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Financial Stress, Sovereign Debt and Economic Activity in Industrialized Countries: Evidence from Nonlinear Dynamic Panels

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Abstract

We analyze how the impact of a change in the sovereign debt-to-GDP ratio on economic growth depends on the state of the financial market. A dynamic growth model is put forward demonstrating that debt affects macroeconomic activity in a non-linear manner due to amplifications from the financial sector. For thirteen industrialized economies we study empirically the relationship between the GDP-growth rate, the debt-GDP ratio, and the financial stress index for the period 1980-2010 using quarterly data and dynamic single-country and dynamic panel threshold regression methods. We find that the debt-to-GDP ratio has impaired economic growth primarily during times of high financial stress and only for countries of the European Monetary Union and not for the stand-alone countries in our sample. A high debt-to-GDP ratio by itself does not seem to necessarily negatively affect growth if financial markets are calm.

Keywords: financial stress, sovereign debt, non-linear econometrics, threshold regression, threshold panel regression

JEL Classification: E20, G15, H63

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1 Introduction

Over the last five years there has been a renewed interest in understanding the interaction between a country's fiscal stance and its macroeconomic performance particularly due to the revival of fiscal policy as a discretionary macroeconomic stabilization tool during the 2007-08 global economic recession and the subsequent crisis of public finances. However, in contrast to previous work which used linear theoretical models and estimation techniques such as Blanchard and Perotti (2002), recent studies have analyzed the macroeconomic impact of fiscal policy and the subsequent feedback mechanisms from a state- or regime-dependent perspective.

On the one hand, Reinhart and Rogoff (2010) identify the debt-to-GDP ratio as a relevant threshold variable in an empirical study of forty-four advanced and emerging economies, arguing that sovereign debt beyond a certain threshold, namely 90% of GDP according to their results, will negatively affect economic growth.¹ Further, a second strand of studies such as Mittnik and Semmler (2012b), Auerbach and Gorodnichenko (2012), Taylor et al. (2012) and Fazzari et al. (2013) has investigated the business-cycle dependency of the growth effect of the fiscal stance, concluding that fiscal multipliers are more pronounced during recessions than during booms. And finally, a third strand of the literature has emphasized *financial-market stress* as a further, and quite relevant source for the non-linear relationship between a country's fiscal stance and its macroeconomic performance (cf. Mittnik and Semmler 2012a). Afonso et al. (2011) and Mittnik and Semmler (2013), for instance, argue that the main factor determining the effectiveness of fiscal policy as well as the sustainability of fiscal debt is the state of the financial markets, and not the extent of public indebtedness itself as postulated by Reinhart and Rogoff (2010).

The mechanism through which financial markets affect the relationship between the fiscal stance and economic activity have been studied extensively in the theoretical literature (cf. Stein 2011, 2012, Brunnermeier and Sannikov 2012 and Mittnik and Semmler 2012a, 2013).² The common theme of

¹As demonstrated by Herndon et al. (2013), however, coding errors and selective exclusion of observations biased the results of Reinhart and Rogoff (2010). Using the same data set, they argue that the threshold debt-to-GDP ratio of 90% is not significant and that growth effects of debt in high- and in low-debt regimes do not differ considerably.

²Stein (2011, 2012) emphasize over-leveraging of economic agents. Because of low interest rates, low credit spreads, rising capital gains and leveraging, economic booms may increase the vulnerability of the banking sector. Feedback loops between the financial sector and the macroeconomy may then give rise to a regime of low financial stress and a stable period of expansion, but may also generate destabilizing forces generating contractions and recessions when the financial sector starts to come under stress with risk premia rising and capital gains rapidly falling affecting aggregate demand and output. The models by Brunnermeier and Sannikov (2012) and Mittnik and Semmler (2012a) focus solely on the banking system which borrows to accumulate assets with returns, while there are preferences over payouts, serving as a consumption stream. When leveraging and payouts are less constrained, and financial stress and risk premia are high, the banking system is vulnerable and more prone to instability. With stronger restrictions, and low interest rates and

this literature is that financial stress affects the relationship between debt and economic growth via its impacts on risk premia, in particular bond spreads. For instance, Brunnermeier and Oehmke (2012) put forward the possibility of a *diabolic loop* according to which sovereign debt held by the banks can make the banking system unstable by exposing it to financial stress, forcing banks to cut down on loans, reducing economic growth and enforcing a downward spiral.

Given the crucial role of bond spreads for the effect of sovereign debt on economic growth, an additional aspect of the non-linear nexus between these two variables is the question whether a country is in a monetary union or not. As argued by De Grauwe and Ji (2013), this point is of particular relevance for the EMU since bond spreads may be more prone to investor's sentiments in countries of a monetary union than in stand-alone countries. According to these authors' findings, while the explanatory power of the debt-to-GDP ratio for bond spreads in EMU countries is significantly higher during times of economic distress than during times of economic stability, for non-EMU countries, however, this empirical regularity cannot be corroborated by statistical tests. A similar result is obtained by Schoder (forthcoming) who additionally argues that investors' sentiments are even more volatile in the EMU countries of the periphery than in the core EMU countries. According to these findings, the non-linearity in the sovereign debt-economic growth relation should be expected to be more pronounced in EMU countries, especially in the peripheral countries, than in stand-alone countries. To analyze empirically the non-linearities in the relationship between growth, sovereign debt and financial stress for core and peripheral EMU countries as well as stand-alone countries is the task taken up in the present paper.

Our contribution to the literature is thus twofold: On the one hand, we discuss a theoretical framework along the lines of Mitnik and Semmler (2012*a*, 2013) where financial stress affects in a non-linear manner the dynamics of the economy due to severe macroeconomic amplifications which arise when the financial sector comes under stress. We show that the macroeconomic amplifications crucially depend on whether there is low or high financial stress by the aid of an finite horizon model. The theoretical model is solved numerically using the non-linear Model Predictive Control (NMPC) technique introduced by Grüne and Pannek (2011). This new solution procedure allows for both a multi-period model, but also includes some of well-known macroeconomic feedback and amplification mechanisms.

On the other hand we estimate the effects of sovereign debt and financial stress on economic growth through an econometric regime-dependent framework where the regimes depend on the debt-to-GDP ratio. When credit spreads are low there is a greater corridor of stability, creating a more stable environment for the banks. On the other hand, with less decision constraints, and the banking system facing state dependent risk premia and credit spreads which increases the cost of leveraging of banks, there may exist only a small corridor of stability, as banks may be more vulnerable to financial stress and crises.

to-GDP ratio, and the level of financial stress. We investigate this relationship empirically for 13 OECD countries from 1980 to 2010 employing quarterly data and using dynamic country-specific and dynamic panel threshold regression analysis. We pay special attention to the differences between EMU and stand-alone countries as well as between northern EMU and southern EMU countries. Our sample includes Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DNK), Germany (DEU), Spain (ESP), France (FRA), the United Kingdom (GBR), Italy (ITA), Japan (JPN), the Netherlands (NLD), and the United States (USA).

Our estimation results suggest the following: First, we do not find evidence for a straightforward and universally valid negative impact of debt on growth in our sample. Second, the debt-to-GDP ratio does not seem to be the relevant measure which determines the switch in the investors' sentiments from growth-enhancing to growth-impairing. That means, it seems that debt does not become a problem just because a country faces a high debt-to-GDP ratio as argued by Reinhart and Rogoff (2010). This non-linearity does not seem to be statistically significant for our sample and sub-samples considered. Third, consistent with our theoretical model, we have identified the financial stress index (FSI) as a crucial source of the non-linearity between debt and economic activity. Only at high levels of financial stress, the debt-GDP ratio may negatively affect growth. Yet, this is still not necessarily the case, because, fourth, we find evidence that debt reduces growth during high financial stress only for countries within a monetary union, i.e. the European Monetary Union. Fifth, the effect of the FSI on growth is highly non-linear by itself and independent from the debt-to-GDP ratio, especially for the group of Italy and Spain.

Our work is mostly related to Afonso et al. (2011), in the sense that we investigate the interaction between public finances and economic growth from a non-linear perspective. However, in contrast to Afonso et al. (2011), who use country-specific threshold VAR models to investigate the interaction between GDP growth, fiscal variables, inflation, the interest rate and the financial stress index (FSI) using the latter variable as the threshold variable, we focus solely on how GDP growth is affected by and large the same variables, but using a threshold dynamic panel approach to exploit the cross-sectional dimension of the data using not only the FSI, but also the debt-to-GDP ratio in an alternative specification. Our work can thus be considered as complementary to Afonso et al. (2011) not only in terms of the choice of variables and countries, but also because our results widely support and extend their results on the basis of the estimation of different country subgroups in a dynamic panel context.

The remainder of the paper is organized as follows. In the next section we investigate the dynamics of a stylized dynamic macroeconomic model of a small open economy in low and high financial stress regimes. Section 3 discusses the data used in this paper, the econometric methodology applied and the estimation results. Section 4 concludes the paper.

2 The Model

In the following we briefly discuss a model variant of Mittnik and Semmler (2012a, 2013) to describe the dynamic interaction of aggregate indebtedness and macroeconomic activity in low and high financial stress regimes, as well as to motivate the subsequent empirical analysis on sovereign debt, financial stress and GDP growth. Even though the current theoretical framework focuses on aggregate debt, its insights are applicable to the empirical analysis of the next section, which focuses on the interaction between sovereign debt and GDP growth due to the high correlation between current account and fiscal imbalances (cf. Berger and Nitsch 2010).

Let us consider a stylized model economy in which a social planner chooses the level of consumption c_t and the growth rate of the capital stock g_t such as to maximize inter-temporal utility. The problem can be formulated as

$$V(k, d) = \max_{c_t, g_t} \int_0^T e^{-rt} U(c_t) dt \quad (1)$$

subject to

$$dk_t = (g_t - \delta)k_t dt \quad (2)$$

$$db_t = (r_t b_t - (y_t - c_t - i_t - \varphi(g_t k_t))) dt \quad (3)$$

where k_t is the capital stock, $i_t = g_t k_t$ aggregate investment, δ the depreciation rate of capital, r_t the real interest rate – to be further discussed below – and b_t the economy’s aggregate debt (private and public).³ Eq. (2) describes the evolution of the economy’s capital stock, and eq.(3) the aggregate debt’s evolution, where $\varphi(\cdot)$ stands for the quadratic adjustment costs of investment (cf. Blanchard and Fischer (1989, ch.2) and Stein (2012, ch.8)).⁴

According to eq.(1) the social planner maximizes the discounted utility from of private consumption not over an infinite time horizon, as it is standard in the literature, but over a finite horizon given by T . We make this assumption to be able to establish a stronger link between the current state of the economy and the social planner’s decisions without deviating from the general notion of forward-looking, inter-temporal utility maximizing behavior. Indeed, as it is widely known, a recurrent problem of infinite horizon models is the too low volatility of macroeconomic variables which results from the extreme consumption smoothing resulting precisely from the infinite horizon underlying the decision

³We could also permit for a spread between interest and discount rates as done, for example, in models with two types of agents as in Eggertsson and Krugman (2011) without changing the results qualitatively. Further, even though our model is interpreted in the context of an open economy, it can also be interpreted as a closed economy with borrowers and lenders as in Eggertsson and Krugman (2011).

⁴Brunnermeier and Sannikov (2012) include a stochastic shock in a Brownian motion and volatility dependent asset prices, and formulate the debt dynamics as a net worth dynamics but in a closed economy framework. In our open economy framework, in contrast, we implicitly also allow for sovereign debt, and could also include stochastic shocks.

rules of the agents. In order to solve this forward-looking, finite horizon model in such a way that its solution may be consistent with the infinite horizon solution if $N \rightarrow \infty$, we apply the so-called Non-Linear Model Predictive Control technique recently developed by Grüne and Pannek (2011).

In a nutshell, the NMPC methodology can be summarized as follows: To start, consider a general dynamic decision problem described by

$$\max \int_0^T e^{-\rho t} \ell(x(t), u(t)) dt, \quad (4)$$

where the evolution of the state variable $x(t)$ is given by $\dot{x}(t) = f(x(t), u(t))$, with $x(0) = x_0$ and where $u(t)$ represents the control variables of the problem. A discrete-time approximation of such a problem is given by

$$\max \sum_{i=0}^T \beta^i \ell(x_i, u_i) dt, \quad (5)$$

where the maximization is now performed over a sequence u_i of decision values and the sequence x_i satisfies $x_{i+1} = \Phi(h, x_i, u_i)$. Here $h > 0$ is the discretization time step, $\beta = e^{-\rho h}$ and Φ is a numerical scheme approximating the solution of $\dot{x}(t) = f(x(t), u(t))$ on the time interval $[ih, (i+1)h]$.⁵ The essence of NMPC lies in replacing the maximization of the above large horizon functional, where we could have $T \rightarrow \infty$, by the iterative maximization of finite horizon functionals

$$\max \sum_{k=0}^N \beta^i \ell(x_{k,i}, u_{k,i}) dt, \quad (6)$$

for a truncated finite horizon $N \in \mathbb{N}$ with $x_{k+1,i} = \Phi(h, x_{k,i}, u_{k,i})$ and the index i indicating the number of the iteration. As discussed in Grüne and Pannek (2011), it can be shown that under appropriate assumptions on the problem – such as the existence of an equilibrium for the infinite horizon problem – the solution (x_i, u_i) (which depends on the choice of N above) converges to the correct, infinite horizon solution of eq.(5) as $N \rightarrow \infty$.⁶

In order to model in an explicit manner the non-linear effect of financial market stress for economic activity, we do not only allow the yields on debt, sovereign or private, to be endogenous, but we also allow for endogenous feedback loops of leveraging and bond yields on output and other macroeconomic variables, as also done e.g. in Corsetti (2012) and Blanchard and Leigh (2013) and Blanchard et al. (2013). Concerning the former, and in order to resemble the observed behavior of the euro area government bond yields since the outbreak of the Greek debt crisis, we assume that the bond yields are a non-linear function of the economy's aggregate debt to capital stock ratio and the financial stress ψ_t i.e.

$$r(b_t/k_t, \psi_t) = \theta \arctan(b_t/k_t, \psi_t). \quad (7)$$

⁵For details and references about the discretization procedure see Grüne et al. (2013).

⁶For details of why models with shorter time horizons can approximate well models with longer time horizons needing much less information, see also Grüne et al. (2013).

We thus assume that the yields on debt are a nonlinear function (represented by the arctan function) of the aggregate indebtedness level and of the level of stress in the financial markets, whereas when both the debt-to-capital ratio and the financial stress are low, the link between these variables and the bond yields are weak, and the yield level itself is low too.⁷ In contrast, when either b_t/k_t and ψ_t , or both, are high, the link between these variables and $r(\cdot)$ is tighter, and the yield level is likely to be much higher too. In this context, we also assume implicitly that b_t/k_t and ψ_t are correlated with each other in a nonlinear manner as⁸

$$\text{Corr}(b_t/k_t, \psi_t) = \arctan(b_t/k_t, \psi_t).$$

Accordingly, an increase of, for instance, b_t/k_t would bring about (not through causality, but through some correlation) a significant increase in ψ_t only when either b_t/k_t or ψ_t are already at high levels, and not in the opposite case. This assumption is helpful from both the theoretical as well as the empirical perspective. Concerning the former, it allows us to implicitly analyze the effects of a higher financial stress through the analysis of the evolution of the debt-to-capital ratio in the following simulations without explicitly modeling the evolution of the (in reality unobservable) variable ψ . Concerning the latter, such a linkage may explain the empirical observations that when the economy's leverage ratio is particularly high, the bond yields rise in a non-linear manner due to the increased financial stress in the economy (cf. De Grauwe and Ji 2012, 2013).

Additionally, we model financial stress as triggering a self-enforcing mechanism which reduces output and capacity utilization due to its direct effect on private consumption and investment demand.⁹ We assume that actual consumption and investment demand, and thus aggregate demand, depend also directly on the level of financial stress in the economy, and thus on the bond yields level, as done e.g. in Adrian et al. (2010), who describe in detail how a rise of an overall macroeconomic risk premia can trigger macroeconomic contractions. Specifically, we assume that actual consumption and investment are determined in the following way:

$$c_t^a = (1 - \phi(r_t))c^{opt} \tag{8}$$

$$i_t^a = (1 - \phi(r_t))i^{opt} \tag{9}$$

⁷In the following simulations we set $\theta = 0.1$.

⁸To what extent these variables are correlated is discussed in Mittnik and Semmler (2013).

⁹This self-enforcing macroeconomic feedback mechanism may be further strengthened by the wealth effect on consumption and investment, and/or the deleveraging process, as discussed e.g. by Eggertsson and Krugman (2011) and Mittnik and Semmler (2012b). Further, as financial market forces trigger financial stress, the central bank may have no instruments available – or may not be willing to reduce the interest rate further – to reduce risk premia and credit spreads, for example by the purchase of sovereign bonds. Additionally, there could occur even a worse feedback: a weak financial sector, holding risky sovereign debt, may come under severe stress, because sovereign bonds may go into default and banks reduce lending to the real economy, or worse, may even default.

where $\phi(r_t)$ is a function of the interest rate, which in its turn is a function of the level of indebtedness and the financial stress in the economy as determined in eq.(7), with the derivatives $\frac{dc^a}{d\phi} < 0$ and $\frac{di^a}{d\phi} < 0$. Accordingly, even though the social planner is indeed capable of computing the economy's optimal consumption and investment plans, the higher the level of financial stress, the lower will be the actual, realized consumption and investment relative to their corresponding optimal levels due to the precautionary saving behavior of households and firms, among other related reasons. Since $y_t^a = c_t^a + i_t^a$, it holds for the realized aggregate output level

$$y_t^a = (1 - \phi(r_t))y^{opt} \quad (10)$$

In order to highlight how the model's properties are affected by the economy's overall indebtedness and/or financial stress levels, in the following we study the dynamics of the system under a regime of low financial stress, and a regime of high financial stress. In the first model variant the interest on aggregate debt is held constant at a low level, as it was the case for example during the 2000s prior to the recent financial crisis. This is a kind of Minsky scenario where financial fragility may arise in a period of tranquility and thus low or zero risk premia can be observed, as for example were seen in the US from the 1990s to 2007.¹⁰

The left graph in Figure 1 shows the NMPC solution paths for capital, debt and the debt-to-capital ratio for $r = 0.02$ with the initial conditions $k(0) = 0.9$ and $b(0) = 0.9$ over time, while the right graph plots the debt-to-capital ratio and the capital against each other, with the debt-to-capital ratio on the vertical axis and the capital stock on the horizontal axis. As it can be observed, if the interest rate remains constant at $r = 0.02$, while the path of aggregate debt and capital still feature a positive growth rate, debt-to-capital ratio converges to a given value which describes the steady state of the economy (this is a property of the present model which applies for multiple initial values of k and b).

As this first simulation shows, as long as the financial stress is low (either through central bank intervention or as a result of the overall market expectations) and the bond yields remain by and large invariant at low levels, the debt-to-capital ratio will eventually stabilize about a finite ratio, with capital growing at a positive rate. However, precisely in such a stable macroeconomic scenario an over-leveraging process may take place which may induce financial instability in the Minsky (1992) sense.

Figure 2 illustrates in contrast the dynamics of a scenario where the interest rate on debt is a

¹⁰Implicitly, in this case, on the asset side, as Stein (2012) shows, the present value of the assets will tend to become very large, because there is no correction through a risk premium, and capital gains help to service the debt. Alternatively, this is equivalent to the case of the central bank pursuing a low – or near zero – interest rate policy. By this, in fact it might attempt to keep the economy in a low financial stress regime, see Christiano et al. (2011), and Woodford (2011).

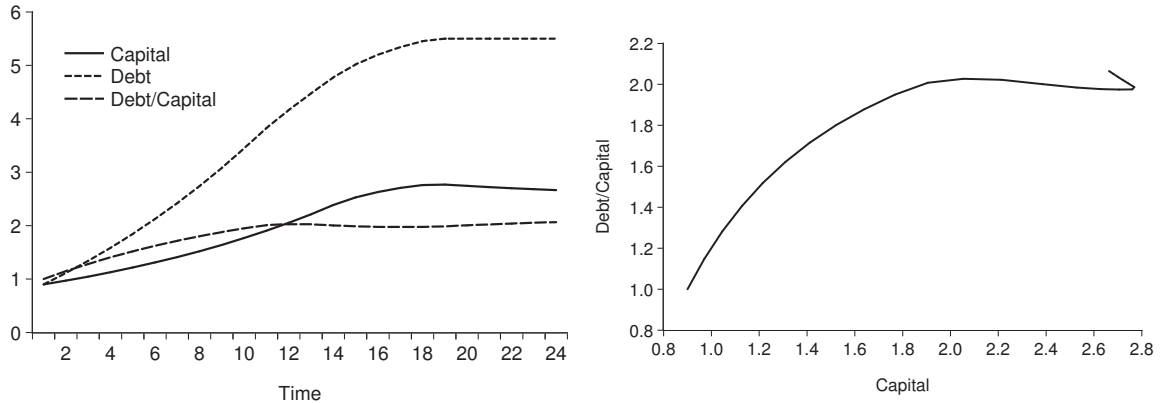


Figure 1: Convergent dynamic paths of sovereign debt for constant interest rate (low financial stress regime), for initial conditions $k(0) = 0.9$, $b(0) = 0.9$, with $r = 0.02$.

non-linear function of ψ_t as in eq.(7), and where realized consumption and investment are determined through eqs. (8) and (9) starting from the same initial values as in the previous simulation. As it can be clearly observed there, a contraction of the capital stock and an accelerating increase both in the level of aggregate debt as well as in the debt-to-capital ratio takes place due to the activation of the non-linear negative impact of financial stress on the government debt yields as well as, more directly, on the determination of consumption and investment, and the subsequent dynamic feedback mechanisms of higher risk premia and yields, larger interest payments and lower consumption and investment.¹¹ This, of course, is an unsustainable scenario, as additional increases in the interest rate on debt lead to further increases in the interest payments, which will become eventually larger than the surplus generated to pay such debt service.¹²

Before turning our attention to the econometric analysis, we would like to stress again the fact that these simulated dynamics represent the optimal solution of a finite-horizon dynamic problem, and are thus consistent with a forward-looking, utility maximizing modeling approach. However, it is precisely due to the finite planning horizon of the current framework that the relationship between debt and capital is much closer than what it would be in an infinite horizon framework.¹³

¹¹Note that a strong contractionary effect could also occur if the creditors become unwilling to lend when a certain debt to GDP ratio is reached and new borrowing or rolling over of old debt will be discontinued. For a model including such a sudden rise of credit market constraint, see Ernst and Semmler (2013).

¹²The shift to a high financial stress regime could also be related to a situation in which the central bank either does not attempt, or is not able to pursue an unconventional monetary policy to bring down credit spreads and so to calm down the financial markets.

¹³Since the transversality condition does not apply for finite horizon models, Ponzi-schemes and, therefore, unsustainable debt accumulation processes cannot be ruled out in the current framework. Yet, as argued by Bohn (2007), the transversality condition is a very weak criteria for assessing the sustainability of debt accumulation, since an exploding debt ratio along the optimal consumption path is possible in infinite horizon models despite the validity of the

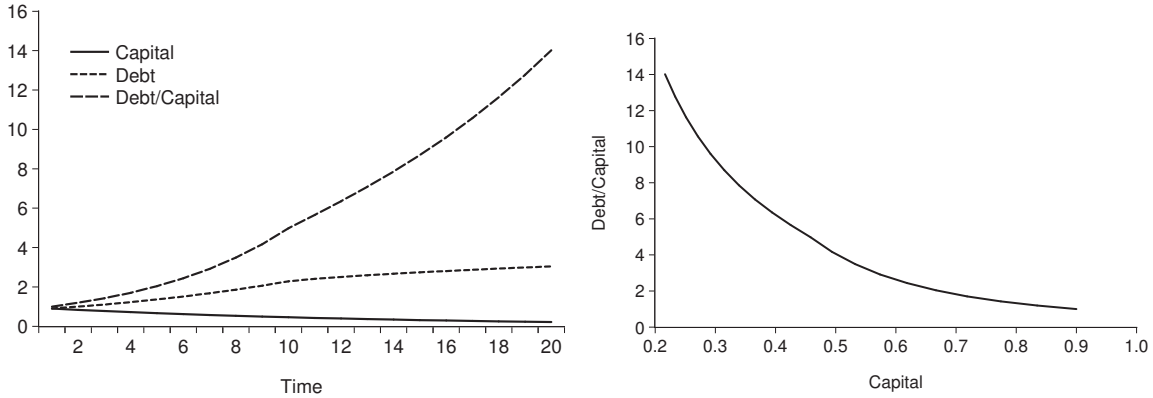


Figure 2: Debt dynamics with endogenous interest rates and macro feedback loops starting from the initial conditions $k(0) = 0.9$, $b(0) = 0.9$.

In the next section we investigate empirically how sovereign debt and financial stress affect economic activity in a representative sample of 13 industrialized countries by means of single-equation and panel nonlinear estimation techniques.

3 Empirical Analysis

3.1 Data Description

For our empirical analysis, we use quarterly seasonally adjusted data on the net sovereign debt of the general government, GDP at constant prices, the financial stress index and the real interest rate on long-term government bonds from 1980:1 to 2010:4 for the following 13 countries: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DNK), Germany (DEU), Spain (ESP), France (FRA), the United Kingdom (GBR), Italy (ITA), Japan (JPN), the Netherlands (NLD), and the United States (USA). The data on GDP and the interest rate on long-term government bonds stems from the OECD Economic Outlook (EO) 89 database and Eurostat.¹⁴ The financial stress

¹⁴For AUS, CAN, JPN and USA quarterly seasonally adjusted data on the general government's net debt-to-GDP ratio is provided by the OECD EO 89 for the time period considered. For AUT, FRA, GER and ITA the computed net debt series consists of two parts (both being normalized by GDP): The discontinued data on net debt of the general government taken from the OECD EO 79, and an interpolated series employing Chow and Lin (1971) using annual net debt taken from the OECD EO 89, and cumulative seasonally adjusted government net lending taken from Eurostat, as also done in Schoder et al. (2012). The last quarter of the year in which the break occurred has been used as the reference quarter to the annual debt series. Note that the former part has been adjusted to match the overlapping quarters. For the remaining countries the net debt series has been completely estimated employing Chow and Lin (1971). Details are spelled out in Appendix B.

index (FSI) stems from the IMF data set discussed in Danninger et al. (2009) and Cardarelli et al. (2009).¹⁵ The debt-to-GDP ratio, the financial stress index and the growth rate of GDP in percent are plotted in figure 3 for all countries investigated.¹⁶

As it can be observed in Fig. 3, the net sovereign debt-to-GDP ratio differs considerably between countries, with DNK and CAN having the lowest ratios at the end of the sample considered, as they managed to reduce their net sovereign debt considerably since the mid 1990s. In contrast, the highest current debt-to-GDP ratio among the considered countries can be observed in ITA and BEL with around 90%. Further, apart from the level of the debt-to-GDP ratio its evolution over time is of interest. Countries such as BEL, CAN, DNK, ESP and NLD managed to reduce their debt-to-GDP ratio since the mid 1990s. Others, in particular AUT, FRA, GBR and ITA more or less stabilized the ratio in that time, whereas DEU and JPN experienced an increase in the debt ratio. In this light, it is interesting to note that the troubled southern EMU countries do not face much higher debt-to-GDP ratios than other countries that are rather considered as financial safe havens such as the USA, JPN or DEU.

Concerning the dynamics and interaction of the FSI and the GDP growth, as Fig. 3 clearly illustrates, there is a strong negative correlation between GDP growth and the FSI, not only during the recent financial crisis, where GDP growth slumped in the majority of countries around the world and the FSI spiked to unprecedented levels, but also in the previous periods. This is not surprising. Yet, due to the way the FSI is constructed, an increase in the credit spread and a drop in stock prices, for instance, – two phenomena closely linked to the occurrence of economic recessions – leads to an increase in the FSI. In this context, it is interesting to note that while the output contraction during the recent financial crisis was rather similar across all countries considered, the FSI reaction was, on the other hand, quite differentiated, with the FSI of countries such CAN, JPN, NLD and USA soaring about three times higher than in the remaining countries.

¹⁵The FSI is a composite indicator comprising information on the *banking-sector beta*, stock market returns, time-varying stock market return volatility, sovereign debt spreads, and an exchange market pressure index. Afonso et al. (2011) use this same variable in their estimations of country-specific threshold vector auto-regressions.

¹⁶It would have been quite interesting to include Greece, Ireland and Portugal in the set of countries of this study, but unfortunately there is no financial stress index available for these countries.

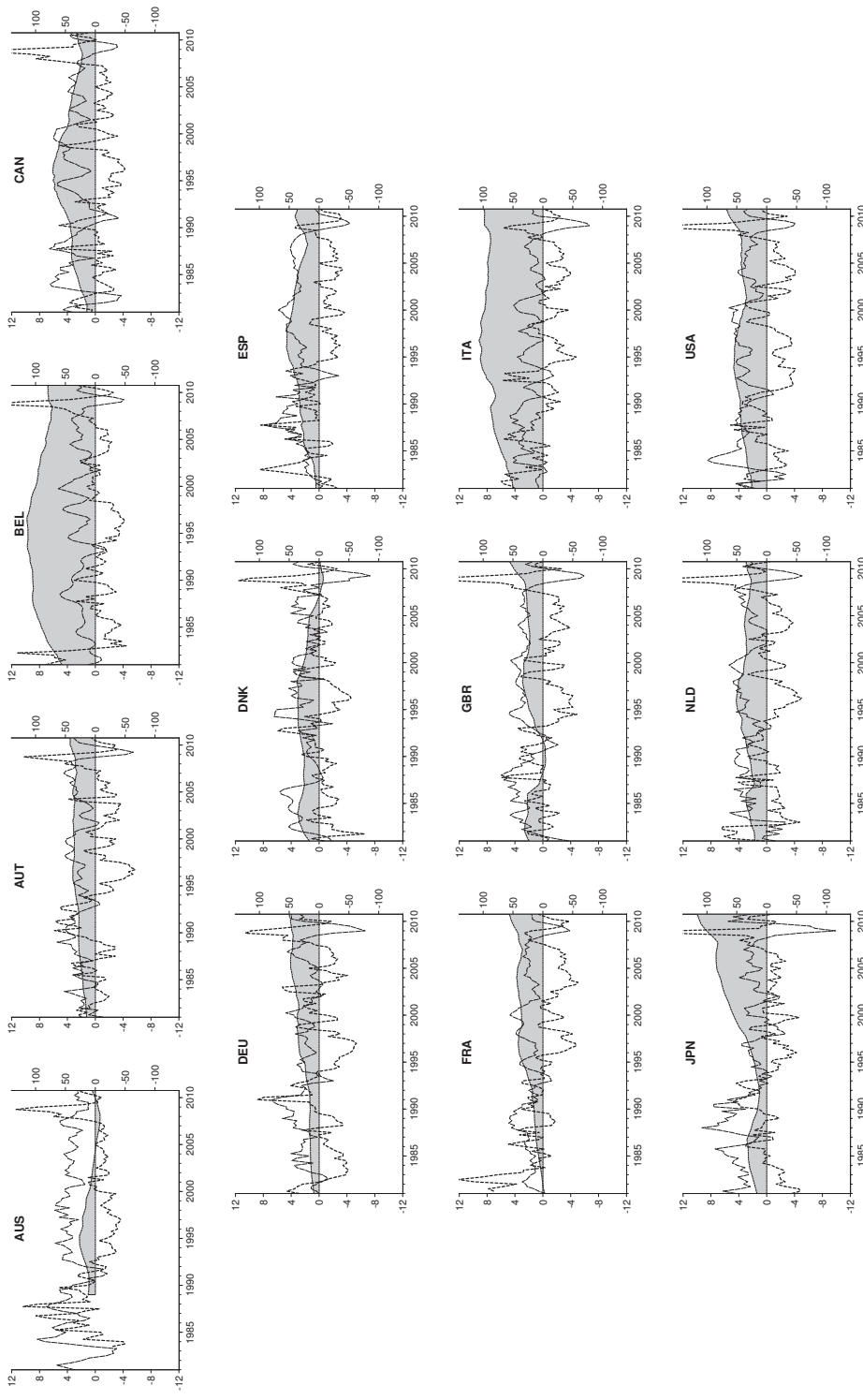


Figure 3: Net sovereign debt-to-GDP ratio (shaded area, left axis), year-to-year GDP growth rate (solid line, right axis) and financial stress index (dashed line, right axis) from 1981:1 to 2010:4

3.2 Econometric Methodology

For the following analysis of the non-linear influence of sovereign debt and the financial stress on economic growth we use country-specific and panel threshold regressions of EMU and non-EMU countries. Threshold regressions allow us to distinguish low-debt/high-debt and low-stress/high-stress regimes, respectively. Panel regressions allow us to additionally exploit the information along the cross-section dimension to obtain more robust results, as well as to identify potential differences between particular country sub-samples by running various dynamic panel threshold regressions. As sub-samples we consider EMU and non-EMU countries as well as northern and southern EMU countries. More specifically, we study first, if the debt-to-GDP ratio's effect on economic growth is non-linear with respect to the debt-to-GDP ratio itself; second, how the debt-to-GDP ratio's effect on growth depends on financial stress; and finally, how the effect of financial stress on growth is related to the level of financial stress.

In general terms, we consider the following dynamic threshold regression model:

$$y_{it} = \mu_i + \mathbf{z}_{it}\boldsymbol{\alpha} + (\delta + x_{it}\beta^L) \cdot I(q_{it} \leq \gamma) + x_{it}\beta^H \cdot I(q_{it} > \gamma) + \varepsilon_{it} \quad (11)$$

where $i = 1, \dots, N$ denotes a country-index, $t = 1, \dots, T$ the time index, μ_i a country-specific fixed effect, ε_{it} an i.i.d. country-specific random disturbance with zero mean and a variance $\sigma_{\varepsilon_i}^2$, and \mathbf{z}_{it} a vector which contains both potentially endogenous as well as exogenous explanatory variables which affect y_{it} in a regime-independent, linear manner. Concerning the nonlinear part of the above regression model, q_{it} is the threshold variable and γ is a given threshold level. $I(\cdot)$ is an indicator function which takes on the value of one if the condition in its argument holds and zero otherwise. Hence, the coefficients β^L and β^H represent the effect of the variable x_{it} on the dependent variable y_{it} for $q_{it} \leq \gamma$ and $q_{it} > \gamma$, respectively. x_{it} is an exogenous variable and δ is the difference between the intercept in regime H, i.e. μ_i , and the intercept in regime L, i.e. $\mu_i + \delta$, (cf. Bick, 2010).

As previously mentioned, we estimate the regression model described by eq.(11) using both single-equation and panel estimation techniques. Concerning the single-equation regressions (where of course the index i is given and the information comes only from the variation in the time index t), we follow Caner and Hansen (2004) and employ their IV estimator to account for the possible endogeneity of the variables comprised in x_{it} and z_{it} . Further, also following Caner and Hansen (2004) the threshold value which determines the switch of the indicator function $I(\cdot)$ is identified as the value which minimizes the residual sum of squares.

Concerning the panel dimension of our analysis, despite the fact that, as recently pointed out by Baum et al. (2012), a full distribution theory for such type of models has not been developed so

far,¹⁷ we estimate the dynamic threshold panel regression described by eq.(11) following Kremer et al. (2013), who extended the IV threshold estimation methodology developed in Caner and Hansen (2004) for the panel case using the data set of 13 countries spanning the same period (1981:1 to 2010:4).

As discussed by Kremer et al. (2013), in order to use the estimation procedure originally proposed by Caner and Hansen (2004) for a cross-sectional framework in a dynamic panel framework it is important to make sure that the country-specific fixed effects are eliminated without violating the distributional assumptions underlying Hansen (1999) and Caner and Hansen (2004). This is achieved by transforming the variables according to the forward orthogonal deviations transformation proposed by Arellano and Bover (1995), where each observation is subtracted by the mean of all future observations, see also Kremer et al. (2013). Accordingly, the disturbance terms resulting from such a transformation are given by

$$\varepsilon_{it}^* = \sqrt{\frac{T-t}{T-t-1}} \left[\varepsilon_{it} - \frac{1}{T-t} (\varepsilon_{i,t+1} + \dots + \varepsilon_{iT}) \right]$$

where

$$\text{Var}(\varepsilon_{it}) = \sigma_\varepsilon^2 \cdot \mathbf{I}_T \implies \text{Var}(\varepsilon_{it}^*) = \sigma_\varepsilon^2 \cdot \mathbf{I}_{T-1}.$$

As proposed by Caner and Hansen (2004), we follow a two-step least squares estimation approach, where the endogenous variables in \mathbf{z}_{it} are regressed on the complete set of instruments in the first step and, in the second step, the resulting fitted values are replaced in the original regression given by eq.(11) for given values of the threshold γ . These steps are repeated for different values of γ , being the finally selected value the one which is associated with the smallest sum of squared residuals S , i.e. $\hat{\gamma} = \arg \min_{\gamma} S(\gamma)$. Finally, once $\hat{\gamma}$ has been determined, eq.(11) is again estimated, now via GMM, using the same set of instruments as in the first-stage equation and $\hat{\gamma}$ as a given value.

3.3 Results

3.3.1 Debt-to-GDP ratio as threshold variable and regime dependent regressor

Let us first consider the following specification of the general threshold model in eq.(11):

$$\begin{aligned} y_{i,t} = & \mu_i + \alpha_y y_{i,t-1} + \alpha_r r_{i,t-1} + \alpha_f f_{i,t-1} \\ & + \beta_b^L b_{i,t-1} I(b_{i,t-1} \leq \gamma) + \beta_b^H b_{i,t-1} I(b_{i,t-1} > \gamma) + \delta I(b_{i,t-1} \leq \gamma) + \varepsilon_{i,t} \end{aligned} \quad (12)$$

where y_{it} is the quarter-to-quarter growth rate of real GDP, r_{it} is the interest rate on long-term government bonds deflated with the GDP deflator, f_{it} is the financial stress index and b_{it} is the

¹⁷The distribution theory developed in Hansen (1999) for threshold panels applies only for the case of non-dynamic panels.

sovereign debt-GDP ratio. The regressors $y_{i,t-1}$ and $r_{i,t-1}$ are assumed to be endogenous. Their lags are available as instruments due to the orthogonal forward transformation of the variables.¹⁸ The regressor $f_{i,t-1}$ and the regime-dependent regressor $b_{i,t-1}$ are assumed to be exogenous.¹⁹

The above specification is appropriate to study the research question raised by Reinhart and Rogoff (2010): Is there a threshold level of the debt-to-GDP ratio beyond which the debt-to-GDP ratio reduces the growth rate of the economy? Table 1 reports the results of the country-specific threshold regressions followed by the results of the panel threshold regressions. For the panel estimations, we consider the following groups of countries: all countries of the sample, EMU countries (AUT, BEL, DEU, ESP, FRA, ITA, NLD), non-EMU countries (AUS, CAN, DNK, GBR, JPN, USA), northern EMU countries (AUT, BEL, DEU, FRA, NLD) and southern EMU countries (ESP, ITA).

Averaging over all countries yields threshold estimates of around 80% which is roughly consistent with the threshold of 90% identified by Reinhart and Rogoff (2010). However, a more differentiated analysis based on the country-subgroups, as well as on the country-specific estimates, qualify significantly the empirical validity of such a threshold value as a general and universal threshold. Both the country-specific estimates as well as the estimates of the subgroup panel regressions indicate quite heterogeneous threshold levels for the different countries, ranging from 9% in France to 85% in Japan.

Let us first interpret the estimates of the regime-independent regressors. As expected, for almost all countries and for all groups of countries, the coefficient of the lagged endogenous variable is positive and highly significant. Further, except for Belgium, the point estimates of the growth effect of the interest rate are negative for all single countries and groups of countries considered. Yet, they are statistically significant only for a few countries and the group of southern EMU countries. In contrast, the effect of the FSI on growth is negative and statistically significant for all country groups and single countries except the United Kingdom and the United States.²⁰ Hence, financial stress seems to be a reliable predictor for economic activity across industrialized countries. The panel estimates indicate that the negative impact on growth of financial stress is most pronounced in stand-alone countries and least pronounced in the southern EMU countries of the sample.

¹⁸In all specifications to follow, we use the maximum number of instruments available for each endogenous regressor unless the instrument matrix is close to singular. In this case we keep reducing the number of instruments for each regressor by 10 and reestimating the model until the instrument matrix is clearly full-rank.

¹⁹We have also considered a specification including the growth rate of the labor force as an additional control variable. Since the results do not change substantially, we only report the results of the more parsimonious specification. Yet, we indicate below when the results of the two specifications are not consistent with each other.

²⁰The United Kingdom and the United States are interesting exceptions which may be related to their standing as safe havens despite financial turmoils. This may cause the transmission channels through which financial stress affects growth to be weaker in these countries. Yet, if we include the growth rate of the labor force as a regressor, the growth effect of the FSI turns negative in both countries.

Table 1: Country-Specific and panel dynamic threshold GMM estimation results with the debt-to-GDP ratio as the threshold variable and the debt-to-GDP ratio as a regime dependent regressor (equation 12)

	γ	α_y	α_r	α_f	β_b^L	β_b^H	δ
COUNTRY-SPECIFIC THRESHOLD REGRESSIONS							
Northern EMU countries							
AUT	19.70	0.267*** (0.036)	-0.090*** (0.009)	-0.081*** (0.011)	-0.204*** (0.053)	-0.027*** (0.005)	2.437** (0.963)
BEL	72.83	0.575*** (0.020)	0.001 (0.003)	-0.002 (0.002)	-0.066*** (0.004)	0.001 (0.001)	3.894*** (0.329)
DEU	41.95	-0.076*** (0.026)	-0.132*** (0.006)	-0.173*** (0.022)	-0.014*** (0.002)	0.260*** (0.027)	12.620*** (1.229)
FRA	8.83	0.334*** (0.021)	-0.097*** (0.006)	-0.027*** (0.009)	-0.104*** (0.012)	-0.021*** (0.002)	0.184*** (0.058)
NLD	38.08	-0.057 (0.043)	-0.133*** (0.013)	-0.027*** (0.010)	-0.020*** (0.005)	-0.056*** (0.008)	-2.066*** (0.389)
Southern EMU countries							
ESP	30.13	0.118*** (0.036)	-0.002 (0.009)	-0.031*** (0.009)	0.022*** (0.005)	0.027*** (0.003)	0.755*** (0.137)
ITA	86.88	0.399*** (0.029)	-0.054*** (0.004)	-0.021*** (0.007)	-0.003 (0.003)	0.034*** (0.003)	3.908*** (0.407)
Non-EMU countries							
AUS	10.99	-0.196*** (0.036)	-0.029*** (0.006)	-0.053*** (0.011)	-0.010* (0.006)	-0.009*** (0.003)	-0.785*** (0.103)
CAN	21.32	0.423*** (0.032)	-0.056*** (0.010)	-0.029*** (0.008)	0.160*** (0.053)	0.001 (0.002)	-2.942*** (0.774)
DNK	15.75	-0.185*** (0.034)	-0.138*** (0.015)	-0.002 (0.008)	0.073*** (0.017)	0.051*** (0.005)	1.123*** (0.135)
GBR	6.55	0.353*** (0.015)	-0.056*** (0.004)	0.018*** (0.006)	0.071*** (0.011)	-0.004*** (0.001)	-0.139*** (0.049)
JPN	84.58	0.034 (0.029)	-0.028* (0.016)	-0.018 (0.023)	-0.006*** (0.002)	0.077*** (0.027)	9.051*** (2.725)
USA	32.12	0.156*** (0.026)	-0.071*** (0.005)	0.043*** (0.007)	0.329*** (0.046)	0.003 (0.002)	-9.314*** (1.312)
PANEL THRESHOLD REGRESSIONS							
All	84.56	0.255*** (0.026)	-0.004 (0.006)	-0.067*** (0.006)	-0.000 (0.001)	0.015*** (0.005)	1.737*** (0.505)
EMU	87.36	0.295*** (0.025)	-0.002 (0.007)	-0.049*** (0.007)	-0.004** (0.002)	0.015*** (0.005)	1.952*** (0.477)
Non-EMU	26.53	0.123*** (0.031)	-0.005 (0.007)	-0.088*** (0.006)	0.007*** (0.003)	-0.008*** (0.002)	-0.644*** (0.099)
North EMU	45.45	0.201*** (0.025)	-0.014 (0.010)	-0.066*** (0.006)	-0.014*** (0.002)	0.002 (0.002)	0.329** (0.140)
South EMU	86.88	0.205*** (0.010)	-0.018*** (0.003)	-0.039*** (0.004)	0.005*** (0.001)	0.031*** (0.002)	2.975*** (0.186)

Notes: Standard errors are in parenthesis. ***, ** and * denote the level of significance at 0.01%, 0.05% and 0.1%, respectively.

In this first specification the core interest is however the estimates for the regime dependent variable, the debt-to-GDP ratio. One striking finding is that, for every country of the EMU except the Netherlands, the point estimate for the effect of the debt-to-GDP ratio on growth is higher in the

high-debt regime than in the low-debt regime for which we find negative growth effects of debt. This result is confirmed by the estimates for the groups of EMU, northern EMU and southern EMU countries. In the stand-alone countries the point estimate typically decreases switching from the low-debt regime to the high-debt regime (except for Australia and Japan). The same holds for the panel estimate for the stand-alone countries. For the group of EMU countries and, in particular, northern EMU countries, the estimated effects of sovereign debt on GDP growth are negative and significant in the low-debt regime. In the high-debt regime, however, they are positive and, averaging over all EMU countries, also significant. For the group of non-EMU countries, we find the effect of debt on growth to be positive and significant in the low-debt regime and to be negative and significant in the high-debt regime. For southern EMU countries, our estimates seem to suggest that sovereign debt has a positive effect on economic growth in both regimes. The positive effect is even more pronounced during periods of high debt. Hence, our results indicate that debt may accelerate growth even at high levels of indebtedness, especially in countries of the EMU and even more so in the catching up EMU countries.

Overall, our results suggest that the impact of sovereign debt on growth may not necessarily be negative. More interestingly, we do not find empirical support for Reinhart and Rogoff's 2010 conclusion that high debt (by itself) negatively affects economic growth when a certain debt threshold is surpassed. Large debt does not necessarily increase the debt's absolute effect on growth nor does it necessarily negatively affect growth. If the relationship between sovereign debt and economic activity is driven by investors' sentiments and expectations, these results imply that the debt-to-GDP ratio is not the relevant variable which causes the trend reversal in the market's beliefs. If investors' sentiments driving the economic activity switched, *ceteris paribus*, at some threshold debt-to-GDP ratio, one would expect EMU countries rather than non-EMU countries to be subject to such a regime change. However, our results indicate that it is non-EMU countries rather than EMU countries which face a pronounced negative impact of debt on growth during times of high sovereign debt.

3.3.2 FSI as threshold variable and debt-to-GDP ratio as regime dependent regressor

Next, we analyze the non-linear effect of debt on economic activity using the FSI as the threshold variable. As argued in the theoretical section, there are good reasons to expect the impact of sovereign debt on economic growth to be negative during times of high financial stress since rising risk premia and credit spreads deteriorate the balance sheet of the banking sector which holds part of the sovereign debt. Since credit spreads may respond more sensitively to changes in debt in member countries of a monetary union than in stand-alone countries (cf. De Grauwe and Ji 2013), this non-linearity in the debt-growth relationship can be expected to be more pronounced in the countries of the EMU than

in the other countries of our sample.

We estimate the following specification:

$$\begin{aligned}
 y_{i,t} = & \alpha_y y_{i,t-1} + \alpha_r r_{i,t-1} + \alpha_f f_{i,t-1} \\
 & + \beta_b^L b_{i,t-1} I(f_{i,t-1} \leq \gamma) + \beta_b^H b_{i,t-1} I(f_{i,t-1} > \gamma) + \delta I(f_{i,t-1} \leq \gamma) + \mu_i + \varepsilon_{i,t}
 \end{aligned} \tag{13}$$

where the variables are as before.

Table 2 reports the estimation results of the regression model described by eq.(11) with the government debt-to-GDP ratio as the only regime dependent variable apart from the constant (with all other regressors being assumed to be regime-independent), using the first lag of the FSI as the threshold variable.

In contrast to the previous specification, the threshold estimates seem to be less heterogeneous across countries when the FSI is the threshold variable. Further, it is interesting to note that, compared to the previous analysis, the value of the threshold variable beyond which a regime change occurs is much higher in the EMU than in the group of stand-alone countries (4.48 vs. 2.06). Hence, in the EMU, the change in the sovereign debt effect on growth occurs only at extremely high values of financial stress. This finding is highly consistent with the argument put forward by De Grauwe and Ji (2012) that countries within a monetary union are more prone to investors sentiments than stand-alone countries. Because of overly optimistic expectations, high financial stress starts affecting growth only at very high levels. The threshold value of the FSI is higher for the northern EMU countries (4.05) than for the southern EMU countries (2.24). Hence, in the latter country group GDP growth is impaired at lower levels of financial stress than in the former group. This suggests that financial markets are more cautious regarding sovereign debt in the southern than in the northern EMU countries.

The parameter estimates for the lagged endogenous variable are very similar to the results obtained in the previous section. Also the estimated effects of the interest rate and the FSI on the growth rate are consistent with the estimates obtained previously.

Concerning the estimates for the regime dependent variable in this second specification, i.e. the debt-to-GDP ratio, the point estimate is negative and larger in absolute terms in the high-stress regime than in the low-stress regime for any country of the EMU, apart from the Netherlands. This result also holds when the estimates are obtained via panel estimation of the two country subgroups in the EMU: the northern EMU and the southern EMU subgroups. Further, according to the panel estimates, for the EMU and for the sub-group of the northern EMU, the growth effect of debt is negative both in the low-stress and high-stress regime but more pronounced in the latter. This is exactly what economic theory would predict. Yet, for most stand-alone countries in our sample (when

Table 2: Country-specific and panel dynamic threshold GMM estimation results with the financial stress index as the threshold variable and the debt-to-GDP ratio as a regime dependent regressor (equation 13)

	γ	α_y	α_r	α_f	β_b^L	β_b^H	δ
COUNTRY-SPECIFIC THRESHOLD REGRESSIONS							
Northern EMU countries							
AUT	2.52	0.229*** (0.043)	-0.034*** (0.011)	-0.066*** (0.013)	-0.003 (0.003)	-0.091*** (0.019)	-2.280*** (0.506)
BEL	3.60	0.561*** (0.030)	0.008* (0.005)	-0.010*** (0.003)	0.003*** (0.001)	-0.027*** (0.006)	-1.668*** (0.398)
DEU	-0.22	-0.084*** (0.023)	-0.250*** (0.013)	-0.189*** (0.019)	-0.008*** (0.002)	-0.018*** (0.002)	-1.141*** (0.099)
FRA	1.97	0.301*** (0.020)	-0.042*** (0.007)	-0.014 (0.009)	-0.009*** (0.001)	-0.040*** (0.002)	-0.145*** (0.054)
NLD	0.96	-0.017 (0.042)	-0.196*** (0.011)	-0.018** (0.007)	-0.002 (0.002)	0.008* (0.004)	-0.363* (0.188)
Southern EMU countries							
ESP	3.27	0.038 (0.025)	0.047*** (0.006)	-0.034*** (0.007)	0.011*** (0.001)	-0.009** (0.004)	0.013 (0.122)
ITA	-0.65	0.465*** (0.033)	-0.091*** (0.012)	0.016** (0.006)	0.016*** (0.003)	-0.007*** (0.002)	-2.498*** (0.349)
Non-EMU countries							
AUS	-0.43	-0.102*** (0.032)	0.013 (0.012)	-0.063*** (0.004)	0.021*** (0.002)	0.026*** (0.003)	0.381*** (0.058)
CAN	-0.13	0.413*** (0.033)	-0.081*** (0.014)	-0.041*** (0.008)	0.004** (0.002)	0.014*** (0.003)	0.115 (0.159)
DNK	-0.87	-0.242*** (0.025)	-0.146*** (0.013)	-0.014* (0.008)	-0.012*** (0.004)	0.037*** (0.002)	1.132*** (0.100)
GBR	3.19	0.295*** (0.018)	-0.028*** (0.007)	0.001 (0.008)	0.007*** (0.001)	-0.031*** (0.006)	-0.200 (0.164)
JPN	2.89	0.064** (0.026)	0.041*** (0.012)	0.043*** (0.017)	-0.004*** (0.001)	-0.023*** (0.003)	0.475*** (0.090)
USA	0.75	0.221*** (0.022)	-0.064*** (0.008)	0.052*** (0.008)	-0.009*** (0.002)	0.039*** (0.006)	2.173*** (0.257)
PANEL THRESHOLD REGRESSIONS							
All	2.04	0.253*** (0.026)	0.003 (0.006)	-0.039*** (0.008)	-0.002* (0.001)	0.000 (0.001)	-0.361*** (0.083)
EMU	4.48	0.287*** (0.024)	0.003 (0.008)	-0.041*** (0.007)	-0.003** (0.001)	-0.009*** (0.003)	-0.083 (0.126)
Non-EMU	2.06	0.135*** (0.032)	0.009 (0.007)	-0.055*** (0.009)	-0.001 (0.001)	0.003* (0.001)	0.507*** (0.099)
North EMU	4.05	0.222*** (0.025)	0.001 (0.008)	-0.047*** (0.007)	-0.005*** (0.001)	-0.015*** (0.002)	-0.104 (0.118)
South EMU	2.24	0.235*** (0.004)	-0.003** (0.001)	-0.042*** (0.004)	-0.002*** (0.001)	-0.008*** (0.001)	-0.569*** (0.048)

Notes: Standard errors are in parenthesis. ***, ** and * denote the level of significance at 0.01%, 0.05% and 0.1%, respectively.

considered individually as well as jointly as a country subgroup via panel estimation), the sovereign debt's coefficient is actually positive (and statistically significant) in the high-stress regime, and of ambiguous sign in the low-stress regime.

These results, especially the finding that sovereign debt has a stronger negative effect on economic growth during times of high financial stress in EMU countries rather than in non-EMU countries reinforces the conclusion by De Grauwe and Ji (2013) that countries within a monetary union are more prone to investors' sentiments than stand-alone countries.

3.3.3 FSI as threshold variable and regime dependent regressor.

Finally, we consider a regression specification with the financial stress index not only as the threshold variable, but also as a regime dependent regressor, i.e.

$$y_{i,t} = \alpha_y y_{i,t-1} + \alpha_r r_{i,t-1} + \alpha_b b_{i,t-1} + \beta_f^L f_{i,t-1} I(f_{i,t-1} \leq \gamma) + \beta_f^H f_{i,t-1} I(f_{i,t-1} > \gamma) + \delta I(f_{i,t-1} \leq \gamma) + \mu_i + \varepsilon_{i,t} \quad (14)$$

where the variables are as before.

Table 3 reports the estimation results for this specification, using the same country subgroups as in the previous regressions. As in the previous specification, despite the significant heterogeneity of the country-specific threshold values resulting from the single-equation regressions, the panel estimates of the different country subgroups are remarkably similar to each other with an average value of about 2.00. The parameter estimates for the lagged endogenous variable and for the interest rate are also broadly in line with the findings of the previous specifications.

The regime independent estimate of the effect of the debt-to-GDP ratio on growth also reveals some interesting insights in the context of our previous finding that, at a given state of the financial markets, high indebtedness impairs growth only in the stand-alone countries of our sample and not in EMU countries. Yet, the results obtained in the present specification suggest that, overall, the debt-to-GDP ratio, here assumed to affect growth linearly and thus independently from its actual level, impairs growth more in the EMU countries, in particular the northern EMU countries, than in the stand-alone countries.

Concerning the regime-dependent regressor in this equation, namely the FSI, our estimates suggest that the negative effect of the FSI on GDP growth is higher in absolute terms in the high financial stress regime than in the low financial stress regime in most countries considered. Comparing EMU and non-EMU countries reveals that, during times of low financial stress, the FSI has a more pronounced growth effect in the former group than in the latter. During times of high financial stress, the estimated coefficients are similar in both groups. Further, within the EMU we find similar growth effects of financial stress for both the northern and southern EMU countries for the low-stress regime. Yet, for the high-stress regime the growth effect of the FSI is rather pronounced in the Southern EMU

Table 3: Country-specific and panel dynamic threshold GMM estimation results with the financial stress index as the threshold variable and the financial stress index as a regime dependent regressor (equation 14)

	γ	α_y	α_r	α_b	β_f^L	β_f^H	δ
COUNTRY-SPECIFIC THRESHOLD REGRESSIONS							
Northern EMU countries							
AUT	1.35	0.200*** (0.030)	-0.006** (0.002)	-0.063*** (0.012)	-0.051*** (0.011)	-0.310*** (0.011)	-0.921*** (0.042)
BEL	3.60	0.594*** (0.027)	0.001 (0.001)	-0.006*** (0.002)	0.000 (0.004)	0.011 (0.020)	0.269 (0.178)
DEU	-0.22	-0.092*** (0.031)	-0.012*** (0.002)	-0.164*** (0.023)	-0.120*** (0.031)	-0.254*** (0.017)	-0.543*** (0.108)
FRA	1.97	0.366*** (0.015)	-0.015*** (0.001)	-0.016* (0.008)	-0.077*** (0.008)	0.033** (0.016)	0.639*** (0.075)
NLD	1.12	-0.051 (0.036)	-0.001 (0.003)	-0.013 (0.010)	-0.108*** (0.023)	-0.216*** (0.013)	-0.667*** (0.063)
Southern EMU countries							
ESP	0.22	0.129*** (0.043)	0.008*** (0.002)	-0.013 (0.012)	0.075*** (0.025)	0.046*** (0.016)	0.518*** (0.075)
ITA	-0.65	0.452*** (0.028)	-0.002* (0.001)	0.013** (0.007)	-0.128*** (0.013)	-0.086*** (0.012)	-0.452*** (0.043)
non-EMU countries							
AUS	-0.43	-0.070* (0.036)	0.019*** (0.003)	-0.056*** (0.006)	-0.052* (0.026)	0.020 (0.013)	0.207*** (0.053)
CAN	-0.13	0.438*** (0.032)	0.006*** (0.002)	-0.048*** (0.007)	-0.059*** (0.021)	-0.110*** (0.016)	-0.383*** (0.072)
DNK	-0.30	-0.217*** (0.030)	0.016*** (0.004)	0.002 (0.011)	-0.155*** (0.038)	-0.272*** (0.033)	-0.561*** (0.086)
GBR	0.27	0.354*** (0.019)	0.001 (0.001)	0.015** (0.008)	0.049*** (0.015)	-0.069*** (0.010)	0.277*** (0.045)
JPN	2.89	0.109*** (0.028)	-0.007*** (0.001)	0.021 (0.018)	0.006 (0.012)	-0.051 (0.056)	0.774*** (0.221)
USA	1.58	0.271*** (0.024)	0.005** (0.002)	0.032*** (0.005)	-0.009 (0.009)	-0.018 (0.015)	0.452*** (0.061)
PANEL THRESHOLD REGRESSIONS							
All	1.86	0.253*** (0.027)	0.003 (0.006)	-0.001 (0.001)	-0.029*** (0.010)	-0.072** (0.015)	0.138* (0.079)
EMU	1.84	0.310*** (0.026)	0.003 (0.008)	-0.004** (0.001)	-0.085** (0.033)	-0.070*** (0.009)	-0.226** (0.101)
non-EMU	2.06	0.131*** (0.032)	0.007 (0.008)	0.000 (0.001)	-0.045*** (0.012)	-0.079*** (0.016)	0.288*** (0.094)
North EMU	1.97	0.243*** (0.026)	0.006 (0.009)	-0.005*** (0.001)	-0.017* (0.010)	-0.048** (0.021)	0.270*** (0.097)
South EMU	2.45	0.277*** (0.008)	-0.005* (0.003)	-0.000 (0.001)	-0.026*** (0.006)	-0.203*** (0.016)	-0.794*** (0.074)

Notes: Standard errors are in parenthesis. ***, ** and * denote the level of significance at 0.01%, 0.05% and 0.1%, respectively.

countries. As expected, high financial stress seems to have had a strong effect on growth in these countries.

In the context of the previous findings, these results imply that the FSI seems to be an important

source of non-linearities in its own relationship to economic activity. Since we control for the growth effect of sovereign debt, the non-linear effects of the FSI on growth are independent of the debt-to-GDP ratio. This has important implications especially for the southern EMU countries. Indeed, according to the estimation results summarized in Tables 1 and 2, debt has a positive effect on GDP growth at high debt-to-GDP ratios and a negative effect at high values of the FSI for this subgroup of countries. Hence sovereign indebtedness impairs economic activity only during times of financial distress. The estimation results of the last regression additionally reveal that much of the slowdown in economic growth over the recent years has been caused by high financial stress itself through channels independent of sovereign debt.

4 Concluding Remarks

How does the debt-to-GDP ratio affect economic activity? We have argued theoretically and empirically that the answer depends on the state of the financial market and on whether the country considered belongs to a monetary union or not. On theoretical terms we proposed a stylized dynamic macroeconomic model based on inter-temporal optimization in a finite horizon framework which illustrated how changing financial market conditions may affect the interaction of growth and debt. By means of numerical simulations, we illustrated the destabilizing effect that a rising financial market stress (assumed to be a function of the degree of aggregate indebtedness in the economy) can have for the actual paths of capital and debt over time, and how a reduction of the former can bring about macroeconomic stability.

On empirical grounds, our econometric analysis based on the application country-specific and dynamic panel threshold regression techniques to investigate non-linearities in the relationship between economic growth, the sovereign debt-to-GDP ratio and financial market stress in industrialized economies delivered a variety of findings relevant for the current discussion of the role of the debt-to-GDP ratio as the main variable driving macroeconomic stability in advanced economies. Summing up, we found the following empirical results: First, there does not seem to exist a straightforward and universally valid negative impact of sovereign debt on economic growth in the country groups and time sample analyzed. Second, the debt-to-GDP ratio does not seem to be the relevant measure along which investors' sentiments switch from growth-enhancing to growth-impairing. In other words, it seems that sovereign debt does not necessarily have to become a problem just because a country has a high debt-to-GDP ratio as argued by Reinhart and Rogoff (2010). This non-linearity does not appear to be statistically relevant for our sample and sub-samples considered. Third, consistently with our theoretical model, we identified the FSI as a crucial source of the non-linearity in the nexus between sovereign debt and economic activity. Only at high levels of financial stress, the debt-GDP

ratio may negatively affect growth. Yet, this is still not necessarily the case, because, fourth, we find evidence that sovereign debt reduces growth when the stress in the financial markets is high only for countries within a monetary union, i.e. the European Monetary Union. And fifth, the effect of the FSI on economic growth is highly non-linear by itself and independent of the debt-to-GDP ratio.

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A The Chow-Lin Interpolation Procedure

To compute the debt-to-GDP ratio some series have to be interpolated from annual data as well as extrapolated. We employ the Chow and Lin (1971) procedure to compute quarterly series. We suppose that there exists a relationship between a $4n \times 1$ vector of quarterly observations of a variable Y and a $4n \times 3$ matrix, X , comprising explanatory variables of the form

$$Y = X\beta + u, \quad (15)$$

where u is a random vector with mean zero and covariance matrix V . Using a dot to indicate annual data, we have

$$Y. = CY = CX\beta + Cu = X.\beta + u., \quad (16)$$

with C being a $n \times 4n$ transformation matrix with the $[i, 4i - 3]$ -th element being 1 for $i = 1, \dots, n$ and the others being zero for an interpolation problem. Assuming that the quarterly residuals follow a first-order auto-regressive process with coefficient a , disturbances ϵ and variance-covariance matrix $E(\epsilon_t \epsilon_s) = \delta_{ts} \sigma^2$, Chow and Lin (1971) show that the best linear unbiased predictor \hat{B}_z of B_z , which is a $(n + m) \times 1$ vector with m denoting the number of quarters to extrapolate, is

$$\hat{Y}_z = X_z(X.'V.^{-1}X.)^{-1}X.'V.^{-1}Y. + (V_z.V.^{-1})\hat{u}. - [Y. - X.(X.'V.^{-1}X.)^{-1}X.'V.^{-1}Y.] \quad (17)$$

where

$$V = \begin{bmatrix} 1 & a & a^2 & \dots & a^{4n-1} \\ a & 1 & a & \dots & a^{4n-2} \\ a^2 & a & 1 & \dots & a^{4n-3} \\ & & & \dots & \\ a^{4n-1} & \dots & a^2 & a & 1 \end{bmatrix} \frac{\sigma^2}{1 - a^2} \quad (18)$$

where a is estimated by an iterative procedure. Taking an initial guess of the autocorrelation coefficient of the annual residuals, q , one computes a as the 4-th root of q in an interpolation problem and uses this value to generate V and the new annual residuals whose autocorrelation coefficient is taken as the q for the next iteration.

The net debt series for BEL, DNK, ESP, GBR and NLD as well as a part of the corresponding series for AUT, FRA, GER and ITA have been interpolated from annual data on net debt taken from the OECD EO 89 and the cumulated seasonally adjusted government net lending employing Chow and Lin (1971). For these countries, government net lending has been computed in the following ways. For GBR, quarterly and seasonally adjusted government net lending can be obtained from the OECD EO 89. For AUT, FRA, GER and ITA the net lending series required for estimating the second part of the debt series has been taken from Eurostat. For BEL and ESP as well as NLD net lending

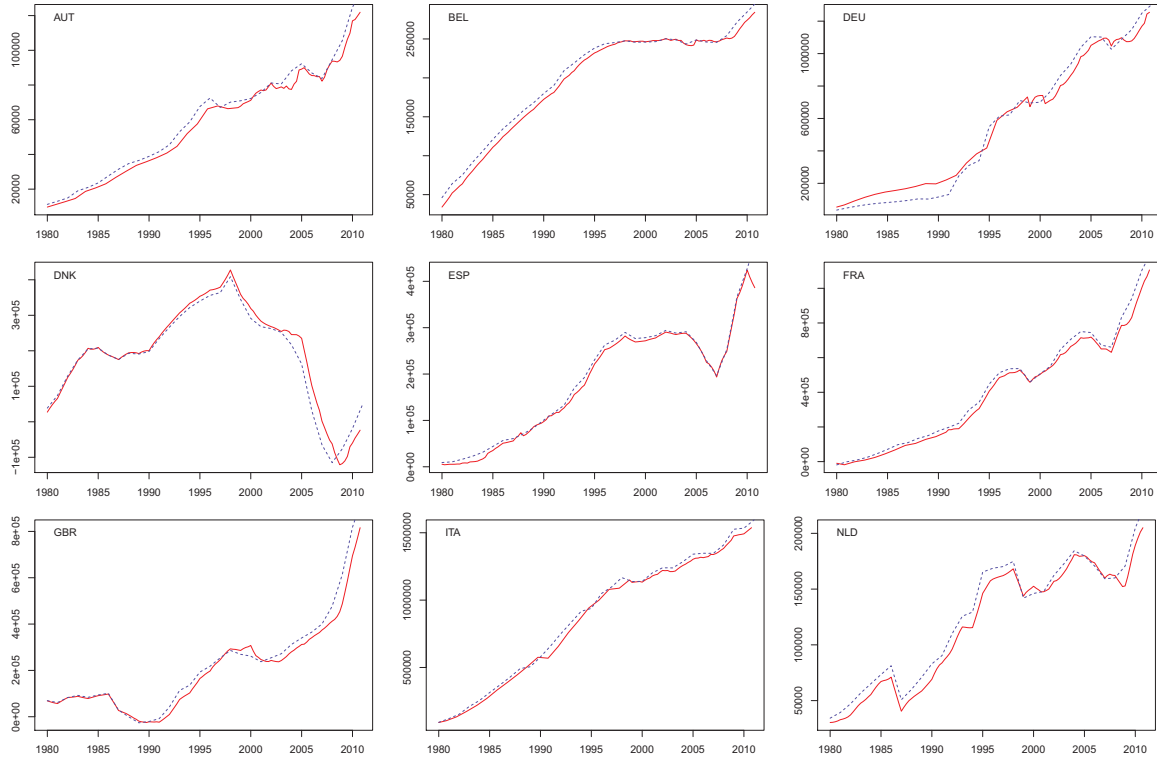


Figure 4: Annual net sovereign debt (dashed line) and interpolated quarterly net sovereign debt (solid line) from 1980:1 to 2010:4

consists of two parts: The first is the discontinued seasonally adjusted government net lending series taken from the OECD EO 79 and from the IMF, respectively. The second part is obtained from Eurostat. The first part has been adjusted to match the overlapping quarters. For DNK, net lending of the general government consists of two parts: Prior to 1995:1 net lending is approximated by taxes on production and imports less subsidies (Eurostat) minus government final consumption (OECD EO 89) minus government gross fixed capital formation (OECD EO 89). The second part has been taken from Eurostat.

Applying Chow and Lin (1971) to the annual debt series using cumulative net lending as the explanatory variable yields the interpolated net debt series as plotted in Figure 4 together with the annual net debt.