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Sovereign default risk and state-dependent twin deficits*

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Abstract

In the backdrop of the European sovereign debt crisis, this paper analyzes the impact of the government debt-to-GDP ratio on the co-movement between the fiscal balance and the current account. The estimated government debt-to-GDP threshold for 15 European countries is 72 percent. Above the estimated threshold the correlation of the fiscal balance and the current account is substantially lower than below the threshold. We explain the empirical evidence of state-dependent twin deficits allowing for risky government debt and riskless international capital markets in a small open economy model. High public debt-to-GDP ratios raise sovereign risk premia as the default probability increases leading to higher uncertainty about future taxes. At high government debt levels household saving increases and partially compensates current account deficits that result from fiscal deficits. In this case household saving reduces the correlation of the two balances by a similar magnitude as found in the data.

Keywords: Twin Deficits, Dynamic Panel Threshold Model, Current Account, Fiscal Limit, Sovereign Default.

JEL Classification: E60, F32, F34, F41, H30, H60.

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1. Introduction

The notion of ‘twin deficits’ is based on the observation that the fiscal deficit and the current account deficit increased in tandem during the 1980s in the U.S. economy. In several European countries twin deficits also occurred in the years before and during the global financial crisis, reviving the debate about whether increasing fiscal deficits cause larger current account imbalances. In particular southern European countries have experienced large increases in current account imbalances and widening fiscal deficits. Since 2008-09 current accounts in these countries have been rebalancing despite protracted fiscal deficits, suggesting that the link between the twin deficits diminished. Fiscal deficits were partially the result of large fiscal stimulus packages that were intended to foster economic growth. These large fiscal deficits increased public debt stocks, bringing several European governments to the brink of default. Greece actually defaulted in 2012. In light of the European sovereign debt crisis, we examine whether public indebtedness affects the co-movement of the fiscal balance and the current account. First, we provide empirical evidence showing that the co-movement of the two balances depends on the government debt-to-GDP ratio. Second, we examine whether a small open economy model with the possibility of sovereign default can explain our empirical evidence.

In the first part of our analysis we estimate the government debt-to-GDP threshold to separate our sample into a low and a high debt regime. For that purpose we estimate a dynamic panel threshold model for 15 European countries to quantify the influence of sovereign indebtedness on the relationship between the fiscal balance and the current account.¹ Based on our estimation strategy we find that the government debt-to-GDP threshold is 72 percent. Splitting our sample into observations above and below the estimated threshold, we find that the correlation of the two balances falls by 0.19 when moving from the low government debt regime to the high government debt regime. In the second part of our analysis we provide a theoretical explanation for the empirical evidence. We allow for the possibility of sovereign default in a non-linear small open economy model. High government debt-to-GDP ratios lead to increasing risk premia as observed in troubled European countries. Facing higher uncertainty about future taxes, households increase saving rather than accumulate debt to smooth consumption during an economic downturn. Private saving increases while fiscal deficits are expanding, which leads to a less pronounced current account deficit. The model-based correlation of the fiscal balance and the current account declines by 0.15 when moving from a low government debt regime to a high government debt regime, which squares well with our empirical evidence.

From a theoretical point of view the relationship between the fiscal balance and the current account is ambiguous. The national income accounting identity states that the current account equals the flow of national savings of the private and the public sector net of investment. A fiscal

¹ Our baseline empirical specification follows Nickel and Vansteenkiste (2008) who estimate a dynamic threshold model employing non-dynamic panel techniques based on Hansen (1999). We apply the recently developed methodology of Kremer, Bick, and Nautz (2013) that allows for the estimation of a dynamic panel threshold model, correcting for the potential bias from using an endogenous regressor.

deficit (i.e. negative public saving) leads, *ceteris paribus*, to a lower current account. Therefore the accounting identity implies a perfect, positive correlation of the twin deficits. However, given fixed investment, the endogenous private saving decision also affects the current account and thus the relationship between the twin deficits. Households internalize the government budget constraint and increase private saving as they expect that higher government debt leads to higher future taxes – a point emphasized by proponents of the Ricardian equivalence. If household saving increases sufficiently it is possible that the current account remains unaffected implying no co-movement of fiscal deficits and current account deficits.

In our theoretical model we try to account for a key feature of the recent European debt crisis, which is the possibility of sovereign default. We assume that the government borrows from international investors and partially defaults when the amount of government debt exceeds the fiscal limit. Following Bi (2012) the fiscal limit is the maximum debt repayment capacity of the government, i.e. the present discounted value of all possible future fiscal surpluses. International investors demand non-linear sovereign default risk premia when public debt approaches unsustainable levels. Labor taxes increase with the public debt stock. Optimizing households receive transfers from the government and they consume, work and trade assets on international financial markets.

The model is calibrated to match data for Greece, which is one of the countries that experienced large external imbalances and high sovereign spreads in recent years. A negative productivity shock at low government debt-to-GDP ratios leads to an increase in taxes and the fiscal balance temporarily moves into deficit. To smooth consumption households increase borrowing. This implies a strong, positive correlation between the fiscal balance and the current account. A negative productivity shock at high government debt levels affects households via expected labor taxes: First, emerging sovereign risk premia destabilize the fiscal balance, triggering government debt accumulation and increasing expected labor taxes. Second, a government default reduces public debt and expected taxes. As a consequence households expect a larger dispersion of tax rates as government debt approaches high levels. These effects induce optimizing households to increase their saving, which partially offsets current account deficits that result from increasing fiscal deficits. Based on non-linear model simulations with productivity shocks and transfer spending shocks at a low and at a high government debt-to-GDP ratio we show that the correlation of the twins changes by a comparable magnitude as in our empirical analysis.

Current account imbalances and their co-movement with fiscal deficits have received much attention in the literature. The first intertemporal current account model is studied in Sachs (1981) and is extended by Obstfeld and Rogoff (1995). Building on these theoretical foundations, the studies of Glick and Rogoff (1995), Corsetti and Müller (2008) and Bussière, Fratzscher, and Müller (2010) provide evidence that productivity shocks are the main driver of current account dynamics. Corsetti and Müller (2006) show that further important drivers of the co-movement of the twin deficits are the persistence of government spending and the

openness of the economy.

Most empirical studies (e.g. Chinn and Prasad, 2003; Chinn and Ito, 2007; Gruber and Kamin, 2007; Lane and Milesi-Ferretti, 2012) find a significant positive relationship in the medium-term between the fiscal balance and the current account using panel methods.² Building on Nickel and Vansteenkiste (2008) this paper finds a positive and significant coefficient for the fiscal balance below the government debt threshold, but above the threshold the estimate is slightly negative and insignificant. We show that the estimated threshold is robust to alternative specifications of the empirical model and that it is important to control for persistence in the current account. Our estimated threshold of 72 percent is slightly higher than the estimate of Baum et al. (2013) who employ a threshold model to examine non-linear effects of debt and real GDP growth rates.

In closed economy frameworks Sutherland (1997) and Perotti (1999) show that the consumption response of the private sector can depend on the government debt-to-GDP ratio. In these models a fiscal deficit leads to an increase in consumption at low debt levels, while a fiscal deficit leads to a decrease in consumption at high debt levels. In difference to our model these models do not allow for a government default. This paper adds to the literature by suggesting a new theoretical channel within an open economy framework. Households' saving changes with the government debt-to-GDP ratio due to the influence of a possible sovereign default and its effect on labor taxes.

Increasing government debt-to-GDP ratios have received much attention in the recent policy debate and the academic literature in the course of the European sovereign debt crisis. This work provides a theoretical framework that includes key features of the recent crisis and shows that optimizing households internalize growing government debt stocks, which leads to state-dependent dynamics.

This paper is structured as follows. Section 2 reports our empirical results. Section 3 outlines our theoretical model, derives the state-dependent fiscal limit and discusses the non-linear solution method. Section 4 presents model simulations which demonstrate that the co-movement of the twins is state-dependent. Section 5 provides the conclusion.

2. Empirical evidence

In the first part of our analysis, we provide empirical evidence on the co-movement of the fiscal balance and the current account and how the relationship of the two balances changes at different government debt-to-GDP ratios. Building on Nickel and Vansteenkiste (2008) who estimate a similar dynamic panel threshold model with non-dynamic panel methods, we apply the methodology of Kremer et al. (2013) to avoid a possible endogeneity bias. Following this procedure we estimate the government debt-to-GDP threshold. We show that the correlation of

² A notable exception is Kim and Roubini (2008), who find evidence in favor of a 'twin divergence' rather than a 'twin deficit' for the U.S. based on VAR methods.

the fiscal balance and the current account for the low and the high government debt regime are significantly different from each other.

2.1. Estimation strategy

We apply the following dynamic panel threshold model to estimate the relationship of the fiscal balance and the current account depending on the government debt-to-GDP ratio:

$$CA_{it} = \mu_i + \chi CA_{i,t-1} + \beta_1 FB_{it} I\left(\frac{Debt_{it}}{GDP_{it}} \leq \gamma\right) + \beta_2 FB_{it} I\left(\frac{Debt_{it}}{GDP_{it}} > \gamma\right) + \alpha' x_{it} + u_{it}, \quad (2.1)$$

where the current account (CA) and the fiscal balance (FB) are measured in percent of GDP.³ The threshold level (γ) splits the threshold variable (the government debt-to-GDP ratio) into two regimes. The set of control variables is denoted by x_{it} . The indicator function $I(\cdot)$ indicates the regime defined by the threshold variable q_{it} and the threshold level γ . Following previous literature (e.g. Bussière et al., 2006) we include the lagged current account as a regressor in the baseline specification.

As in Caner and Hansen (2004), we first estimate a reduced form regression for the endogenous variable on a set of instruments, in our case higher lags of the dependent variable. We use the predicted values of the lagged dependent variable $\widehat{CA}_{i,t-1}$ to replace $CA_{i,t-1}$. Second, we repeatedly estimate equation (2.1) via least squares for all n threshold candidates to obtain the sum of squared residuals $S_n(\gamma)$. The estimated threshold is selected as the one that minimizes the sum of squared residuals:

$$\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}} S_n(\gamma).$$

The confidence interval for the estimated threshold level $\hat{\gamma}$ according to Caner and Hansen (2004) is given by

$$\hat{\Gamma} = \{\gamma : LR_n(\gamma) \leq C\},$$

where C denotes the 95% percentile of the asymptotic distribution of the likelihood ratio statistic $LR_n(\gamma)$. Given the estimate of the threshold $\hat{\gamma}$, the slope coefficients of equation (2.1) are estimated using the generalized method of moments (GMM). Further details on the estimation strategy can be found in Appendix B.

2.2. Estimation results

The data set is an unbalanced panel of 15 European countries from 1980 to 2010.⁴ Table 1 presents the main results of our baseline estimation. The series of threshold candidates ranges

³ Following previous literature (e.g. Chinn and Prasad, 2003; Gruber and Kamin, 2007) we assume that the fiscal balance is not endogenous to the current account. It seems unlikely that European policymakers systematically adjust the fiscal balance to changes in the current account.

⁴ Detailed information about the data set is given in Appendix A.

from 29.2 percent to 101.6 percent of government debt-to-GDP.⁵ The threshold estimate of the government debt-to-GDP ratio is 71.8 percent. This threshold value splits the sample into 260 observations below and 93 observations above the threshold. The 95 percent confidence interval of the threshold ranges from 69.4 percent to 75.0 percent.

The estimated coefficients for the fiscal balance differ significantly across both regimes. The fiscal balance is positively correlated (0.16) with the current account if government debt is below the threshold. However, in the high government debt regime, the relationship between the fiscal balance and the current account is slightly negative (-0.04). Thus, a one percent increase in the fiscal deficit is associated with a current account deterioration of 0.16 percent in the low government debt regime, while the same increase in the fiscal deficit has virtually no influence on the current account in the high government debt regime. The point estimates of the control variables are consistent with previous studies and in line with implications of theoretical open economy models.

Table 1: Estimation results

Variable	Coefficient	Std. dev.
Current account ($t - 1$)	0.59***	(0.16)
Fiscal balance (Debt/GDP $\leq \hat{\gamma}$)	0.16**	(0.07)
Fiscal balance (Debt/GDP $> \hat{\gamma}$)	-0.04	(0.05)
Terms of trade	0.05***	(0.02)
Openness	-0.01	(0.01)
Relative income to U.S.	0.01	(0.04)
Output gap (in % of potential GDP)	-0.28***	(0.11)
Change of total investment (in % of GDP)	-0.14	(0.08)
Labor productivity	0.04	(0.03)
Real effective exchange rate	-0.06***	(0.02)
Dependency ratio (% of working-age pop.)	0.16**	(0.08)
Threshold estimate (in % of GDP)	$\hat{\gamma} = 71.8$	
95% confidence region	[69.4 – 75.0]	
Total number of observations	353	

Dependent Variable: Current account (t). ***/*** indicate significance at the 10/5/1 percent level. Standard errors in brackets. The threshold of 71.8% splits the sample into 260 observations below and 93 observations above the threshold. The current account and the fiscal balance are measured in percent of GDP.

For a range of robustness checks the estimated threshold and the change in the regime-dependent fiscal balance coefficient is similar to our baseline findings (see Appendix B.3). We use the estimated threshold to split our sample into a low and a high debt regime to compute correlations of the fiscal balance and the current account for each regime.

⁵ We follow Hansen (1999) and trim the series of threshold candidates by excluding those that lie in the highest and in the lowest 5% quantile to avoid that the threshold sorts too few observations in one of the regimes.

A number of previous studies (see Chinn and Prasad, 2003; Chinn and Ito, 2007; Gruber and Kamin, 2007; Bussière, Fratzscher, and Müller, 2010; Lane and Milesi-Ferretti, 2012) estimate the relationship of the fiscal balance and the current account without applying a threshold model. These studies find a positive relationship between these two balances ranging from 0.06 to 0.3. Our fiscal balance estimate for the low government debt regime is in line with these previous estimates. The estimated coefficient of the lagged current account is positive (0.59) and highly significant. This estimate reflects the high persistence of current account dynamics and, thus, the importance of estimating a dynamic model of the current account.

The estimation yields evidence for significant differences in the regime-dependent fiscal balance coefficients indicating that the co-movement of the fiscal balance and the current account is state-dependent. The estimated regime-dependent coefficients (β_i) are *partial* correlations. In our theoretical analysis (in Section 3) we examine the model-implied correlation of the two balances at a low and at a high government debt level. The correlation of the twins implied by the model cannot be directly compared to the estimated *partial* correlations of the panel threshold model. Table 2 reports the correlation of the two balances in the data for observations below and above the estimated government debt-to-GDP threshold. For observations below the threshold of 71.8 percent the correlation of the fiscal balance and the current account is 0.57, whereas the correlation is 0.38 for observations above the threshold. Therefore, the difference amounts to 0.19. The confidence intervals for the correlations in both debt regimes indicate that these values are significantly different at a 10 percent significance level. The change in the correlation (0.22) of the two balances is robust to considering the lower (69.4%) and the upper (75.0%) bound of the confidence region.

Table 2: Regime-dependent correlations of fiscal balance and current account

Threshold: γ_i	corr(FB,CA) < γ_i	corr(FB,CA) > γ_i	Δ corr(FB,CA)
71.8	0.57 [0.50, 0.64]	0.38 [0.26, 0.49]	0.19
69.4	0.58 [0.51, 0.64]	0.35 [0.25, 0.47]	0.22
75.0	0.56 [0.50, 0.63]	0.33 [0.21, 0.46]	0.22

Notes: The left column states the estimated threshold value $\hat{\gamma}$ of 71.8 percent and its confidence bounds of 69.4 and 75.0 percent debt-to-GDP. The second and third column report the correlations of the fiscal balance (FB) and the current account (CA) below and above the threshold value. The 90 percent confidence interval of the correlations is reported in brackets. Δ corr(FB,CA) denotes the difference between the correlation in the low debt regime and the correlation in the high debt regime.

In the backdrop of the current account identity our empirical findings suggest that households' behavior responds differently to fiscal deficits at low government debt-to-GDP ratios compared to high ratios: The higher the government debt-to-GDP ratio, the stronger households compensate a fiscal deficit by increasing saving, offsetting the effect of a fiscal deficit on the current account. This finding is robust to considering the correlations as well as the regime-

dependent *partial* correlation estimates. The behavior of households at high government debt-to-GDP ratios is consistent with the implications of the Ricardian equivalence hypothesis. In the next section we examine the occurrence of twin deficits in a structural model to provide a theoretical explanation for the observed change in the correlation of the ‘twins’.

3. The Model

In our theoretical analysis, we consider a small open economy model with defaultable public debt and private asset holdings that are both held by foreign investors. Households borrow and lend at a time-invariant world interest rate facing portfolio adjustment costs. The government raises distortionary labor taxes, pays transfers to households and invests in unproductive government expenditures. The government can default on its outstanding debt. Risk-neutral foreign investors require an endogenous default risk premium when government debt approaches the ‘effective fiscal limit’. Following Bi (2012) the effective fiscal limit is a random draw from the model-implied state-dependent distribution of the fiscal limit. A sovereign default occurs when the government debt stock exceeds the effective fiscal limit.

3.1. Households

Consider an economy populated by an infinite number of identical households that choose consumption c_t , leisure L_t , and debt d_t^H to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, L_t) , \quad (3.1)$$

where $\beta \in (0, 1)$ is the discount factor, subject to the budget constraint

$$c_t = W_t (1 - \tau_t) (1 - L_t) + z_t + d_t^H - (1 + r)d_{t-1}^H - \frac{\psi}{2} (d_t^H - d^H)^2 , \quad (3.2)$$

and a no-Ponzi scheme condition. The budget constraint includes consumption c_t , wage W_t , labor taxes τ_t , government transfers z_t to the households and operations in international financial markets. Households trade a riskless bond d_t^H (positive values of d_t^H denote debt) at a constant world interest rate r . Following Schmitt-Grohé and Uribe (2003) we assume quadratic portfolio adjustment costs that are weighted by the parameter $\psi > 0$, where d^H denotes the steady state net foreign asset position of households. We set the discount factor β equal to one over the gross world interest rate:

$$\beta(1 + r) = 1 . \quad (3.3)$$

We assume Greenwood, Hercowitz, and Huffman (1988) preferences

$$u(c, L) = \frac{\left(c_t - \chi \frac{(1-L_t)^\omega}{\omega}\right)^{1-\sigma} - 1}{1-\sigma}, \quad (3.4)$$

where the Frisch elasticity of labor supply is $1/(\omega - 1)$ and $\chi > 0$ determines the relative disutility of labor. The degree of relative risk aversion is measured by $\sigma > 0$. As pointed out by Schmitt-Grohé and Uribe (2003) as well as by Mendoza and Yue (2012), these preferences simplify the supply side of the model and help to explain international business cycle facts.⁶

The households' first-order conditions are

$$\left(c_t - \frac{\chi(1-L_t)^\omega}{\omega}\right)^{-\sigma} = \lambda_t \quad (3.5)$$

$$1 - L_t = \left[\frac{W_t(1-\tau_t)}{\chi}\right]^{\frac{1}{\omega-1}} \quad (3.6)$$

$$\lambda_t (1 - \psi(d_t^H - d^H)) = \beta(1+r)\mathbb{E}_t\lambda_{t+1}, \quad (3.7)$$

where λ_t is the Lagrange multiplier of the budget constraint.

3.2. Production

The production function of output is linear in labor:

$$y_t = A_t(1 - L_t). \quad (3.8)$$

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

$$\ln\left(\frac{A_t}{A}\right) = \rho_A \ln\left(\frac{A_{t-1}}{A}\right) + \epsilon_{A,t}, \quad \epsilon_{A,t} \sim \mathcal{N}(0, \sigma_{\epsilon_A}^2), \quad (3.9)$$

where A denotes steady state productivity.

Wages are determined on a competitive labor market. Thus, the wage equals the marginal product of labor which in our case equals TFP:

$$W_t = A_t. \quad (3.10)$$

3.3. Government

The government receives tax revenues $\tau_t W_t(1 - L_t)$ through distortionary labor taxation and issues new public debt b_t at a given price q_t . It finances government spending g_t and transfers

⁶ Greenwood et al. (1988) preferences remove the wealth effect, which helps to avoid counterfactual increases in labor when total factor productivity falls.

z_t . In addition, the government can default on the fraction Δ_t of its outstanding debt and pays back the remaining debt from last period $b_t^d = (1 - \Delta_t) b_{t-1}$. Hence, the government budget constraint is:

$$\tau_t W_t (1 - L_t) + b_t q_t = b_t^d + g_t + z_t . \quad (3.11)$$

We assume that the tax rate τ_t adjusts linearly to the public debt stock:

$$\tau_t - \tau = \gamma_b (b_t^d - b) . \quad (3.12)$$

Government spending is a stationary process that responds systematically to changes in productivity. The parameter γ_g measures the elasticity of government spending g_t with respect to productivity:

$$\log \left(\frac{g_t}{g} \right) = \gamma_g \log \left(\frac{A_t}{A} \right) . \quad (3.13)$$

Transfers follow a Markov switching process with a stationary and a non-stationary regime as in Davig and Leeper (2011):

$$z_t = \begin{cases} (1 - \rho_z)z + \rho_z z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 1 \\ \mu z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 2 , \end{cases} \quad (3.14)$$

where $|\rho_z| < 1$, $\mu > 1$ and $\epsilon_{z,t} \sim \mathcal{N}(0, \sigma_{\epsilon_z}^2)$. Transfers follow a stationary path when $S_{Z,t} = 1$ and an explosive path when $S_{Z,t} = 2$, where the regimes, $S_{Z,t}$, follow a Markov chain with transition matrix

$$\begin{pmatrix} p^{MS} & 1 - p^{MS} \\ 1 - p^{MS} & p^{MS} \end{pmatrix} . \quad (3.15)$$

With probability p^{MS} government transfers stay in one of the regimes. For example, in case of a high probability p^{MS} transfers are likely to grow for many periods in the non-stationary regime leading to government debt accumulation. The process switches from one regime to the other with probability $1 - p^{MS}$, such that transfers are ultimately stabilized (as $\rho_z < 1$). Non-stationary transfers are observed in a number of countries (see Bi, 2012). If transfers stay in the non-stationary regime for a prolonged period the increase in government expenditures causes government debt accumulation.

3.4. Foreign investors

Domestic households and the domestic government borrow and lend from foreign investors. Unlike the households, the government can default on a fraction of its outstanding debt stock. Foreign investors have access to an international credit market where they can borrow or lend

unlimited amounts at a constant world interest rate $r > 0$.

Foreign investors act in competitive markets and choose loans b_t in each period to maximize expected profits ϕ_t , taking prices as given. Risk-neutral investors price bonds such that they break even in expected value:

$$\phi_t = -b_t q_t + \mathbb{E}_t \left[\frac{(1 - \Delta_{t+1})}{1 + r} b_t \right]. \quad (3.16)$$

Consequently the equilibrium government bond price q_t reflects the risk of default that investors face:

$$q_t = \mathbb{E}_t \left[\frac{(1 - \Delta_{t+1})}{1 + r} \right]. \quad (3.17)$$

As international investors are risk neutral and are fully compensated for the default risk they are indifferent between holding household debt and government bonds.

3.5. Current account

In our model household and government liabilities are held vis-à-vis the rest of the world. Borrowing and lending of the private and public sector affect the current account as follows:

$$CA_t^{private} = -d_t^H + d_{t-1}^H, \quad (3.18)$$

$$CA_t^{public} = -b_t q_t + b_{t-1} q_{t-1}. \quad (3.19)$$

The private sector current account equals the change in households' saving. The public current account is identical to the fiscal balance as the entire public debt stock is held abroad. The sum of both sub-balances amounts to the aggregate current account CA_t .⁷

3.6. Laffer curve and fiscal limit

The proportional labor tax induces a distortion in the economy as it influences the households' labor decision, which in turn affects government tax revenues. Distortionary labor taxation gives rise to a Laffer curve and, hence, to a revenue-maximizing tax rate. With Greenwood et al. (1988) preferences tax revenues amount to:

$$T_t = \tau_t W_t (1 - L_t) = \tau_t W_t \left[\frac{W_t (1 - \tau_t)}{\chi} \right]^{\frac{1}{\omega-1}}. \quad (3.20)$$

The maximum amount of tax revenues, T_t^{\max} , is generated at the revenue-maximizing tax rate which is at the peak of the Laffer curve. The revenue-maximizing tax rate, τ_t^{\max} , is derived as

⁷ Note that positive values of d_t^H and b_t^d mean that households and the government have external liabilities. An increase of d_t^H or b_t^d implies a negative current account.

follows:

$$\begin{aligned} \frac{\partial T_t}{\partial \tau_t} &= W_t \left[\frac{W_t(1-\tau_t)}{\chi} \right]^{\frac{1}{\omega-1}} + \tau_t W_t \frac{1}{\omega-1} \left[\frac{W_t(1-\tau_t)}{\chi} \right]^{\frac{1}{\omega-1}-1} \left(-\frac{W_t}{\chi} \right) = 0 \\ \Leftrightarrow \tau_t^{\max} &= \frac{\omega-1}{\omega}. \end{aligned}$$

Although the revenue-maximizing tax rate only depends on the Frisch elasticity of labor supply, the maximum amount of tax revenues also depends on the state of the economy (in our case TFP).

Next, we use the revenue-maximizing tax rate to derive the fiscal limit which is a state-dependent distribution. Following Bi (2012) the state-dependent fiscal limit $\mathcal{B}^*(A_t, z_t, S_{Z,t})$ is the maximum level of debt that the government is able to service, i.e. the present discounted value of all possible future fiscal surpluses.⁸ The fiscal limit depends on the exogenous states A_t , z_t and $S_{Z,t}$ as well as their future realizations ($j \geq 1$) and the parameters of the model:

$$\mathcal{B}^*(A_t, z_t, S_{Z,t}) = \sum_{j=0}^{\infty} \beta^{t+j} (T_{t+j}^{\max} - g_{t+j} - z_{t+j}).$$

We derive the fiscal limit from the perspective of risk-neutral foreign investors, who price the bonds, and thus we set the stochastic discount factor to β . To simulate the fiscal limit $\mathcal{B}^*(A_t, z_t, S_{Z,t})$ for given initial conditions $(A_t, z_t, S_{Z,t})$ we randomly draw future shocks A_{t+j} , z_{t+j} and $S_{Z,t+j}$ for $j = 1, 2, \dots, N$.⁹ Based on $m = 1, 2, \dots, M$ simulations of $\mathcal{B}_m^*(A_t, z_t, S_{Z,t})$, we approximate the state-dependent fiscal limit $\mathcal{B}^*(A_t, z_t, S_{Z,t})$ by a normal distribution for each state of the economy.

It is often challenging for investors to determine whether a government is actually willing to increase taxes or to cut spending to avoid a default. Possible resistance by the population against austerity measures might also influence political decisions. Hence, international investors face a high degree of uncertainty that surrounds political processes in countries with high government debt-to-GDP ratios when pricing government bonds. In our model the political uncertainty is reflected by randomly drawing an *effective fiscal limit*, which follows a state-dependent distribution. As in Bi (2012) the government defaults when the public debt stock b_{t-1} exceeds the *effective fiscal limit* b_t^* .¹⁰

Sturzenegger and Zettelmeyer (2008) show that international investors can usually negotiate a repayment of a large share of the original claim after a default. Therefore, we assume that the government does not default on its entire debt stock, but on the fraction $\delta \in [0, 1]$ which

⁸ As Bi (2012) we do not consider the expected value of the fiscal limit, but all possible realizations and thus the fiscal limit is a distribution.

⁹ We simulate $N = 200$ periods and repeat this calculation $M = 100000$ ($m = 1, 2, \dots, M$) times. At longer horizons the discounted value of government fiscal surpluses is virtually zero.

¹⁰ In contrast, Eaton and Gersovitz (1981) and Arellano (2008) provide a model of sovereign default where the government has an incentive to default despite being able to repay its debt.

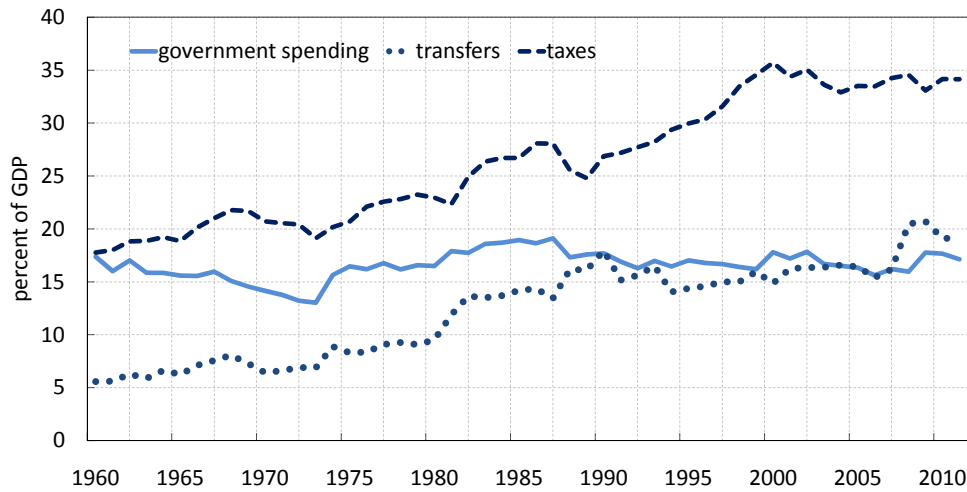
reflects the size of the ‘haircut’. Hence, the default scheme is:

$$\Delta_t = \begin{cases} 0 & \text{if } b_{t-1} < b_t^* \sim \mathcal{B}^*(A_t, z_t, S_{Z,t}) \\ \delta & \text{if } b_{t-1} \geq b_t^* \sim \mathcal{B}^*(A_t, z_t, S_{Z,t}) . \end{cases} \quad (3.21)$$

3.7. Calibration

We calibrate the model to match annual data for Greece from 1960 to 2010. The case of Greece is particularly interesting for our analysis as the country currently has the highest debt stock in Europe, experiences surging sovereign interest rates and has large external imbalances.¹¹ Table 3 summarizes the calibration of the model. In line with previous literature we use conventional values for the discount factor, the coefficient of relative risk aversion, the Frisch elasticity and the disutility of labor. Portfolio adjustment costs are chosen to match the standard deviation of the trade balance to output ratio following Schmitt-Grohé and Uribe (2003). The steady state level of TFP is normalized to 1.

Figure 1: Government spending, transfers and taxes in Greece



Source: OECD Economic Outlook No. 86 (2009).

Figure 1 shows that the ratio of government spending relative to GDP in Greece remained stable over the last decades. Average government spending is 16.57 percent of GDP and average lump-sum transfers amount to 12.27 percent of GDP. The elasticity of government spending with respect to real GDP per worker, γ_g , is estimated in a linear regression for the full sample. The estimation yields a value of -0.07. The estimated response of taxes to an increase of the

¹¹ State-dependent twin deficits would also occur when calibrating the model to another country with a different fiscal limit as households saving increases in the proximity of the respective fiscal limit.

debt-to-GDP ratio is 0.42 in a linear regression. The government therefore raises taxes by about 1 percentage point in response to an increase of government debt by 2.5 percent of GDP.

Table 3: Model calibration to Greek economy

Parameter		Value	Target/Source
Discount factor	β	0.95	Annual interest rate: 5.26%
Relative risk aversion	σ	2	Schmitt-Grohé and Uribe (2003)
Frisch elasticity	$1/(1 - \omega)$	0.9	Kimball and Shapiro (2008)
Disutility of labor	χ	3.173	Steady state labor supply: 25%
Portfolio adjustment costs	Ψ	0.005	Std(trade balance/GDP): 7.3%
Steady state TFP	A	1	TFP normalized to one
Government spending/GDP	g/y	16.57%	OECD EO No. 86 (2009)
Transfer/GDP	z/y	12.27%	OECD EO No. 86 (2009)
Gov. spending elasticity	γ_g	-0.07	Own estimate
Tax reaction coefficient	γ_b	0.42	Own estimate
Government debt/GDP	b/y	60%	Bank of Greece (2013)
Household debt/GDP	d^H/y	60%	Average external private debt/GDP
Tax rate	τ	31.84%	Average government debt/GDP
Default rate	δ	15%	Bi (2012), EU Commission
Productivity persistence	ρ_A	0.53	Own estimate
Std. dev. of productivity shock	σ_{ϵ_A}	0.027	Own estimate
Transfer spending persistence	ρ_z	0.9	Bi et al. (2013)
Explosive transfer growth	μ	1.01	Bi et al. (2013)
Markov switching probability	p^{MS}	0.9	Bi et al. (2013)
Std. dev. of transfer shock	σ_{ϵ_z}	0.07	Own estimate
<u>Average fiscal limit:</u>			
Mean (% of GDP)	\mathcal{B}^*	156%	MCMC simulation
Std. dev. (% of GDP)	$\sigma_{\mathcal{B}^*}$	21%	MCMC simulation

We set the steady state of total external debt-to-GDP ratio to 120 percent to match average total external liabilities of Greece from 1995 to 2010. About half of total gross external debt are public sector liabilities.¹² Thus, in our calibration, half of total external debt is public external debt and the other half is private sector external debt. As total external liabilities are 120 percent of GDP, we set both the private and public external debt-to-GDP ratio to 60 percent of GDP. To match the average government debt-to-GDP ratio of 60 percent we set the steady state tax rate to 31.84 percent.

We consider various sources to calibrate the size of the haircut in our model for the case of Greece. The European Commission (2011) forecast in autumn 2011 published before the debt restructuring in 2012 reports a government debt-to-GDP ratio of 198.3 percent at the end of 2012. The most recent forecast release in spring 2013 of the European Commission (2013) for

¹² Based on data from the Bank of Greece 56 percent of total external debt is government debt. To our knowledge disaggregated data for the pre-1995 period is not available.

the government debt-to-GDP ratio after the debt restructuring is 161.6 percent, suggesting that the haircut is estimated to effectively lower public debt by 18 percent at the end of 2012. Considering the empirical evidence of previous debt restructurings, Bi (2012) computes historical haircuts indicating an average size of 13 percent (excluding default events below a haircut of 3 percent). A haircut of this size is also in line with estimates in Sturzenegger and Zettelmeyer (2008), Panizza (2008) and Moody's (2011). Therefore, we choose a conservative value of 15 percent for the default fraction.¹³

We estimate the exogenous processes for productivity and transfers using HP-filtered data. The log of productivity as measured by real GDP per worker has a persistence of 0.53 and a standard deviation of 0.027 of the shock. Figure 1 illustrates that transfer payments from the government to households continuously increased in Greece over the last decades. Following Bi, Leeper, and Leith (2013) we set the Markov switching probability p^{MS} of the transfer process to 0.9. This implies that on average the transfer process stays in each regime for ten years. The parameter of the explosive transfer growth μ is set to 1.01 to match the growth of transfers in Greece since 1960 and ρ_z is set to 0.9. The estimated standard deviation of the transfer shock is 0.07 in a least squares regression.

Based on the calibration we determine the resulting average mean and standard deviation across all fiscal limits. The mean of all fiscal limits is 156 percent of steady state output and the standard deviation is 21 percent as a fraction of steady state GDP. The next section addresses how the fiscal limit changes with the state of the economy.

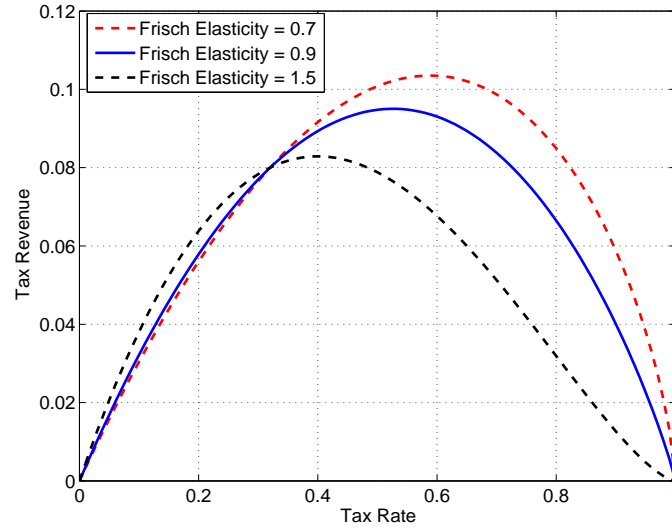
3.8. Laffer curve and fiscal limit for Greece

The revenue maximizing tax rate only depends on the Frisch elasticity. Figure 2 shows the Laffer curve for three different values of the Frisch elasticity. Based on the calibration of our model the revenue-maximizing tax rate is 52.6 percent. This tax rate is close to the revenue maximizing labor tax rate of about 60 percent for Greece estimated by Trabandt and Uhlig (2011).

Figure 3 displays the distribution of the fiscal limit based on the calibrated model. The fiscal limit depends on the state of the economy. The left panel depicts the probability density function for different productivity states, while the right panel shows the cumulative density function. As the fiscal limit shifts with the state of the economy, the default probability is also state-dependent. In a recession, i.e. in a low productivity state, the average fiscal limit is much lower compared to an economy that is in a high productivity state. During an economic downturn tax revenues are smaller and productivity is likely to stay at low levels due to its per-

¹³ In March 2012 Greece implemented a 53.5 percent haircut to the nominal value of debt held by the private sector, which roughly held half of the total debt stock suggesting a haircut of around 25 percent. Later in 2012 the Troika (ECB, IMF and European Commission) had to recapitalize the Greek banking system, which was holding around one-third of government debt, effectively reducing the net impact of the debt restructuring. However, assuming a higher default fraction does not alter the mechanism of the model and only changes the maximum risk premia that the international investors demand from the government.

Figure 2: Sensitivity of Laffer curve to the Frisch elasticity of labor supply



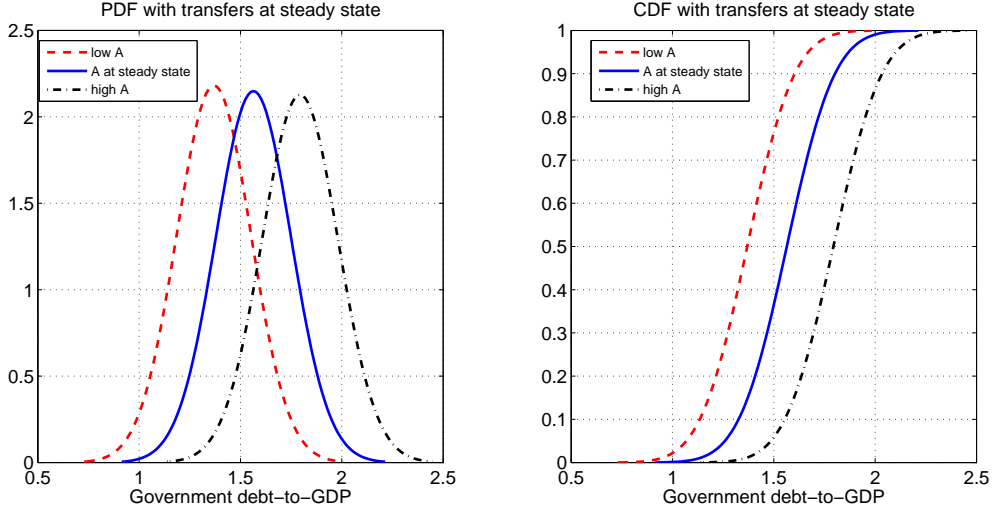
sistence. These two effects lower average future fiscal surpluses, shifting the mean of the fiscal limit to lower government debt-to-GDP ratios. The mean of the fiscal limit is at 163 percent of GDP for an intermediate TFP state, 146 percent of GDP for the lowest TFP state and 183 percent of GDP for the highest TFP state when transfers are at the mean and in the stationary regime.¹⁴ For low TFP states sovereign risk premia occur around 130 percent government debt-to-GDP. This value is close to actual data for Greece as sovereign bond spreads have increased dramatically since April 2010 when government debt-to-GDP was 131 percent. Since 2008 the country is also in a severe recession, which is reflected by a low TFP state in the model.

3.9. Solution method

The model features non-linearities due to the possibility of government default and the regime switching of government transfers. For our calibration the fiscal limit is far away from the steady state. For these reasons we use a global solution method to solve the model. The complete set of model equilibrium conditions is listed in Appendix C. We express the model by two first-order difference equations to solve for two policy functions. In particular, the first equilibrium condition is the households' first-order condition (3.7) and the second equilibrium condition is the government budget constraint (3.11) combined with the first-order condition of

¹⁴ The fiscal limit also shifts with different states of transfer spending and the Markov switching process between stable and explosive transfer growth. The mean of the fiscal limit is at 140 percent of GDP when transfers are in the highest state and at 189 percent of GDP when transfers are in the lowest state with productivity at steady state and in the stationary transfer regime. A shift from the stable to the explosive transfer regime leads to a shift of the mean of the fiscal limit from 163 percent of debt to GDP to 150 percent of debt to GDP with productivity and transfers at their steady state.

Figure 3: State-dependent distribution of the fiscal limit



Notes: State-dependent distributions of the fiscal limit for different TFP states and transfers in steady state of the stationary regime. Each distribution is approximated by a normal distribution. The left panel shows the probability density functions and the right panel shows the cumulative density functions.

foreign investors (3.17):

$$\lambda(\Psi_t) \left(1 - \psi((f^{d^H}(\Psi_t) - d^H))\right) = \beta(1+r) \mathbb{E}_t \lambda(\Psi_{t+1}) \quad (3.22)$$

$$\frac{b_t^d + g_t + z_t - \tau(\Psi_t)A_t(1 - L(\Psi_t))}{f^b(\Psi_t)} = \mathbb{E}_t \left\{ \frac{(1 - \Delta(f^b(\Psi_t), f^{d^H}(\Psi_t), A_{t+1}, z_{t+1}, S_{Z,t+1}))}{1+r} \right\} \quad (3.23)$$

where $\Psi_t = \{b_t^d, d_{t-1}^H, A_t, z_t, S_{Z,t}\}$ is the state vector of the economy. To solve the model we employ the non-linear algorithm described in Coleman (1991) and Davig (2004). This procedure discretizes the state space Ψ_t and finds a fixed point in the policy rules $b_t = f^b(\Psi_t)$ and $d_t^H = f^{d^H}(\Psi_t)$ for each grid point in the state space. Further details on the solution method are provided in Appendix D.

4. Model results

First, we show that the correlation of the fiscal balance and the current account changes with the government debt-to-GDP ratio. Then, we provide intuition for the change of the correlation examining policy rules. Finally, to illustrate the state-dependent model dynamics, we present impulse responses to productivity shocks at a low and at a high government debt-to-GDP ratio.

4.1. State-dependence of twin deficits

Table 4 presents the correlations between the fiscal balance and the current account at a low and at a high government debt-to-GDP ratio.¹⁵ The correlation of the two balances declines as government debt-to-GDP levels increase, in line with our empirical results in Section 2. The model with both shocks implies a perfect correlation of the fiscal balance and the current account for public debt-to-GDP at 60 percent. The correlation of the twins declines to 0.85 at a government debt-to-GDP ratio of 140 percent. Therefore the change in the correlation is 0.15 when moving from the low government debt regime to the high debt regime. At low government debt levels government and household debt co-move almost one-for-one ($\text{corr}(CA^{\text{private}}, FB) = 0.99$). However, at high government debt-to-GDP levels the correlation is much lower ($\text{corr}(CA^{\text{private}}, FB) = 0.04$).

Table 4: State-dependent correlations of fiscal balance and current account

<u>Low vs. high government debt-to-GDP: $\Delta \text{corr}(FB, CA)$</u>	
Data	0.19
Model	0.15
<u>Low government debt-to-GDP at 60 percent: $\text{corr}(FB, CA)$</u>	
Both shocks	1.00
TFP shocks	1.00
Transfer shocks	0.86
<u>High government debt-to-GDP at 140 percent: $\text{corr}(FB, CA)$</u>	
Both shocks	0.85
TFP shocks	0.86
Transfer shocks	-0.36

Notes: Correlations of fiscal balance (FB) and current account (CA), both in percent of GDP. The low government debt level is the steady state value of the model. $\Delta \text{corr}(FB, CA)$ denotes the difference between the correlation of the low debt regime and the correlation of the high debt regime. All simulations are based on the stationary transfer regime.

To compare our model-implied correlation with actual data we report the change of the state-dependent correlation of the fiscal balance and the current account calculated in Section 2 for 15 European countries. Table 4 reports the absolute change (0.19) in the correlations of the twins

¹⁵ The reported statistics for the model are an average over 500 simulations of eight years each. We only include simulations without default episodes. We choose a short simulation period to avoid a possible bias in the reported results by excluding too many draws that result in a government default that implies a large current account surplus.

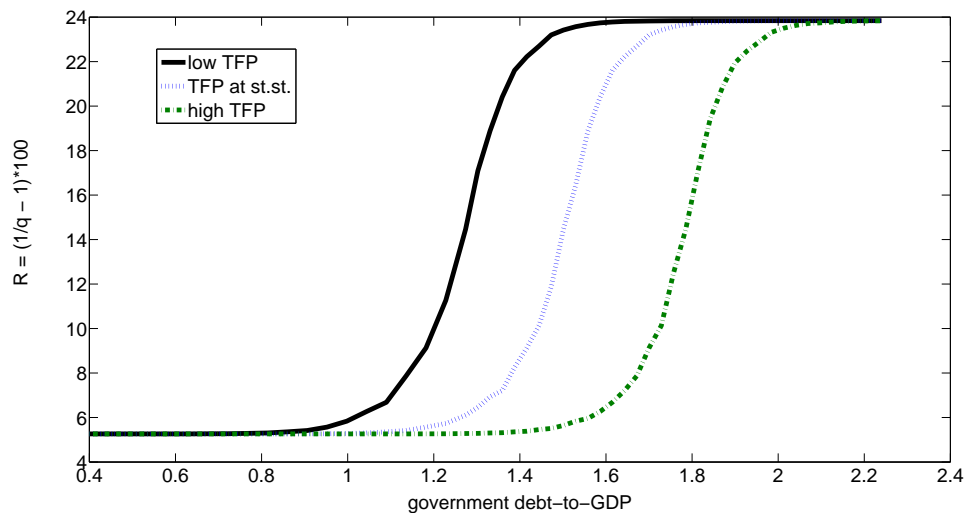
between the high and low government debt regime in the data. The model-implied change in the correlation (0.15) closely matches the one found in the data.

To shed light on the relative importance of each shock Table 4 also reports the model-implied correlations conditional on each shock. Even though the correlation of the fiscal balance and the current account conditional on transfer shocks is high (0.86) in the low debt regime, it is negative (-0.36) in the high debt regime. In line with Corsetti and Müller (2008) we find that the unconditional correlation of the two balances in the model is dominated by TFP shocks.

4.2. Model dynamics

To highlight the key transmission mechanisms we discuss the properties of two policy functions: sovereign interest rates and households' saving. International investors demand risk premia when government debt approaches the fiscal limit and the probability of default increases (see Figure 4). Up to a government debt-to-GDP ratio of around 100 percent foreign investors do not demand sovereign default risk premia as they expect no risk of a government default in the next period independent of today's productivity state. Hence, sovereign bond yields equal the risk-free rate. Sovereign interest rates increase up to 24 percent for high government debt levels. Since international investors are risk neutral they demand risk premia that offset the expected loss due to the possible government default.

Figure 4: Sovereign interest rates at different government debt-to-GDP



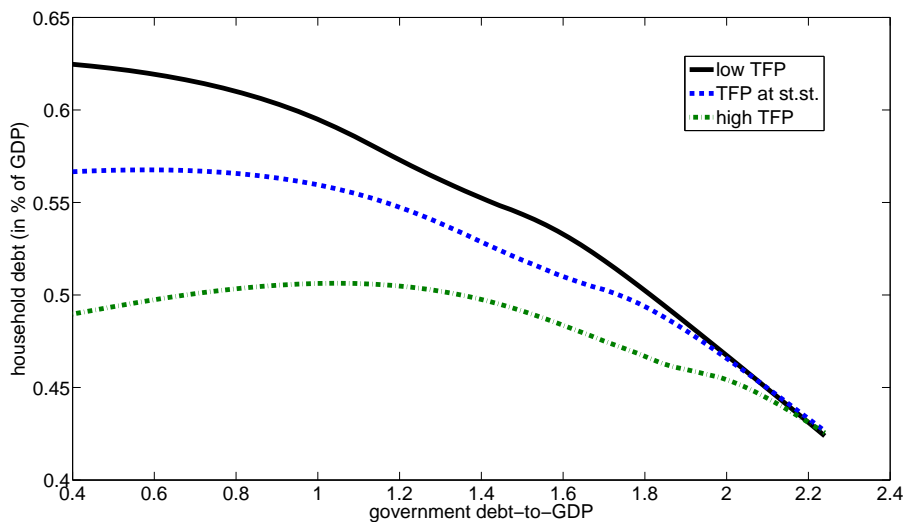
Notes: Household debt and transfer spending are both set to steady state and transfer spending is in the stationary regime. Horizontal axis: ratio of government debt-to-GDP. Vertical axis: in percentage points.

The government debt level at which investors demand risk premia depends on the state of the economy as the latter affects the fiscal limit. For example, if the economy is in a recession, i.e. in a low TFP state, tax revenues are low and the fiscal limit is shifted to the left. Hence, in

a recession the probability of sovereign default is much higher as compared to an economy in a high productivity state. Consequently, at the lowest productivity state default risk premia begin to emerge at around 100 percent of government debt-to-GDP, whereas at the highest TFP state risk premia emerge at around 160 percent of government debt-to-GDP.

Households trade assets with foreign investors to smooth consumption and to insure against expected tax changes due to the risk of government default. The saving decision at different productivity states depends non-linearly on the public debt stock (see Figure 5). When government debt-to-GDP is around 60 percent (steady state) households accumulate debt relative to steady state household debt to smooth consumption at a low TFP state. However, around 140 percent government debt-to-GDP ratio households save relative to steady state household debt in all TFP states as public debt increases.

Figure 5: Households' saving decision at different government debt-to-GDP ratios



Notes: Transfer spending is at steady state and in the stable process. Horizontal axis: ratio of government debt-to-GDP. Vertical axis: households' choice of debt in percent of GDP when the households' debt stock in the last period is at steady state.

The households' saving decision is influenced by the level of government debt due to the possibility of government default in the proximity of the fiscal limit. A more costly roll-over of government debt increases the fiscal deficit and leads to higher expected future labor taxes. However, households benefit from a realized government default as a default leads to lower government debt and, thus, to lower distortionary taxes.¹⁶ The distortion caused by labor tax increases with higher government debt levels. To insure against higher expected future labor taxes households save relative to steady state household debt when government debt is high

¹⁶ Introducing an exogenous cost of default as in Arellano (2008) would lead to a stronger increase of household saving at high government debt as households would try to insure against this cost. This would lead to a stronger reduction of the correlation of the twins.

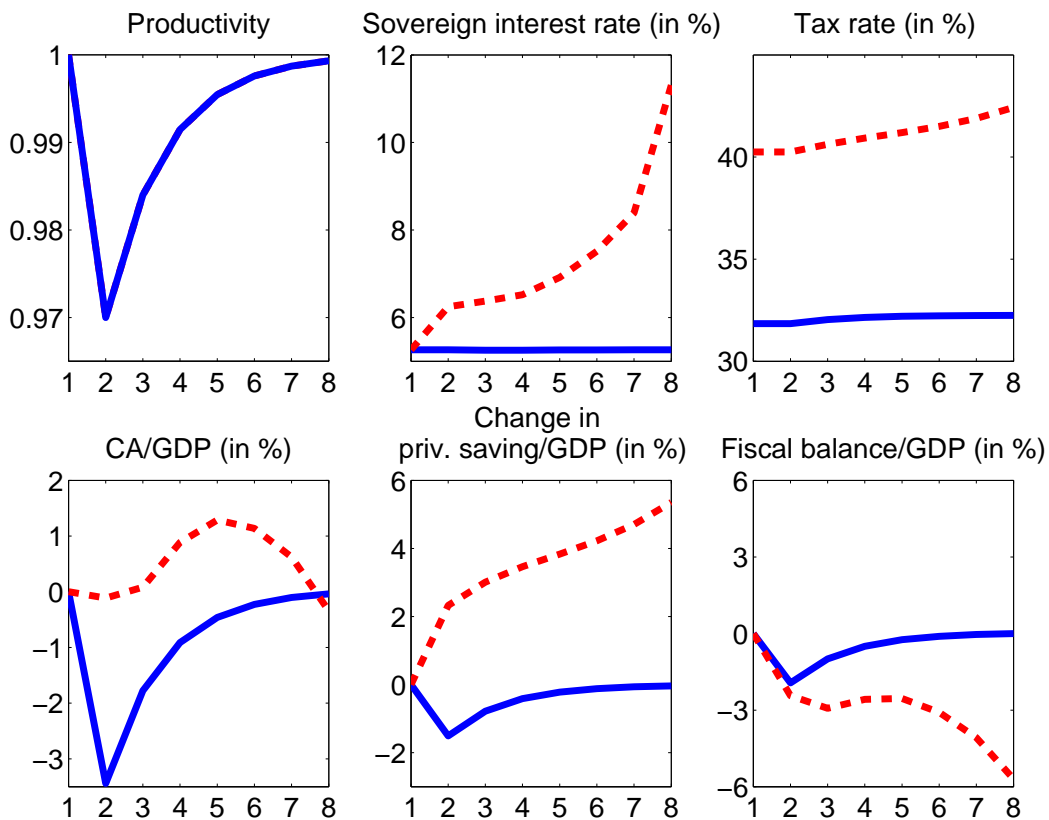
even when faced with negative TFP shocks.

4.3. Impulse response functions

We simulate the model conditional on a negative productivity shock at different government debt-to-GDP ratios to assess the state-dependent dynamics. A negative TFP shock captures the economic downturn of Greece which is in a recession since 2008. The shock destabilizes the fiscal sector leading to sovereign interest rate spreads at high public debt levels.

Figure 6 displays the effects of a negative TFP shock at a low (60%) and a high (140%) government debt-to-GDP ratio. At a low government debt-to-GDP ratio higher tax rates and lower output leads households to increase debt to smooth consumption. Households therefore increase private debt, i.e. the change in private saving is negative. Hence, the change in private saving and the fiscal balance co-move positively and the aggregate current account turns negative. Thus, the correlation of the fiscal balance and the current account is unity.

Figure 6: Simulation of negative TFP shock at low vs. high government debt



Notes: Impulse responses to a 3 percent negative productivity shock. We initialize the simulation at 60% government debt-to-GDP (blue solid line) and 140% government debt-to-GDP (red dashed line). Household debt is set to its ergodic mean. A time unit is one year.

At high government debt levels the negative productivity shock of the same size causes labor and tax revenues to decline, government spending to increase and the fiscal balance turns negative. Growing government debt brings the stock of sovereign debt close to the fiscal limit, leading to a surge of sovereign risk premia. Households increase saving as they expect that further increases of government debt and tax rates are very likely and the dispersion of tax rates increases. The change in private saving therefore turns positive and outweighs the negative contribution of the fiscal balance such that the current account moves into surplus. Due to the endogenous reaction of household saving, the correlation between the fiscal balance and the current account is much lower at high government debt-to-GDP than at a low ratio. In addition, the simulation reflects a situation where increasing risk premia destabilize the government debt-to-GDP ratio as observed during the current European sovereign debt crisis. Without a strong reduction of government expenditures or higher tax revenues the government debt stock is not sustainable resulting in a default in accordance with the actual debt restructuring of Greece in 2012.

In line with the empirical results our model provides an explanation for the decline in the correlation of the fiscal balance and the current account as the government debt-to-GDP ratio increases. In the model the households' optimal saving decision changes with the government debt-to-GDP ratio which explains the change of the correlation. In particular, as illustrated by the impulse responses to a negative TFP shock, private saving increases at high government debt, but falls at low government debt-to-GDP ratios. Hence, the correlation of the 'twins' is state-dependent and at high government debt households' saving behavior alleviates the fall in the current account. The change in the model-based correlation of the fiscal balance and the current account is 0.15, which is in line with the change in the empirical correlation of the twins.

5. Conclusion

In the first part of this paper, we estimate a government debt-to-GDP threshold based on a dynamic panel threshold model following Kremer et al. (2013) for a sample of 15 European countries. One advantage of the dynamic panel estimation procedure is that we estimate the threshold rather than exogenously imposing it. We contribute to the twin deficits debate by showing that the correlation of the fiscal balance and the current account depends on the government debt-to-GDP ratio. Based on the estimated threshold of 72 percent we distinguish between a low and a high government debt regime. For each regime we calculate the correlation of the fiscal balance and the current account and find that the state-dependent correlation falls by 0.19 when moving from observations below the threshold to those that are above the threshold.

In the second part of this paper, we examine a small open economy model allowing for sovereign default to show that the correlation of the twin deficits depends on the level of gov-

ernment debt in line with the observed empirical findings. At high government debt-to-GDP ratios the looming sovereign default risk increases sovereign interest rates, which deteriorate the fiscal balance. Rising sovereign debt levels lead to higher labor taxes, inducing households to increase saving. Also, precautionary saving increases as the dispersion of future expected taxes rises the closer the government debt stock moves to the fiscal limit. Non-linear model simulations reveal that the households' saving channel partially offsets fiscal deficits at high government debt-to-GDP ratios, inducing a decline in the correlation of the fiscal balance and the current account. The decline in the correlation of 0.15 is close to the change of the correlation in the empirical analysis.

The results of this paper suggest that households' saving has an offsetting effect on substantial and persistent fiscal deficits due to high sovereign risk premia. At high government debt-to-GDP ratios households save more than at times when the economy has a low government debt-to-GDP ratio. Therefore, our evidence — in line with recent data for southern European countries — points to a potential rebalancing of the current account as households increase saving, because of large fiscal deficits that prevail due to high borrowing costs.

The recent global financial crisis and the European sovereign debt crisis with their severe macroeconomic effects have shown that state-dependent dynamics can be important. Households and investors, but also central banks and governments face a higher uncertainty about the economy and 'rare' events such as the occurrence of sovereign default are perceived to be much more likely. This paper considers one aspect of state-dependence and shows that the size of the government debt-to-GDP ratio affects non-linear default risk premia and the co-movement of the fiscal balance and the current account. Further areas in which state-dependent dynamics are likely to play a crucial role are, for example, the size of fiscal multipliers and the effectiveness of austerity programs.

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A. Data description

Table 5: List of variables and definitions

Variable	Source	Description
Current account	IMF WEO	Current account balance (in percent of GDP)
Fiscal balance	IMF WEO	Fiscal balance (in percent of GDP). Net lending is calculated as revenue minus total expenditure.
Government debt	IMF WEO	Government debt (in percent of GDP). Gross debt consists of all liabilities that require payment or payments of interest and/or principal by the debtor to the creditor.
Terms of trade	IMF IFS	Export price index divided by import price index
Openness	OECD	Absolute value of exports plus absolute value of imports (in percent of GDP)
Relative income	IMF WEO	GDP per capita (PPP) relative to U.S. GDP per capita (PPP)
Output gap	IMF WEO	Output gap (in percent of potential GDP)
Change of total investment	IMF WEO	Change of total investment (in percent of GDP)
Labor productivity	OECD	Labor productivity of the total economy
REER	BIS	Weighted average of bilateral exchange rates adjusted by relative consumer prices
Dependency ratio	World Bank WDI	Age dependency ratio (in percent of working-age population)

Data sources: IMF WEO: IMF World Economic Outlook (October 2012), IMF IFS: IMF International Financial Statistics (May 2012), OECD: OECD Economic Outlook No. 92 (December 2012), BIS: Bank for International Settlements effective exchange rate indices: narrow indices (January 2013), World Bank WDI: World Bank Development Indicators (January 2013).

Table 6: Summary statistics of dataset

Country	T	mean(<i>CA/GDP</i>)	mean(<i>FB/GDP</i>)	mean(<i>Debt/GDP</i>)
Austria	23	0.46	-2.75	63.1
Belgium	20	3.33	-2.70	109.4
Germany	16	2.47	-2.79	64.5
Denmark	13	2.68	1.24	51.7
Spain	31	-2.95	-3.41	46.6
Finland	31	1.41	1.01	33.9
France	31	0.12	-3.34	48.7
Great Britain	31	-1.41	-3.16	44.5
Greece	23	-6.01	-8.20	97.8
Ireland	31	-1.84	-4.52	68.7
Italy	22	-0.41	-5.83	108.1
The Netherlands	16	5.29	-1.73	58.2
Norway	31	6.31	7.25	41.3
Portugal	16	-4.84	-2.01	61.3
Sweden	18	5.11	-1.06	55.7

Notes: T: Maximum number of time periods available, *CA/GDP*: Current account in percent of GDP, *FB/GDP*: Fiscal balance in percent of GDP, *Debt/GDP*: Government debt in percent of GDP.

B. Empirical estimation

B.1. Data

The data set is an unbalanced panel of 15 European countries from 1980 to 2010.¹⁷ We include a broad set of control variables that potentially affect the current account. In particular, along with the fiscal balance the baseline specification includes the terms of trade, openness, relative income to the U.S. economy, output gap (in percent of potential GDP), the change in total investment (in percent of GDP), labor productivity (of the total economy), the real effective exchange rate and the dependency ratio (in percent of working-age population). Detailed information about the data set is given in Appendix A.

B.2. Methodology

We estimate a dynamic panel threshold model of the form

$$y_{it} = \mu_i + \chi y_{i,t-1} + \beta_1 z_{it} I(q_{it} \leq \gamma) + \beta_2 z_{it} I(q_{it} > \gamma) + \alpha' x_{it} + u_{it}, \quad (\text{B.1})$$

where subscript $i = 1, \dots, N$ represents the country and subscript $t = 1, \dots, T$ denotes the time period. y_{it} is the dependent variable, μ_i is the country specific fixed effect and $y_{i,t-1}$ is an endogenous regressor. z_{it} is a vector of explanatory regressors, $I(\cdot)$ is an indicator function indicating the regime defined by the threshold variable q_{it} , and γ is the threshold level. Thus, the impact of z_{it} on y_{it} can potentially vary depending on whether the threshold variable q_{it} is below or above the threshold. The threshold level γ splits the sample into two regimes, allowing for the estimation of the regime-dependent impact of z_{it} as measured by the coefficients β_1 and β_2 . Furthermore, x_{it} contains a set of explanatory regressors which are independent of the threshold. The error term u_{it} is independent and identically distributed with mean zero and finite variance.

Our estimation strategy follows Kremer et al. (2013) who overcome several econometric challenges. In particular, they combine the estimation methods of non-dynamic panel threshold models in Hansen (1999) with the estimation strategy in Caner and Hansen (2004) that applies to cross-sectional threshold models with endogenous regressors. Hansen (1999) provides a method to estimate threshold effects in non-dynamic panel models where all regressors have to be exogenous. To eliminate the fixed effects mean differencing is applied. However, in a dynamic panel model as considered in equation (B.1) mean differencing potentially leads to inconsistent estimates as the lagged dependent variable will always be correlated with the mean of the individual errors and, thus, with all transformed individual errors (see Arellano, 2003, p. 17). Caner and Hansen (2004) develop an estimator and an inference theory for mod-

¹⁷ The sample includes the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, The Netherlands, Norway, Portugal, Spain and Sweden.

els with endogenous regressors and an exogenous threshold variable. Their theory applies to cross-sectional data and therefore needs to be extended to the estimation of panel data. For the endogenous regressor an instrumental variable estimation is applied. Building on these two papers, Kremer et al. (2013) provide a new, dynamic version of Hansen's panel threshold model. As in Caner and Hansen (2004) their procedure eliminates fixed effects with the forward orthogonal deviations transformation suggested by Arellano and Bover (1995). Subtracting the average of all future available observations of a variable avoids serial correlation of the transformed errors.

For our empirical exercise we apply the dynamic panel threshold model to estimate the relationship of the fiscal balance and the current account depending on the ratio of government debt-to-GDP:

$$CA_{it} = \mu_i + \chi CA_{i,t-1} + \beta_1 FB_{it} I\left(\frac{Debt_{it}}{GDP_{it}} \leq \gamma\right) + \beta_2 FB_{it} I\left(\frac{Debt_{it}}{GDP_{it}} > \gamma\right) + \alpha' x_{it} + u_{it}, \quad (\text{B.2})$$

where the current account (CA) and the fiscal balance (FB) are measured in percent of GDP. The threshold variable is the ratio of government debt-to-GDP. The set of control variables x_{it} includes the variables described above.

Following previous literature (e.g. Bussière et al., 2006), we include the lagged current account as a regressor in the baseline specification. We instrument for $CA_{i,t-1}$ using lagged variables ($CA_{i,t-3}$, $CA_{i,t-4}$ and $CA_{i,t-5}$). Employing few lags prevents overfitting the predicted variable and reduces a possible bias of the coefficient estimates. However, as there is a trade-off between bias and efficiency in small samples, using only few lags comes at the cost of losing efficiency. To assess the importance of the number of lags included we repeat the estimation using all of the available lags and find that the results are very close to the baseline results.

B.3. Robustness

We estimate a range of alternative specifications to confirm and extend our baseline estimation results. First, we estimate the model for the period 1980 to 2007, excluding the period from 2008 to 2010. The financial crisis with its strong influence on average debt levels, fiscal balances and current accounts could potentially affect our estimation results. Second, we re-estimate the model excluding countries with very high or low government debt-to-GDP ratios.

Excluding the financial crisis period we estimate the same government debt-to-GDP threshold of 71.8 percent (see first column of Table 7). The coefficients for the control variables are close to those of our baseline results. The exclusion of the financial crisis period slightly affects the estimate of the fiscal balance: The estimate at low government debt-to-GDP ratio increases from 0.16 to 0.30 and at the same time becomes statistically more significant. The estimate at high government debt-to-GDP ratio decreases from -0.04 to -0.21, such that the difference between the state-dependent coefficients becomes larger when excluding the financial

crisis episode. In comparison to the baseline results household saving therefore compensates a fiscal deficit less in the low debt regime.¹⁸ The exclusion of the crisis period confirms our baseline results: households become more Ricardian at high government debt levels, increasingly compensating the impact of fiscal deficits on the current account by higher household saving.

Table 7: Robustness

Variable	Subperiod 1980-2007	Excluding Belgium	Excluding Italy	Excluding Greece	Excluding Finland
Current account ($t - 1$)	0.44*** (0.16)	0.56*** (0.16)	0.59*** (0.15)	0.62*** (0.16)	0.50*** (0.17)
Fiscal balance (Debt/GDP $\leq \hat{\gamma}$)	0.30*** (0.08)	0.17** (0.07)	0.20** (0.08)	0.17** (0.08)	0.23*** (0.08)
Fiscal balance (Debt/GDP $> \hat{\gamma}$)	-0.21** (0.09)	-0.03 (0.05)	0.03 (0.07)	-0.01 (0.07)	0.08 (0.07)
Terms of trade	0.05*** (0.02)	0.05*** (0.02)	0.04*** (0.02)	0.05*** (0.02)	0.05** (0.02)
Openness	0.004 (0.01)	0.005 (0.01)	0.001 (0.01)	-0.01 (0.01)	-0.01 (0.01)
Relative income to U.S.	-0.01 (0.04)	0.004 (0.04)	-0.01 (0.05)	0.02 (0.05)	0.04 (0.05)
Output gap (in % of pot. GDP)	-0.49*** (0.12)	-0.30*** (0.11)	-0.32*** (0.11)	-0.27** (0.11)	-0.38*** (0.12)
Change of total inv. (in % of GDP)	-0.13 (0.11)	-0.13 (0.09)	-0.17** (0.07)	-0.17** (0.08)	-0.20** (0.09)
Labor productivity	0.07** (0.03)	0.03 (0.02)	0.04* (0.02)	0.04 (0.03)	0.05* (0.03)
Real effective exchange rate	-0.07*** (0.02)	-0.06*** (0.02)	-0.04** (0.02)	-0.05*** (0.02)	-0.04* (0.02)
Dependency ratio (% of working-age pop.)	0.25*** (0.09)	0.19** (0.09)	0.22** (0.10)	0.19** (0.10)	0.22** (0.09)
Threshold est. (% of GDP)	$\hat{\gamma} = 71.8$	$\hat{\gamma} = 71.8$	$\hat{\gamma} = 71.8$	$\hat{\gamma} = 86.9$	$\hat{\gamma} = 71.8$
95 % confidence region	[69.4-74.1]	[69.4-75.0]	[69.4-75.0]	[82.3-91.05]	[69.4-88.0]
Total number of obs.	308	333	331	330	322

Dependent Variable: Current account (t). ***/*** indicate significance at the 10/5/1 percent level. Standard errors in brackets. The current account and the fiscal balance are measured in percent of GDP.

In a second robustness check we exclude the country with the lowest and several countries with a high average government debt-to-GDP ratio from our sample (see Table 7). These

¹⁸ The increase of the estimated coefficient β_1 is consistent with the view that household saving compensates a fiscal deficit less (more) at lower (higher) debt-to-GDP ratios as the lower estimate for the threshold sorts a smaller number of high debt observations into the low debt regime.

countries might influence the estimation results as a majority of their observations are assigned to only one of the two debt regimes. Finland is the country with the lowest average government debt-to-GDP ratio, while there are three countries with relatively high average debt-to-GDP ratios: Belgium, Greece and Italy. We exclude one country at a time. Excluding Belgium (the country with the highest average debt-to-GDP ratio) yields the same estimated threshold of 71.8 percent and the exclusion is inconsequential for the estimation results. The threshold estimate is somewhat larger when excluding Greece, but the point estimates are very similar to the results of the complete sample. Excluding Italy or Finland also yields the same estimated thresholds and similar coefficient estimates as in the baseline estimation.

C. Non-linear model equilibrium conditions

$$(1 - L_t) = \left[\frac{A_t(1 - \tau_t)}{\chi} \right]^{\frac{1}{\omega-1}} \quad (\text{C.3})$$

$$\lambda_t = \left(c_t - \frac{\chi(1 - L_t)^\omega}{\omega} \right)^{-\sigma} \quad (\text{C.4})$$

$$\lambda_t (1 - \psi(d_t^H - d^H)) = \beta(1 + r)\mathbb{E}_t(\lambda_{t+1}) \quad (\text{C.5})$$

$$c_t + \frac{\psi}{2} (d_t^H - d^H)^2 = A_t(1 - \tau_t)(1 - L_t) + z_t + d_t^H - (1 + r)d_{t-1}^H \quad (\text{C.6})$$

$$y_t = A_t(1 - L_t) \quad (\text{C.7})$$

$$\tau_t A_t(1 - L_t) + b_t q_t = (1 - \Delta_t) b_{t-1} + g_t + z_t \quad (\text{C.8})$$

$$b_t^d = (1 - \Delta_t) b_{t-1} \quad (\text{C.9})$$

$$q_t = \mathbb{E}_t \left[\frac{(1 - \Delta_{t+1})}{1 + r} \right] \quad (\text{C.10})$$

$$T_t = \tau_t A_t \left[\frac{A_t(1 - \tau_t)}{\chi} \right]^{\frac{1}{\omega-1}} \quad (\text{C.11})$$

$$\tau_t - \tau = \gamma_b (b_t^d - b) \quad (\text{C.12})$$

$$z_t = \begin{cases} (1 - \rho_z)z + \rho_z z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 1 \\ \mu z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 2 \end{cases} \quad (\text{C.13})$$

$$\log \left(\frac{A_t}{A} \right) = \rho_A \log \left(\frac{A_{t-1}}{A} \right) + \epsilon_{A,t} \quad (\text{C.14})$$

$$\log \left(\frac{g_t}{g} \right) = \gamma_g \log \left(\frac{A_t}{A} \right) \quad (\text{C.15})$$

D. Non-linear computational methods

1. *Policy rules.* To solve the non-linear model we use the monotone map method that is described in Coleman (1991) and Davig (2004). First, we discretize the state space for each state variable, i.e. $\Psi_t = \{b_t^d, d_{t-1}^H, A_t, z_t, S_{Z,t}\}$. Second, we solve a simplified version of the model without default ($\delta = 0$) with a first-order approximation and use these policy functions to generate an initial set of decision rules denoted by $b_t^d = f_j^b(\Psi_t)$ and $d_t^H = f_j^d(\Psi_t)$. These rules are substituted into the two core equations of the model (the Euler equations (3.22) and (3.23)). Numerical integration is used to evaluate expectations about future variables. Solving this system for the state variables at each grid point yields updated values for the decision rules, i.e. $b_t^d = f_{j+1}^b(\Psi_t)$ and $d_t^H = f_{j+1}^d(\Psi_t)$ which we use as a new guess to substitute into (3.22) and (3.23). We repeatedly update the decision rules until the decision rules converge at every grid point in the state space i.e. $|f_j^b(\Psi_t) - f_{j+1}^b(\Psi_t)| < \epsilon$ and $|f_j^d(\Psi_t) - f_{j+1}^d(\Psi_t)| < \epsilon$, where $\epsilon = 10^{-6}$. We obtain a solution of the non-linear model on our grid points. Using the decision rules $f^b(\Psi_t)$ and $f^{d^H}(\Psi_t)$ of the model, we can solve for the remaining variables.
2. *Simulation results.* Given the policy rules we simulate the model economy. We initialize the simulation in the ergodic mean for all variables and then feed in various shock sequences for our exogenous processes. Given these shock sequences, we evaluate the evolution of the endogenous states using linear interpolation. In each period we randomly draw the effective fiscal limit from the state-dependent distribution of the fiscal limit. The government defaults on the fraction δ when its debt stock exceeds the effective fiscal limit.