Sovereign default risk and state-dependent twin deficits

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Abstract

This paper analyzes the impact of the government debt-to-GDP ratio on the correlation of the fiscal balance and the current account. Above a government debt-to-GDP ratio of 90 percent the correlation of the two balances decreases by 0.16 in a sample of 12 euro area countries and by 0.17 for Greece, Ireland, Portugal and Spain. This paper develops a small open economy model with defaultable government debt and riskless international capital markets to explain the empirical evidence of a state-dependent change in the correlation. In the model high public debt-to-GDP ratios raise sovereign risk premia as the default probability increases, leading to higher uncertainty about future taxes. In this case precautionary savings of households increase and partially compensate current account deficits that result from fiscal deficits. The increase in households' saving reduces the correlation of the two balances by the same magnitude as documented in the data. The model calibrated to Greece matches further business cycle moments and the empirical default frequency.

KEYWORDS: Twin Deficits, Current Account, Fiscal Limits, Sovereign Default.

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1. Introduction

The notion of 'twin deficits' originates from the observation that the fiscal deficit and the current account deficit increased in tandem during the 1980s in the U.S. economy. Twin deficits also occurred in several European countries 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 increasing sovereign risk premia and of large fiscal stimulus packages that were intended to foster economic growth. Large fiscal deficits induced surging public debt stocks, bringing several European governments to the brink of default and leading to a sovereign debt restructuring of Greece in 2012. Between 2007 and 2012 the government debt-to-GDP ratio has increased by about 30 percentage points in 12 euro area countries (EA-12).[1] In light of these developments we examine how public indebtedness affects the correlation of the fiscal balance and the current account. First, we provide empirical evidence showing that the co-movement of the two balances decreases at a higher government debt-to-GDP ratio. Second, we develop a small open economy model with the possibility of sovereign default to study the dynamic link between households' saving and sovereign indebtedness that can explain the empirical evidence.

In the first part of our analysis we document that the correlation between the fiscal balance and the current account in the euro area decreases at high government debt-to-GDP ratios. Previous literature has pointed to a debt-to-GDP threshold of around 90 percent at which we split our sample for our baseline results.[2] In the EA-12 sample the correlation of the two balances drops by 0.16 for observations above the threshold of 90 percent based on annual data from 1980 to 2012.[3] The effect is even slightly stronger for the sub-sample of Greece, Ireland, Portugal and Spain. These countries experienced the largest increase in the government debt-to-GDP ratio within the euro area between 2007 and 2012 and had to rely on financial assistance from the European Stability Mechanism (ESM). For this sub-sample the correlation of the two balances drops by 0.17 above the government debt-to-GDP threshold of 90 percent.

The relationship between the fiscal balance and the current account is also ambiguous from a theoretical

[1] This increase has been mainly driven by Greece, Ireland, Portugal, and Spain. In these countries on average the government debt-to-GDP ratio has increased by more than 60 percentage points between 2007 and 2012.

[2] See, for example Nickel and Vansteenkiste (2008), Reinhart and Rogoff (2010), Checherita-Westphal and Rother (2012) and Baum, Checherita-Westphal, and Rother (2013). Section 2 in this paper provides more details on selected studies.

[3] The complete sample consists of the 12 euro area countries that adopted the euro in 2001.

perspective. 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 ($CA_t = S_t^{private} + S_t^{public} - I_t$). A fiscal deficit (i.e. negative public saving) leads, ceteris paribus, to a decline in the current account. Therefore the accounting identity implies a perfect, positive correlation of the twin deficits. However, the endogenous private saving decision also affects the current account and thus the relationship between the twin deficits. For example, when households internalize the government budget constraint they increase private saving as they expect that higher government debt leads to higher future taxes — a point emphasized by proponents of Ricardian equivalence. The stronger households' saving increases and thereby compensates the decline in public saving, the lower the co-movement of fiscal deficits and current account deficits. This paper investigates the role of a state-dependent precautionary savings effect which is shown to depend on government indebtedness.

The aim of this paper is to provide a theoretical explanation for the empirical observation of state-dependent twin deficits. For this purpose we develop a small open economy model with the possibility of sovereign default. High government debt-to-GDP ratios lead to increasing risk premia as observed in troubled European countries.[4] Facing higher uncertainty about future taxes, households increase saving rather than accumulate debt to smooth consumption during an economic downturn. The increase of private saving counterbalances the current account deficit that results from expanding fiscal deficits. In line with our empirical evidence the model-based correlation of the fiscal balance and the current account declines by 0.16 when shifting from a low to a high government debt-to-GDP ratio.

In our theoretical model 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.[5] 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 consume, work and trade assets on international financial markets. Increasing government debt affects households via labor taxes and expectations about future tax rates.

The model is calibrated to match data for Greece, which is one of the euro area countries that experi-

[4] See Figure 9 in the Appendix for a scatter plot of the government debt-to-GDP ratio and 10-year sovereign bond yields.

[5] The concept of a fiscal limit has been employed widely in the literature to study the role of sovereign default risk. Among these studies are, for example, Bi and Traum (2012), Daniel and Shiamptanis (2012), Bi, Leeper, and Leith (2013), and Coimbra (2014).

enced large external imbalances and high sovereign spreads. A negative productivity shock at a relatively low government debt-to-GDP ratio of 60 percent leads to a fall in tax revenues 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 a high government debt-to-GDP ratio of 140 percent affects households strongly via expected labor taxes: First, emerging sovereign risk premia destabilize the fiscal balance, triggering government debt accumulation and increasing expected labor taxes. Second, a possible government default could reduce public debt and hence 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 private saving, which counterbalances 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 two balances decreases by 0.16 in line with our empirical analysis.

We also consider a version of the model with a low degree of households' relative risk-aversion. In this case the change in the correlation of the fiscal balance and the current account is much smaller when moving from the low to the high debt regime compared to our benchmark economy. This calibration shows that when the precautionary savings channel is muted households' saving does not compensate the decline in the fiscal balance. The model also matches further business cycle moments of the data. Among these, the model matches the volatility of the current account, the trade balance and government debt (in percent of GDP). Moreover, the model matches the strong negative correlation between sovereign spreads and output found in the data. In the past two centuries the default frequency of Greece is 2.8 percent (see Reinhart and Rogoff, 2011) or in more recent times with one default event since 1965 the default frequency is around 2.0 percent. Simulations of our model result in a default frequency of 2.0 percent and are therefore in line with the actual default frequency of Greece.

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 compelling evidence that productivity shocks are the main driver of current account dynamics. We also show that productivity shocks strongly dominate the correlation of the fiscal balance and the current account. Corsetti and Müller (2006) argue that further important drivers of the co-movement of the twin deficits are the persistence of government spending and the openness of the economy. In addition to the existing literature, this paper contributes empirical evidence and a theoretical channel that the co-movement decreases with the public indebtedness of the economy.

Several 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.[6] Nickel and Vansteenkiste (2008) estimate a dynamic panel threshold regression of the current account for a sample of 22 industrialized countries. They find a positive and significant coefficient for the fiscal balance below the estimated government debt-to-GDP threshold of 90 percent, whereas above this threshold the estimate is slightly negative and insignificant in line with our empirical evidence. In an interacted panel VAR for 17 European countries from 1970 to 2010 Nickel and Tudyka (2013) find that the private sector responds differently at higher levels of government debt-to-GDP. In particular the higher is the government debt-to-GDP ratio the more Ricardian households behave pointing to a precautionary savings channel. In earlier work Nicoletti (1988) investigates the interaction of private consumption and public debt for eight OECD countries and concludes that "debt accumulation induces precautionary savings precisely when it surpasses the threshold beyond which its consequences on the economy [...] are felt to be unsustainable". Our paper complements the empirical literature in supplying a model counterpart that features a theoretical channel where households' saving increases endogenously with public indebtedness.

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 these papers our model allows for the possibility of 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.

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 to demonstrate that the co-movement of the twins is state-dependent

[6] 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.

and reports further business cycle moments. Section 5 provides the conclusion.

2. Empirical evidence

This section documents the empirical observation that the correlation of the fiscal balance and the current account decreases when moving from low to high government debt-to-GDP ratios. First, we consider Greece, Ireland, Portugal, and Spain (GIPS) which have been affected particularly strong by the financial crisis and the European debt crisis. These countries have received financial assistance from the ESM and have experienced by far the largest increase in the government debt-to-GDP ratio in the euro area. Between 2007 and 2012 the government debt-to-GDP ratio in these countries on average increased by more than 60 percentage points. In comparison the average increase of the government debt-to-GDP ratio in the euro area was about 30 percentage points. Second, we also examine the correlation of the two balances based on the complete sample of 12 euro area (EA-12) countries from 1980 to 2012. The EA-12 countries are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Summary statistics of the data set are in Table 6 in the Appendix.

[Figure 1 about here.]

Figure 1 depicts the fiscal balance and the current account for Greece, Ireland, Portugal and Spain (top panel) and for the euro area (bottom panel). We split the sample into observations below (left panel) and above (right panel) a government debt-to-GDP threshold of 90 percent. It is striking that in both samples the correlation of these two balances declines markedly when moving from low to high government debt-to-GDP ratios. The black line obtained from a least squares regression illustrates that the co-movement between these two variables becomes smaller at a high government debt-to-GDP ratio. For the full sample without splitting the data set the scatter plot indicates a small positive correlation between these two balances in line with a number of previous studies.[7]

Table 1 reports the correlation of the two balances for observations below and above the government debt-to-GDP threshold of 90 percent. For observations in GIPS below 90 percent government debt-to-GDP the correlation of the fiscal balance and the current account is 0.17, whereas the correlation is zero

[7] See Figure 9 in the Appendix which depicts a scatter plot of the full euro area sample without using a debt-to-GDP threshold. Chinn and Prasad (2003); Chinn and Ito (2007); Gruber and Kamin (2007); Bussière et al. (2010); Lane and Milesi-Ferretti (2012) estimate panel regressions of the current account finding a positive partial correlation coefficient of the fiscal balance and the current account.

for observations above the threshold. Therefore, the correlation declines by 0.17 when moving from the low to the high government debt-to-GDP ratio. The observation of state-dependent twin deficits does also extend to all EA-12 countries for which the correlation declines by 0.16.

[Table 1 about here.]

We also consider the sub-sample from 1980 to 2006 to show that our results are not driven by any outliers during the crisis period from 2007 to 2012. Figure 2 depicts the fiscal balance and the current account for Greece, Ireland, Portugal and Spain (top panel) and for the euro area (bottom panel) excluding the recent crisis period. This figure confirms that at a high government debt-to-GDP ratio the correlation of the two balances decreases by a similar magnitude as for the full sample.[8]

[Figure 2 about here.]

We split our sample at a government debt-to-GDP threshold of 90 percent. This threshold is in the range of estimates provided in previous literature. Among these, Nickel and Vansteenkiste (2008) estimate a dynamic panel threshold model of the current account for 22 industrialized countries for the period from 1981 to 2005 and find a threshold of 90 percent above which the co-movement of the fiscal balance and the current account significantly declines. Baum et al. (2013) also estimate a government debt-to-GDP threshold around 90 percent above which additional government debt has a negative effect on real activity. We also find evidence for state-dependent twin deficits when considering alternative thresholds somewhat above and below 90 percent government debt-to-GDP.[9]

Moreover, our findings are also robust to excluding Greece from the euro area sample. We also consider the sample of EA-12 countries for a shorter time-period since joining the European Monetary Union. Also in this case the correlation decreases above 90 percent of government debt-to-GDP. This robustness check shows the results are not driven by factors associated with joining the common currency area. Finally, we also consider the case in which we net out investment in the fiscal balance-to-GDP ratio and the current account-to-GDP ratio showing that also without investment the correlation decreases markedly.[10] This

[8] For the sub-sample from 1980 to 2006 the correlation of the twins declines by 0.14 above a government debt-to-GDP threshold of 90 percent.

[9] Aizenman, Hutchison, and Jinjarak (2013) investigate the role of fiscal space as measured by the debt-to-tax ratio on CDS spreads. In our sample of the euro area the government debt-to-revenue ratio, which ranges from values between 0.1 and 4.0, is highly correlated (around 0.96) with the government debt-to-GDP ratio. Splitting our sample into observations above and below a government debt-to-revenue ratio of 2.0 we find that the twin balances correlation decreases by 0.14 when shifting to observations with little fiscal space (i.e. government debt-to-revenue ratio ≥ 2.0). This result indicates that our empirical evidence is also robust to alternative measures of fiscal space.

[10] Using the government debt-to-GDP threshold of 90 percent the correlation of the two balances declines by 0.14. Above a government-to-revenue ratio of 2.0 the decrease in the correlation of the two balances is 0.12 in the euro area sample.

evidence reinforces the view that investment dynamics are relatively less important than private saving in accounting for the change in the correlation of the two balances.

Considering the national income identity our empirical findings suggest that households' behavior may respond 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. 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 vis-à-vis foreign investors. Households borrow and lend at a time-invariant world interest rate facing portfolio adjustment costs. The government raises distortionary labor taxes, pays (possibly non-stationary) transfers to households and invests in unproductive government purchases. 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

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

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

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

and a no-Ponzi scheme condition. The budget constraint includes consumption, wages 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:

$$\beta(1+r) = 1 \; . \tag{3.3}$$

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

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

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.[11]

The households' first-order conditions are

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

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

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

where λ_t is the Lagrange multiplier of the budget constraint.

[11] Greenwood et al. (1988) preferences remove the wealth effect, which helps to avoid counterfactual increases in labor when total factor productivity falls. A further advantage of this class of preferences is that the economy's fiscal limit does not depend on endogenous variables as we show later.

3.2. Production

The production function of output is linear in labor:

$$y_t = A_t \left(1 - L_t\right) \ . \tag{3.8}$$

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

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

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:

$$W_t = A_t \ . \tag{3.10}$$

3.3. Government

The government receives tax revenues $\tau_t W_t \left(1 - L_t\right)$ through distortionary labor taxation and issues new public debt b_t at a given price q_t. It finances government purchases g_t and transfers z_t. In addition, the government can default on the fraction $\triangle_t$ of its outstanding debt and pays back the remaining debt from last period $b^d_t = \left(1 - \triangle_t\right) b_{t-1}$. Hence, the government budget constraint is:

$$\tau_t W_t \left(1 - L_t\right) + b_t q_t = b^d_t + g_t + z_t \ . \tag{3.11}$$

Government purchases are stationary and respond systematically to changes in productivity. The parameter γ_g measures the elasticity of government purchases g_t with respect to productivity:

$$\log\left(\frac{g_t}{g}\right) = \gamma_g \log\left(\frac{A_t}{A}\right) \ . \tag{3.12}$$

Transfers follow a Markov switching process with a stationary and a non-stationary regime as in Davig et al. (2010):

$$z_t = \begin{cases} (1-\rho_z)z + \rho_z z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 1 \\ \mu z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 2 \ , \end{cases} \tag{3.13}$$

where $|\rho_z| < 1$, $\mu > 1$ and $\epsilon_{z,t} \sim \mathcal{N}\left(0, \sigma^2_{\epsilon_z}\right)$. 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 MS

$$MS = \begin{pmatrix} p^{MS} & 1 - p^{MS} \\ 1 - p^{MS} & p^{MS} \end{pmatrix}. \tag{3.14}$$

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

We assume that the tax rate τ_t adjusts linearly to the public debt-to-GDP ratio:

$$\tau_t - \tau = \gamma_b \frac{b_t^d - b}{y} \qquad (\gamma_b > 0). \tag{3.15}$$

Higher values of the tax adjustment parameter γ_b captures one aspect of tax policy which is the aim to reduce the government debt-to-GDP ratio by raising the tax rate more strongly. As taxes are distortionary the model features a Laffer curve as we discuss later. The responsiveness of taxes to debt needs to be large enough to ensure that government debt is stationary and that debt fluctuations are not counterfactually large.

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. Domestic households 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:

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

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

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

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:

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

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

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.[12]

3.6. Dynamic Laffer curve

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:

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

The maximum amount of tax revenues, $T_t^{\max}$, is generated at the revenue-maximizing tax rate which is

[12] Positive values of d_t^H and b_t^d denote that households and the government have external liabilities. An increase of d_t^H or b_t^d implies a negative current account.

at the peak of the Laffer curve. The revenue-maximizing tax rate, $\tau_t^{\max}$, is derived as follows:

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

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). Hence, the state-dependence gives rise to a dynamic Laffer curve.

3.7. The fiscal limit

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.[13] 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:

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

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 $j = 1, 2, .., N$.[14] Based on $m = 1, 2, ..., M$ 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.[15]

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

[13] 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.

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

[15] In our model calibration the fiscal limit is well approximated by a normal distribution. For different calibrations that would imply a skewed distribution of the fiscal limit or fat tails it is advisable to employ a simulated distribution function. A key advantage of using a normal distribution to approximate the fiscal limit distribution is that we can operate on a grid with fewer points which is computationally more efficient.

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.[16]

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 reflects the size of the 'haircut'. As in Bi (2012) the government defaults when the public debt stock b_{t-1} exceeds the *effective fiscal limit* b_t^*.[17] Hence, the default scheme is:

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

3.8. 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-to-GDP ratio in Europe, experiences surging sovereign interest rates and has large external imbalances.[18] Table 2 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 3 about here.]

Figure 3 shows that the ratio of government purchases relative to GDP in Greece remained stable over the last decades. Average government purchases are 16.57 percent of GDP and average lump-sum transfers amount to 12.27 percent of GDP. The elasticity of government purchases with respect to real GDP per

[16] Our definition of the fiscal limit can be viewed as the maximum repayment capacity. Introducing a political risk factor or a stochastic discount factor would shift the fiscal limit to a lower sustainable debt-to-GDP ratio. Nonetheless, our results regarding the households' saving channel would still prevail and occur in the proximity of the respective fiscal limit.

[17] 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. This strand of literature typically considers exogenous costs of default. In this paper we abstract from output costs as we are mainly interested in the model dynamics before an actual default materializes.

[18] 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.

worker, γ_g, is estimated in a linear regression for the full sample. The estimation yields a value of -0.07. We set the tax adjustment parameter to 0.105 following estimates from previous literature.[19] The government therefore raises taxes by about 1 percentage point in response to an increase of government debt by 10 percent of GDP. Later we show that this calibration matches well the volatility of the government debt-to-GDP ratio. At much lower values of γ_b the government debt-to-GDP ratio would be counterfactually large.

[Table 2 about here.]

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.[20] 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 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.[21]

[19] Related literature provides estimates of the tax responsive parameter directly to government in the range from 0.2 to 0.6 (see, for example Bi, 2012; Bi and Traum, 2012). The tax adjustment parameter from our calibration has to be re-scaled to be comparable to previous estimates. The re-scaled tax adjustment parameter is 0.42 and thus in the middle range of previous estimates.

[20] 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.

[21] 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 international investors demand from the government.

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 3 illustrates that transfer payments from the government to households continuously increased in Greece over the last decades. Following Davig et al. (2010) 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 or, put differently, the probability of staying in one regime is 90 percent. 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. These parameter values are also in line with Bi, Leeper, and Leith (2013).

Based on our 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.

3.9. Laffer curve and fiscal limit for Greece

The revenue maximizing tax rate only depends on the Frisch elasticity. Figure 4 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 4 about here.]

Figure 5 displays the distribution of the fiscal limit based on the calibrated model. The fiscal limit depends on the state of the economy.

[Figure 5 about here.]

The left panel depicts the probability density function for different TFP 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 TFP state, the average fiscal limit is much lower compared to an economy that is in a high TFP state. During an economic downturn tax revenues are smaller and TFP is likely to stay at low levels due to its persistence. 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.[22] 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.

3.10. Solution method

The model features strong 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 foreign investors (3.17):

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

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

where $\Psi_t = \left\{b_t^d, d_{t-1}^H, A_t, z_t, S_{Z,t}\right\}$ is the state vector of the economy.[23] To solve the model we employ the non-linear time iteration algorithm described in Coleman (1991) and Davig (2004). This procedures 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 E.

4. Model results

First, we investigate how 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 the shape of two policy rules. To illustrate the state-dependent model dynamics, we present non-linear

[22] 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 TFP 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 TFP and transfers at their steady state.

[23] We use the remaining equilibrium conditions to evaluate endogenous variables.

simulation of productivity shocks at a low and at a high government debt-to-GDP ratio. Finally, we examine further business cycle moments and show how the relative risk aversion of households affects these moments.

4.1. State-dependence of twin deficits

Table 3 presents the correlations between the fiscal balance and the current account at a low and at a high government debt-to-GDP ratio.[24] The correlation of the two balances declines as the government debt-to-GDP ratio increases, in line with our empirical results in Section 2. The model with both shocks implies a 0.96 correlation of the fiscal balance and the current account at a government debt-to-GDP ratio of 60 percent. At a government debt-to-GDP ratio of 140 percent the correlation of the twins declines to 0.80. Therefore the decrease in the correlation is 0.16 when moving from the low to the high government debt-to-GDP ratio.

[Table 3 about here.]

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 the GIPS countries. As reported in Table 3 the absolute change in the correlations of the twins for high and low government debt in the data for the GIPS sample is 0.17. The model-implied change in the correlation is 0.16 and therefore closely matches the one found in the data.

To shed light on the relative importance of TFP and transfer shocks Table 3 also reports the model-implied correlations conditional on each shock. The correlation of the fiscal balance and the current account conditional on changes in transfers is negative (around -0.8) at both low and high government debt-to-GDP ratio. In line with Corsetti and Müller (2008) we find that the unconditional correlation of the two balances in the model is clearly 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 gov-

[24] The reported statistics for the model at high debt are an average over 500 simulations of eight years each. We consider simulations without default event as a goverment default event leads to a large current account surplus as government debt is held abroad. A short simulation period is chosen to ensure that only a small fraction of simulations leads to a government default. For the low debt case (for which a default is much less likely) we report an average over 500 simulation of forty years each.

ernment debt approaches the fiscal limit and the probability of default increases (see Figure 6). 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 irrespective 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 6 about here.]

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 TFP state.[25] Consequently, at the lowest TFP 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 TFP states depends non-linearly on the public debt stock. Figure 7 shows that high government debt increases private saving. Specifically, this figure shows the end-of-period t debt stock chosen by households at different values of government debt-to-GDP ratios when households' debt stock in the previous period is at steady state. When the government debt-to-GDP ratio is around 60 percent (steady state value) and TFP is in the low state households accumulate debt relative to the beginning-of-period debt stock to smooth consumption. At a high TFP state households reduce debt to smooth consumption at a low government debt-to-GDP ratio. However, above 160 percent government debt-to-GDP households save relative to the beginning-of-period households' debt stock and that in all TFP states. Thus, the policy function indicates that the households' saving channel dominates with higher government debt-to-GDP ratios.

[Figure 7 about here.]

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

[25] Low and high TFP refer to values that are four standard deviations below and above the steady state value.

from a realized government default as a default leads to lower government debt and, thus, to lower distortionary taxes.[26] Due to the higher dispersion of expected tax rates households save relative to steady state household debt when government debt is high even when faced with negative TFP shocks.

4.3. Non-linear simulations

We simulate the model conditional on a negative TFP shock at different government debt-to-GDP ratios to assess the state-dependent model dynamics. A negative TFP shock captures the economic downturn that Greece experienced in 2008 before the beginning of the sovereign debt crisis. The shock induces lower tax revenues and stimulates a countercyclical increase in government purchases and, thus, destabilizes the fiscal sector and triggers an increase in the government debt stock. Figure 8 displays the effects of a one-time negative TFP shock both at a low (60%) and a high (140%) government debt-to-GDP ratio. TFP subsequently follows an autoregressive process and eventually returns to its steady state value.

At a low government debt-to-GDP ratio a negative TFP shock leads to lower tax revenues as labor supply decreases, government purchases increase countercyclically and output declines. Households increase debt to smooth consumption, i.e. private saving is negative. Hence, 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 positive.

[Figure 8 about here.]

At a high government debt-to-GDP ratio the negative TFP shock (of the same size) also causes labor and tax revenues to decline, government purchases to increase and the fiscal balance to turn negative. In contrast to the previous scenario growing government debt brings the stock of sovereign debt close to the fiscal limit, leading to a surge of sovereign risk premia. The rise in sovereign risk premia leads to government debt accumulation dynamics as the roll-over of debt becomes more costly. Households increase saving as they expect that further increases of government debt and tax rates are very likely and because 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 savings reaction of households, the correlation between the fiscal balance and the current account is much lower at high government debt-to-GDP ratio than at a low ratio.

[26] Introducing an exogenous cost of default as in Arellano (2008) would lead to a stronger increase of households' 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.

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 simulation of 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 0.16, which is in line with the change in the empirical correlation of the twins.

From a more general perspective the non-linear simulation at a high government debt-to-GDP ratio reflects a situation as observed during the current European sovereign debt crisis during which increasing risk premia destabilized the government debt-to-GDP ratio in several countries. Although in the simulation in Figure 8 government debt is accumulated strongly within the first years after the shock no default event occurs during this period. As sovereign risk premia typically triggers further government debt accumulation, in subsequent periods a default is very likely to occur (not shown in the Figure). However, policy measures such as a substantial decrease in government expenditure or higher tax revenues can potentially stabilize government debt accumulation and stop the negative feedback effect between increasing government debt and rising sovereign risk premia.

4.4. Business cycle moments

This section investigates the quantitative performance of the model by comparing moments from the data with theoretical moments of the model. Table 4 reports business cycle moments of Greece and the theoretical model counterparts. The second column contains the results for our benchmark economy at a low government debt-to-GDP ratio. The standard deviation of consumption in the model matches the data well, while output volatility is overpredicted by the model. In line with the data consumption is less volatile than output. The volatility of the external balances as measured by the current account and the trade balance are in line with Greece. The volatility of the government debt-to-GDP ratio of 4.76 percent is also closely matched by the model.[27] The standard deviation of sovereign spreads in our model is lower than recent data suggests. However, our non-linear simulations (Figure 8) and the policy function

[27] The stronger taxes respond to the public debt stock the lower is the volatility of government debt-to-GDP. Relatively low values for the responsiveness of taxes would not be sufficient to stabilize the debt stock. In addition, the volatility of government debt-to-GDP would be much higher than actual data suggests.

(Figure 6) of sovereign interest rates illustrate that the spreads at high government debt can be sizable which is in line with the recent increase in sovereign spreads observed in Greece.

An implication of the model that derives from the assumption that output is linear in labor is a perfect correlation between labor and output, which in actual data is much lower. The slightly negative (-0.06) correlation of the trade balance with output — a common observation across several countries — cannot be exactly matched by the model. The reason is that the model does not feature capital which would help to better match this unconditional correlation.[28] For the same reason the model does not exactly replicate the unconditional correlation of the fiscal balance and current account of 0.44 in the data, but it is somewhat larger in the model. A common finding for countries that experienced increases in sovereign spreads, including emerging market economies such as Argentina, is a strong negative correlation of sovereign spreads and output, which is well matched by the model (-0.56 vs. -0.63 in the data).

[Table 4 about here.]

Consulting historical records Greece has experienced six external debt restructurings since 1800 including the most recent default event in 2012 (see Reinhart and Rogoff, 2011). Therefore, the default frequency in the past two centuries is 2.8 percent. During the postwar period Greece has only experienced one external debt restructuring. Thus, in line with the long-term default probability, the default frequency is 2.04 percent for the period from 1965 to 2013. The actual default frequency fits remarkably well to our model simulations, where at the low initial government debt-to-GDP ratio the default frequency is about 2 percent. At high government debt when the economy is closer to its fiscal limit the default frequency is substantially higher as the fiscal sector in this case is relatively instable. This observation is also in line with Bi (2012), who finds that the likelihood of a default increases strongly when the economy operates closer to its fiscal limit. In fact only substantial fiscal reforms or favourable economic conditions (strong productivity growth) can help to stabilize government debt and reduce sovereign risk spreads.

4.5. Sensitivity to households' risk aversion

Table 4 also reports business cycle moments for a lower degree of households' relative risk-aversion ($\sigma = 1$). In this case and at a high government debt-to-GDP ratio households' saving does not increase

[28] Backus et al. (1994) show that within their two country model investment is crucial in generating a negative correlation between the trade balance and output. However, the similar small open economy framework of Schmitt-Grohé and Uribe (2003) without a government sector but with investment does not necessarily generate a negative correlation of the trade balance and output.

much and, consequently, the change in the correlation of the fiscal balance and the current account is much smaller as compared to our benchmark calibration (-0.04 vs. -0.16). If households are less risk-averse the precautionary savings motive does not dominate the consumption smoothing motive and hence households rather increase debt or save very little in response to a negative TFP shock.[29] The remaining business cycle moments are very similar across these two different degrees of households' relative risk-aversion.

Overall, our simulation results suggest that a precautionary savings motive drives down the correlation of the fiscal balance and the current account. Finally it should be noted that a relative risk aversion value of $\sigma = 2$ is in line with many other studies of international macroeconomic models (see, for example Schmitt-Grohé and Uribe, 2003; Mendoza and Yue, 2012).

5. Conclusion

This paper first establishes the empirical observation that a decrease in the correlation of the fiscal balance and the current account occurs above a 90 percent government debt-to-GDP threshold. These results hold both for the euro area and for the sub-sample of Greece, Ireland, Portugal and Spain. These four countries have experienced the largest absolute increase in the government debt-to-GDP ratio in recent years. For these countries the decrease in the correlation is slightly larger with 0.17 as compared to 0.16 for 12 euro area countries.

We develop a small open economy model with defaultable government debt to show that the correlation of the twin deficits depends on the government debt-to-GDP ratio 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. Precautionary saving increases as the dispersion of future expected taxes rises the closer the government debt stock moves to the fiscal limit. 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 quantitative importance of this channel is shown to increase with higher relative risk-aversion of households. Non-linear model simulations show that a reduction of external imbalances typically occurs in general equilibrium for conventional degrees

[29] Figure 10 in the Appendix shows the simulation of a negative TFP shock for low and high risk aversion for the high debt-to-GDP case.

of relative risk-aversion. The decline in the correlation of 0.16 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 revealed that state-dependent dynamics can be important. Households and investors, but also central banks and governments face a higher uncertainty about developments in the macroeconomy 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 about here.]

[Table 6 about here.]

B. Additional empirical evidence

[Figure 9 about here.]

C. Non-linear model equilibrium conditions

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

$$\lambda_t = \left(c_t - \frac{\chi(1-L_t)^{\omega}}{\omega}\right)^{-\sigma} \tag{C.2}$$

$$\lambda_t\left(1-\psi(d_t^H - d^H)\right) = \beta(1+r)\mathbb{E}_t(\lambda_{t+1}) \tag{C.3}$$

$$c_t + \frac{\psi}{2}\left(d_t^H - d^H\right)^2 = A_t\left(1-\tau_t\right)\left(1-L_t\right) + z_t + d_t^H - (1+r)d_{t-1}^H \tag{C.4}$$

$$y_t = A_t\left(1-L_t\right) \tag{C.5}$$

$$\tau_t A_t\left(1-L_t\right) + b_t q_t = \left(1-\triangle_t\right)b_{t-1} + g_t + z_t \tag{C.6}$$

$$b_t^d = \left(1-\triangle_t\right)b_{t-1} \tag{C.7}$$

$$q_t = \mathbb{E}_t\left[\frac{(1-\Delta_{t+1})}{1+r}\right] \tag{C.8}$$

$$T_t = \tau_t A_t\left[\frac{A_t(1-\tau_t)}{\chi}\right]^{\frac{1}{\omega-1}} \tag{C.9}$$

$$\tau_t - \tau = \gamma_b\left(b_t^d - b\right) \tag{C.10}$$

$$z_t = \begin{cases} (1-\rho_z)z + \rho_z z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 1 \\ \mu z_{t-1} + \epsilon_{z,t} & \text{for } S_{Z,t} = 2 \end{cases} \tag{C.11}$$

$$\log\left(\frac{A_t}{A}\right) = \rho_A \log\left(\frac{A_{t-1}}{A}\right) + \epsilon_{A,t} \tag{C.12}$$

$$\log\left(\frac{g_t}{g}\right) = \gamma_g \log\left(\frac{A_t}{A}\right) \tag{C.13}$$

D. Model sensitivity

[Figure 10 about here.]

E. Non-linear computational methods

1. *Policy rules.* To solve the non-linear model we use a time iteration algorithm that is described in Coleman (1991) and Davig (2004). First, we discretize the state space for each state variable, i.e. $\Psi_t = \left\{b_t^d, d_{t-1}^H, A_t, z_t, S_{Z,t}\right\}$. 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.

Table 1: State-dependent correlations of fiscal balance and current account

Country sample	public debt/GDP<90%	public debt/GDP>90%	Δcorr(FB,CA)
GIPS	0.17	0.0	0.17
Euro area	0.40	0.24	0.16

Notes: GIPS: Greece, Ireland, Portugal, and Spain. Euro area refers to the EA-12 countries. The second and third column report the correlations of the fiscal balance (FB) and the current account (CA) below and above the threshold value. Δcorr(FB,CA) denotes the difference between the correlation of the low and the high government debt-to-GDP ratio case. Data is extracted from the IMF World Economic Outlook October 2013 and covers the period from 1980 to 2007 using annual data.

Table 2: 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): 3.7%
Steady state TFP	A	1	TFP normalized to one
Government purchases/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	0.105	Previous literature
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	Davig et al. (2010)
Explosive transfer growth	μ	1.01	Davig et al. (2010)
Markov switching probability	p^{MS}	0.9	Davig et al. (2010)
	Average fiscal limit:		
Mean (% of GDP)	$\mathcal{B}^*$	156%	MCMC simulation
Std. dev. (% of GDP)	$\sigma_{\mathcal{B}^*}$	21%	MCMC simulation

Table 3: State-dependent correlations of fiscal balance and current account

Low vs. high government debt-to-GDP: Δcorr(FB,CA)	
Data	0.17
Model	0.16
Low government debt-to-GDP at 60 percent: corr(FB,CA)	
All shocks	0.96
TFP shocks	1.00
Transfer shocks	-0.80
High government debt-to-GDP at 140 percent: corr(FB,CA)	
All shocks	0.80
TFP shocks	0.81
Transfer shocks	-0.82

Notes: Correlations of fiscal balance (FB) and current account (CA), both measured in percent of GDP. The low government debt level equals the steady state value of the model. Δcorr(FB,CA) denotes the difference between the correlation at the low and at the high government debt-to-GDP ratio. Transfer shocks refer to the case of both transfer shocks and regime switching of transfers.

Table 4: Business cycle moments: data and theoretical moments

		benchmark		low risk aversion	
	Data	low debt	high debt	low debt	high debt
Standard deviations (in %)					
Consumption	2.52	2.24	2.22	2.40	2.14
Output	2.67	4.50	3.71	4.46	3.70
Labor	1.41	2.09	1.70	2.07	1.70
Current account/GDP	3.26	3.31	2.73	3.29	2.68
Trade balance/GDP	3.73	3.31	3.56	3.19	5.73
Government debt/GDP	4.76	4.45	6.75	4.46	7.11
Sovereign spreads	6.11	0.09	0.31	0.14	0.29
Correlation with output					
Consumption	0.70	0.98	0.83	0.98	0.97
Labor	0.18	1.00	1.00	1.00	1.00
Current account/GDP	-0.20	0.95	0.90	0.96	0.94
Trade balance/GDP	-0.06	0.89	0.64	0.79	0.46
Sovereign spreads	-0.63	-0.56	-0.51	-0.47	-0.51
Other statistics					
Corr(CA/GDP,FB/GDP)	0.44	0.96	0.80	0.94	0.90
Default frequency (in %)	2.04	1.96	16.09	1.94	16.14

Notes: The first column reports data moments for Greece with data from 1960 to 2010. The remaining columns report theoretical counterparts for low (60% of GDP) and high (140% of GDP) debt as well as for our benchmark model ($\sigma = 2$) and low ($\sigma = 1$) households' risk aversion. All data are HP-filtered except current account/GDP, trade balance/GDP and sovereign spreads. The simulation horizon is eight and 40 years for high and low debt, respectively. The default frequency is based on the period from 1965 to 2013. The model implied default frequency is calculated on the basis of 3000 simulations of the model. Sovereign spreads (spread between Greece long term rates vs. German long term rates) are for the period from 1999 to 2013.

Table 5: List of variables and definitions

Variable	Source	Code	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.
Consumption	EO86	CPV	Private final consumption expenditure (volume)
Output	EO86, EO91	GDPV	Gross domestic product (volume), market prices
Nominal Output	EO86	GDP	Gross domestic product (value), market prices
Transfers	EO86	SSPG, TSUB, TKPG, TKTRG	Social security benefits paid by general government (value) plus subsidies (value) plus capital Transfers paid and other capital payments (value) minus capital tax and transfers receipts (value)
Government purchases	EO86	CGV	Government final consumption expenditure (volume)
Sovereign spreads	ECB SDW		Greece long term interest rates minus Germany long term interest rates
Labor	TED	thwgrc	Total hours worked
Productivity	PWT	rgdpwok	PPP Converted GDP Chain per worker at 2005 constant prices

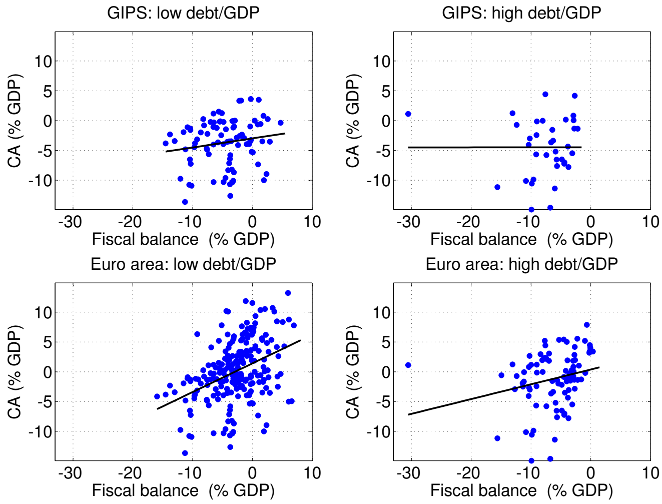
Data source: IMF WEO: IMF World Economic Outlook October 2013, EO: OECD Economic Outlook, ECB SDW: ECB Statistical Data Warehouse, TED: Total Economy Database extracted from The Conference Board (2014), PWT: Penn World Tables 7.0 extracted from Heston et al. (2011).

Table 6: Summary statistics of the euro area

Country	T	Average Debt/GDP	Average CA/GDP	Average FB/GDP	Change in Debt/GDP from 2007 to 2012
Austria	25	64.32	0.56	-2.72	13.86
Belgium	32	110.32	1.99	-5.39	15.77
Finland	33	34.92	1.23	0.85	18.41
France	33	51.09	0.00	-3.44	26.02
Germany	22	62.25	2.19	-2.58	16.49
Greece	33	86.79	-5.60	-8.02	49.63
Ireland	33	71.48	-1.58	-4.82	92.54
Italy	25	109.35	-0.55	-5.57	23.70
Luxembourg	14	10.34	9.20	1.60	14.11
The Netherlands	18	59.37	5.93	-2.02	25.97
Portugal	23	65.16	-6.36	-5.41	55.42
Spain	33	48.52	-2.92	-3.79	49.59

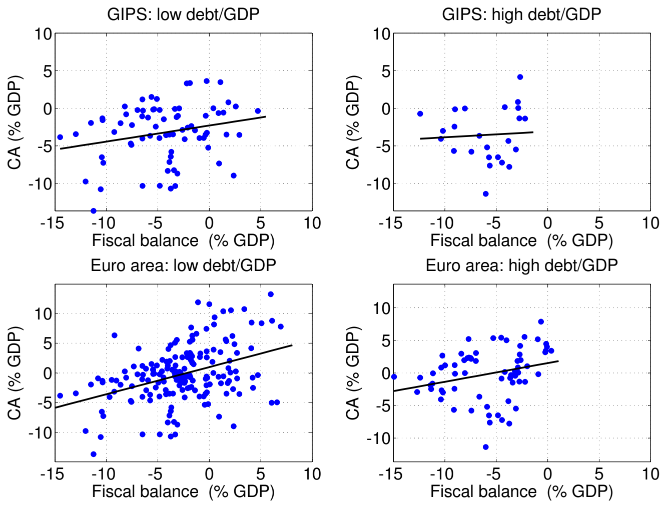
Notes: Columns 3, 4 and 5 report mean values in percent of GDP. The last column reports absolute change in percentage points of GDP. T: Number of time periods available, CA/GDP: Current account in percent of GDP, FB/GDP: Fiscal balance in percent of GDP, Debt/GDP: Government debt in percent of GDP.

Figure 1: Fiscal balance and current account for low and high debt/GDP in GIPS and euro area



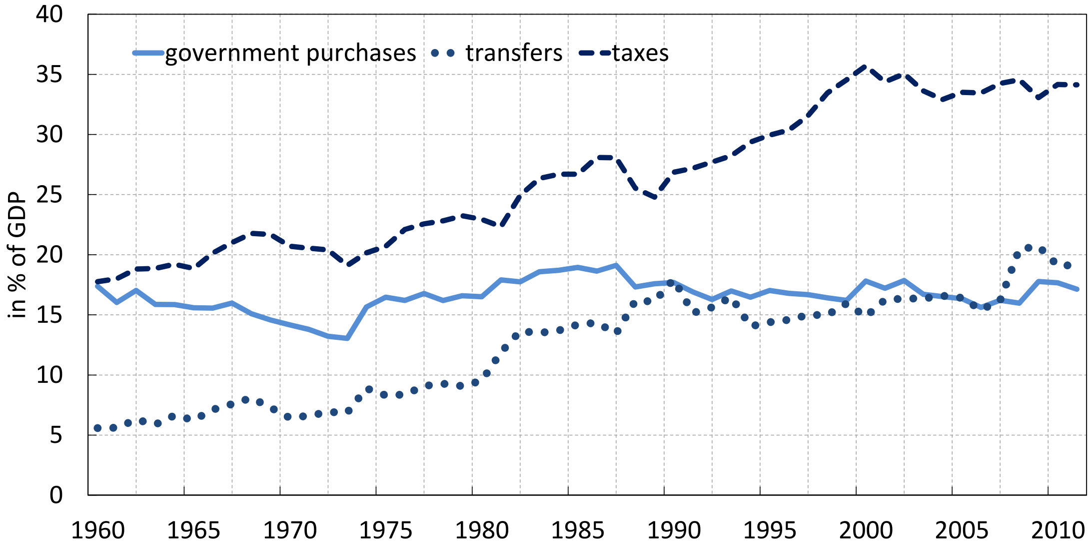
Notes: High debt/GDP is above 90 percent and low debt/GDP are observations below the threshold of 90 percent debt/GDP. Top panel refers to the sub-sample of GIPS countries which are Greece, Ireland, Portugal and Spain. The bottom panel refers to the EA-12 countries. Data is extracted from the IMF WEO 2013 and covers the period from 1980 to 2012 using annual data. Black lines depict fitted least squares regression lines.

Figure 2: Fiscal balance and current account for low and high debt/GDP in GIPS and euro area: 1980–2006



Notes: High debt/GDP is above 90 percent and low debt/GDP are observations below the threshold of 90 percent debt/GDP. Top panel refers to the sub-sample of GIPS countries which are Greece, Ireland, Portugal and Spain. The bottom panel refers to the full sample of EA-12 countries. Data is extracted from the IMF WEO 2013 and covers the period from 1980 to 2006. Black lines depict fitted least squares regression lines.

Figure 3: Government purchases, transfers and taxes in Greece



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

Figure 4: Sensitivity of Laffer curve to the Frisch elasticity of labor supply

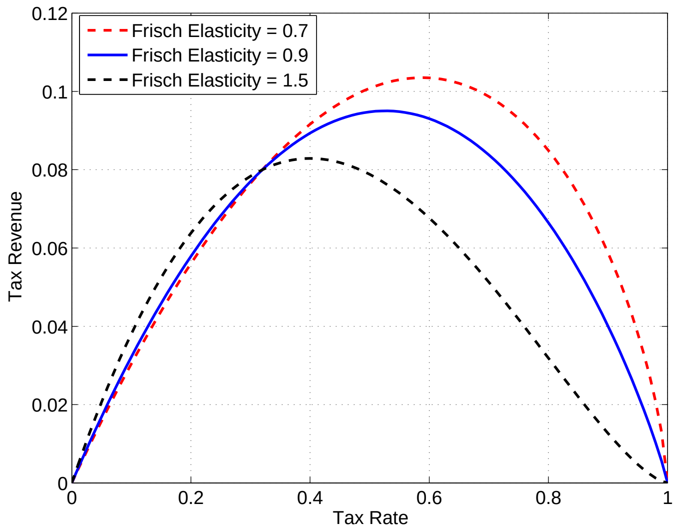
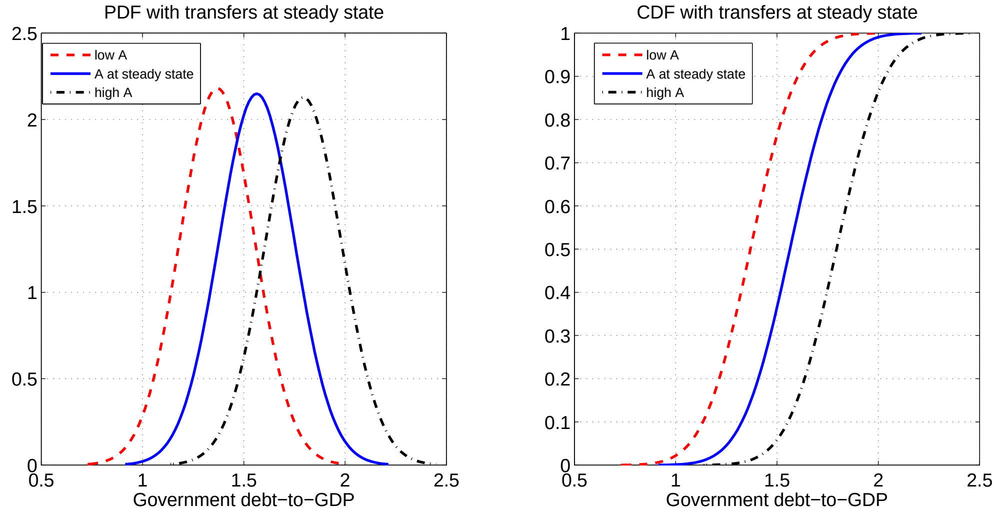
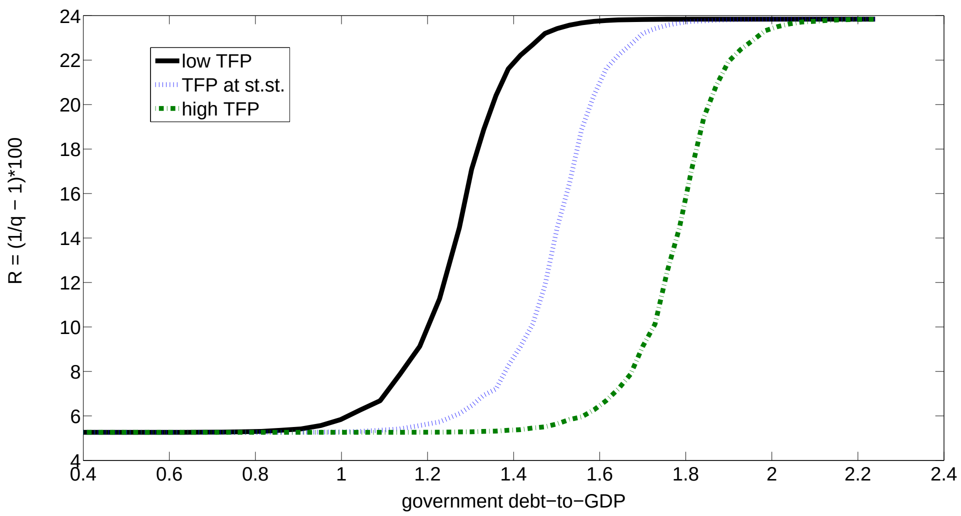


Figure 5: State-dependent distribution of the fiscal limit



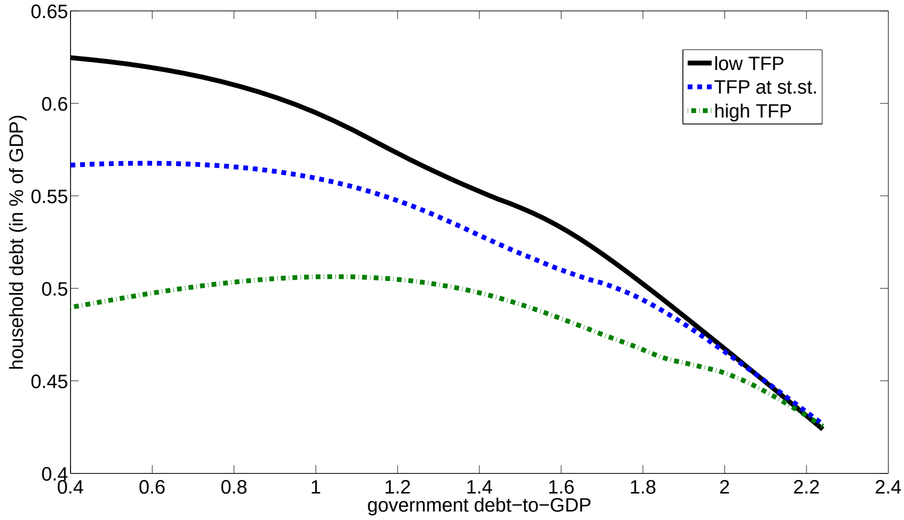
Notes: State-dependent distributions of the fiscal limit for different TFP states and transfers in steady state of the stationary regime. Each distribution is approximated by a normal distribution. The left panel shows the probability density functions and the right panel shows the cumulative density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

Figure 6: Sovereign interest rates at different government debt-to-GDP



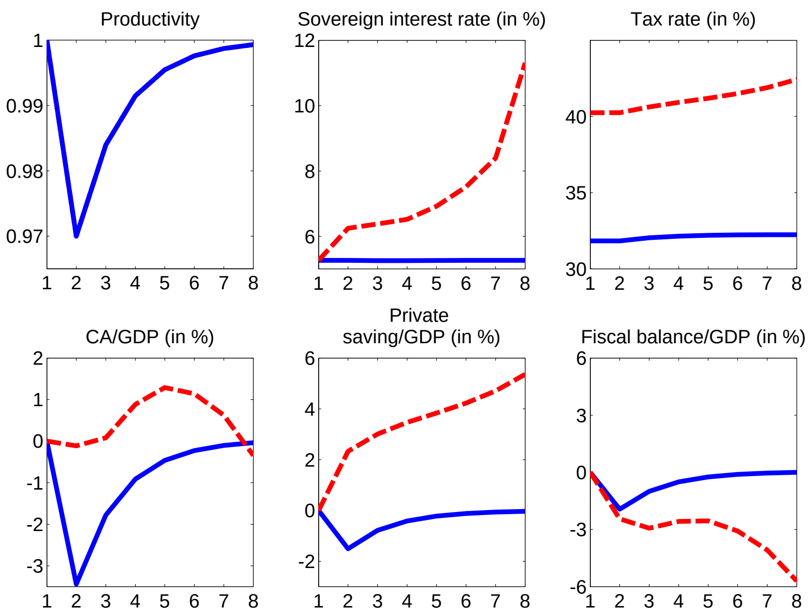
Notes: Household debt and transfer spending are both set to steady state and transfer spending is in the stationary regime. Horizontal axis: ratio of government debt-to-GDP. Vertical axis: in percentage points.

Figure 7: Households' debt stock at different government debt-to-GDP ratios



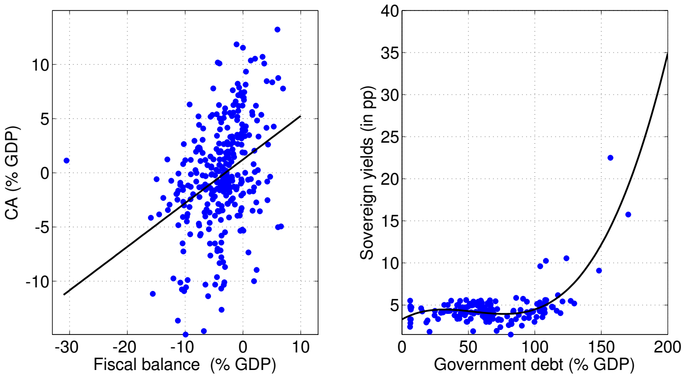
Notes: Transfer spending is at steady state and in the stable regime. Horizontal axis: ratio of government debt-to-GDP. Vertical axis: households' debt stock in percent of GDP when the households' debt stock in the previous period is at steady state.

Figure 8: Simulation of negative TFP shock at low vs. high government debt



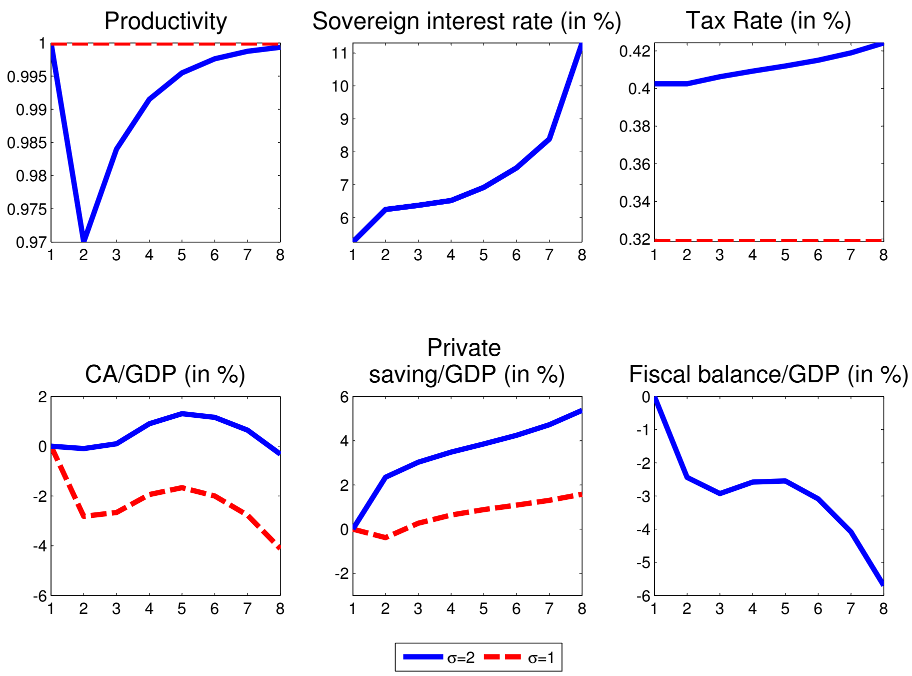
Notes: Simulation of a 3 percent negative productivity shock. We initialize the simulation at 60% government debt-to-GDP (blue solid line) and 140% government debt-to-GDP (red dashed line). Household debt is set to its ergodic mean. A time unit is one year.

Figure 9: Current account, fiscal balance, government debt and sovereign yields in the euro area



Notes: Left panel includes the full sample of the EA-12 countries. Right panel includes data for the EA-12 countries since joining the European Monetary Union to have a good measure of sovereign spreads due to default risk. The black line in the left panel is a fitted least squares regression line. In the right panel the black line is a fitted fourth order polynomial function. Data: IMF World Economic Outlook October 2013, OECD Economic Outlook and ECB SDW.

Figure 10: Simulation of negative TFP shock at high debt for different degrees relative risk aversion



Notes: Impulse responses to a 3 percent negative productivity shock. We initialize the simulation at 140% government debt-to-GDP for the benchmark case with a household risk aversion parameter value of $\sigma = 2$ (blue solid line) and for low risk aversion $\sigma = 1$ (red dashed line). Household debt is set to its ergodic mean. A time unit is one year.