, we shall experiment with alternative monetary policies, yet always maintain that $\phi_\pi > 1$. With regards the fiscal policy parameters γ_y and γ_b, we consider a wide range of values to illustrate the trade-offs faced by the government between stabilizing output and debt. Since the tax instrument of the government is a non-distortionary lump-sum tax, or a transfer if negative, we choose a range for γ_y based on estimates of the output elasticity of unemployment-related government expenditures. In a recent empirical study covering OECD countries, Price et al. (2015) estimate this elasticity to be 3.9 on average (with a maximum of 7.65 for the US).

The long-run, steady-state value of the convenience yield, θ, is governed by the parameters σ_b and χ. Rannenberg (2019) considers $\sigma_b \in [0, 0.5]$, where the upper-end of this range matches micro evidence on the marginal propensity to save by high-income households (see Dynan et al., 2004; Kumhof et al., 2015). Kaplan and Violante (2018), however, find that setting $\sigma_b = 2.5$ allows RANK models to match HANK models along various dimensions, such as the aggregate marginal propensity to consume and the decomposition of impulse responses to TFP shocks. We therefore take $\sigma_b = 2.5$ as an upper bound in our analysis. Given σ_b, we then back out the value for χ by calibrating θ. Since $\theta = 1 - \beta R$, information about θ can be inferred from appropriate market rates and estimates on individual discount rates. A survey by Rannenberg (2019) shows that θ lies in the range of 0 and 0.18, which implies a range for χ of $[0, 1.7]$. For an overview of the benchmark calibration, see Table 2.

4 Policy requirements for equilibrium stability

In this section, we study the implications of the convenience yield for the stability requirements of fiscal policy and fiscal-monetary policy coordination. To do so, we take a first-order linear approximation of the model presented in the previous section around a non-stochastic, zero-inflation steady state. Then, based on the Blanchard and Kahn (1980) conditions, we check how the equilibrium properties of the model depend on the convenience yield and the fiscal and monetary policy parameters.

4.1 Model dynamics

A reduced version of the linear model is given by the following system of first-order difference equations:

$$\sigma \hat{c}_t = \sigma \beta R E_t \hat{c}_{t+1} - \beta R \left(\phi_\pi \hat{\pi}_t - E_t \hat{\pi}_{t+1}\right) + \sigma_b \theta \hat{b}_t + \beta R \left(1 - \rho_D\right) \hat{z}_{D,t}, \tag{16}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \omega \hat{c}_t, \tag{17}$$

$$\hat{b}_t = R \left(\phi_\pi \hat{\pi}_{t-1} - \hat{\pi}_t\right) + \left(R - \gamma_b\right) \hat{b}_{t-1} - \gamma_y \frac{c}{b} \hat{c}_t, \tag{18}$$

$$\hat{z}_{D,t} = \rho_D \hat{z}_{D,t-1} + \varepsilon_{D,t}, \tag{19}$$

where $R = \left(1 - \theta\right) / \beta$, $\kappa \equiv \left(1 - \theta_p\right) \left(1 - \beta \theta_p\right) / \theta_p$ and $\omega \equiv \varphi c / y + \sigma$. Variables with a hat denote percentage deviations from steady state. Equation (16) is the Euler equation which shows that current consumption is affected directly by debt dynamics if $\theta \neq 0$. Equation (17) is the New Keynesian Phillips curve, while Equation (18) is the government budget constraint. Finally, Equation (19) is the AR(1) process for the demand shock.

Using the auxiliary variable $\hat{\pi}'_t = \hat{\pi}_t$ and defining $x_t \equiv \left[\hat{c}_t,\ \hat{\pi}_t,\ \hat{b}_{t-1},\ \hat{\pi}'_{t-1}\right]'$, we can write the system above more compactly as follows:

$$A_0 E_t x_{t+1} = A_1 x_t + B_0 \hat{z}_{D,t}, \tag{20}$$

$$\hat{z}_{D,t} = \rho_D \hat{z}_{D,t-1} + \varepsilon_{D,t}, \tag{21}$$

where

$$A_0 \equiv \begin{bmatrix} \beta R & \frac{1}{\sigma}\beta R & \frac{1}{\sigma}\theta\sigma_b & 0 \\ 0 & \beta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad A_1 \equiv \begin{bmatrix} 1 & \frac{1}{\sigma}\beta R\phi_\pi & 0 & 0 \\ -\kappa\omega & 1 & 0 & 0 \\ -\gamma_y \frac{c}{b} & -R & R-\gamma_b & R\phi_\pi \\ 0 & 1 & 0 & 0 \end{bmatrix}, \quad B_0 \equiv \begin{bmatrix} -\frac{1}{\sigma}\beta R\left(1-\rho_D\right) \\ 0 \\ 0 \\ 0 \end{bmatrix}.$$

Since the model features two forward-looking endogenous variables, $\hat{c}_t$ and $\hat{\pi}_t$, and one backward-looking endogenous variable, $\hat{b}_t$, a stable and unique equilibrium requires the matrix $A \equiv A_0^{-1}A_1$ to have two eigenvalues outside the unit circle and one eigenvalue within the unit circle. To satisfy these conditions by means of fiscal policy, one could impose restrictions on the policy parameter γ_b. In order to obtain an analytical expression for this restriction, we follow Ascari et al. (2017) and transform the characteristic polynomial associated with A into a Hurwitz polynomial. We then obtain the following fiscal policy requirement for equilibrium stability:

Proposition 1. *Given the benchmark parameter calibration in Table 2 and a fiscal rule of the form (12), a sufficient condition for a stable and unique rational expectations equilibrium is given by*

$$\gamma_b > R - 1 - \sigma_b\theta\left[\frac{\gamma_y \frac{c}{b}\left(\frac{1}{\beta}-1\right) - \frac{1}{\beta}\left(\phi_\pi - 1\right)R\kappa\omega}{\sigma\theta\left(\frac{1}{\beta}-1\right) + \left(\phi_\pi - 1\right)R\kappa\omega}\right], \tag{22}$$

provided that $\gamma_b < R+1+\sigma_b\theta/\beta\left[\phi_1+(1+\beta)\,c/b\gamma_y\right]/\left(\phi_1+\phi_2\right)$ *with* $\phi_1 \equiv (1+\phi_\pi)\,R\kappa\omega$ *and* $\phi_2 \equiv \sigma\,(2-\theta)\,(1/\beta+1)$.

Proof. See Appendix A. □

Proposition 1 shows that the stability requirement for fiscal policy is a complex function of the model's parameters, and most notably of those that govern the size of the convenience yield, θ, the cyclical stance of fiscal policy, γ_y, and the monetary policy stance, ϕ_π. We shall discuss the role of each of these parameters in the next sub-sections.

4.2 Equilibrium stability and the convenience yield

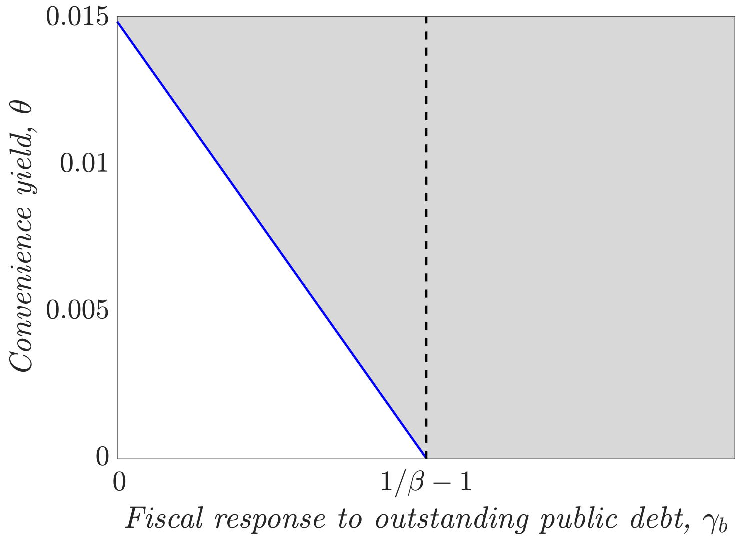
Figure 4 plots the number of eigenvalues of A that are outside the unit circle as a function of γ_b and θ. The gray area shows the combinations of γ_b and θ that yield a stable and unique equilibrium, while the white area shows those combinations for which no stable equilibrium exists. For now, we consider a fiscal policy that is a-cyclical and therefore does not respond directly to economic conditions, i.e. $\gamma_y = 0$. From Proposition 1, we find that, under this assumption, the stability requirement for fiscal policy is given by

$$\gamma_b > R - 1 + \sigma_b\theta\frac{\frac{1}{\beta}\left(\phi_\pi - 1\right)R\kappa\omega}{\sigma\theta\left(\frac{1}{\beta}-1\right)+\left(\phi_\pi-1\right)R\kappa\omega}. \tag{23}$$

The downward-sloping solid line in the figure traces out this restriction on γ_b for different values of θ and thereby partitions the parameter space into regions characterized by stable and explosive dynamics.

In the absence of the convenience yield on government bonds, when $\theta = 0$, the standard fiscal requirement for stability from Leeper (1991) emerges: in order to guarantee a stable equilibrium, the fiscal response to changes in government debt, γ_b, should be greater than $1/\beta - 1$, which in this case is equal to the steady-state real interest rate and which is located at the point where the vertical dashed line crosses the horizontal axis. However, when interest rates are low due to positive values of θ, the set of sustainable fiscal policies *expands*,

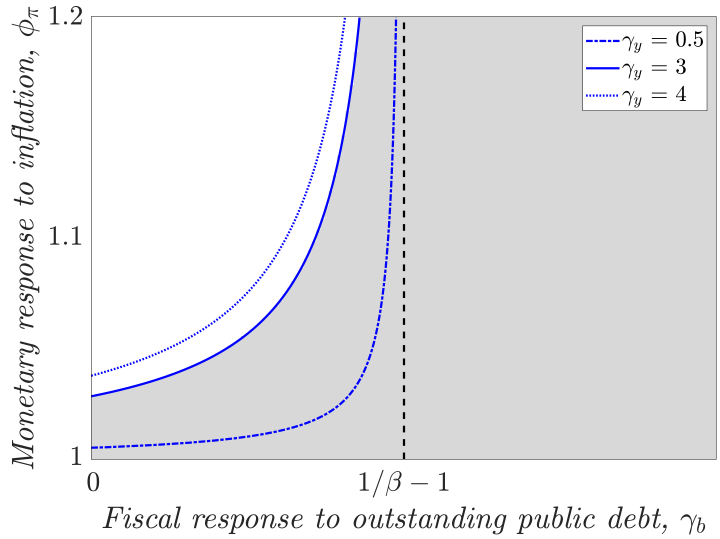
Figure 4: Stability requirements for fiscal policy and the role of the convenience yield



Notes: The figure shows the stability properties of the model (20)-(21) as a function of the fiscal policy parameter γ_b and the steady-state convenience yield, θ. We set $\sigma_b = 0.5$. Fiscal policy is a-cyclical, i.e. $\gamma_y = 0$. Gray = stable and unique equilibrium; white = no stable equilibrium. The solid line refers to the stability frontier shown in (23).

which can be seen by the reduction in the minimum required value for γ_b to guarantee stable dynamics as we move up the solid line. The intuition behind this result is that agents are willing to hold government bonds for reasons that are beyond their desire to smooth consumption over time, which is reflected by the wedge between the government bond rate, R, and the discount rate, β. The desire to hold safe and liquid assets ensures a positive demand for government bonds, even under less debt-stabilizing fiscal policies, which depresses the borrowing rate faced by the government. Consequently, the restriction imposed on fiscal policy to ensure debt sustainability is loosened. In fact, Figure 4 shows that if the convenience yield is sufficiently high, and the interest rate on government debt correspondingly sufficiently low, debt sustainability can be ensured even if the government sets $\gamma_b = 0$ and does not adjust its primary surplus in response to changes in government debt at all. Hence, included in the set of feasible fiscal policies in times of low interest rates are policies that *ignore* debt stabilization. This result on the implication of the convenience yield for fiscal sustainability could partly explain why US government debt remains to be perceived as risk-free, despite the US federal government running persistent deficits (and

Figure 5: Stability requirements for fiscal-monetary policy coordination under counter-cyclical fiscal policy



Notes: The figure shows the stability properties of the model (20)-(21) as a function of the fiscal policy parameter γ_b and the monetary policy parameter ϕ_π. The steady-state convenience yield is set to $\theta = 0.01$ with $\sigma_b = 1$. The fiscal response to output, governed by γ_y, is assumed to be positive such that fiscal policy is counter-cyclical. Gray = stable and unique equilibrium; white = no stable equilibrium. The solid line refers to the stability frontier shown in (22).

hence exhibiting weak debt-stabilization efforts) in the past century.

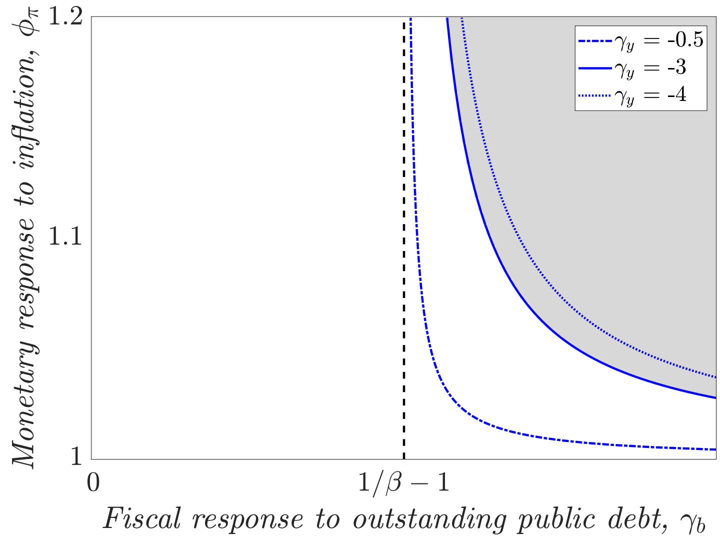
4.3 The importance of fiscal and monetary policy coordination

In Figure 5, we again plot the number of unstable roots of A, yet this time as a function of the fiscal and monetary policy parameters γ_b and ϕ_π, while keeping $\phi_\pi > 1$ and $\theta > 0$ such that government bonds carry a positive convenience yield. As before, equilibrium is stable and unique in the gray area, while no stable equilibrium exists in the white area, and the solid line represents the stability restriction on γ_b, given by Equation (22) in Proposition 1, yet now for different values of ϕ_π. In the baseline model without the convenience yield, the results from Leeper (1991) again hold and a stable and unique equilibrium can be obtained only if the active monetary policy stance adopted by the central bank is accompanied by a passive fiscal policy with $\gamma_b > 1/\beta - 1$ (which implies that the entire area to the left (right) of the vertical dashed line would be white (gray)). Importantly, the 'activeness' of monetary policy relative to the 'passiveness' of fiscal policy is irrelevant for the stability outcome. However, in a low-interest rate world with a positive convenience yield, the stability requirements for fiscal and monetary policy coordination change considerably in a way that depends on the cyclical stance of fiscal policy, which is governed by the policy parameter γ_y. In Figure 5, we consider a counter-cyclical fiscal policy and set $\gamma_y > 0$, such that taxes are raised (lowered) endogenously when output rises (falls). The figure shows that, in this case, the region that admits stable and unique equilibria *expands*, implying that a sustainable path for government debt can be ensured even if fiscal and monetary policy are both active. Moreover, the stronger is the counter-cyclical bent of fiscal policy, i.e. the higher is γ_y, the greater is the expansion of the region associated with stable dynamics.

To provide some intuition underlying this result, consider, for instance, a positive demand shock in the private sector that raises household consumption. The consequent economic boom will, under a counter-cyclical fiscal policy, be met by a fiscal contraction in the form of higher taxes. As a result, the government budget balance improves and the stock of government debt shrinks. For a given desire to hold government bonds by households, the corresponding reduction in the supply of government bonds outstanding then raises the convenience yield and lowers the interest rate which reduces public borrowing costs and the minimal required fiscal effort to stabilize debt. Hence, counter-cyclical fiscal policies in times of low interest rates loosen the requirement for equilibrium stability as they effectively exploit the negative relationship between the convenience yield and government debt.

Figure 5 further shows that this stability-enhancing property of counter-cyclical fiscal policy depends, not only on the size of the convenience yield, but also on how fiscal and monetary policy are coordinated. Continuing with our previous thought experiment, assume that the central bank would only mildly raise the interest rate in response to a surge in consumption (and the resulting rise in inflation). In that case, the economic boom will be stronger than if the central bank were to adopt a more hawkish stance, and so the consequent counter-cyclical fiscal consolidation will be larger, implying a more pronounced decline in the supply of government bonds and a steeper rise in the convenience yield. Therefore, debt

Figure 6: Stability requirements for fiscal-monetary policy coordination under pro-cyclical fiscal policy



Notes: The figure shows the stability properties of the model (20)-(21) as a function of the fiscal policy parameter γ_b and the monetary policy parameter ϕ_π. The steady-state convenience yield is set to $\theta = 0.01$ with $\sigma_b = 1$. The fiscal response to output, governed by γ_y, is assumed to be negative such that fiscal policy is pro-cyclical. Gray = stable and unique equilibrium; white = no stable equilibrium. The solid line refers to the stability frontier shown in (22).

sustainability can be achieved more easily under a positive convenience yield and counter-cyclical fiscal policy if monetary policy is 'less active'. In fact, for ϕ_π sufficiently close to (but still above) unity, debt sustainability can be guaranteed even if the government entirely abandons its debt target and sets $\gamma_b = 0$.

Figure 6 shows the stability properties of the model, again as a function of γ_b and $\phi_\pi > 1$, yet this time under the assumption that fiscal policy is pro-cyclical, such that $\gamma_y < 0$. We now find that equilibrium stability may *not* be attained in the region where fiscal policy is passive and monetary policy active, a policy mix that would be sufficient to guarantee stability in the baseline model. Moreover, the likelihood of explosive dynamics is greater, the stronger is the pro-cyclicality of fiscal policy (i.e. the more negative is γ_y). To understand why, we refer back to our previous thought experiment of a demand-driven economic boom. If fiscal policy is pro-cyclical, a rise in output prompts the government to cut taxes, which leads to a buildup of government debt. For a given demand for government bonds, the convenience yield then *falls* and the interest rate rises, which implies an increase in public borrowing costs that complicates the task of ensuring debt sustainability. Again, fiscal and monetary policy coordination is important: the less active is monetary policy (i.e. the closer is ϕ_π to unity), the stronger will be the consumption boom for a given demand shock, and therefore the greater will be the pro-cyclical fiscal expansion, which results in a steeper decline in the convenience yield compared to the case with a more hawkish monetary stance. The latter implies that pro-cyclical fiscal policies in times of low interest rates can result in *higher* public borrowing costs that require the government to adopt a more debt-oriented policy to ensure fiscal solvency.

Figures 4 through 6 illustrate the importance of the convenience yield and the cyclical stance of budgetary policies for the fiscal-monetary policy mix that delivers a stable and determinate equilibrium. If the primary budget balance does not respond to economic conditions directly, then a positive convenience yield keeps the interest rate on government debt low and therefore loosens the stability requirements for fiscal policy, provided that monetary policy actively targets inflation. If monetary policy is somehow constrained and only weakly active, for instance because the interest rate is near its lower bound, then a government that pursues counter-cyclical fiscal policies can further reduce the risk of explosive debt dynamics by exploiting the fact that the convenience yield and the supply of government bonds move in opposite directions. On the other hand, pro-cyclical fiscal policies may make it more difficult to ensure debt sustainability. From a positive perspective, these results imply that, during a severe economic recession, when monetary policy is (close to) being constrained by the ELB (implying ϕ_π is low) and anxious investors push up the convenience yield and drive down the safe interest rate (implying θ is high), an aggressive counter-cyclical fiscal response would be feasible and, conveniently, also supportive of long-run debt sustainability. In the following section, we evaluate counter-cyclical fiscal policies from a more normative perspective.

5 Fiscal stabilization policy and the convenience yield

5.1 A simplified model

We can show analytically how a low interest rate environment due to a positive convenience yield on government bonds affects the economy's exposure to aggregate shocks and the corresponding role for fiscal stabilization policy by first using a simplified version of the model given by (20)-(21). In particular, assume that the central bank ensures a constant real interest rate, i.e. $\hat{R}_t = E_t\hat{\pi}_{t+1}$, such that the role of fiscal policy is fully isolated from that of monetary policy. With government debt, $\hat{b}_{t-1}$, and the demand shock, $\hat{z}_{D,t}$, being the only two state variables, the policy function for consumption, $\hat{c}_t$, in this simplified model will be of the following form:

$$\hat{c}_t = \psi_1\hat{b}_{t-1} + \psi_2\hat{z}_{D,t}. \tag{24}$$

Using the method of undetermined coefficients, and assuming that $\gamma_y \neq 0$, we obtain the following (stable) solutions for ψ_1 and ψ_2:

$$\psi_1 = \frac{1}{2\beta R\gamma_y}\left[\left(\xi_1^2 - 4\beta R\gamma_y\frac{c}{b}\xi_2\right)^{\frac{1}{2}} - \xi_1\right]\frac{b}{c}, \tag{25}$$

$$\psi_2 = \frac{1}{\sigma}\frac{(1-\theta)(1-\rho_D)}{1-(1-\theta)\rho_D + \left((1-\theta)\psi_1 + \sigma_b\frac{1}{\sigma}\theta\right)\gamma_y\frac{c}{b}}, \tag{26}$$

where $\xi_1 \equiv 1 + \gamma_y\theta\sigma_b/\sigma c/b - \beta R(R-\gamma_b)$ and $\xi_2 \equiv -\theta\sigma_b/\sigma(R-\gamma_b)$. We highlight a few noteworthy results under the following two cases:

Case 1. *If* $\theta = 0$, $\psi_1 = 0$ *and* $\psi_2 = 1/\sigma$, *provided* $\gamma_y \neq 0$.

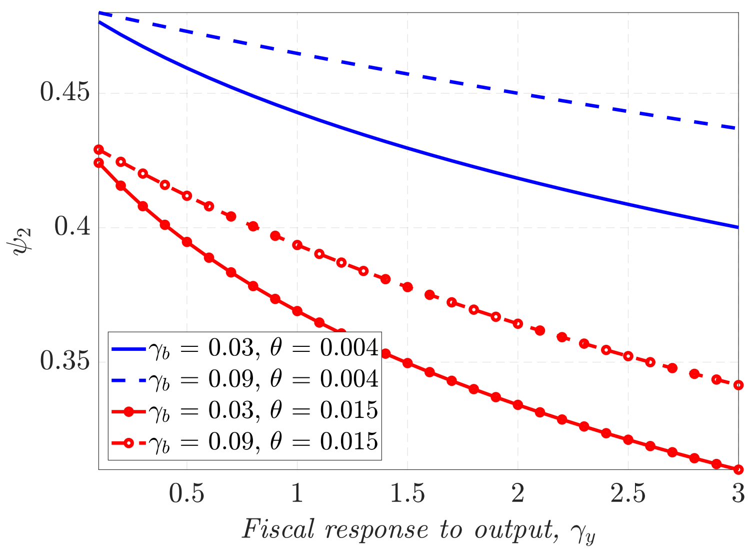
Case 2. *If* $\theta > 0$, $\psi_1 > 0$, *provided* $\gamma_y \neq 0$. *Furthermore,* $\psi_2 \to 0$ *if* $\theta \to 1$ *or* $\gamma_y \to \infty$, *and* $\partial\psi_2/\partial\gamma_y \to 0$ *if* $\gamma_b \to \infty$.

In the baseline model without the convenience yield (Case 1), we find that $\psi_1 = 0$, which implies that government debt has no effect on consumption. This result is a direct consequence of Ricardian equivalence and the assumption that taxes are lump-sum: because changes in government debt generate income and wealth effects that offset each other exactly, they can be decoupled from the consumption-savings decisions of the household. Therefore, no matter the cyclical bent of fiscal policy, the government cannot stabilize consumption through adjustments in lump-sum taxes. This result is also reflected by the observation that if $\theta = 0$, $\psi_2 = 1/\sigma$, which means that the general equilibrium effect of a demand shock on aggregate consumption depends solely on the household's desire to substitute future for current consumption, and is completely independent from fiscal policy.

When the convenience yield is positive (Case 2), we find that $\psi_1 > 0$ and so a positive link between consumption and government debt arises. With $\psi_1 > 0$, Ricardian equivalence breaks down and the scope for fiscal stabilization policy is enlarged as fiscal policy changes will have non-neutral effects on consumption through changes in the supply of government bonds. Also, when $\theta > 0$, the consumption response to demand shocks depends on factors other than the elasticity of intertemporal substitution. In particular, the greater is θ, the lower is ψ_2. This is due to the fact that savings are valued, not only because they facilitate intertemporal consumption smoothing, but also because they contribute to the accumulation of government bonds that affect utility directly. The stronger is the desire to hold government bonds, the higher is θ and the weaker is the effect of a demand shock on consumption, regardless of the cyclical stance of fiscal policy. In the extreme case when $\theta \to 1$, $\psi_2 \to 0$ and consumption becomes impervious to aggregate shocks.

For a given positive convenience yield, counter-cyclical fiscal policy can further stabilize the economy. Particularly, the greater is the counter-cyclical bent of fiscal policy, i.e. the more positive is γ_y, the lower is ψ_2 and thus the better insulated the economy becomes from aggregate shocks. In fact, in the simplified model, $\psi_2 \to 0$ if $\gamma_y \to \infty$, meaning that the government can *fully* stabilize consumption by pursuing sufficiently contractionary (expansionary) fiscal policies during economic booms (busts). This is because fiscal contractions help stem consumption growth by reducing the supply of government bonds, whereas fiscal expansions stimulate consumption by satiating the market with government bonds. However,

Figure 7: Policy function for consumption and the role of fiscal policy



Notes: The figure shows how the coefficient ψ_2 of the policy function for consumption corresponding to a simplified version of the model (see [25]) depends on the fiscal policy parameters, γ_b and γ_y, and the convenience yield, θ, with $\sigma_b = 0.5$.

if such counter-cyclical policies are accompanied by greater efforts to minimize fluctuations in the level of outstanding government debt, the link between consumption and government debt is weakened and so the scope to stabilize the economy is reduced. Technically, we find that $\partial\psi_2/\partial\gamma_2 \to 0$ if $\gamma_b \to \infty$. Intuitively, fiscal policies that focus more on government debt stabilization leave less room to stabilize consumption and output. Hence, there seems to be a trade-off between, on the one hand, stabilizing output and, on the other hand, stabilizing government debt.

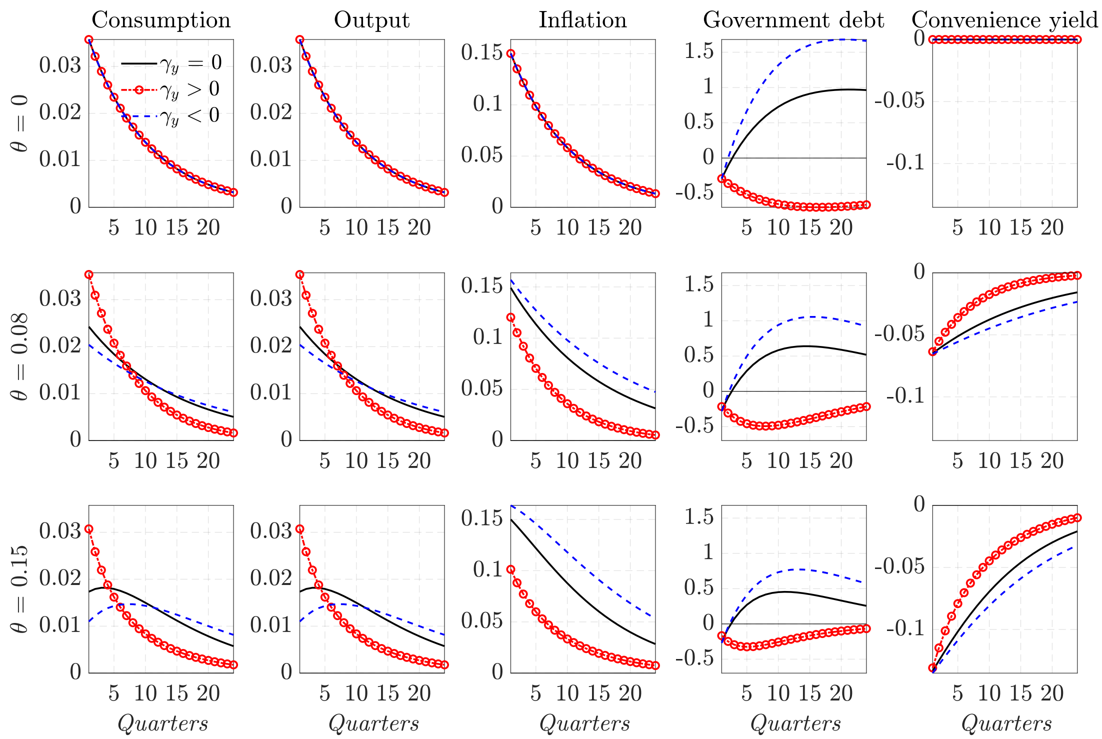
We demonstrate the results corresponding to Case 2 numerically in Figure 7. The figure shows how the economy's sensitivity to demand shocks, captured by ψ_2, is decreasing in the counter-cyclical bent of fiscal policy, γ_y. The figure also illustrates the fiscal policy trade-off between stabilizing output and stabilizing debt: the more the government aims to stabilize debt, i.e. the higher is γ_b, the weaker becomes the relationship between consumption and government debt and thereby between ψ_2 and γ_y. This is evidenced by the flatter slope of the dashed lines for which we assume a higher fiscal response to debt than under the solid lines. Note, however, that this trade-off is more favorable under a higher convenience yield, since the latter reduces the consumption response to shocks for any fiscal policy mix. This is reflected by the downward shift of the lines when assuming a higher convenience yield. In order to provide more intuition underlying these results, and to study the implications for household welfare, we now turn back to the full model.

5.2 Stability and welfare properties of cyclical fiscal policy

In Figure 8, we show the impulse responses of selected endogenous variables to a positive demand shock under different assumptions about the convenience yield and the cyclical stance of fiscal policy. In the top row, we consider the baseline model in which the convenience yield is absent and $\theta = 0$, whereas in the second and third rows we set $\theta > 0$. Each panel shows the responses of a particular variable when fiscal policy is a-cyclical (solid lines), counter-cyclical (marked lines) and pro-cyclical (dashed lines). In the absence of the convenience yield, these responses (except those of government debt) are all the same: whether the government adopts an a-cyclical, counter-cyclical or pro-cyclical fiscal policy is irrelevant for how the economy responds to the demand shock. The cyclical fiscal stance only matters for government debt dynamics: the consumption boom leads to a weaker (stronger) buildup of government debt under counter-cyclical (pro-cyclical) fiscal policy. This result is consistent with the result under Case 1 from the simplified model: due to Ricardian equivalence, fiscal stabilization policies are ineffective because taxes are lump-sum and government debt dynamics are decoupled from the decisions of the household, the firm and the central bank.

The results change markedly, however, when considering an environment in which the interest rate is low due to a positive convenience yield. Compared to the baseline case without the convenience yield, the responses of consumption and output to the demand shock under an a-cyclical fiscal policy are now much more muted. As mentioned before, this is because households have greater incentives to save and accumulate government bonds. The full model, in which the central bank sets the interest rate according to (13) and the real interest rate is allowed to fluctuate, provides a richer intuition for the corresponding

Figure 8: Responses to a positive demand shock



Notes: The figure shows the impulse response functions of selected variables to a one standard deviation, transitory demand shock. θ measures the steady-state convenience yield on government bonds. We set $\sigma_b = 0.5$. The parameter $\gamma_y = \{-3, 0, 3\}$ determines the cyclical stance of fiscal policy. When $\gamma_y < 0$ ($\gamma_y > 0$), fiscal policy is said to be pro-cyclical (counter-cyclical). All units are expressed in percentage deviations from steady state.

underlying mechanism. In particular, the initial shock to demand causes the central bank to raise the interest rate in order to stem the response of inflation. Since we assume monetary policy is active, the nominal interest rate rises by more than inflation and so the real interest rate increases. The associated higher public borrowing costs cause the fiscal authority to raise taxes in an attempt to lower and stabilize government debt. In turn, the lower supply of government bonds raises the marginal utility of holding government bonds, thereby inducing households to reduce consumption and accumulate more bonds through higher savings. This latter effect partially offsets the initial surge in consumption, which stabilizes economic activity.

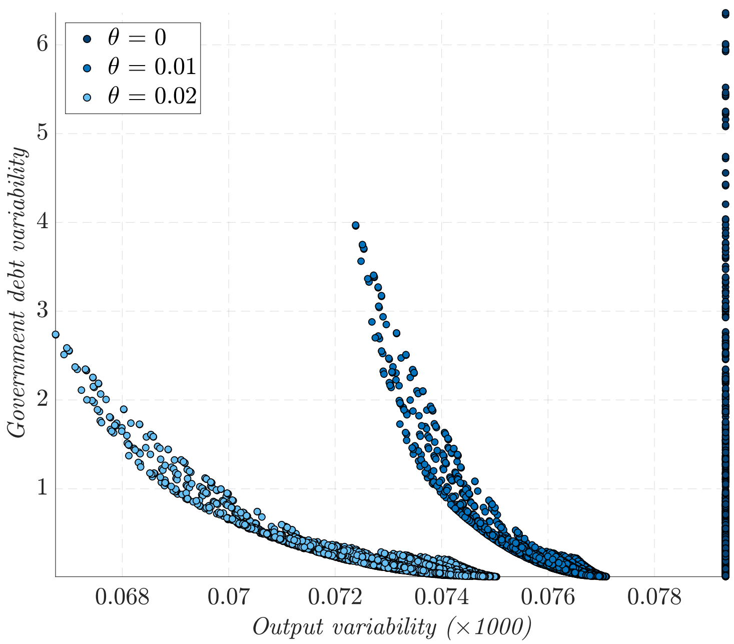
Figure 8 demonstrates that the government can enhance this stabilizing feature of the convenience yield by adopting an appropriate cyclical fiscal stance. Indeed, when fiscal policy is counter-cyclical (i.e. $\gamma_y > 0$) we find that consumption, output and inflation revert more quickly to steady state following the demand shock than if fiscal policy were a-cyclical ($\gamma_y = 0$). Thus, counter-cyclical fiscal policies are successful in stabilizing business cycle fluctuations when the convenience yield is responsible for keeping the interest rate on government debt low. Recall from the simplified model and the results under Case 2 that, indeed, a sufficiently strong counter-cyclical bent in fiscal policy can fully stabilize consumption if the convenience yield is positive. This is because of the positive link that arises between consumption and government debt which renders debt non-neutral and breaks Ricardian equivalence.

Again, the full model provides a more detailed description of the underlying channels at work. Following the demand shock, fiscal policy contracts by more under a counter-cyclical stance compared to when the government were to adopt an a-cyclical stance. The stronger fiscal contraction implies a steeper reduction in the supply of government bonds. Because government debt is a slow-moving state variable and households are forward-looking optimizing agents, they respond by consuming more immediately following the shock, yet quickly cutting consumption when the utility of holding government bonds is high. When the government pursues a pro-cyclical fiscal policy, the opposite happens: the consumption boom prompts the government to cut taxes, causing a surge in government debt. The utility of holding government bonds will therefore be lower in the future and so households do not wish to cut down their consumption over time as rapidly as they would have if fiscal policy were counter-cyclical. The sustained upward pressure on aggregate demand further amplifies the response of inflation. Hence, under pro-cyclical fiscal policy, the effect of the demand shock is more persistent.

The results under Case 2 from the simplified model also revealed a trade-off faced by the government between stabilizing output and stabilizing debt. Figure 9 illustrates this trade-off and its relationship to the size of the convenience yield. Specifically, the figure plots the variability in output and government debt (measured by their variances) after simulating the model for 2,000 periods (and discarding the first 1,000 periods) for different combinations of γ_y and γ_b, and under different assumptions about the convenience yield. The resulting scatterplot of the output-debt variability pairs gives rise to what we refer to as the *fiscal policy frontier*, which shows the minimum output variability that can be attained for a given variability in government debt. Obviously, the slope and position of the fiscal policy frontier depends on the structure of the model and the calibration of the model parameters. Here, we keep the structural parameters fixed at their benchmark calibration and only consider how changes in the fiscal policy parameters and the convenience yield affect the fiscal policy frontier.

We see that, if $\theta = 0$, switching between fiscal policies and assigning different weights on the output and debt targets has no effect on output variability, yet only on debt variability. As a result, the fiscal policy frontier is a straight line and there is no trade-off between stabilizing output and government debt. Again, this is due to Ricardian equivalence and the fact that fiscal policy is neutral when taxes are lump-sum. However, in the presence of a positive convenience yield, the fiscal policy frontier becomes downward sloping which implies that, by choosing a different fiscal policy mix, the government can reduce the variability in

Figure 9: The fiscal policy frontier



Notes: The figure shows the variability in output and government debt after simulating the model for 2,000 periods (and dropping the first 1,000 periods) for different combinations of γ_y and γ_b, which govern the fiscal response to output and government debt, and for different assumptions about the convenience yield, θ. The fiscal policy parameters were drawn randomly from a uniform distribution, with the permissible sets given by $\gamma_y \in [-3, 3]$ and $\gamma_b \in (1/\beta - 1, 0.1]$. Throughout, we set $\sigma_b = 0.5$. The fiscal policy frontier shows the minimum output variability that can be attained for a given variability in government debt. Units are in percentages.

output at the expense of greater debt variability, and vice versa. The figure shows that the higher is the convenience yield, and the lower is the steady-state interest rate, the more favorable this trade-off becomes as implied by the flattening of the slope and inward shift of the fiscal policy frontier. Again, this result arises from the fact that the convenience yield dampens the consumption response to aggregate shocks and therefore reduces the variability in output, regardless of the fiscal policy mix.

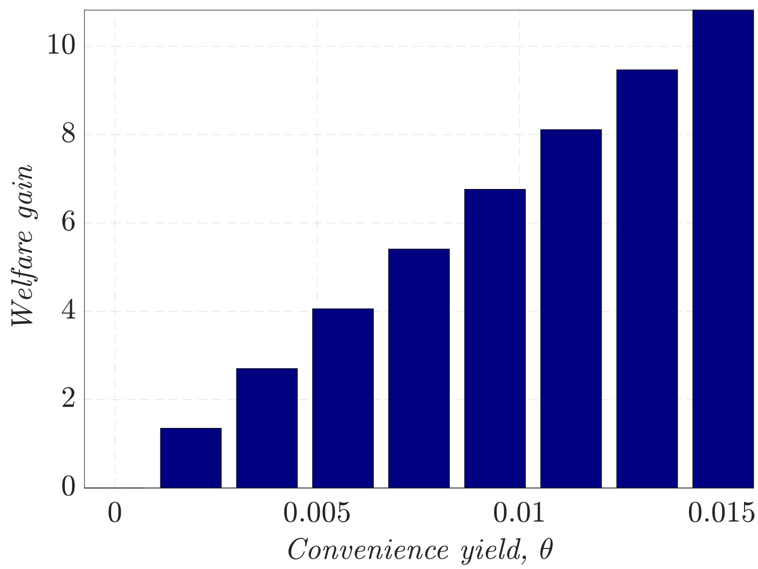
The stabilizing properties of the convenience yield have significant implications for household welfare, which we denote by $\mathbb{W}_t$. Based on Equation (3), household welfare can be expressed as follows:

$$\mathbb{W}_t = z_{D,t} \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \frac{n_t^{1+\varphi}}{1+\varphi} + \chi \frac{b_t^{1-\sigma_b}}{1-\sigma_b} \right) + \beta E_t \mathbb{W}_{t+1}. \tag{27}$$

In order to correctly evaluate welfare, we now take a second-order approximation of the full model (see Kim and Kim, 2003). Figure 10 shows the welfare outcome (evaluated at steady state) for different values of the convenience yield, θ, relative to the level of welfare that corresponds to the baseline model without the convenience yield. Here, we have maintained the assumption that fiscal policy is a-cyclical such that $\gamma_y = 0$, which allows us to isolate the welfare consequences of the convenience yield from those arising from the cyclical fiscal stance. According to the figure, welfare is (ceteris paribus) a monotonically increasing function of the convenience yield, which follows immediately from our earlier discussion on the stabilizing nature of the convenience yield.

The welfare gains from adopting either counter- or pro-cyclical fiscal policies when the convenience yield is positive and the interest rate is low is illustrated in Figure 11. Consistent with the results from the simplified model under Case 2 and the impulse response functions corresponding to the full model shown in Figure 8, we find that the welfare gain of adopting counter-cyclical fiscal policies is positive as it dampens business cycle fluctuations when the convenience yield is positive. In contrast, adopting pro-cyclical fiscal policies reduces

Figure 10: Welfare implications of the convenience yield

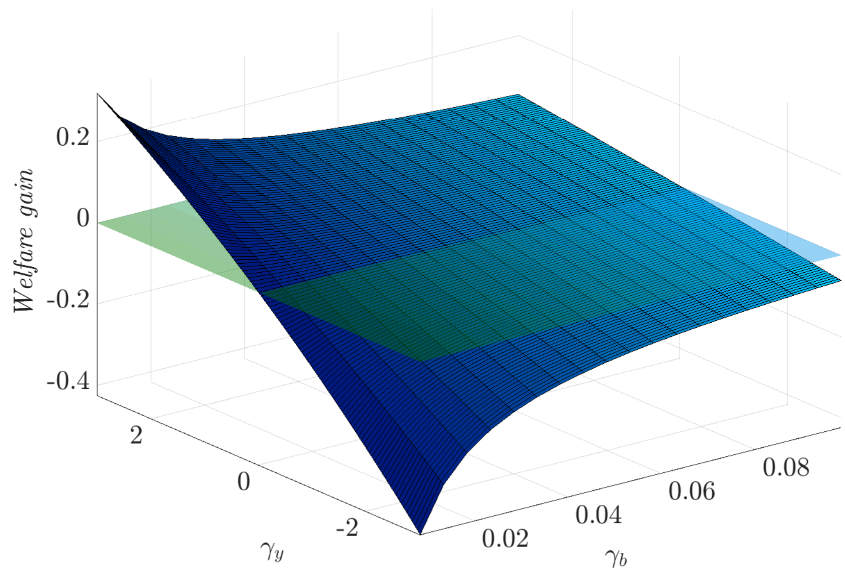


Notes: The figure shows the welfare gain of moving from an economy without the convenience yield ($\theta = 0$) to an economy with a positive convenience yield ($\theta > 0$). We set $\sigma_b = 0.5$. Welfare units are measured in consumption perpetuities, which means they show the perpetual increase in consumption as a percentage of steady-state consumption.

welfare as such policies tend to aggravate business cycle fluctuations. The biggest welfare gain is attained when fiscal policy is strongly counter-cyclical and γ_y is set very high, while simultaneously the government only weakly responds to government debt by setting γ_b equal to the minimum value required to ensure a sustainable path for debt. Recall from our discussion in Section 4 and the result shown in Proposition 1 that the higher are θ and γ_y, the lower is the minimum required value for γ_b to guarantee debt sustainability, and therefore the more feasible are less debt-oriented policies. From a normative perspective, we can conclude on the basis of these results that when a government enjoys a positive convenience yield on its debt, the best policy mix to adopt is one that puts a lot of weight on stabilizing economic conditions and very little weight on stabilizing government debt.

Whereas Section 4 showed that counter-cyclical fiscal policies help ensure long-run debt sustainability, the key takeaway of this section is that such policies successfully stabilize business cycle fluctuations and are welfare improving if the government faces a positive convenience yield on its debt. While there is a trade-off between stabilizing output and government debt, the highest gains to household welfare can be attained if the former receives

Figure 11: Welfare implications of counter- and pro-cyclical fiscal policies



Notes: The figure shows the welfare gain of moving from an a-cyclical fiscal policy (with $\gamma_y = 0$) to either a pro-cyclical ($\gamma_y < 0$) or counter-cyclical ($\gamma_y > 0$) fiscal policy, for different values of γ_b which governs the fiscal response to government debt. We set the steady-state convenience yield on government bonds equal to $\theta = 0.02$ and set $\sigma_b = 0.5$. Welfare units are measured in consumption perpetuities.

relatively more weight than the latter.[10]

6 Conclusion

With interest rates displaying a secular decline in many advanced economies, thereby increasingly limiting the scope for monetary policy to respond to economic disturbances, some policymakers and academics now argue for a greater role of fiscal stabilization policy. Although some governments may find it difficult to engage in expansionary fiscal policies without threatening long-run fiscal solvency, others face historically low interest rates on their

[10]The results on the welfare implications of the convenience yield and counter-cyclical fiscal policy are robust to extending the model in various ways, e.g. allowing for limited asset market participation, introducing the effective lower bound on the policy interest rate and including physical capital and investment. These robustness checks are available upon request. Results under two other extensions are presented in Appendix B. In the first, we expand the set of instruments available to the fiscal authority by including income taxes, consumption taxes and government consumption. In the second, we use endogenous regimes witching techniques to allow for the possibility of very high levels of public debt to generate welfare losses.

government debt due to a strong demand for safe and liquid assets. Since not all are created equal, the efficacy of fiscal policy will differ across countries and is likely to be greatest in those parts of the world that face ample fiscal space.

In this paper, we examined the role of fiscal stabilization policy in times when interest rates are low due to a positive convenience yield on government bonds. The convenience yield reflects investors' desire to hold government bonds for reasons other than their pecuniary return, such as their unique safety and liquidity attributes. We show that the convenience yield on US Treasuries is especially high in times of financial crises, during which many investors flee to safety and push up the demand for Treasuries. Using a New Keynesian model in which government bonds enter the utility function of households, we then study the implications of the convenience yield for fiscal policy. We find that the convenience yield (1) expands the set of sustainable fiscal policies, including those that ignore debt stabilization, and (2) renders counter-cyclical fiscal policy welfare enhancing as they successfully stabilize business cycle fluctuations. Moreover, we show that, although there is a trade-off between stabilizing output and debt, the fiscal policy mix that maximizes household welfare in times of a positive convenience yield is one that assigns a large weight on output fluctuations and a small (or zero) weight on government debt. These results follow from a positive link between consumption and government debt that arises under a positive convenience yield, which implies that Ricardian equivalence breaks down.

Combined, our results point towards a powerful role for fiscal policy in stabilizing the economy, at least when government bonds are in high demand and carry a sufficiently high convenience yield. Such conditions are likely to apply for countries with a AAA rating, such as the US, Germany, the Netherlands, Switzerland and Canada, given the global scarcity of safe and liquid assets. For these countries, our analysis suggests that a greater role for fiscal stabilization policy is warranted, and can be realized by, for instance, enhancing built-in automatic stabilizers. However, fiscal rules and budgetary restrictions may limit the scope to provide sufficient fiscal stabilization, and may even promote pro-cyclical fiscal policies during a crisis, which our analysis shows can be welfare reducing. Therefore, to allow fiscal stabilization policy be effective, one requires fiscal rules that offer a sufficient degree of flexibility to reap the benefits of prolonged spells of low interest rates.

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A Proof of Proposition 1

The state-space representation of a linear version of the New Keynesian model presented in Section 3 is given by

$$A_0 E_t x_{t+1} = A_1 x_t + B_0 \hat{z}_{D,t}, \tag{28}$$

$$\hat{z}_{D,t} = \rho_D \hat{z}_{D,t-1} + \varepsilon_{D,t}, \tag{29}$$

where $x_t \equiv \left[\hat{c}_t,\ \hat{\pi}_t,\ \hat{b}_{t-1},\ \hat{\pi}'_{t-1}\right]'$ and with $\hat{\pi}'_t = \hat{\pi}_t$ an auxiliary variable. The stability properties of the model depend on the eigenvalues of the matrix $A \equiv A_0^{-1}A_1$, which is given by[11]

$$A = \begin{bmatrix} \frac{\frac{c}{b}\gamma_y\sigma_b\theta+\sigma+\kappa\omega R}{\sigma\beta R} & \frac{\beta\phi_\pi+\sigma_b\theta-1}{\sigma\beta} & -\frac{(R-\gamma_b)\sigma_b\theta}{\sigma\beta R} & -\frac{\phi_\pi\sigma_b\theta}{\sigma\beta} \\ -\frac{\kappa\omega}{\beta} & \frac{1}{\beta} & 0 & 0 \\ -\frac{c}{b}\gamma_y & -R & R-\gamma_b & \phi_\pi R \\ 0 & 1 & 0 & 0 \end{bmatrix},$$

where $R = (1-\theta)/\beta$, $\kappa \equiv (1-\theta_p)(1-\beta\theta_p)/\theta_p$ and $\omega \equiv \varphi c/y + \sigma$. Since the model features two forward-looking endogenous variables, $\hat{c}_t$ and $\hat{\pi}_t$, and one backward-looking endogenous variable, $\hat{b}_t$, A should have two eigenvalues outside the unit circle and one eigenvalue within the unit circle for the model to have a unique and stable equilibrium (Blanchard and Kahn, 1980). To obtain an analytical expression for the restriction on γ_b that satisfies these conditions, we follow Ascari et al. (2017) and first transform the characteristic polynomial corresponding to A, i.e.

$$P_C(\gamma) = \gamma^4 + a_1\gamma^3 + a_2\gamma^2 + a_3\gamma + a_4, \tag{30}$$

[11] We can ignore the law of motion for the exogenous demand shock, $\hat{z}_{D,t}$, as its stationarity is ensured by the fact that $\rho_D \in [0,1]$.

into a Hurwitz polynomial using the transformation $\gamma = (1+s)/(1-s)$, such that

$$\tilde{P}_H(s) = \left(\frac{1+s}{1-s}\right)^4 + a_1\left(\frac{1+s}{1-s}\right)^3 + a_2\left(\frac{1+s}{1-s}\right)^2 + a_3\left(\frac{1+s}{1-s}\right) + a_4,$$

which implies

$$P_H(s) = \tilde{a}_4 + s\tilde{a}_3 + s^2\tilde{a}_2 + s^3\tilde{a}_1 + s^4, \tag{31}$$

where

$$\begin{aligned}
\tilde{a}_1 &= \frac{2(a_3 - a_1 - 2a_4 + 2)}{a_2 - a_1 - a_3 + a_4 + 1}, \\
\tilde{a}_2 &= \frac{2(3a_4 - a_2 + 3)}{a_2 - a_1 - a_3 + a_4 + 1}, \\
\tilde{a}_3 &= \frac{2(2 + a_1 - a_3 - 2a_4)}{a_2 - a_1 - a_3 + a_4 + 1}, \\
\tilde{a}_4 &= \frac{a_1 + a_2 + a_3 + a_4 + 1}{a_2 - a_1 - a_3 + a_4 + 1}.
\end{aligned}$$

This transformation allows us to obtain stability conditions based on the signs of the $\tilde{a}_i$ coefficients in (31) rather than on the absolute sizes of the eigenvalues of A, which is typically more difficult. In particular, with two forward-looking endogenous variables, one backward-looking endogenous variable and one auxiliary variable, we need $P_H(s)$ to have two positive roots and two negative roots.

The coefficients a_i in (30) can be found by applying the following rules:[12]

- $a_1 = -$sum of the principal first-order minors of $A = \mathrm{Tr}(A)$
- $a_2 =$ sum of the principal second-order minors of A
- $a_3 = -$sum of the principal third-order minors of A
- $a_4 =$ sum of the principal fourth-order minors of $A = \det(A)$

[12]Given an $n \times n$ matrix A, the corresponding kth-order principal minors are the determinants of the $k \times k$ sub-matrices obtained by deleting $n-k$ columns and the same $n-k$ rows from A.

such that

$$a_1 = -\left[\frac{\frac{c}{b}\gamma_y\sigma_b\theta + \sigma + \kappa\omega R}{\sigma\beta R} + \beta^{-1} + R - \gamma_b\right],$$

$$a_2 = \frac{1}{\beta R}\left\{\left(1 + \kappa\omega R\sigma^{-1} + R\right)(R - \gamma_b) + \frac{1}{\sigma\beta}\left[\frac{c}{b}\gamma_y\sigma_b\theta + \sigma + R\left(\beta\phi_\pi + \sigma_b\theta\right)\kappa\omega\right]\right\},$$

$$a_3 = -\frac{1}{\sigma\beta R}\left[\phi_\pi\kappa\omega R\sigma_b\theta\beta^{-1} + \left(\beta^{-1}\sigma + R\kappa\omega\phi_\pi\right)(R - \gamma_b)\right],$$

$$a_4 = 0.$$

We then obtain the $\tilde{a}_i$ coefficients in (31):

$$\tilde{a}_1 = \frac{4 - 2\frac{1}{\sigma\beta R}\left\{\left[\frac{1}{\beta}\sigma + (\kappa\omega\phi_\pi - \sigma\beta)R\right](R - \gamma_b) - \frac{c}{b}\gamma_y\sigma_b\theta - \sigma - R\left[\kappa\omega\left(1 - \phi_\pi\sigma_b\theta\frac{1}{\beta}\right) + \sigma\right]\right\}}{D},$$

$$\tilde{a}_2 = \frac{6 - 2\frac{1}{\beta R}\left\{(1 + \kappa\omega R\sigma^{-1} + R)(R - \gamma_b) + \frac{1}{\sigma\beta}\left[\frac{c}{b}\gamma_y\sigma_b\theta + \sigma + R\left(\beta\phi_\pi + \sigma_b\theta\right)\kappa\omega\right]\right\}}{D},$$

$$\tilde{a}_3 = \frac{4 - 2\frac{1}{\sigma\beta R}\left\{\left[(\sigma - \beta^{-1}\kappa\omega\phi_\pi)(1 - \theta) - \beta^{-1}\sigma\right](R - \gamma_b) + \frac{c}{b}\gamma_y\sigma_b\theta + \sigma + R\left[\kappa\omega\left(1 - \phi_\pi\sigma_b\theta\beta^{-1}\right) + \sigma\right]\right\}}{D},$$

$$\tilde{a}_4 = \frac{\frac{1}{\sigma\beta R}\left[\kappa\omega(1 - \theta)(1 - \phi_\pi) - \theta\sigma(1 - \beta)\right]\beta^{-1}(R - \gamma_b)}{D}$$
$$+ \frac{\frac{1}{\sigma\beta R}\left[(\beta^{-1} - 1)\frac{c}{b}\gamma_y\sigma_b\theta + R\kappa\omega\left(\sigma_b\theta\beta^{-1} - 1\right)(1 - \phi_\pi) + \left(\beta^{-1}\theta - 1\right)\sigma\right] + 1}{D},$$

where

$$D = \frac{1}{\sigma\beta R}\left\{(R + 1 - \gamma_b)(\phi_1 + \phi_2) + \beta^{-1}\left[(1 + \beta)\frac{c}{b}\gamma_y + \phi_1\right]\sigma_b\theta\right\},$$

and with $\phi_1 \equiv (1 + \phi_\pi)\kappa\omega R$ and $\phi_2 \equiv \sigma(2 - \theta)(1/\beta + 1)$. Given our benchmark calibration shown in Table 2, we have that $D > 0$ if

$$\gamma_b < R + 1 + \sigma_b\theta\beta^{-1}\frac{\phi_1 + (1 + \beta)\frac{c}{b}\gamma_y}{\phi_1 + \phi_2}. \tag{32}$$

Using Decartes' rule of sign, we can then infer from the number of sign changes of $\tilde{a}_i$ the number of positive and negative roots.

We proceed by exploiting the result from Leeper (1991) that no stable equilibrium exists in the baseline model when $\theta = 0$ and $\gamma_b < 1/\beta - 1$ (provided that $\phi_\pi > 1$, an assumption that we maintain throughout). For simplicity, we consider the case where $\gamma_b = 0$. The $\tilde{a}_i$ coefficients then collapse to

$$
\begin{aligned}
\tilde{a}_1 &= \frac{2\frac{1}{\sigma\beta}\left[\left(1-\beta^{-1}\phi_\pi\right)\kappa\omega + \sigma\left(3\beta+1\right) - \beta^{-1}\left(1-\beta\right)\sigma\right]}{D} > 0, \\
\tilde{a}_2 &= \frac{6 - 4\beta^{-1} - 2\beta^{-2}\left[1+\sigma^{-1}\kappa\omega\left(\phi_\pi+1\right)\right]}{D} < 0, \\
\tilde{a}_3 &= \frac{4 + 2\frac{1}{\sigma\beta}\left\{\left[\sigma\left(1-\beta\right)+\kappa\omega\phi_\pi\right]\beta^{-1} - \sigma\left(\beta+1\right) - \kappa\omega\right\}}{D} > 0, \\
\tilde{a}_4 &= \frac{\frac{1}{\sigma\beta}\left(1-\beta^{-1}\right)\left(\phi_\pi-1\right)\kappa\omega}{D} < 0.
\end{aligned}
$$

Starting from s^4, we find the following signs of the coefficients of $P_H(s)$: $+, +, -, +, -$. Note that there are three sign changes, which, as expected, implies the system has too many eigenvalues outside the unit circle to deliver a stable and unique equilibrium. In order for there to be only two sign changes, $\tilde{a}_4$ should be positive. In that case, $P_H(-s)$ also yields two sign changes, since we then have $+, -, -, -, +$. For $\tilde{a}_4$ to be positive, it must be that

$$
\gamma_b > R - 1 - \sigma_b\theta\left[\frac{\gamma_y\frac{c}{b}\left(\beta^{-1}-1\right) - \beta^{-1}\left(\phi_\pi-1\right)\kappa\omega R}{\sigma\theta\left(\beta^{-1}-1\right) + \left(\phi_\pi-1\right)\kappa\omega R}\right], \tag{33}
$$

provided the condition in (32) is satisfied. This proves Proposition 1.

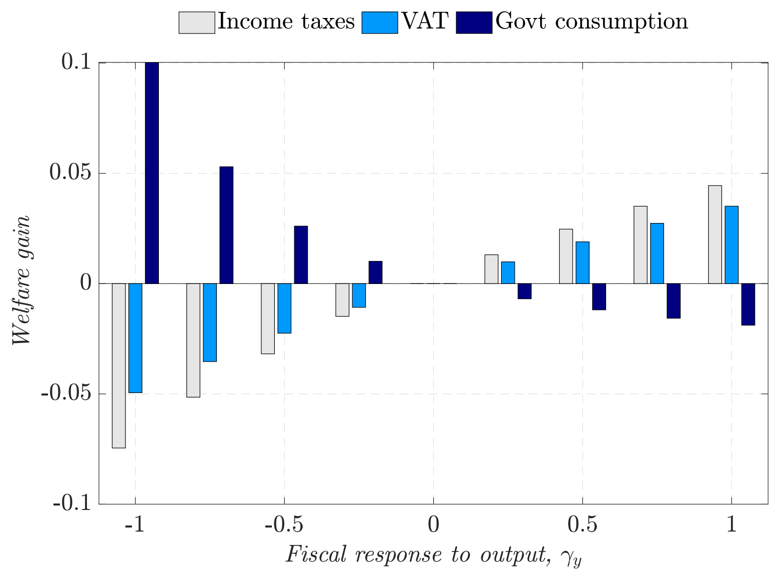
B Model extensions

In this section, we explore two extensions to the model to assess the robustness of the welfare implications of the convenience yield and counter-cyclical fiscal policy.

B.1 Alternative fiscal instruments

In the baseline model, the government had access to only one type of fiscal instrument, i.e. lump-sum taxes. This assumption not only renders the model more tractable analytically,

Figure 12: Welfare implications of pro- and counter-cyclical fiscal policies
with alternative fiscal instruments



Notes: The figure shows the welfare gain of moving from an economy characterized by an a-cyclical fiscal policy ($\gamma_y = 0$) to an economy with either pro-cyclical fiscal policies ($\gamma_y < 0$) or counter-cyclical fiscal policies ($\gamma_y > 0$), with different fiscal instruments used to respond to output fluctuations. We set $\sigma_b = 0.5$ and $\chi = 0.04$. Welfare units are measured in consumption perpetuities.

but also enables us to isolate the implications of the convenience yield on optimal fiscal policy from those arising from the potential distortionary effects of fiscal policy. A straightforward extension to the model would be to consider alternative instruments at the disposal of the fiscal authority. In particular, we shall now assume that lump-sum taxes are solely used to stabilize public debt, whereas either one of the following instrument responds (either pro- or counter-cyclically) to output fluctuations: a proportional tax on labor income, a value-added tax on consumption, and government consumption expenditures. With regards the latter, we assume that government spending on goods and services is not completely wasteful, as it enters the household's utility function and thereby enhances welfare. Our goal is to investigate whether adopting a more counter-cyclical fiscal policy stance delivers positive welfare gains, compared to a baseline scenario characterized by an a-cyclical fiscal stance, when the economy faces a positive convenience yield.

Figure 12 plots the results. Consistent with the results from our baseline model, having income and value-added taxes move counter-cyclically with the business cycle yields positive welfare gains. Having them move in a pro-cyclical manner generates welfare losses. As discussed in Section 5, the reason why such counter-cyclical policies are welfare enhancing is because they effectively exploit the co-movement between government debt and household consumption. A rise in taxes in response to an economic boom reduces the supply of government bonds, thereby raising the marginal utility of holding government bonds, which in turn dampens the economic boom by prompting households to cut back on consumption.

The figure further shows that employing counter-cyclical government consumption expenditures is, under the baseline calibration, welfare reducing. The reason is that government consumption has, in the presence of a positive convenience yield, two offsetting effects on consumption. On the one hand, counter-cyclical government consumption stabilizes household consumption through the same channel outlined above: when government consumption falls in response to a consumption-induced economic boom, the supply of government bonds falls, which makes households want to consume less, as long as $\theta > 0$. On the other hand, a reduction in government consumption also lowers aggregate demand, thereby inducing firms to cut their prices. The consequent fall in inflation then leads the central bank to lower the policy interest rate which, in turn, makes households want to consume more. The stronger is the monetary policy response to inflation, i.e. the higher is ϕ_π in the reaction function of the central bank in (13), the stronger is the latter effect such that counter-cyclical government consumption is more likely to lead to welfare losses. Conversely, when the monetary response to inflation is sufficiently weak, for instance in times when the central bank is near the ELB causing ϕ_π to be very low or the interest rate rule to exhibit a high degree of persistence, we find positive welfare effects from counter-cyclical government consumption.

B.2 Risks of high public debt

We now consider the case where strong surges in public debt may trigger concerns with regards to long-run debt sustainability. As argued by Blanchard (2019), and documented empirically by Laubach (2009), the interest rate on government bonds may rise above the growth rate of the economy when the level of government debt is sufficiently high. Once investors cease to believe government debt to be safe, but rather perceive it as risky, then they may require a risk premium to be compensated for bearing the additional sovereign risk. Such beliefs may push the economy into a 'bad equilibrium', in which higher risk premia make it more difficult for the government to service its debt burden, such that debt indeed becomes risky, thereby confirming investors' initial beliefs (Calvo, 1988).

To capture such risks of high levels of public debt, we allow for the utility weight of government bonds, χ, to switch signs and become negative once the debt ratio exceeds some threshold. In other words, when debt is so high that it is perceived as risky, rather than safe, then further increases in public debt incur a welfare cost. These costs may, for instance, capture negative wealth effects arising from expected losses due to sovereign default or from persistent large-scale fiscal consolidations needed to repay the debt.

Let $\tilde{b}_t$ denote the debt-to-output ratio and $\tilde{b}^*$ the (perceived) debt threshold. The value of $\chi(\mathcal{S}_t)$ may then vary endogenously across two different regimes, $\mathcal{S}_t = \{1, 2\}$, in which it takes different values, depending on deviations of the debt ratio from the threshold:

$$\chi(\mathcal{S}_t) = \begin{cases} \geq 0 & \text{if } \mathcal{S}_t = 1 \text{ and } \tilde{b}_t \leq \tilde{b}^* \\ < 0 & \text{if } \mathcal{S}_t = 2 \text{ and } \tilde{b}_t > \tilde{b}^* \end{cases}. \tag{34}$$

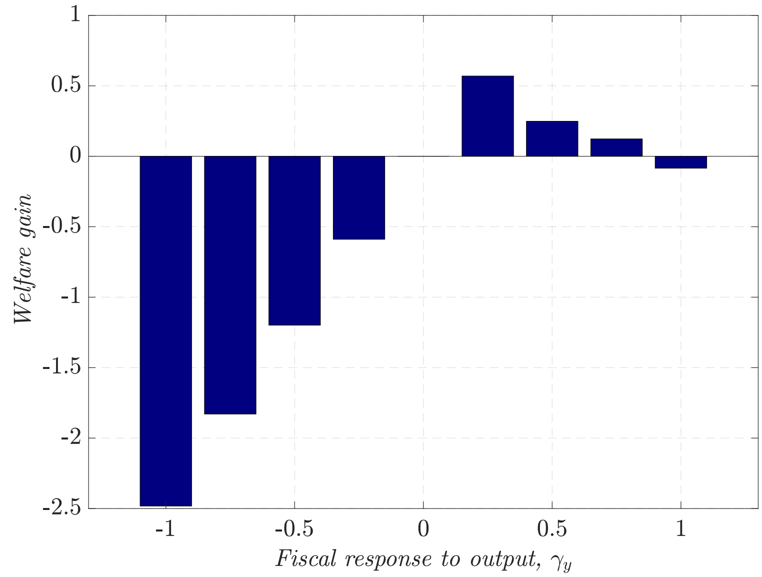
The transition probabilities, $p_{ij,t}$, that govern these endogenous switches between the two regimes i and j, with $i, j = \{1, 2\}$, are determined by the following logistic functions:

$$p_{12,t} = \frac{1}{1 + \exp\left(-\eta\left(\tilde{b}_t - \tilde{b}^*\right)\right)}, \tag{35}$$

$$p_{21,t} = \frac{1}{1 + \exp\left(\eta\left(\tilde{b}_t - \tilde{b}^*\right)\right)}, \tag{36}$$

where the parameter η governs how abruptly the switches occur. We augment the model to allow for this type of endogenous regime switching and investigate the welfare impact of

Figure 13: Welfare implications of pro- and counter-cyclical fiscal policies with risks to high public debt



Notes: The figure shows the welfare gain of moving from an economy characterized by an a-cyclical fiscal policy ($\gamma_y = 0$) to an economy with either pro-cyclical fiscal policies ($\gamma_y < 0$) or counter-cyclical fiscal policies ($\gamma_y > 0$), while allowing for endogenous switching in the utility weight of government bonds, $\chi(\mathcal{S}_t)$. We set $\sigma_b = 0.5$, $\chi(1) = 0.04$ and $\chi(2) = -0.04$. See (34) for details. Welfare units are measured in consumption perpetuities.

pro- and counter-cyclical fiscal policies when $\chi(\mathcal{S}_t)$ is determined by (34). We calibrate the threshold at $\tilde{b}^* = 90\%$ (annualized), set $\eta = 50$, $\chi(1) = 0.04$ and $\chi(2) = -0.04$.[13]

Figure 13 shows the results. We find that, for sufficiently low, yet positive values of γ_y, a more counter-cyclical bent in fiscal policy is welfare enhancing, in line with the results from our baseline model. However, once γ_y is set above a certain critical point, the welfare gains from pursuing counter-cyclical fiscal policies become smaller and can even turn negative. Intuitively, a stronger counter-cyclical response to output fluctuations causes the government to run higher levels of public debt on average, thereby raising the likelihood of pushing the debt ratio beyond the threshold value, at which point debt starts to generate welfare losses. Evidently, the more capable are governments to maintain a sufficiently high threshold level $\tilde{b}^*$, e.g. through a sound institutional framework with credible budgetary restrictions and an overall strong commitment to ensure long-run fiscal solvency, the more likely are counter-

[13] We use the RISE toolbox from Junior Maih to solve the model at a second-order linear approximation with endogenous regime switching.

cyclical fiscal policies to deliver positive welfare outcomes. Countries at risk of entering a bad equilibrium of self-fulfilling expectations and high sovereign risk premia should be cautious when making use of strong counter-cyclical fiscal measures.

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