WP/20/71

IMF Working Paper

The Fiscal State-Dependent Effects of Capital Income Tax Cuts

by Alexandra Fotiou, Wenyi Shen, and Shu-Chun Susan Yang

INTERNATIONAL MONETARY FUND

 WP/20/71

IMF Working Paper

Fiscal Affairs Department

The Fiscal-State Dependent Effects of Capital Income Tax Cuts

Prepared by Alexandra Fotiou, Wenyi Shen, and Shu-Chun S. Yang

Authorized for distribution by Catherine Pattillo

May 2020

Abstract

Using the post-WWII data of U.S. federal corporate income tax changes, within a Smooth Transition VAR, this paper finds that the output effect of capital income tax cuts is government debt-dependent: it is less expansionary when debt is high than when it is low. To explore the mechanisms that can drive this fiscal state-dependent tax effect, the paper uses a DSGE model with regime-switching fiscal policy and finds that a capital income tax cut is stimulative to the extent that it is unlikely to result in a future fiscal adjustment. As government debt increases to a sufficiently high level, the probability of future fiscal adjustments starts rising, and the expansionary effects of a capital income tax cut can diminish substantially, whether the expected adjustments are through a policy reversal or a consumption tax increase. Also, a capital income tax cut need not always have large revenue feedback effects as suggested in the literature.

JEL Classification Numbers: E62, E63, H24, H30

Keywords: capital income tax effects, tax multiplier, fiscal policy effects, regime-switching models, non-linear DSGE model

Authors' E-Mail Address: afotiou@imf.org; wenyi.shen@okstate.edu; syang@imf.org

---

*Fotiou: Fiscal Affairs Department, International Monetary Fund; Shen: Department of Economics, Oklahoma State University; Yang: Fiscal Affairs Department, International Monetary Fund. We thank Antoine Arnoud, Huixin Bi, Vitor Gaspar, Shafik Hebous, Marialuz Moreno Badia, Ryota Nakatani, Adrian Paralta Alva, Catherine Pattillo, Juan F. Rubio-Ramirez, David Savitski, the Office of Tax Analysis at the U.S. Treasury, an anonymous referee, and participants in the seminar of the Fiscal Affairs Department, IMF and the 2019 Midwest Macro Meetings for helpful comments and discussion.

Contents

1 Introduction

Since the 1980s, corporate income tax rates have largely fallen, particularly in advanced economies. In the U.S., the Tax Cuts and Jobs Act (the 2017 Tax Act) reduced the federal statutory corporate tax rate from 35 to 21 percent. In Japan, a series of reductions since 2015 has lowered the statutory corporate tax rates from about 35 to 30 percent for large firms. While the literature has long recognized the supply-side benefits of capital income tax cuts,[1] preliminary estimation finds small growth effects and reduced investment responses of the 2017 Tax Act (Gravelle and Marples, 2019; Kopp *et al.*, 2019). Since recent corporate tax cuts in the U.S. and Japan have been implemented amid high government debt with projected rising debt-to-GDP ratios,[2] this paper asks whether the reduced expansionary effects of capital income tax cuts can be explained by a deteriorated fiscal state.

To proceed, we first provide empirical evidence of government debt-dependent capital income tax effects on output. Within a nonlinear smooth transition vector autoregressive model (STVAR), we estimate the macroeconomic effects of corporate income tax changes, conditional on government debt levels. We model the state of the economy as a continuous process dependent on a debt-transition variable. In this way, we incorporate regime switching behavior but do not restrict our sample in specific periods of high-debt dates.[3] In addition, we compute generalized impulse response functions that give us the flexibility to allow the economy to endogenously move between high- and low-debt states. We find that a corporate income tax cut has a less expansionary effect on output in a high-debt state compared to a low-debt state, and in some cases it can even turn contractionary. Considering the tax revenue change, the eight-quarter cumulative output multiplier is -0.36 when government debt is low and -0.14 when government debt is high.

Next, we use a neoclassical dynamic stochastic general equilibrium (DSGE) model with

[1] For example, see Judd (1985, 1987), Chamley (1986), Braun (1994), Ireland (1994), McGrattan (1994), Jones (2002), Forni *et al.* (2009), and De Mooij and Saito (2014).

[2] International Monetary Fund (2019) projects the U.S. net public debt to increase from 80 percent of GDP in 2012 to 94 percent in 2024 and the Japanese net debt from 147 percent in 2012 to 154 percent in 2024.

[3] For example, we could define a dummy variable of high-debt being equal to one in periods that the economy has a debt ratio above, say 60 percent of GDP. However, this would limit our data points under study for the high-debt regime. Instead, in our framework all the data points are included in the analysis but have different weights in different periods.

two policy regimes to explore the mechanisms that can drive fiscal state-dependent capital income tax effects. In the tax cut regime, the government does not pursue a fiscal adjustment, as often observed in reality. In the fiscal adjustment regime, the government increases primary surplus to stabilize debt. Under rational expectations, agents in the tax cut regime form expectations about regime switching. When a government is highly indebted, a deficit-financed capital income tax cut increases government debt further, inducing expectations of fiscal adjustments. Specifically, the regime switching probability is assumed to link to the current debt level and the government's debt repayment capacity, captured by the fiscal limits of an economy in the sense of Bi (2012). The switching probability is assumed to be the probability that the current debt level can exceed a randomly drawn fiscal limit from a simulated distribution.

Our modeling differs from the common approach which uses a fiscal reaction function that implements fiscal adjustment periodically (e.g., Leeper *et al.*, 2010; Traum and Yang, 2011; Erceg and Lindé, 2014; Zubairy, 2014; Canzoneri *et al.*, 2016). Fiscal adjustments in our specification are nonlinear and stochastic. In reality, although fiscal adjustments are often implemented when fiscal states change,[4] there is no certain debt threshold triggering an adjustment. Figure 1 plots the U.S. federal income tax legislation aimed at reducing deficits: some legislation was enacted immediately following an upward trend in debt (e.g., the Tax Equity and Fiscal Response Act of 1982 and the Deficit Reduction Act of 1984), but there has not been such tax legislation since the latest upward trend starting in 2009. Our modeling implies that an adjustment is more likely to occur in a high debt regime, but timing is uncertain.

We simulate the effects of a persistent capital income tax cut, as of a similar magnitude to the reduction in the corporate income tax rate in the 2017 Tax Act. Fiscal adjustments in the baseline analysis are implemented through a transfer reduction and a policy reversal (an increase in the capital income tax rate). Adjustments in an alternative simulation are

[4]For example, in the U.S., the reduction in income tax rates in 1964 was partially reversed in 1968 because of the spending needs arising from the Vietnam War and the inflationary pressure (see Yang (2009)). In Japan, out of concern of fiscal sustainability, a series of reductions in corporate income tax rates were followed by consumption tax hikes from five to eight percent in 2014 and to ten percent in 2019.

through consumption tax increases, reflecting the recent practice in Japan.

Simulation results show that the tax multipliers are fiscal state-dependent, whether the expected adjustments are through a policy reversal or a consumption tax increase. Conditional on a potential policy reversal and an initial U.S. federal net debt of 45 percent of GDP (the average federal debt held by the public from 1980 to 2018), the impact output multiplier is -0.5 and the five-year cumulative output multiplier is about -1. With the initial debt at 80 percent (roughly the net federal debt level in 2019), the stimulative effects diminishes: the impact and five-year output multipliers become -0.4 and -0.7. Moreover, the same tax cut turns contractionary when debt rises to 120 percent of GDP. Since a higher probability of policy reversal implies a lower expected after-tax return to current investment, this weakens the incentive provided by the capital income tax cut. Reduced investment lowers capital and the marginal product of labor, generating a smaller output multiplier in absolute value compared to the results with lower debt. When the expected adjustment instrument is through consumption taxes, the qualitative patterns of the multipliers with respect to debt are similar to those under a policy reversal. Note that during the analyzed horizon, fiscal adjustments do not occur. Thus, the differences of multipliers across various debt levels solely come from the expectation channel.

The literature on the macroeconomic effects of fiscal policy is voluminous, and our paper is related to both empirical and theoretical research.[5] On the empirical front, the recent development has moved away from estimating single multipliers to state-dependent ones. Studies on business cycle state-dependent government spending effects include e.g., Auerbach and Gorodnichenko (2012, 2013), and Ramey and Zubairy (2018), and on business cycle or uncertainty state-dependent tax effects include Arin *et al.* (2015), Candelon and Liebman (2015), Demirel (2016), and Eskandari (2019).

As for the fiscal state-dependent fiscal policy effects, several empirical papers document more expansionary effects of government spending in low-debt than in high-debt state (e.g.,

[5] Ramey (2019) provides a thorough survey on empirical fiscal policy studies and discusses how the different identification approaches—i.e., the structural identification based on structural vector autoregressive models (e.g., Blanchard and Perotti, 2002; Mountford and Uhlig, 2009) and the narrative approach (e.g., Romer and Romer, 2010)—may result in different multiplier estimation results.

Kirchner *et al.*, 2010; Ilzetzki *et al.*, 2013; Nickel and Tudyka, 2014; Huidrom *et al.*, 2016) and the government debt-dependent effects of fiscal consolidations through a mix of tax-based increases and government spending cuts (Alesina *et al.*, 2018; Fotiou, 2019). Our analysis focuses on how fiscal states can affect capital income tax effects, both empirically and theoretically. To our knowledge, the literature has not explored whether tax policy effects also depend on the fiscal state.[6]

On the theoretical approach, several papers have used DSGE models with regime-switching policy to study fiscal policy effects (e.g., Davig, 2004; Davig and Leeper, 2011; Davig and Foerster, forthcoming). Our paper is particularly related to Bi *et al.* (2013), which studies uncertain fiscal consolidations in the European countries. We follow their approach to link fiscal adjustment implementation with fiscal limits, but abstract from the uncertainty about the instruments to be used.

Finally, the key mechanism underlying our results is the policy expectations regarding potential fiscal adjustments. Bertola and Drazen (1993) model a "trigger point"—an upper bound of government spending-to-output ratio—to explain counterintuitive expansionary effects of fiscal consolidation, instead of using stochastic adjustments. Sutherland (1997) also links debt levels to policy expectations to explain that a fiscal deficit may not have traditional Keynesian effects related to consumption increases, if the current generation expects that fiscal adjustments would occur within the same generation. With a linear fiscal reaction function of government spending to debt, Corsetti *et al.* (2012) find that private consumption can rise to a government spending increase when agents expect a policy reversal. Also, Bi *et al.* (2016) study how expectations of fiscal adjustment can drive debt-dependent government spending effects as found in the empirical literature. Our findings add to this literature by focusing on how expectations of future policy can matter for capital income tax effects, accounting for an increasing probability of fiscal adjustments as the fiscal state deteriorates.

[6] Sims and Wolff (2018) study the theoretical effects of business-cycle state dependent tax multipliers.

2 Empirical Evidence

In this section, we adopt a Smooth Transition VAR (STVAR) model to study the debt-dependent effects of capital income tax cuts in the U.S.[7] Auerbach and Gorodnichenko (2012) and Caggiano *et al.* (2015) use an STVAR model to estimate a business cycle state-dependent government spending multipliers. Fotiou (2019) within an interacted-STVAR shows evidence that debt matters in the transmission of fiscal policy. Using the same framework, we focus on debt-dependent tax effects. Following Mertens and Ravn (2013), we disaggregate income taxes into corporate and personal income taxes. We focus on corporate income tax effects, since they are the main component in capital income taxes and thus are used as their proxy.

2.1 Empirical Model and Estimation

Our baseline specification of the empirical model is as follows:

$$\mathbf{Y}_t = (1 - F(z_t))\mathbf{A}_L\,(l)\,\mathbf{Y}_{t-1} + F(z_t)\mathbf{A}_H\,(l)\,\mathbf{Y}_{t-1} + \varepsilon_t, \qquad \varepsilon_t \sim N\left(0, \mathbf{\Omega}_t\right), \tag{1}$$

$$\mathbf{\Omega}_t = (1 - F(z_t))\mathbf{\Omega}_L + F(z_t)\mathbf{\Omega}_H, \qquad F\left(z_t\right) = \frac{\exp\left[-\gamma z_t\right]}{1 + \exp\left[-\gamma z_t\right]}, \quad \gamma > 0.$$

The vector of endogenous variables, $\mathbf{Y}_t$, includes the following variables in the order of government spending (G_t), the average personal income tax rate ($APITR_t$), the average corporate income tax rate ($ACITR_t$), the personal income tax base (PB_t), the corporate income tax base (CB_t), output (GDP_t), fiscal news, and the debt-to-GDP ratio.[8] The sample covers the period from 1950Q1 to 2006Q4 in the quarterly frequency. The different tax components come from the National Income and Product Accounts (NIPA, Bureau of Economic Analysis (2018)) and all taxes are at the federal level. The average corporate tax rate is the ratio of taxes on corporate profits (TCP_t) to corporate profits (CP_t): $ACITR_t = \frac{TCP_t}{CP_t}$. The personal income tax rate is the sum of personal current taxes (PT_t) and contributions for gov-

[7] For a detailed presentation of this family of models, see Tersvirta *et al.* (2010).

[8] The order follows Auerbach and Gorodnichenko (2012), which assumes that shocks in tax revenues and output have no contemporaneous effect on government spending, and taxes respond to their own shock but also to government spending. In robustness checks, we also use narratively constructed, exogenous corporate tax changes to address the endogeneity concerns and try different ordering in the baseline specification. See Section 2.3.

ernment social insurance (SI_t) divided by personal tax income (PTI_t): $APITR_t = \frac{PT_t + SI_t}{PTI_t}$. GDP and corporate and personal income tax bases are all in logarithms and real terms. In our baseline specification, fiscal news is Ramey's defense spending news (e.g., Ramey, 2019). See Appendix A for data description.[9]

In specification (1), the debt state is determined by z_t. To construct z_t, we de-trend the debt-to-GDP series through a third-order polynomial and look into cases that the debt-to-GDP ratio is above or below the trend. The parameter γ controls transition smoothness, with large (small) values associated with immediate (smooth) switches. We calibrate $\gamma = 2.1$ to match the frequency and duration in a high-debt state. $\mathbf{A}_L$ and $\mathbf{A}_H$ are the VAR coefficients corresponding to the dynamic behavior of the economy in low- and high-debt states. ε_t is the vector of reduced-form residuals, with zero-mean and a time-varying state-contingent variance-covariance matrix $\mathbf{\Omega}_t$, which considers the covariance structure of the residuals in both states (i.e., $\mathbf{\Omega}_L$, in low-debt periods, and $\mathbf{\Omega}_H$, in high-debt periods). Based on the Akaike criterion, the lag length of our model is set to three.

To estimate the empirical model, we follow the Monte-Carlo Markov-chain (MCMC) algorithm proposed by Chernozhukov and Hong (2003). A structural Cholesky-type identification is used. We then derive the generalized impulse response functions based on Koop *et al.* (1996). All impulse response functions are for a reduction in the corporate income tax rate, normalized to one percentage point, and cover a forecast horizon of 20 quarters.[10]

2.2 Estimation Results

Figure 2 shows the impulse responses to a shock of a federal corporate income tax cut derived both with the linear and nonlinear VARs. The black line corresponds to the generalized impulse response function (GIRF) of the linear model, the red line to the GIRF in a high-debt state, and the blue line is for a low-debt state. The responses of the linear model point to a persistent output increase which then stabilizes. For the nonlinear model, on the other hand, we observe reversal dynamics with heterogeneous responses among various fiscal

[9]The NIPA corporate data do not include proprietors' income and taxes.

[10]See the appendices of Auerbach and Gorodnichenko (2012) and Caggiano *et al.* (2015) for the estimation process.

variables.

Given the evidence of debt-dependent effects and to better understand our results, we focus on the outcomes of the smooth-transition nonlinear model. Figure 3 reports the GIRFs in high- and low-debt states. All GIRFs are constructed by taking into account all histories of a given debt state. The associated confidence bands are the 90-percent bands. The effect of a corporate income tax cut in a low-debt state is expansionary but less so in a high-debt state. In the short-run, a negative shock to the average corporate income tax rate generates heterogeneity in the responses of the two different states after two quarters. We observe a stronger increase in the personal and corporate income tax base in the low-debt state, which results in a more pronounced output increase. Also, both government spending and the average personal income tax rate increase more in the low-debt state.

Turning to the multipliers, we compute the cumulative multiplier as the integral of the output response divided by the integral of the response of corporate tax revenues. The response of tax revenues (TR_t) are computed as $TR_t^{girf} = \frac{ACITR_t^{girf}}{\overline{ACITR}} + CB_t^{girf}$, where $\overline{ACITR}$ is the mean average corporate income tax rate. Table 1 reports the multipliers and the associated 90-percent confidence intervals. In the low-debt state, the only statistically significant multiplier is at the 8 quarter horizon (-0.36), which is lower than the respective high-debt state multiplier (-0.14).

The STVAR together with the GIRF gives us the flexibility to estimate the impact of the tax shock on the probability of being in a low- or high- debt state for each horizon after the shock. This allows us to track the endogenous transition of the economy from one state to the other. Figure 4 shows the estimated transition function of our baseline specification, together with the 90-percent confidence intervals. The likelihood of remaining in a high-debt state is high and persistent, and the probability of switching to a low-debt state may occur after 15 quarters.

Compared to the tax multipliers in the literature, our estimates are much smaller in absolute value than some existing estimates for the U.S. general tax multiplier. For example, Romer and Romer (2010) estimate a long-run output multiplier of -3, and Blanchard and

Perotti (2002) estimate the twenty-quarter multiplier of -0.8 (-1.3) under a deterministic (stochastic) trend specification. Within a structural VAR with sign-restrictions, Mountford and Uhlig (2009) find a five-year cumulative multiplier of -5. Barro and Redlick (2011) study the relevance of an increase in marginal tax rates and find a tax multiplier around -1.1. Within a linear specification, Mertens and Ravn (2013) report a multiplier at about -2.5 to -3.

2.3 Robustness Checks

To see whether our results that debt-dependent effects of corporate income tax cuts are robust, we estimate alternative specifications in light of endogeneity and foresight concerns (Leeper *et al.*, 2013). Instead of using the average corporate tax rate series, we use the exogenous, unanticipated corporate income tax series, narratively constructed in Mertens and Ravn (2013), to identify the corporate income tax rate shocks, and order it first in the estimation. Figure 5 shows that the debt-dependent effects of corporate income tax cuts from the estimation of the baseline specification continue to hold. The output response is mostly positively in response to an unanticipated corporate income tax cut in a low-debt state but mostly negative in a high-debt state.[11]

Other robustness checks conducted, while not presented here, include 1) adding to the baseline specification (1) the aggregate narratively constructed tax news measures in Mertens and Ravn (2012), 2) adding to (1) the unanticipated, exogenous aggregate tax changes, narratively constructed in Mertens and Ravn (2012), and 3) different orderings of the variables in (1). By and large, our empirical conclusion that the effects of capital income tax cuts are more expansionary in a low-debt state than in a high-state state remains robust among these alternative estimations. See the results of these additional robustness checks in Appendix B.

[11] We also estimate with the series of the unanticipated corporate income tax changes ordered last. The debt-dependent corporate income tax effects are even more pronounced than those presented in Figure 5.

3 The Baseline Model

To explain possible theoretical channels that can drive debt-dependent capital income tax effects, we pursue a theoretical analysis using a neoclassical growth model with regime-switching fiscal policy. In the baseline model, fiscal adjustments are jointly implemented through a policy reversal and a transfer reduction. In Section 5.5, we revise the model to allow for adjustments jointly implemented by a consumption tax increase and a transfer reduction.

3.1 The Private Sector

A representative agent chooses private consumption (c_t), labor (l_t), gross investment (i_t), and capital (k_t) to maximize expected utility:

$$E_t \sum_{t=0}^{\infty} d_t \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1+\varphi}}{1+\varphi} \right) \tag{2}$$

subject to the budget constraint

$$c_t + i_t + q_t b_t = \left(1 - \tau_t^l\right) w_t l_t + \left(1 - \tau_t^k\right) r_t^k k_{t-1} + b_{t-1} + z_t, \tag{3}$$

where b_t is a one-period government bond with a price q_t and paying one unit of goods at $t+1$, τ_t^l is the labor income tax rate, w_t is the real wage rate, τ_t^k is the capital income tax rate, r_t^k is the rental rate for capital, and z_t is government transfers. Define $d_t = \prod_{j=1}^{t} \beta_j$ for $t > 0$, and $d_0 \equiv 1$, where β_j is a time-varying discount factor, which follows an AR(1) process:

$$\ln \frac{\beta_t}{\beta} = \rho^\beta \ln \frac{\beta_{t-1}}{\beta} + \varepsilon_t^\beta, \qquad \varepsilon_t^\beta \sim N(0, \sigma_\beta^2), \tag{4}$$

where ε_t^β is the discount factor shocks. A variable without a time subscript indicates its initial steady-state level.

The law of motion for capital is

$$k_t = (1-\delta)k_{t-1} + i_t - \frac{\kappa}{2}\left(\frac{i_t}{k_{t-1}} - \delta\right)^2 k_{t-1}, \tag{5}$$

where $\frac{\kappa}{2}\left(\frac{i_t}{k_{t-1}} - \delta\right)^2 k_{t-1}$ is the capital adjustment cost.

Firms are perfectly competitive and produce with a Cobb-Douglas technology:

$$y_t = a_t k_{t-1}^{\alpha} l_t^{1-\alpha}. \tag{6}$$

The total factor productivity (TFP), a_t, follows an AR(1) process:

$$\ln \frac{a_t}{a} = \rho^a \ln \frac{a_{t-1}}{a} + \varepsilon_t^a, \qquad \varepsilon_t^a \sim N(0, \sigma_a^2). \tag{7}$$

While we do not analyze the effects of macroeconomic shocks, the discount factor shock (ε_t^{β}) and the TFP shocks (ε_t^a) represent demand and supply shocks in the economy. These shocks are then used in the simulation of fiscal limit distributions.

3.2 Government

The government collects taxes and issues debt to pay for its purchases, transfers, and debt service. Its budget constraint is

$$tax_t + q_t b_t = g_t + b_{t-1} + z_t, \tag{8}$$

where $tax_t \equiv tax_t^l + tax_t^k$, $tax_t^l = \tau_t^l w_t l_t$, and $tax_t^k = \tau_t^k r_t^k k_{t-1}$. We assume that the government purchases and the labor income tax rate are equal to the steady-state value in each period, so $g_t = g$ and $\tau_t^l = \tau^l \; \forall t$.

For the capital income tax rate, the economy is in the initial steady state before the tax rate cut, so

$$\tau_t^k = \tau^k. \tag{9}$$

After implementing the tax cut (with the shock ε^{τ^k}) at $t = 0$, the capital income tax rate can be in one of the two regimes starting at $t = 1$:

$$\begin{cases} \mathcal{R}1: \ \mathcal{R}_t = 1, \quad \tau_t^k = \tau^k - \varepsilon^{\tau^k}, & z_t = z; \\ \mathcal{R}2: \ \mathcal{R}_t = 2, \quad \tau_t^k = \bar{\tau}^k + \gamma_\tau(b_{t-1} - \bar{b}), & z_t = \bar{z} - \gamma_z(b_{t-1} - \bar{b}), \end{cases} \tag{10}$$

where $\gamma_\tau, \gamma_z > 0$, and $\bar{\tau}^k$ and $\bar{z}$ are the target fiscal policy values if the government pursues fiscal adjustments. Agents are assumed to know the targeted fiscal policy values.

$\mathcal{R}1$ denotes "the tax cut regime," in which there is no fiscal instrument that stabilizes government debt. As debt can grow exponentially without adjustments, the tax cut regime is not expected to prevail forever. The alternative regime, $\mathcal{R}2$, is "the fiscal adjustment regime." As some VAR evidence shows that a tax reversal often follows a tax shock in the U.S. data (e.g., Blanchard and Perotti (2002) under the deterministic trend specification, Favero and Giavazzi (2007), and Mountford and Uhlig (2009)), we assume that the fiscal adjustment is implemented through a policy reversal. In this regime, the government stabilizes debt towards its targeted debt level, $\bar{b}$, consistent with a capital income tax rate $\bar{\tau}^k$ and transfers $\bar{z}$. As we focus on advanced economies, which face rising transfer spending as population ages, we allow transfers to be a separate instrument.[12] The regime index, $\mathcal{R}_t$, evolves according to the transition matrix

$$\begin{pmatrix} p_{1,t} & 1 - p_{1,t} \\ 1 - p_2 & p_2 \end{pmatrix},$$

which means that switching from $\mathcal{R}1$ to $\mathcal{R}2$ occurs with probability $1 - p_{1,t}$. To capture agents' expectations of switching to $\mathcal{R}2$, depending on the fiscal state, we let $1 - p_{1,t+1}$ be the probability that government debt at the end of t can exceed a randomly drawn fiscal limit from its distribution (described in Section 4). At one extreme, very high debt implies that the probability of exceeding a fiscal limit is close to 1, meaning $p_{1,t+1} \approx 0$: agents expect that the government will almost certainly switch to the fiscal adjustment regime the next period.

[12] As transfers are a non-distorting instrument in our model, they do not play a role on the effect of capital income tax cut.

3.3 Calibration and Solution Method

The model is calibrated at a quarterly frequency and we adopt standard values for the structural parameters: the discount factor $\beta = 0.99$, the depreciation rate $\delta = 0.025$, the capital income share $\alpha = 0.36$, the capital adjustment parameter $\kappa = 1.7$ (Gourio, 2012), and the steady-state TFP $a = 1$. We take the mean estimates of Smets and Wouters (2007) using the U.S. data to set $\sigma = 1.38$ (the inverse of the intertemporal elasticity of substitution) and $\varphi = 1.83$ (the inverse of the Frisch labor elasticity).

In the baseline analysis, the fiscal variables in the initial steady state are calibrated using U.S. federal government data. Based on the average federal capital and labor income tax rates from 1980 to 2017, we set $\tau^k = 0.208$ and $\tau^l = 0.204$, where the two average tax rate data are constructed following Jones's (2002) definitions with the NIPA data (Bureau of Economic Analysis, 2018) but only applying to the federal government.[13] We set the debt-to-annual output ratio to $\frac{b}{4y} = 0.45$, corresponding to the average federal debt held by the public as a share of GDP from 1980 to 2017 (Table 7.1 of Historical Tables (Office of Management and Budget, 2018)). Also, the federal government purchases as a share of output are set to $\frac{g}{y} = 0.08$ based on the historical average of discretionary outlays (Table 8.4 of Historical Tables (Office of Management and Budget, 2018)). The implied transfers-to-output ratio is 0.11, matching the average mandatory spending-to-GDP ratio from 1980 to 2017 (Table 8.4 of Historical Tables (Office of Management and Budget, 2018)).

In the fiscal adjustment regime, the debt target is chosen such that the targeted debt-to-output ratio is 0.7, which is the post-crisis (2009-2017) average of the debt-to-GDP ratio. Since there is no guidance in setting the long-run federal debt target, sensitivity analysis explores a different targeted debt-to-output ratio of 0.9. In the fiscal adjustment regime, we assume $\gamma_\tau = 0.005$ and $\gamma_z = 0.04$. We let transfers stabilize a substantial part of outstanding debt and keep the adjustment through a policy reversal small. In the sensitivity analysis, we also examine a higher adjustment magnitude through a policy reversal ($\gamma_\tau = 0.01$).

[13] See Appendix 2 in Jones (2002) for the method and data used for constructing average capital and labor income tax rates with the NIPA data.

Consistent with the debt target, we assume that the capital income tax rate eventually returns to the pre-cut level, and the labor income tax rate and government purchases remain at the steady-state levels, implying that targeted transfers ($\bar{z}$) as a share of output are reduced from 0.11 to 0.09.

Regarding the regime switching probabilities, we set $p_2 = 0.9375$, implying that, on average, a fiscal adjustment continues for four years, roughly the average length of consolidation episodes documented in Devries *et al.* (2011) for 17 OECD countries from 1978 to 2009.[14] Table 2 summarizes the parameter and fiscal policy values in the initial steady state. The switching probability, $p_{1,t}$, is endogenously determined based on the relative position of current debt in a fiscal limit distribution.

With a regime-switching fiscal policy, we solve the model nonlinearly using the monotone mapping method, as in Coleman (1990) and Davig (2004). Appendix C.1 lists the equations in the equilibrium system of the baseline model, and Appendix C.2 describes the solution algorithm.

4 Fiscal Limits

To endogenize the switching probability from the tax cut to the fiscal adjustment regime, we resort to a simulated fiscal limit distribution based on the future fiscal policy paths under the maximum implementable tax rates. Following Bi (2012), we define fiscal limits as

$$\mathbf{b}_{t-1} \sim \sum_{i=0}^{\infty} \frac{d_{t+i}}{d_t} E_t \left[\frac{\lambda_{t+i}^{max}}{\lambda_t^{max}} \left(tax_{t+i}^{max} - g - z_{t+i} \right) \right], \tag{11}$$

where the superscript *max* indicates a variable's value calculated under $\tau_{t+i}^{l,max}$ and $\tau_{t+i}^{k,max}$ $\forall$ i, and λ_t^{max} is the marginal utility of consumption computed under the maximum tax rates. The expression resembles the intertemporal government budget constraint of the baseline model, but with the maximum implementable tax rates imposed. It thus has the interpretation of the maximum sustainable debt, signaling a government's debt repayment capacity.

[14] The calculation is based on the data in Table A1 in Devries *et al.* (2011). Sensitivity analysis analyzes an average fiscal adjustment duration of ten years.

When simulating the fiscal limit distribution for the federal government in the baseline analysis, we follow Bi *et al.* (2019) and set the maximum implementable average capital and labor income tax rates as $\tau^{k,max} = 0.240$ and $\tau^{l,max} = 0.292$. These values are much lower than the typical values of the Laffer curve peaks, but are implementable based on historical experience.[15] The future transfers used in simulating fiscal limits take the values of the extended baseline projection by the Congressional Budget Office (2018a) from 2019 to 2038: rising from 12.7 percent to 16.5 percent of output at the end of the 20 years. We then assume that transfers follow an AR(1) process, to very slowly return to the original steady state value of 11 percent of output. Since Social Security and health care programs are the key drivers to an increasing debt ratio for the U.S. federal government, accounting for a rising transfers-to-output path is important to capture its impact on the federal government's ability to repay debt.

To simulate the fiscal limit distribution, we conduct 10,000 simulations with 1,000 periods each. In each simulation, we randomly draw sequences of the technology shocks (ε^a_{t+i}) and discount factor shocks (ε^β_{t+i}) for $i = \{1, 2, ..., 1000\}$ starting from the initial steady state. The parameters in the technology shock are calibrated in line with the RBC literature: $\rho^a = 0.9$ and $\sigma^a = 0.01$. Following Fernández-Villaverde *et al.* (2015), the persistence of the discount factor, ρ^β, is set to 0.8 so a discount factor shock has a half life of about three quarters. Given the wide range of estimation on the standard deviation in the discount factor used in the literature, from 0.002 in Plante *et al.* (2018) to 0.0237 in Ajello (2016), we set $\sigma^\beta = 0.005$. Assuming that the labor and capital income tax rates are always at their maximum values each period, the discounted sum of maximum fiscal surpluses is computed by (11). We repeat the simulation $10,000$ times to collect $\{\mathbf{b}_j\}_{j=1}^{10,000}$, which forms the fiscal limit distribution to be used for setting $1 - p_{1,t}$.

The solid line in Figure 6 plots the simulated fiscal limit distribution for the U.S. federal government in the baseline analysis. At the current net federal debt of 80 percent, the fiscal limit implies that the probability that this debt level can exceed a randomly drawn fiscal

[15] Bi (2012) uses the peak of Laffer curve peak to simulate fiscal limits. For the U.S., using the peak of the Laffer curve would imply a fiscal limit distribution with a very high mean (see Bi (2017)).

limit is virtually zero. This suggests that the current debt burden of the federal government can be well supported by future primary surpluses. If the federal debt continues to rise—as projected by Congressional Budget Office (2018a,b), some risk to debt sustainability might emerge when the net federal debt exceeds 100 percent of GDP.

5 The Effects of Capital Income Tax Cuts

We begin with the baseline analysis for a persistent capital income tax cut and show how the implications on the fiscal state-dependent tax cut effects differ from a linear model. Then, we compute the revenue feedback effects and tax multipliers, which are the two indicators often used to assess the macroeconomic effects of tax policy. In addition to the baseline specification with a policy reversal, we investigate a fiscal adjustment regime with a consumption tax increase.

5.1 The Baseline Analysis

We simulate the effects of a persistent capital income tax cut. The magnitude of the cut is the difference in the effective marginal tax rate on capital income as estimated in Congressional Budget Office (2017)—the estimate that does not incorporate the 2017 Tax Act—to that in Congressional Budget Office (2018a)—the estimate after the enactment of the 2017 Tax Act. The comparison shows a reduction of roughly two percentage points.[16]

In our simulations, we assume that at $t = 0$, the economy is in the tax cut regime with an unexpected capital income tax cut. Upon observing rising government debt burden resulted from the tax cut, agents form expectations about switching to the fiscal adjustment regime at $t = 1$, according to the probability that debt at $t = 0$ can exceed a randomly drawn fiscal limit. Agents are aware of the fiscal limit distribution and the fiscal reaction functions adopted in the fiscal adjustment regime. Moreover, in our simulations, we assume that the regime does not switch for the first five years after the tax cut (which is the horizon that

[16] The capital income tax rates reported in Table 5 of Congressional Budget Office (2017) are 0.155, 0.181, and 0.191 for 2017, 2027, and 2047 and in Table 5 of Congressional Budget Office (2018a) are 0.147, 0.165, and 0.170 for 2018, 2028, and 2048. The effective marginal tax rate is the share of the return on an additional dollar of investment made in a particular year that will be paid in taxes over the life of that investment.

our analysis is focused on). A priori, agents are unaware when the regime will switch.

Figure 7 compares the impulse responses under different initial government debt levels for a two-percentage-point cut in the capital income tax rate from 0.208 to 0.188. The solid lines represent the low-debt case with the initial debt at 45 percent of output—the steady state value. The dotted lines represent the debt ratio at 80 percent of output, and the dotted-dashed lines represent a high-debt case at 120 percent of output. The x-axis is in quarters after the tax cut. All variables are in percent deviations from the path without a capital income tax cut, except for those specified in parentheses. For the simulation without a tax cut, we assume that the income tax rates and government purchases stay in the initial steady state throughout the simulation horizon. In this case, transfers respond periodically to debt to maintain debt sustainability.

With moderate amounts of government debt (45 and 80 percent of output), a persistent capital income tax cut is expansionary, consistent with the conventional wisdom. An expected higher after-tax return to investment from a lower capital income tax encourages agents to increase saving. Higher investment leads to more capital accumulation, higher marginal product of labor, and hence more labor inputs. Output rises because of more capital and labor. Consumption initially responds negatively, as more investment drives up the demand of goods, increasing the real interest rate. A higher real interest rate then increases the opportunity cost to consume: agents substitute away from consumption into investment. As the agents' income rises over time because of the rising wage rate, consumption responses turn positive eventually. The real wage rate falls in the short run from an increased labor supply but becomes increasingly positive from higher labor productivity as a result of more capital.

On the fiscal side, a capital income tax cut reduces tax revenues, despite more labor taxes resulting from higher labor inputs. Since no fiscal adjustment is implemented in the tax cut regime, and the expansion of the tax base from the tax cut is insufficient to offset the revenue loss, the debt burden as a share of output increases. With the initial debt at 45 percent of output, it rises to 49 percent of output five years after the tax cut, indicating a worsening of the fiscal outlook.

For debt at 80 percent of output, the same capital income tax cut is less expansionary compared to the 45 percent case. Against the fiscal limit distribution (the solid line in Figure 6), an initial debt ratio of 80 percent implies that agents start to place a small probability on switching to the fiscal adjustment regime, and this probability increases over time to 1.3 percent five years after the tax cut as government debt rises from 80 to 93 percent of output. Despite a small probability, it lowers the expected future return on current investment relative to the 45 percent scenario, weakening the stimulative effect on investment and, hence, output.

When the initial debt level is 120 percent of output, the dotted-dashed lines in Figure 7 show that the capital income tax cut becomes contractionary. Under this circumstance, debt rises to 144 percent of output five years after the tax cut. Although the capital income tax rate remains low, a policy reversal is, to some extent, anticipated as the switching probability rises substantially to almost 50 percent. Agents expect that once a policy reversal is realized, the government will raise the capital income tax rate substantially to stabilize debt at 70 percent of output.[17] Such expectations affect economic behavior in the tax cut regime, which dominate the stimulative effect of the original capital income tax cut and generate an unusual contractionary capital income tax cut.

Our results, that a capital income tax cut is expansionary to the extent that they are unlikely to result in a future fiscal adjustment, are consistent with Sutherland (1997). In Sutherland's model, finite-lived agents ignore the negative wealth effect of higher taxes when current debt is low, as the debt stabilization program is expected to take place beyond their lifetime. If, instead, debt is sufficiently high, the probability of tax hikes within their generation becomes high. Although we do not model fiscal adjustment expectations associated with inter-generational tax distribution, the mechanism that links fiscal adjustment expectations to government indebtedness is the same as in our model with infinitely-lived agents.

[17] Following (10), when fiscal policy actually switches from the tax cut regime to the fiscal adjustment regime, the capital income tax rate increase from the level after the tax cut would be quite large, because of the large difference between the targeted debt level (70 percent of output) and the current debt level (120 percent of output). Sensitivity analysis explores an alternative value of the debt target.

5.2 Capital Income Tax Effects with a Linear Model

One motivation to solve the model fully nonlinearly concerns that nonlinearity in economic decisions may lead to poor quality of linear approximation when the economy moves substantially away from its steady state. To see how our nonlinear model reveals the important difference on the implications of capital income tax effects, we compare the policy functions and impulse responses from the nonlinear and linear models.

In the linear model for comparison, we replace the fiscal policy, (10), by the following rules:

$$\tau_t^k = \gamma_\tau^{lin} \left(b_{t-1} - b\right) + \varepsilon_t^k, \quad z_t = z. \tag{12}$$

We calibrate $\gamma_\tau^{lin} = 0.0001$, the minimum value to maintain debt sustainability in the linear model. The capital income tax rate responds to the debt deviation from its steady-state level by one-period lag, a fiscal reaction function typically used in a linear model.[18]

Figure 8 plots the policy functions of the realized and expected capital income tax rate for the baseline nonlinear model and the linear model described above.[19] The realized capital income tax rates in the two models (left panel) are quite close. In the nonlinear model, as a policy reversal does not occur in the tax cut regime, the capital income tax rate stays constant at two percentage points below the steady-state level. In the linear model, although the capital income tax rate responds systematically to debt following (12), the magnitude of the response is set to be quite small, so the path in the nonlinear model is only slightly higher.

Despite close magnitudes in the realized tax rates, the expected capital income tax rates ($E_t \tau_{t+1}^k$) are quite different (right panel) especially under high debt-to-output ratios. In the linear model, as the fiscal adjustment is periodic, agents expect that the capital income tax cut will gradually reverse as debt grows. In the nonlinear model, the expected tax rate remains constant when debt is below 100 percent of output, but increases rapidly as the

[18]Since the nonlinear model has both transfers and capital income tax reversals as adjustment instruments, an alternative specification in the linear model is to replace τ_t^k with z_t for fiscal adjustment in the linear model. While the responses under the two adjustment instruments are quite different, the implication that a linear model cannot differentiate capital income tax effects among different fiscal states holds with a transfer rule.

[19]When plotting the policy functions against debt, other state variables are set at their steady-state values.

debt ratio rises above 120 percent, as high debt implies a nontrivial probability of fiscal adjustment. The policy function on the expected capital tax rate reveals the source of fiscal state-dependent tax cut effects in the nonlinear model. This is something that a linear model is unable to capture.

Figure 9 plots the impulse responses for a two-percentage-point capital income tax cut in the linear and nonlinear models under an initial low debt ratio of 45 percent versus a high debt ratio of 120 percent. Consistent with the policy functions, the linear model (dashed lines) predicts a positive output response, investment, and labor respond similar to the nonlinear model with an initial debt-to-output ratio of 45 percent. However, when the initial debt-to-output ratio reaches 120 percent, the nonlinear model predicts a contractionary capital income tax cut. This is driven by a higher expected capital income tax rate. Instead, the linear model implies that the tax cut effects are independent of debt levels. The comparison shows that as government debt deviates from its steady-state level, the bias from using a linear model increases and even produces qualitatively different results from a nonlinear model.

5.3 Revenue Feedback Effects

Figure 7 shows that government debt rises following a capital income tax cut, regardless of the initial debt levels. While there is no free lunch associated with a capital income tax cut, the expanded tax base (at least for the initial debt of 45 and 80 percent of output) offsets some revenue loss from the tax cut. The fiscal state-dependent tax cut effects suggest that the revenue feedback effects—the extent to which a capital income tax cut pays for itself—should also be fiscal state-dependent. To better understand this, the bottom-right plot in Figure 7 reports the revenue feedback effect, defined as

$$x_t \equiv 1 - \frac{tax_t^{\text{dynamic scoring}} - tax_t^{\text{no tax cut}}}{tax_t^{\text{static scoring}} - tax_t^{\text{no tax cut}}}, \tag{13}$$

where $tax_t^{\text{static scoring}}$ is the tax revenue under static scoring (which computes tax revenues of a tax cut by holding the tax base at the level without such a cut) and $tax_t^{\text{dynamic scoring}}$ is the tax revenue under dynamic scoring (which accounts for the macroeconomic effect on the tax base). In the extreme case where a capital income tax cut has no expansionary effect on the tax base, $tax_t^{\text{dynamic scoring}} = tax^{\text{static scoring}}$, so $x_t = 0$; none of the revenue loss is self-financed.

In our baseline simulation, the revenue feedback effects are much smaller than those reported in Mankiw and Weinzierl (2006), who calculate that 53 percent of the revenue loss associated with a capital income tax cut is self financing. Even with the initial debt ratio at 45 percent, the impact revenue feedback effect is 0.10—only 10 percent of revenue loss is self-financed. In later years, as capital is gradually built up to generate more output, the feedback effect rises to 0.25 five years after the tax cut. When the initial debt ratio is 80 percent, the five-year revenue feedback effect falls to 0.17. Relative to Leeper and Yang (2008), we confirm that debt-financed income tax cuts have smaller revenue feedback effects than those financed by lump-sum taxes (as in Mankiw and Weinzierl (2006)). Also, we show that revenue feedback of a capital income tax cut is fiscal state-dependent.

5.4 Tax Multipliers

To summarize the state-dependent effects of capital income tax cuts, we compute the cumulative multipliers at various horizons for output, consumption, and investment as shown in Table 3. Cumulative tax multipliers for output l periods after a tax shock are computed as

$$\frac{\sum_{j=0}^{l} \left(\prod_{i=0}^{j} {r_{t+i}}^{-1} \right) \triangle y_{t+j}}{\sum_{j=0}^{l} \left(\prod_{i=0}^{j} {r_{t+i}}^{-1} \right) \triangle tax_{t+j}^{k}}, \tag{14}$$

where $\triangle y$ and $\triangle tax^k$ are level changes in output and capital tax revenue relative to the path without a capital income tax cut. $r_t = \frac{1}{q_t}$ is the real interest rate, and when $j = 0$, $\prod_{i=0}^{j} {r_{t+i}}^{-1} \equiv 1$. To compute the consumption and investment multipliers, $\triangle y$ is replaced by $\triangle c$ and $\triangle i$.

Table 3 shows that, with an initial debt of 45 percent of output, a capital income tax cut has a five-year cumulative multiplier of about -1, in line with the VAR evidence (e.g., Blanchard and Perotti, 2002; Perotti, 2008; Favero and Giavazzi, 2012). The output multipliers, however, fall in absolute value as the initial debt level increases, particularly in the longer horizon. With debt at 80 percent of output, the five-year output multiplier is -0.7, suggesting a less expansionary tax cut. When the government debt ratio increases to 120 percent, both impact and five-year output multipliers turn positive, at 0.1 and 0.4, suggesting a contractionary capital income tax cut. Similarly, we find that both consumption and investment multipliers also change signs when debt is 120 percent, consistent with the impulse responses in Figure 7.

As the current net federal debt ratio is about 80 percent, our simulation suggests that the capital income tax cut as enacted in the 2017 Tax Act is expansionary but has a multiplier less than one in absolute value. The simulation is conditional on a fiscal limit distribution assuming no transfer reform in the next 20 years. If credible reform can be enacted, the output multiplier need not reduce (in absolute value) relative to the low-debt case. In the sensitivity analysis, we explore a case that future transfer spending stabilizes at a higher level than what is assumed in the baseline fiscal limit distribution.

5.5 Fiscal Adjustment via Consumption Tax Increases

Facing the highest level of public debt in the developed world, Japan has gradually increased its consumption tax rate following a recent reduction in the corporate income tax rates. This section analyzes an alternative fiscal adjustment instrument via consumption tax increases. We modify (10) in the baseline model as follows:

$$\begin{cases} \mathcal{R}1: \ \mathcal{R}_t = 1, \quad \tau_t^k = \tau^k - \varepsilon^{\tau^k}, \qquad\qquad z_t = z \\ \mathcal{R}2: \ \mathcal{R}_t = 2 \quad \tau_t^c = \bar{\tau}^c + \gamma_\tau(b_{t-1} - \bar{b}), \quad z_t = \bar{z} - \gamma_z(b_{t-1} - \bar{b}), \end{cases} \tag{15}$$

where $\gamma_\tau, \gamma_z > 0$. Similarly to the baseline fiscal adjustment regime, the government has a targeted debt-to-output ratio and the consumption tax rate ($\bar{\tau}^c$). We assume $\bar{\tau}^c = 0.10$, and $\bar{b}$ is consistent with a targeted debt-to-output ratio of 150 percent, roughly the current debt burden. Moreover, the budget constraints, (3) and (8), are modified as

$$\left(1+\tau_t^c\right)c_t+i_t+q_tb_t=\left(1-\tau_t^l\right)w_tl_t+\left(1-\tau_t^k\right)r_t^kk_{t-1}+b_{t-1}+z_t, \tag{16}$$

$$\tau_t^cc_t+\tau_t^lw_tl_t+\tau_t^kr_t^kk_{t-1}+q_tb_t=g_t+b_{t-1}+z_t, \tag{17}$$

where $\tau_t^l=\tau^l$ and $g_t=g$.

To facilitate the comparison to the baseline simulation, we keep the tax cut magnitude at two percentage points as in the baseline. Since the reference country for a consumption tax adjustment is Japan, we simulate a fiscal limit distribution based on the fiscal data of Japan from 2000 to 2017 (the database of International Monetary Fund (2019)). We use the average of general government revenue-to-GDP ratio to set the tax revenue-to-output ratio to 0.31 and use the average of the general government net debt-to-GDP ratio to set the debt-to-output ratio to 1.19 in the initial steady state. Based on the corporate income tax rate data summarized in Table 1 of De Mooij and Saito (2014), we set $\tau^k=0.32$. While the statutory consumption tax rate is now 10 percent, we set $\tau^c=0.07$ to reflect the average from 2010 to 2019. Given the tax revenue-to-output ratio, and the consumption and capital income tax rates, we have $\tau^l=0.24$. For a transfers-to-output of 0.036 and given other fiscal values, the government budget constraint implies that the government purchase-to-output ratio is 0.23. The structural parameters are set to those used in the baseline model.

Based on the recommendation of International Monetary Fund (2018), we set $\tau^{c,max}=0.15$, when simulating Japan's fiscal limit distribution. The reason is that the consumption tax rate is assumed to likely be the main instrument for raising the future primary surplus in Japan. Other fiscal variables are set as in the initial steady state. Figure 10 plots the simulated fiscal limit distribution for Japan. In the context of our model, the distribution suggests that at the current net government debt of 153 percent of GDP (the net debt level in 2018), there exists a nontrivial probability (about 0.1) that the government will switch to the fiscal adjustment regime.

Figure 11 plots the impulse responses to a persistent two-percentage-point cut in the capital income tax rate under three initial debt levels: 119 percent of output (the historical average), 150 percent (roughly the current debt burden), and 200 percent (a very high debt scenario). Table 4 summarizes the output, consumption, and investment multipliers as computed by (14).

Similarly to the baseline simulations with a potential policy reversal, the expansionary effects of a capital income tax cut diminish when debt is rising. When agents place an increasing switching probability to the fiscal adjustment regime, an expected higher consumption tax rate lowers Tobin's q, indicating a decrease in the value of the installed capital from investment. To see this, note that equation (C.2) in 7 in the model with consumption taxes is modified as

$$\lambda_t = \frac{c_t^{-\sigma}}{(1+\tau_t^c)}. \tag{18}$$

Tobin's q, as described by (C.4), implies that the right-hand-side term, $E_t \frac{\lambda_{t+1}}{\lambda_t} = E_t \frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c}$. With a higher expected consumption tax rate, this means that the Tobin's q is lower, inducing agents to substitute away from current investment into consumption. When the current debt level is sufficiently high, this effect can dominate the investment incentives provided by a capital income tax cut and make current investment respond negatively, as shown by the dotted-dashed lines in Figure 11.

Note that in the baseline simulation, higher initial debt makes the real interest rate increase less because aggregate goods demand does not increase as much when agents expect higher future capital income taxes (see Figure 7). While this channel still operates in the model with consumption tax adjustment, the real interest rate is also affected by the expected consumption tax rate. A higher initial debt leads to a bigger increase in the real interest rate instead. With higher debt, the future consumption tax rate is expected to rise more. This implies that the relative price of future goods is expected to increase more, which drives the real interest rate more up relative to the case with less government debt.

6 Sensitivity Analysis

To see if the fiscal state-dependent effects of capital income tax cuts are robust to alternative parameterization and modeling assumptions, we pursue a variety of sensitivity analysis with respect to fiscal adjustment calibrations and duration, regime- switching probability, and an alternative fiscal limit distribution.

6.1 Fiscal Adjustment Speed and Debt Target

First, we investigate different values of γ_τ and $\bar{b}$ in (10). The output multipliers in Table 5 are under $\gamma_\tau = 0.01$ (compared to 0.005 in the baseline) and the targeted debt-to-output ratio is 0.9 (compared to 0.7 in the baseline). When the initial debt is relatively low, the size of multipliers does not change from the baseline as agents place zero probability of switching to the fiscal adjustment regime. Thus, we focus on initial debt ratios of 80 and 120 percent.

As expected, a higher adjustment magnitude ($\gamma_\tau = 0.01$) leads to a smaller expansionary effect for a given initial debt level. A higher γ_τ means that once a policy reversal occurs, the government facilitates the fiscal adjustment to reach a given debt target. Conditional on a given initial debt level, this decreases the expected investment return and produces a less expansionary capital income tax cut compared to the baseline with $\gamma_\tau = 0.005$.

In addition, conditional on the same initial debt level, the last column of Table 5 shows a higher debt target that leads to a more expansionary capital income tax cut. A higher debt target means that the fiscal adjustment magnitudes in the fiscal adjustment regime are smaller. The difference in the output multipliers between the higher debt target at 0.9 is trivial when the initial debt ratio is 80 percent, but is more pronounced when the initial debt ratio is 120 percent.

6.2 Average Duration of Fiscal Adjustment

Next, we explore how the average duration of consolidation episodes affects the capital income tax cut effects. The parameter p_2, in the regime transition matrix governs the average consolidation length. The baseline analysis assumes four years ($p_2 = 0.9375$), and the sensitivity analysis assumes $p_2 = 0.975$, or an average duration of ten years (Table 6).

An expected longer duration of the consolidation period makes a capital income tax cut slightly more contractionary when the initial debt ratio is 120 percent. The one-year (five-year) cumulative output multiplier is 0.26 (0.55), compared to 0.17 (0.42) in the baseline analysis. As agents expect a longer duration of the fiscal consolidation regime, this implies that the expected future capital income tax rates are higher than in the baseline case, leading to a more contractionary capital income tax cut when the debt ratio is high. As the economy is currently at the tax cut regime, the average duration of the fiscal adjustment only plays a role when the probability of switching to the fiscal adjustment regime is sufficiently high. When the initial debt ratio is 80 percent, the effects of a longer fiscal consolidation horizon from four to ten years are much smaller. The one-year (five-year) cumulative output multiplier is -0.49 (-0.66), compared to -0.51 (-0.71) in the baseline.

6.3 Alternative Fiscal Limit Distributions

The baseline analysis simulates the fiscal limit distribution for the U.S. federal government, assuming that government transfers will be gradually reduced following the projection by the CBO (see Section 4). We now assume that the transfers-to-output ratio would stabilize at a higher level—0.165, the end of 20-year projection value by the CBO. Higher transfer spending lowers future primary surplus, shifting the fiscal limit distribution to the left. As shown by the dashed line in Figure 6, the mean of the fiscal limit distribution lowers from 1.44 in the baseline analysis to 0.90.

With lower fiscal limits, agents place a higher probability to switch to the fiscal adjustment regime for a given debt ratio. As shown in the last column of Table 6, even at an initial debt ratio of 80 percent, the capital income tax cut becomes barely expansionary, with the one-year cumulative output multiplier at -0.05. When the initial debt ratio is 120 percent, the tax cut becomes quite contractionary with the one-year multiplier at 0.43, compared to 0.17 in the baseline analysis.

7 Conclusion

We examine the macroeconomic effects of a capital income tax cut, accounting for the fiscal state in terms of government indebtedness and its future debt repayment capacity. Empirically, we find that the U.S. federal capital income tax cuts are expansionary in a low-debt state and less so or even turn contractionary in a high-debt state. Theoretically, we find that fiscal state-dependent capital income tax effects can be driven by the expectations of future fiscal adjustments. In the simulations for a capital income tax cut in the U.S., the cumulative five-year output multiplier is -1 with an initial government debt at 45 percent of GDP, is only -0.7 with an initial government debt at 80 percent of GDP (roughly the current net federal debt level), and turns contractionary when debt reaches 120 percent. The fiscal state-dependent tax effects are robust when the expected fiscal adjustment is consumption tax increases, as in the simulation for Japan. These results illustrate that tax policy effects are highly nonlinear, and the fiscal state is important to consider when assessing fiscal policy effects.

One major component in the U.S. 2017 Tax Act is corporate tax reductions. Preliminary evidence shows that its growth benefits and the stimulative effect on investment may be limited (e.g., Gravelle and Marples, 2019). Kopp *et al.* (2019) attribute the reduced investment responses to rising corporate market power. Our paper provides an alternative explanation: as the fiscal state of the federal government has deteriorated, expectations of future fiscal adjustments to stabilize debt can dampen the expansionary effects of a capital income tax cut.

Horizon/ Initial debt	***low-debt***	***high-debt***
	output multiplier	
h=4	1.6	-0.11
	$[-10.84, 12.62]$	$[-0.17, -0.06]$
h=8	-0.36	-0.14
	$[-1.24, -0.12]$	$[-0.23, -0.09]$
h=12	-0.07	-0.38
	$[-0.83, 0.01]$	$[-0.47, -0.26]$
h=16	-0.03	-0.85
	$[-0.68, 0.06]$	$[-2.1, -0.6]$
h=20	0.01	1.1
	$[-0.66, 0.35]$	$[-1.08, 1.9]$

Table 1: **Estimated cumulative multipliers for the U.S. corporate income tax changes: baseline specification**. The brackets contain the 90-percent confidence intervals.

	parameters/fiscal values in the initial steady state	
β	the discount factor	0.99
σ	inverse of intertemporal elasticity of substitution for consumption	1.38
φ	inverse of Frisch labor elasticity	1.83
δ	capital depreciation rate for capital	0.025
α	capital income share	0.36
κ	investment adjustment cost parameter	1.7
a	normalized TFP	1
p_2	probability to continue stay in $\Re 2$	0.9375
γ_τ	capital tax response to debt	0.005
γ_z	transfer response to debt	0.04
ρ_β	AR(1) coefficient for β_t	0.8
ρ_a	AR(1) coefficient for a_t	0.9
σ_β	standard deviation of ε^β	0.005
σ_a	standard deviation of ε^a	0.01
τ^k	capital income tax rate	0.208
τ^l	labor income tax rate	0.204
$\frac{b}{4y}$	net public debt-to-annual output ratio	0.45
$\frac{g}{y}$	government spending-to-output ratio	0.08
$\frac{z}{y}$	government transfers-to-output ratio	0.11

Table 2: **Baseline calibration**.

initial debt	*45% of output*	*80% of output*	*120% of output*
	output multiplier		
impact	−0.53	−0.45	0.13
1 year	−0.61	−0.51	0.17
5 years	−0.95	−0.71	0.42
	consumption multiplier		
impact	0.94	0.79	−0.24
1 year	0.86	0.71	−0.25
5 years	0.50	0.35	−0.27
	investment multiplier		
impact	−1.48	−1.24	0.37
1 year	−1.47	−1.22	0.42
5 years	−1.44	−1.06	0.70

Table 3: **Cumulative multipliers: the baseline model with a policy reversal**.

initial debt	*119% of output*	*150% of output*	*200% of output*
	output multiplier		
impact	−0.56	−0.40	0.19
1 year	−0.64	−0.45	0.24
5 years	−1.00	−0.61	0.53
	consumption multiplier		
impact	0.82	0.59	−0.29
1 year	0.74	0.52	−0.29
5 years	0.38	0.21	−0.26
	investment multiplier		
impact	−1.38	−0.99	0.48
1 year	−1.38	−0.97	0.53
5 years	−1.38	−0.82	0.79

Table 4: **Cumulative multipliers: the alternative model with consumption tax increases**.

scenario	baseline ($\gamma^\tau = 0.005$, debt target 0.7)	$\gamma^\tau = 0.01$	debt target 0.9
	initial debt: 80% of output		
impact	−0.45	−0.42	−0.46
1 year	−0.51	−0.47	−0.53
5 years	−0.71	−0.62	−0.75
	initial debt: 120% of output		
impact	0.13	0.41	0.04
1 year	0.17	0.50	0.07
5 years	0.42	1.00	0.25

Table 5: **Sensitivity analysis: a faster fiscal adjustment speed and a higher debt target.**

scenario	baseline	$p_2 = 0.975$	higher future transfers
		initial debt: 80% of output	
impact	-0.45	-0.43	-0.06
1 year	-0.51	-0.49	-0.05
5 years	-0.71	-0.66	0.02
		initial debt: 120% of output	
impact	0.13	0.21	0.37
1 year	0.17	0.26	0.43
5 years	0.42	0.55	0.74

Table 6: **Sensitivity analysis: longer adjustment duration and an alternative fiscal limit distribution.**

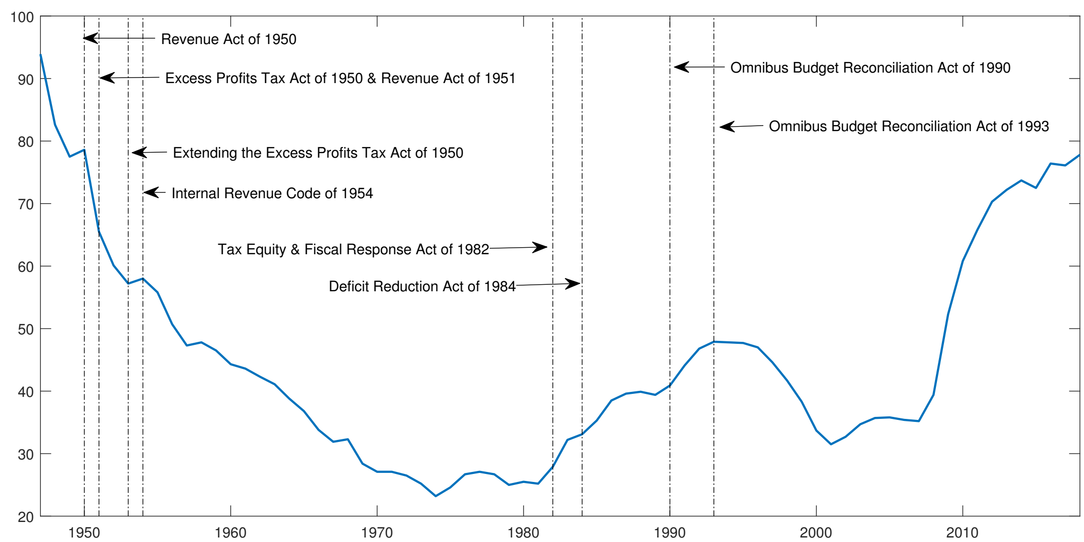

Figure 1: **Federal tax legislations driven by deficit and debt concerns against government debt.** The vertical dashed lines indicate the timing of a tax legislation enacted. The blue line is U.S. gross federal debt held by the public in percent of GDP (Table 7.1 of Historical Tables (Office of Management and Budget, 2018)).

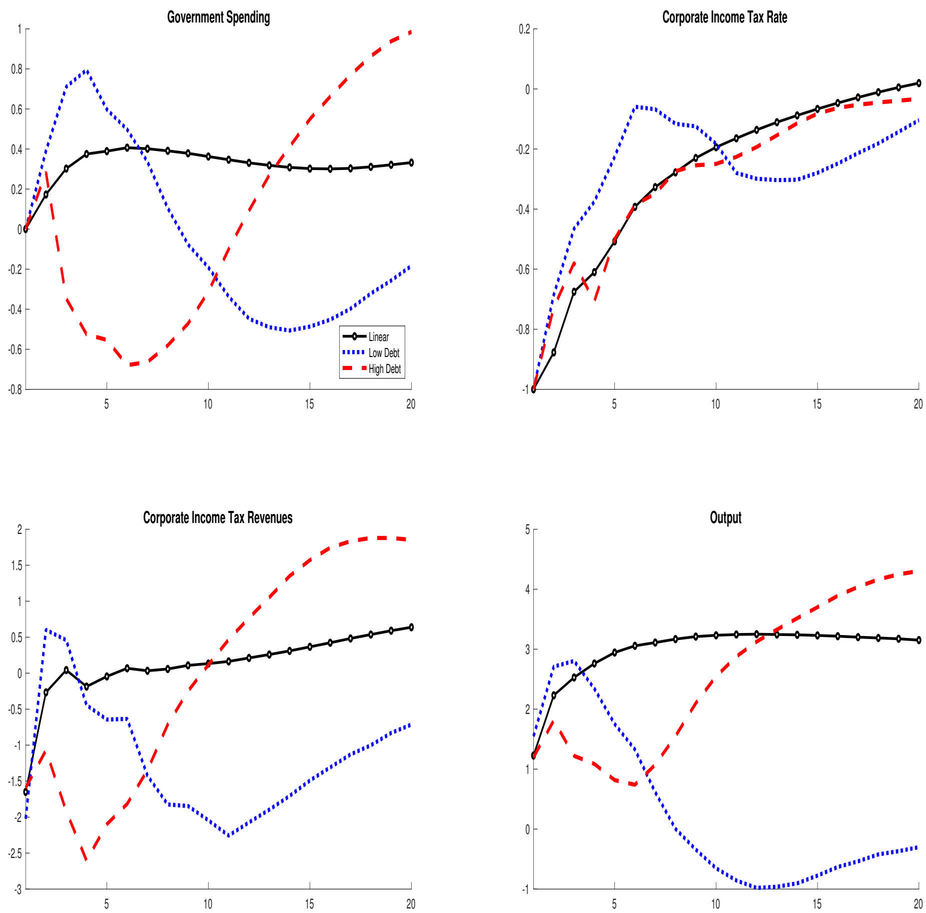

Figure 2: **Responses of a federal corporate income tax cut: linear vs. nonlinear models.** Black lines are the GIRF to a federal corporate income tax cut for the linear VAR, the red (blue) lines are the GIRFs to a federal corporate income tax cut when federal government net debt is at a high- (low-) debt state for the STVAR. The y-axis is in percent deviation from the path without the tax shock. The x-axis is in quarters after the shock.

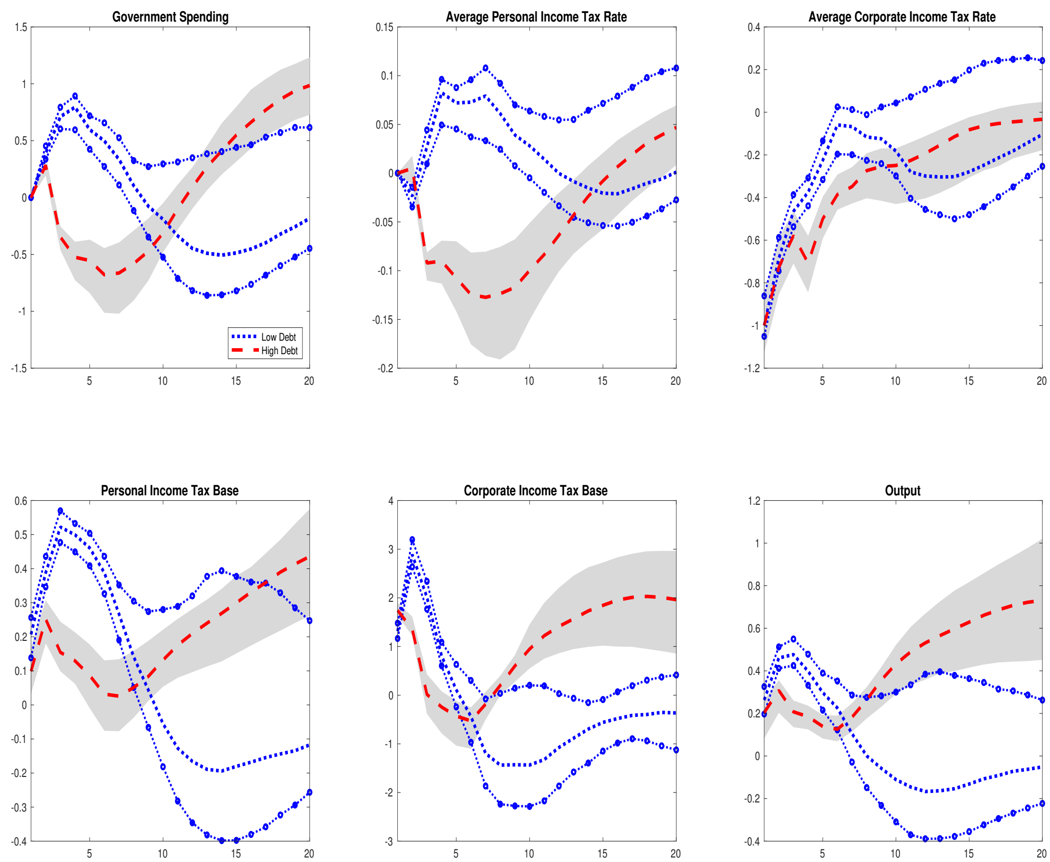

Figure 3: **Responses of a federal corporate income tax cut.** The red (blue) lines are the generalized impulse response functions (GIRFs) to a federal corporate income tax cut when federal government net debt is at a high- (low-) debt state. See Figure 2 for axis units.

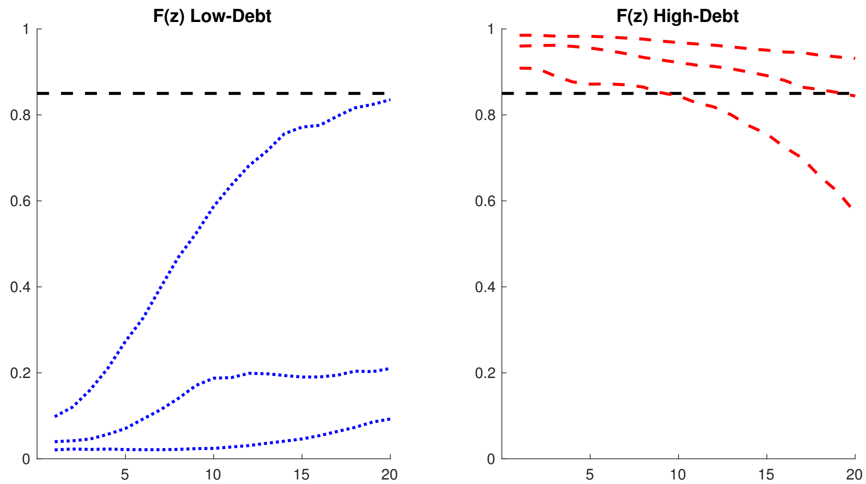

Figure 4: **Probability of being in a high-debt state.** The red (blue) lines are when debt is at a high- (low-) debt state. The dashed lines are the 90-percent confidence intervals. The x-axis is in quarters.

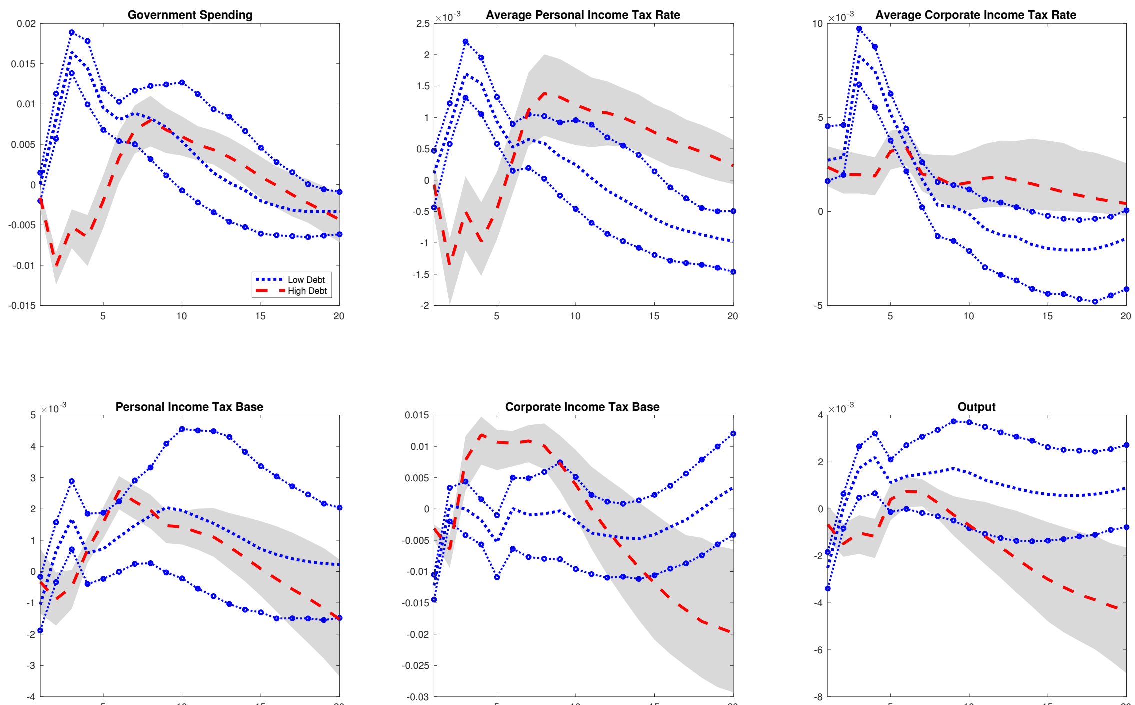

Figure 5: **Responses of an unanticipated corporate income tax cut: narratively constructed shocks (ordered first).** The red (blue) lines are the GIRFs to a federal corporate income tax cut when federal government net debt is at a high- (low-) state. The dashed lines are the 90-percent confidence intervals. See Figure 2 for axis units.

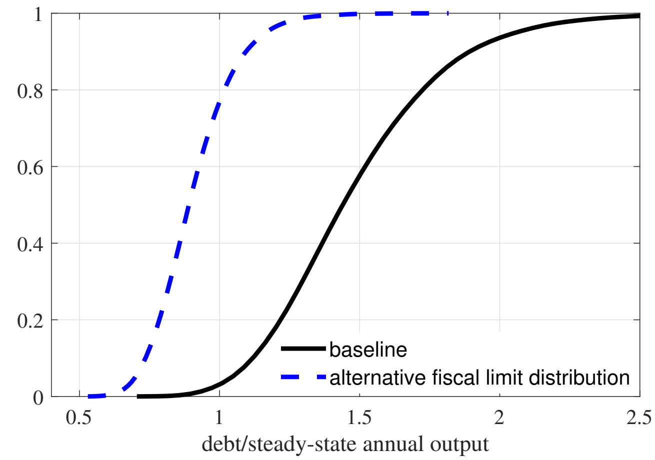

Figure 6: **Simulated fiscal limit distributions for the U.S. federal government in net debt.** The alternative simulation assumes higher future transfers. The fiscal limit distribution is simulated using the U.S. federal government fiscal data.

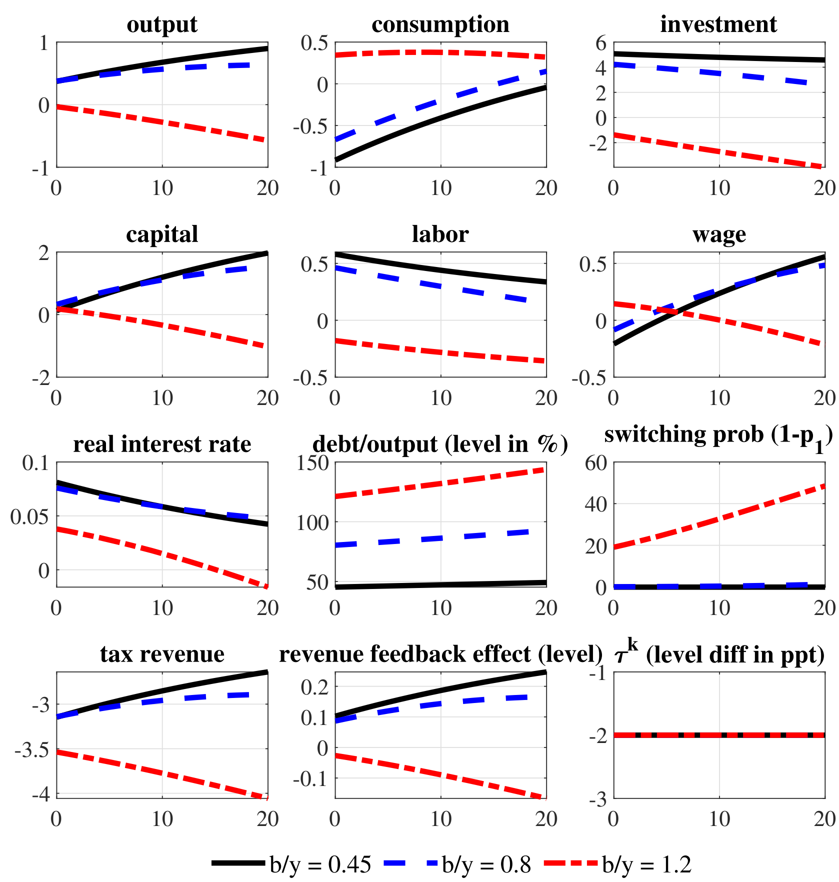

Figure 7: **Impulse responses to a capital income tax rate cut with different initial debt levels: expected fiscal adjustment through a policy reversal.** Unless specified in parentheses, the units are in percent deviation from the path without the tax cut. The x-axis is in quarters after the tax cut.

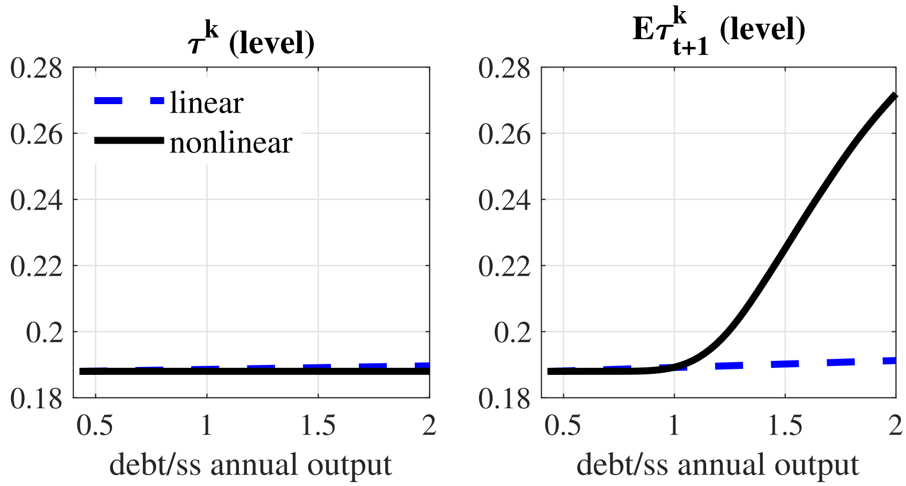

Figure 8: **Policy functions under different government debt ratios.** The left panel is the realized capital income tax rate, and the right panel is the expected capital income tax rates of next period.

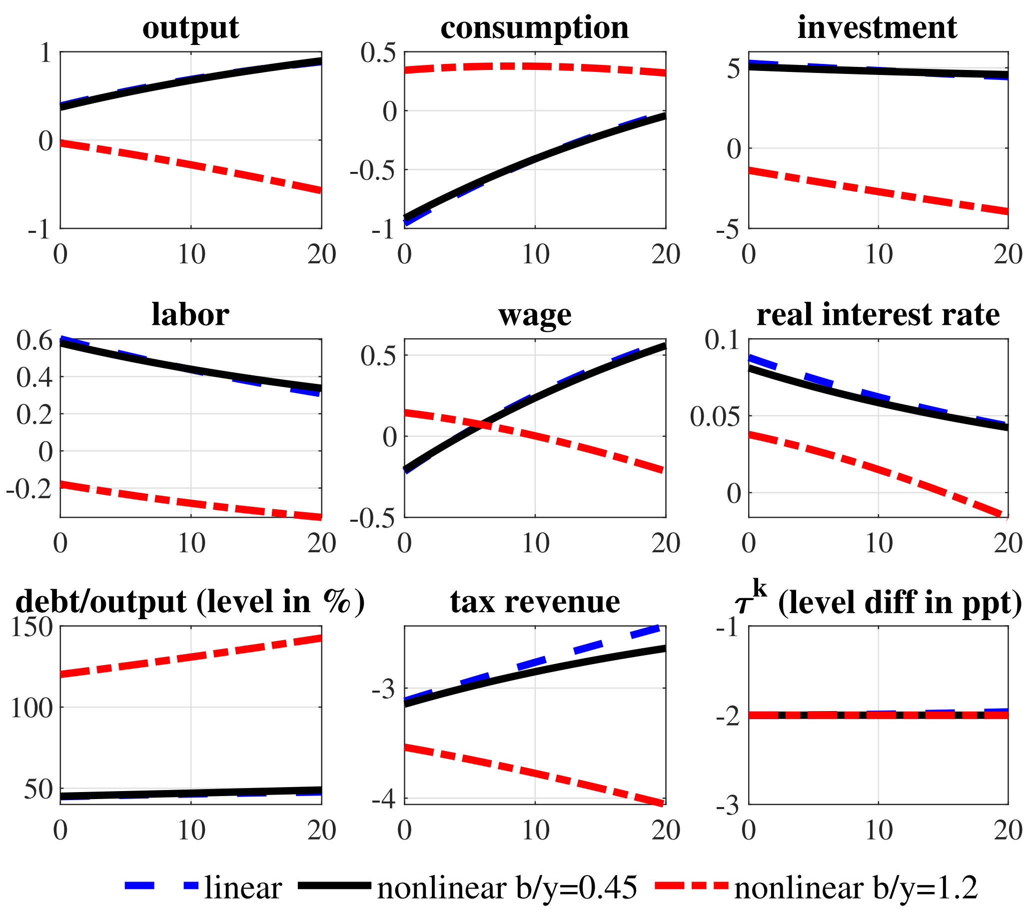

Figure 9: **Impulse responses: linear vs. nonlinear models**. The y-axes are in percent deviation from the deterministic steady state unless specified in parentheses.

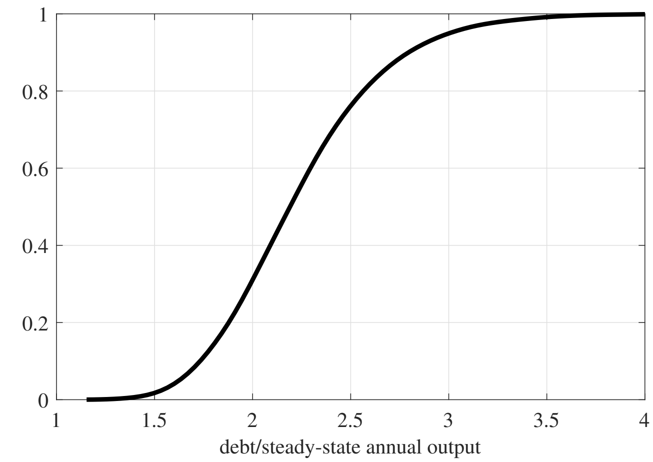

Figure 10: **A simulated fiscal limit distribution for the general government of Japan in net debt.**

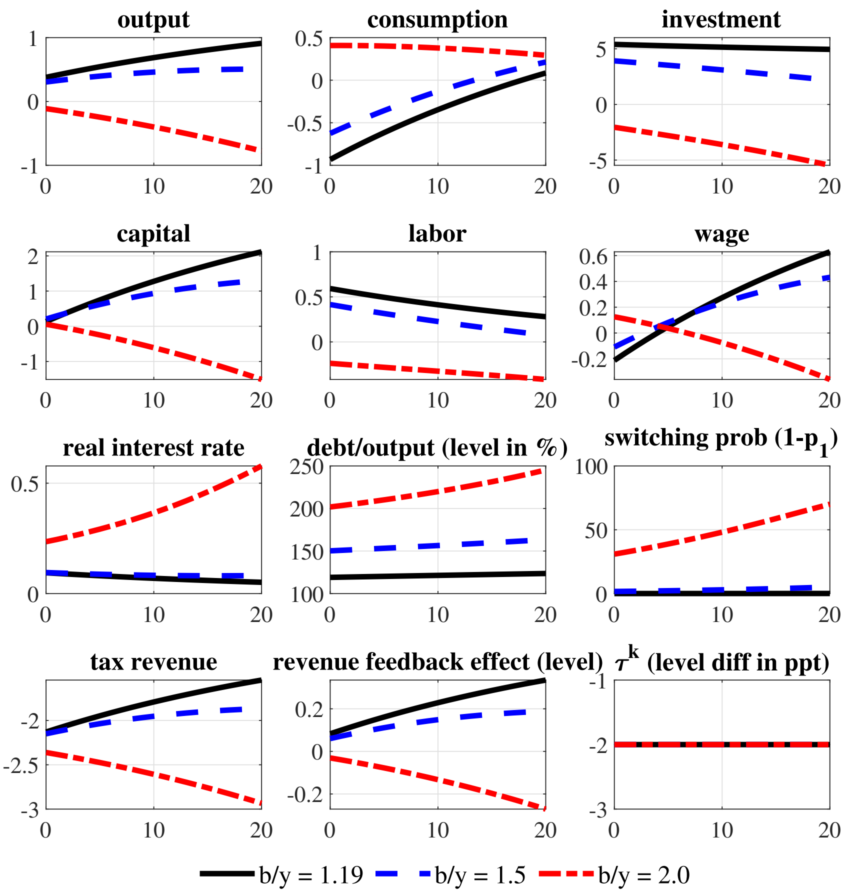

Figure 11: **Impulse responses to a capital income tax rate cut with different initial debt levels: expected fiscal adjustment through a consumption tax rate increase.** Unless specified in parentheses, the units are in percent deviations from the path without the tax cut. The x-axis is in quarters after the tax cut.

References

Ajello, A. (2016). Financial intermediation, investment dynamics, and business cycle fluctuations. *American Economic Review*, **106** (8), 2256–2303.

Alesina, A., Azzalini, G., Favero, C. and Giavazzi, A., Miano (2018). Is it the "how" or the "when" that matters in fiscal adjustments? *IMF Economic Review*, **66** (1), 144–188.

Arin, K. P., Koray, F. and Spagnolo, N. (2015). Fiscal multipliers in good times and bad times. *Journal of Macroeconomics*, **44** (June), 303–311.

Auerbach, A. and Gorodnichenko, Y. (2012). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, **4** (2), 1–27.

— and — (2013). *Fiscal Multipliers in Good Times and Bad Times*, pp. 63–98. In Fiscal Policy after the Financial Crisis, edited by A. Alesina and F. Giavazzi, University of Chicago Press.

Barro, R. J. and Redlick, C. J. (2011). Macroeconomic effects from government purchases and taxes. *Quarterly Journal of Economics*, **123** (1), 51–102.

Bertola, G. and Drazen, A. (1993). Trigger points and budget cuts: Explaining the effects of fiscal austerity. *American Economic Review*, **83** (1), 11–26.

Bi, H. (2012). Sovereign default risk premia, fiscal limits, and fiscal policy. *European Economic Review*, **56** (3), 389–410.

— (2017). Fiscal sustainability: A cross-country analysis. Economic Review, Fourth Quarter, 5-35, Federal Reserve Bank of Kansas City.

—, Leeper, E. M. and Leith, C. (2013). Uncertain fiscal consolidations. *Economic Journal*, **123** (February), F31–F63.

—, Shen, W. and Yang, S.-C. S. (2016). Debt-dependent effects of fiscal expansions. *European Economic Review*, **88**, 142–157.

—, — and — (2019). Fiscal implications of interest rate normalization in the United States. IMF Working Paper 19/90, International Monetary Policy, Washington, D.C.

Blanchard, O. J. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *Quarterly Journal of Economics*, **117** (4), 1329–1368.

Braun, R. A. (1994). Tax disturbances and real economic activity in the postwar United States. *Journal of Monetary Economics*, **33** (June), 441–462.

Bureau of Economic Analysis (2018). National Income and Product Accounts.

Caggiano, G., Castelnuovo, E., Colombo, V. and Nodari, G. (2015). Estimating fiscal multipliers: News from a non-linear world. *The Economic Journal*, **125** (584), 746–776.

Candelon, B. and Liebman, B. L. (2015). Fiscal policy in good and bad times. *Journal of Economic Dynamics & Control*, **37** (12), 2679–2694.

Canzoneri, M., Collard, F., Dellas, H. and Diba, B. (2016). Fiscal multipliers in recessions. *The Economic Journal*, **590** (February), 75–108.

Chamley, C. (1986). Optimal taxation of capital income in general equilibrium with infinite lives. *Econometrica*, **54** (3), 607–622.

Chernozhukov, V. and Hong, H. (2003). An MCMC approach to classical estimation. *Journal of Econometrics*, **115** (2), 293–346.

Coleman, W. J., II (1990). Solving the stochastic growth model by policy-function iteration. *Journal of Business and Economic Statistics*, **8** (1), 27–29.

Congressional Budget Office (2017). The 2017 long-term budget outlook. The U.S. Congress, Washington, D.C., available at https://www.cbo.gov/publication/52480.

Congressional Budget Office (2018a). The 2018 long-term budget outlook. The U.S. Congress, Washington, D.C.

Congressional Budget Office (2018b). The long-term budget outlook under alternative scenarios for fiscal policy. The U.S. Congress, Washington, D.C.

Corsetti, G., Meier, A. and Müller, G. J. (2012). Fiscal stiumulus with spending reversals. *Review of Economics and Statistics*, **94** (4), 878–895.

Davig, T. (2004). Regime-switching debt and taxation. *Journal of Monetary Economics*, **51** (4), 837–859.

— and Foerster, A. (forthcoming). Uncertainty and fiscal cliffs. *Journal of Money, Credit and Banking*.

— and Leeper, E. M. (2011). Monetary-fiscal policy interactions and fiscal stimulus. *European Economic Review*, **55** (2), 211–227.

De Mooij, R. and Saito, I. (2014). Japan's corporate income tax: Facts, issues and reform options. IMF Working Paper 14/138, International Monetary Fund, Washington, DC.

Demirel, U. D. (2016). The short-term effects of tax changes—Evidence for state dependence. CBO Working Paper 2016-03, Congresional Budget Office, U.S. Congress.

Devries, P., Guajardo, J., Leigh, D. and Pescatori, A. (2011). A new action-based dataset of fiscal consolidation. IMF Working Paper 11/128, International Monetary Fund, Washigngton, D.C.

Erceg, C. J. and Lindé, J. (2014). Is there a fiscal free lunch in a liquidity trap? *Journal of the European Economic Association*, **12** (1), 73–107.

Eskandari, R. (2019). State-dependent macroeconomic effects of tax changes. Working Paper, available at SSRN: https://ssrn.com/abstract=3374984.

Favero, C. and Giavazzi, F. (2007). Debt and the effects of fiscal policy. NBER Working Paper 12822.

— and — (2012). Measuring tax multipliers: The narrative method in fiscal VARs. *American Economic Journal: Economic Policy*, **4** (2), 69–94.

Fernández-Villaverde, J., Gordon, G., Guerrón-Quintana, P. and Rubio-Ramírez, J. (2015). Nonlinear adventures at the zero lower bound. *Journal of Economic Dynamics & Control*, **57** (August), 180–204.

Forni, L., Monteforte, L. and Sessa, L. (2009). The general equilibrium effects of fiscal policy: Estimates for the euro area. *Journal of Public Economics*, **93** (3-4), 559–585.

Fotiou, A. (2019). Non-linearities and fiscal policy. *EUI Working Papers*, **MWP** (2019/11), 1–55.

Gourio, F. (2012). Disaster risk and business cycles. *American Economic Review*, **102** (6), 2734–2766.

Gravelle, J. G. and Marples, D. J. (2019). The Economic Effects of the 2017 Tax Revision: Preliminary Observations. CRS Report R45736, Congressional Research Service, the U.S. Congress.

Huidrom, R., Kose, M. A., Lim, J. J. and Ohnsorge, F. L. (2016). Do fiscal multipliers depend on fiscal positions? Policy Research Working Paper 7724, World Bank Group.

Ilzetzki, E., Mendoza, E. G. and Végh, C. A. (2013). How big (small?) are fiscal multipliers? *Journal of Monetary Economics*, **60** (2), 239–254.

International Monetary Fund (2018). Japan—Staff Report for the 2018 Article IV Consultation. IMF Country Report No. 18/333, Washington, D.C.

International Monetary Fund (2019). World Economic Outlook, April. Chapter 1: Global Prospects and Policies, Washington, D.C.

Ireland, P. N. (1994). Supply-side economics and endogenous growth. *Journal of Monetary Economics*, **33** (3), 559–571.

Jones, J. B. (2002). Has fiscal policy helped stabilize the postwar U.S. economy? *Journal of Monetary Economics*, **49** (May), 709–746.

Judd, K. L. (1985). Redistributive taxation in a simple perfect foresight model. *Journal of Public Economics*, **28** (1), 59–83.

— (1987). The welfare cost of factor taxation in a perfect-foresight model. *Journal of Political Economy*, **95** (4), 675–709.

Kirchner, M., Cimadomo, J. and Hauptmeier, S. (2010). Transmission of government spending shocks in the euro area time variation and driving forces. Working Paper Series No. 1219, European Central Bank.

Koop, G., Pesaran, M. and Potter, S. (1996). Impulse response analysis in non-linear multivariate models. *Journal of Econometrics*, **74** (1), 119–47.

Kopp, E., Leigh, D., Mursula, S. and Tambunlertchai, S. (2019). U.S. Investment since the Tax Cuts and Jobs Act of 2017. IMF Working Paper 19/120, International Monetary Fund, Washington, D.C.

Leeper, E. M., Plante, M. and Traum, N. (2010). Dynamics of fiscal financing in the United States. *Journal of Econometrics*, **156** (2), 304–321.

—, Walker, T. B. and Yang, S.-C. S. (2013). Fiscal foresight and information flows. *Econometrica*, **81** (3), 1115–1145.

— and Yang, S.-C. S. (2008). Dynamic scoring: Alternative financing schemes. *Journal of Public Economics*, **92**, 159–182.

Mankiw, N. G. and Weinzierl, M. (2006). Dynamic scoring: A back-of-the-envelope guide. *Journal of Public Economics*, **90** (8-9), 1415–1433.

McGrattan, E. R. (1994). The macroeconomic effects of distortionary taxation. *Journal of Monetary Economics*, **33** (3), 573–601.

Mertens, K. and Ravn, M. (2013). The dynamic effects of personal and corporate income tax changes in the United States. *American Economic Review*, **103** (4), 1212–1247.

— and Ravn, M. O. (2012). Empirical evidence on the aggregate effects of anticipated and unanticipated us tax policy shocks. *American Economic Journal: Economic Policy*, **4** (2), 145–181.

Mountford, A. and Uhlig, H. (2009). What are the effects of fiscal policy shocks? *Journal of Applied Econometrics*, **24** (6), 960–992.

Nickel, C. and Tudyka, A. (2014). Fiscal stimulus in times of high debt: Reconsidering multipliers and twin deficits. *Journal of Money, Credit and Banking*, **46** (7), 1313–1344.

Office of Management and Budget (2018). Historical tables. Retrived from https://www.whitehouse.gov/omb/historical-tables/, August 25, 2018.

Perotti, R. (2008). *In Search of the Transmission Mechanism of Fiscal Policy*, pp. 169–226. In NBER Macroeconomics Annual 2007, Volumn 22, edited by D. Acemoglu, K. Rogoff, and M. Woodford, University of Chicago Press.

Plante, M., Richter, A. W. and Throckmorton, N. A. (2018). The zero lower bound and endogenous uncertainty. *The Economic Journal*, **128** (611), 1730–1757.

Ramey, V. A. (2019). Ten years after the financial crisis: What we learned from the Renaissance in fiscal research? *Journal of Economic Perspective*, **33** (2), 89–114.

— and Zubairy, S. (2018). Government spending multipliers in good times and in bad: Evidence from U.S. historical data. *Journal of Political Economy*, **126** (2), 850–901.

Romer, C. D. and Romer, D. H. (2010). The macroeconomic effects of tax changes: Estimated based on a new measure of fiscal shocks. *American Economic Review*, **100** (3), 763–801.

Sims, E. and Wolff, J. (2018). The state-dependent effects of tax shocks. *European Economic Review*, **107** (C), 57–85.

SMETS, F. and WOUTERS, R. (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review*, **97** (3), 586–606.

SUTHERLAND, A. (1997). Fiscal crises and aggregate demand: Can high public debt reverse the effects of fiscal policy? *Journal of Public Economics*, **65** (2), 147–162.

TERSVIRTA, T., TJOSTHEIM, D. and GRANGER, C. (2010). *Modelling Nonlinear Economic Time Series*. Oxford: Oxford University Press.

TRAUM, N. and YANG, S.-C. S. (2011). Monetary and fiscal policy interactions in the post-war U.S. *European Economic Review*, **55** (1), 140–164.

YANG, S.-C. S. (2009). A chronology of federal income tax policy: 1947-2009. CAEPR Working Paper No. 2007-021, Center for Applied Economics and Policy Research, Indiana University Bloomington.

ZUBAIRY, S. (2014). On fiscal multipliers: Estimates from a medium scale DSGE model. *International Economic Review*, **55** (1), 169–195.

Appendix A Data Sources

Output: Real GDP (NIPA Table 1.1.3 line 1).

Government spending: Real federal government consumption expenditures and gross investment (NIPA Table 1.1.3 line 22).

Personal income tax base: Personal income (NIPA Table 2.1 line 1) less government transfers (NIPA Table 2.1 line 17) plus contributions for government social insurance (NIPA Table 3.2 line 11), deflated by the GDP deflator (NIPA Table 1.1.9 line 1).

Corporate income tax base: Corporate profits (NIPA Table 1.12 line 13) less Federal Reserve Bank profits (NIPA Tables 6.16 B-C-D), deflated by the GDP deflator (NIPA Table 1.1.9 line 1).

Average personal income tax rate: Sum of federal personal current taxes (NIPA Table 3.2 line 3) and contributions for government social insurance (NIPA Table 3.2 line) divided by the nominal personal income tax base.

Average corporate income tax rate: Federal taxes on corporate income excluding Federal Reserve banks (NIPA Table 3.2 line 9) divided by the nominal corporate income tax base.

Debt: Federal debt is total public debt as percent of GDP (FRED, Federal Reserve Bank of Saint Louis).

Defense spending news: Valerie Ramey's news series (e.g., Ramey, 2019).

Narrative corporate income taxes: Mertens and Ravn narrative series (Mertens and Ravn, 2013).

Appendix B Empirical Results: Robustness Checks

To assess the robustness of our baseline specification and whether a corporate income tax cut results to a more expansionary effect in periods of low-debt, we proceed with further checks. Within our STVAR framework we report results for specifications in which we replace

Ramey's military news with alternative measures of fiscal news, or we change the ordering of the variables, or we treat a narratively identified measure of corporate taxes as our shock. The results of our checks include:

a) *The aggregate narratively identified tax news measure of Mertens and Ravn (2012).* This is the only case that we do not find a strong evidence of debt-dependent effects (Figure B.1). We observe that the output responses are debt-dependent around the 5th quarter, with output being more expansionary in periods of low debt, compared to periods of high debt.

b) *The aggregate narratively identified unanticipated tax measure.* The results for this specification are very close to our baseline specification (Figure B.2).

c) *The corporate narratively identified unanticipated income tax cut series, order first in our VAR specification and treated as the shock.* In both states the output is contractionary, but not statistically significantly different in the short run (Figure 5). After 4 quarters, the effect on output at the high-debt state remains negative, but turns positive for the low-debt state.

d) Finally, we conducted some checks in which we changed the ordering of the variables. Interestingly, when we order government spending as the 5th variable, in this case the effect on output is contractionary in a high-debt state (Figure B.4).

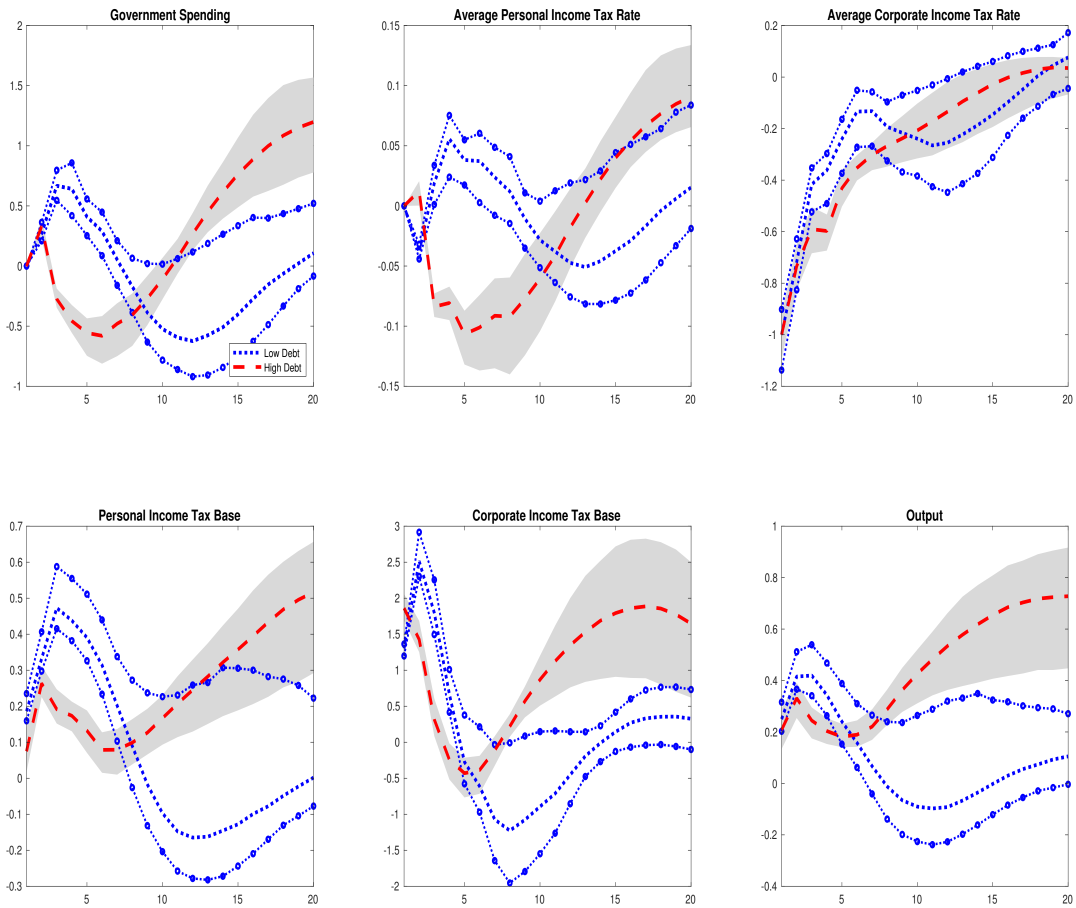

Figure B.1: **Generalized impulse response functions of a federal corporate income tax cut, with the aggregate tax news measure—narratively identified—included in the system.** The red (blue) lines are the GIRFs to a federal corporate income tax cut when federal government net debt is at a high- (low-) debt state. The dashed lines are the 90-percent confidence intervals.

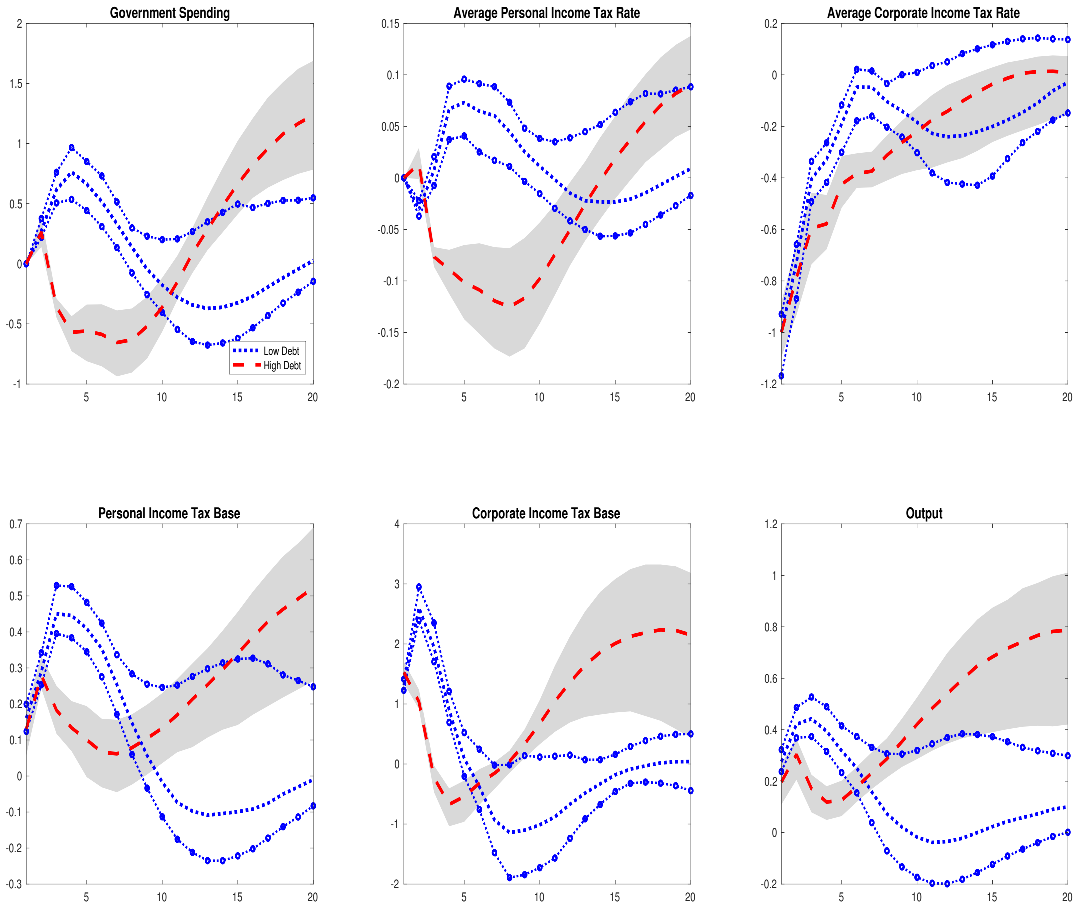

Figure B.2: **Generalized impulse response functions of a federal corporate income tax cut, with the aggregate unanticipated tax measure—narratively identified—included in the system.** The red (blue) lines are the GIRFs to a federal corporate income tax cut when federal government net debt is at a high- (low-) debt state. The dashed lines are the 90-percent confidence intervals.

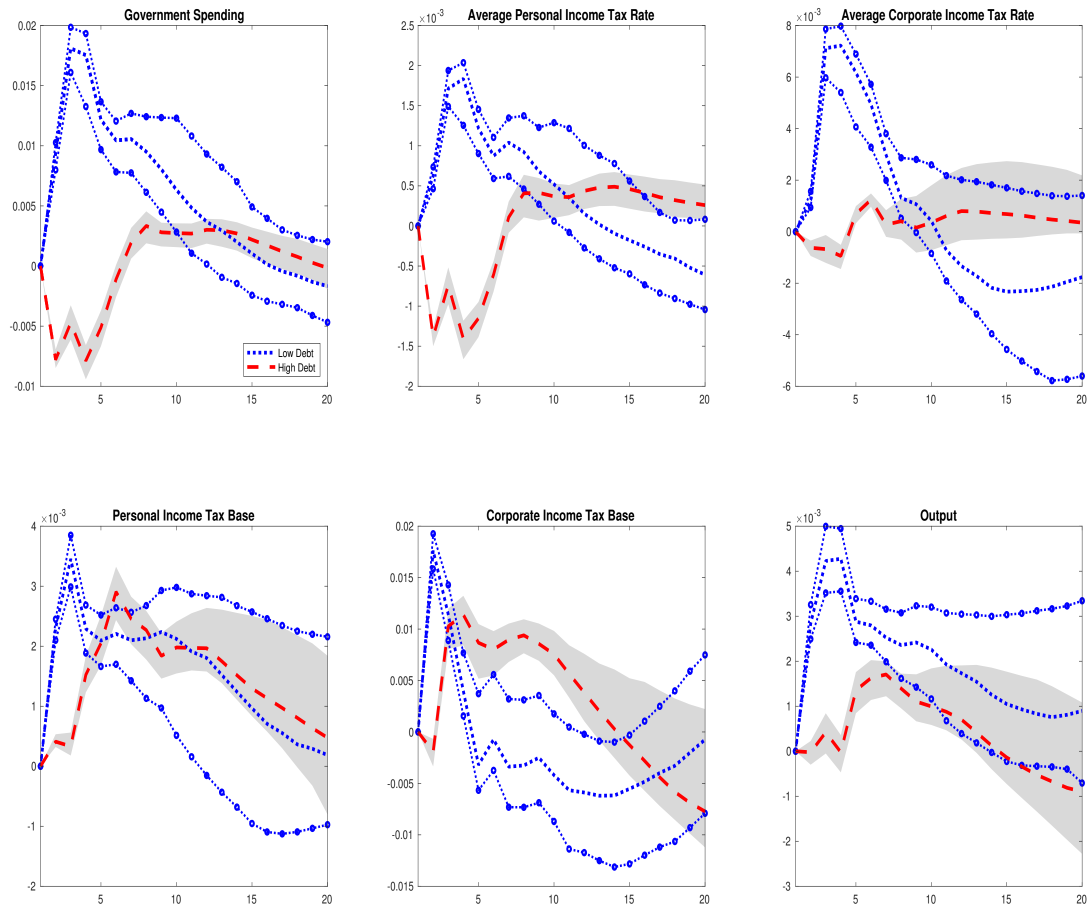

Figure B.3: **Generalized impulse response functions of an unanticipated corporate income tax cut, narratively identified shock, ordered last.** The red (blue) lines are the GIRFs to a federal corporate income tax cut when federal government net debt is at a high- (low-) debt state. The dashed lines are the 90-percent confidence intervals.

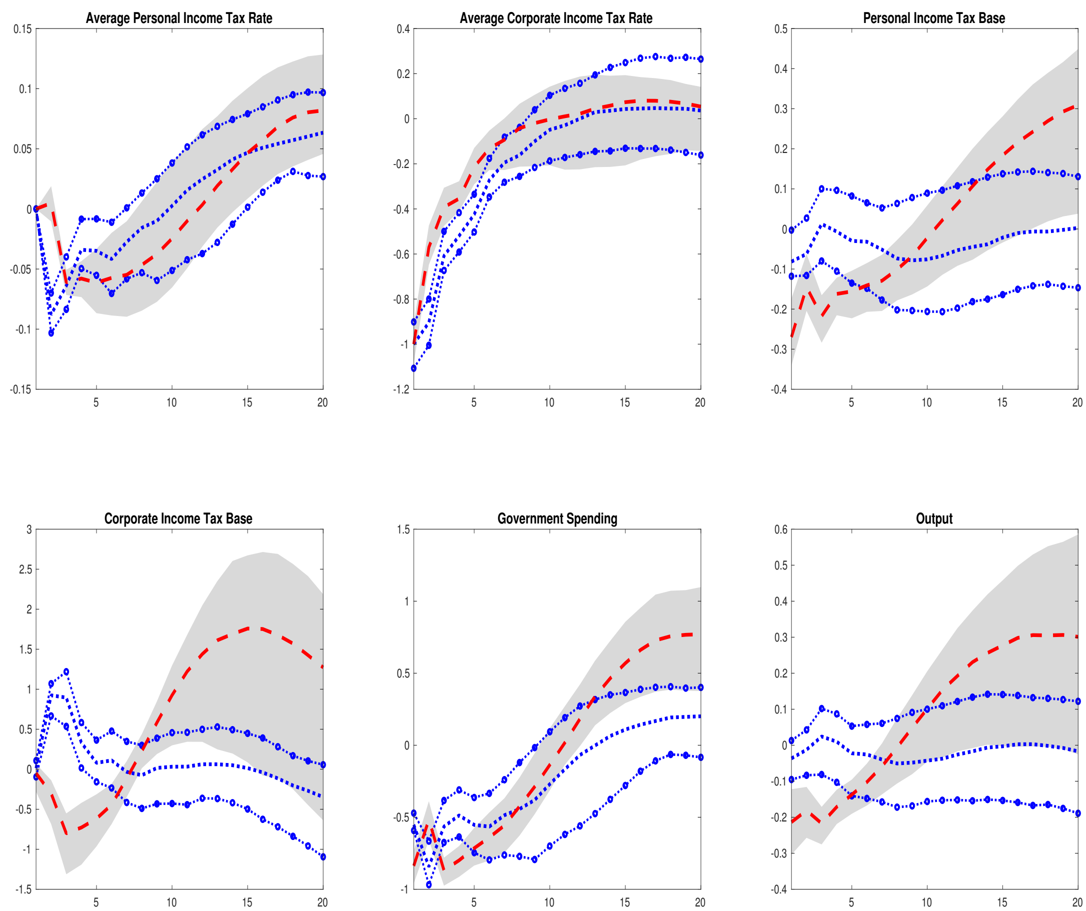

Figure B.4: **Generalized impulse response functions of a federal corporate income tax cut, with government spending ordered 5th.** The red (blue) lines are the GIRFs to a federal corporate income tax cut when federal government net debt is at a high- (low-) debt state. The dashed lines are the 90-percent confidence intervals.

Appendix C Model Solution

This appendix lists the equilibrium conditions of the baseline model and describes the procedure to solve the model fully nonlinearly.

Appendix C.1 Equilibrium Conditions

$$\lambda_t = c_t^{-\sigma} \tag{C.1}$$

$$l_t^{\varphi} = \lambda_t (1 - \tau^l) w_t \tag{C.2}$$

Let λ_t and ξ_t be the Lagrangian multipliers for the agent's budget constraint and the law of motion for capital. Also, define Tobin's Q as $TQ_t = \frac{\xi_t}{\lambda_t}$. Then,

$$1 = TQ_t \left[1 - \kappa \left(\frac{i_t}{k_{t-1}} - \delta \right) \right]. \tag{C.3}$$

$$TQ_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left\{ (1 - \tau_{t+1}^k) r_{t+1}^k + TQ_{t+1} \left[(1-\delta) + \kappa \left(\frac{i_{t+1}}{k_t} - \delta \right) \frac{i_{t+1}}{k_t} - \frac{\kappa}{2} \left(\frac{i_{t+1}}{k_t} - \delta \right) \right] \right\} \tag{C.4}$$

$$k_t = (1-\delta) k_{t-1} + i_t - \frac{\kappa}{2} \left(\frac{i_t}{k_{t-1}} - \delta \right)^2 k_{t-1} \tag{C.5}$$

$$\lambda_t q_t = \beta_{t+1} E_t \lambda_{t+1} \tag{C.6}$$

$$y_t = a_t k_{t-1}^{\alpha} l_t^{1-\alpha} \tag{C.7}$$

$$(1-\alpha) y_t = w_t l_t \tag{C.8}$$

$$\alpha y_t = r_t^k k_{t-1} \tag{C.9}$$

$$y_t = c_t + i_t + g_t \tag{C.10}$$

$$\tau^l w_t l_t + \tau_t^k r_t^k k_{t-1} + q_t b_t = g_t + b_{t-1} + z_t \tag{C.11}$$

$$\tau_t^l = \tau^l \tag{C.12}$$

$$g_t = g \tag{C.13}$$

Before a capital income tax cut, capital tax rate stays at the initial steady state, and debt is stabilized by transfers:

$$\tau_t^k = \tau^k \tag{C.14}$$

$$z_t = z - \gamma_z(b_{t-1} - b) \tag{C.15}$$

With a capital income tax cut, the capital income tax rate and transfers follow a Markov switching process,

$$\begin{cases} \tau_t^k = \tau^k - \varepsilon^{\tau^k}, & z_t = z & \text{for} \quad \mathcal{R}_t = 1, \\ \tau_t^k = \bar{\tau}^k + \gamma_\tau(b_{t-1} - \bar{b}), & z_t = \bar{z} - \gamma_z(b_{t-1} - \bar{b}) & \text{for} \quad \mathcal{R}_t = 2. \end{cases} \tag{C.16}$$

The regime index, $\mathcal{R}_t$, evolves according to the transition matrix

$$\begin{pmatrix} p_{1,t} & 1 - p_{1,t} \\ 1 - p_2 & p_2 \end{pmatrix}. \tag{C.17}$$

Appendix C.2 The Numerical Solution Method

The method discretizes the state space and finds a fixed point in decision rules for each point in the state space. The solutions converge to functions that map the minimum set of state variables into values of endogenous variables.

When solving the model, the minimum set of state variables is $\mathcal{S}_t = \{a_t, b_{t-1}, k_{t-1}, \mathcal{R}_t\}$.[20] Define the decision rules for hours as $l_t = f^l(\mathcal{S}_t)$ and debt as $b_t = f^b(\mathcal{S}_t)$. The decision rules are solved as follows.

1. Define the grid points by discretizing the state space. Make initial guesses for f_0^l and f_0^b over the state space.

2. At each grid point, solve the nonlinear model and obtain the updated rules f_i^l and f_i^b

[20] As we focus on the capital income tax cut effect in the simulation exercise, β_t is dropped from the state space to facilitate numerical convergence.

using the given rules f^l_{i-1} and f^b_{i-1}. Specifically:

(a) Before the capital income tax cut, derive τ^k_t and z_t using (C.14) and (C.15). With the capital income tax cut, derive τ^k_t and z_t using (C.16), given $\mathcal{R}_t$.

(b) Derive y_t, w_t, λ_t, and c_t in terms of a_t, k_{t-1}, and l_t using (C.1), (C.2), (C.7), and (C.8).

(c) Compute r^k_t, i_t, TQ_t, and k_t from (C.3), (C.5), (C.9), and (C.10).

(d) From (C.11), we can derive the bond price q_t.

(e) Use the simulated fiscal limit and current debt level, b_t, to derive the switching probability to the fiscal adjustment regime in the next period, $(1 - p_{1,t+1})$.

(f) Use linear interpolation to obtain $f^l_{i-1}(\mathcal{S}_{t+1})$ and $f^b_{i-1}(\mathcal{S}_{t+1})$, where the state vector is $\mathcal{S}_{t+1} = \{a_{t+1}, b_t, k_t, \mathcal{R}_{t+1}\}$. Then follow the above steps to solve λ_{t+1}, τ^k_{t+1}, r^k_{t+1}, TQ_{t+1}, and i_{t+1} for $\mathcal{R}_{t+1} = 1$ and $\mathcal{R}_{t+1} = 2$.

(g) Update the decision rules f^l_i and f^b_i, using (C.4) and (C.6), where the expectation terms are evaluated given the transition probability, conditional on the current tax regime $\mathcal{R}_t$:

$$\begin{aligned} E[x_{t+1}|\mathcal{R}_t = 1] &= p_{1,t+1}E[x^1_{t+1}|\mathcal{R}_{t+1} = 1] + (1 - p_{1,t+1})E[x^2_{t+1}|\mathcal{R}_{t+1} = 2] \\ E[x_{t+1}|\mathcal{R}_t = 2] &= (1 - p_2)E[x^1_{t+1}|\mathcal{R}_{t+1} = 1] + p_2E[x^2_{t+1}|\mathcal{R}_{t+1} = 2] \end{aligned} \tag{C.18}$$

3. Check convergence of the decision rules. If $|f^l_i - f^l_{i-1}|$ or $|f^b_i - f^b_{i-1}|$ is above the desired tolerance (set to $1e - 6$), go back to step 2. Otherwise, f^l_i and f^b_i are the decision rules.