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Keywords: sovereign debt, sustainability, debt crisis, bounds testing approach, pooled mean-group estimator

JEL Classication: H62, H63, E60

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The fundamentals of sovereign debt sustainability: Evidence from 15 OECD countries.*

Christian Schoder†
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We study the sustainability of sovereign debt accumulation in 15 OECD countries using quarterly data from 1980 to 2010 with a focus on how and in what countries debt sustainability changed after the commencement of the Euro Convergence Criteria in 1997 as well as after the financial meltdown in 2007. We define *sustainability* as the validity of the inter-temporal budget constraint of the government and test a sufficient condition motivated by Bohn (1998) using single-country and pooled regressions. We find evidence that the Euro Convergence Criteria contributed to the sustainability of debt accumulation. Further, while the yield spreads suggest the debt crisis is a problem of the southern Euro countries, we find a lack of debt sustainability for Greece, Portugal and France but not for Italy and Spain. In terms of debt sustainability, the crisis adversely affected primarily stand-alone countries rather than members of the European Monetary Union. Nevertheless, yield spreads increased more in the southern countries of the monetary union than in stand-alone countries. Our results support the view that countries within a monetary union are more prone to investors' sentiments than stand-alone countries.

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1 Introduction

After the recent financial meltdown, government debt has risen enormously in many OECD countries.[1] Whereas the yields on government bonds of many countries with tremendous increases in public debt such as the United Kingdom, Japan and the United States stayed at low levels, the refinancing of sovereign debt became exceptionally costly for the southern members of the European Monetary Union (EMU), Greece, Portugal, Spain and Italy, triggering a severe European debt crisis. This observation lead De Grauwe (2011) and De Grauwe and Ji (2012) to argue that countries within monetary unions are more prone to bond holders' sentiments and bubble-driven pricing of sovereign default risk than stand-alone countries.

To overcome the debt crisis, unprecedented measures have been taken by EU authorities involving the establishment of the European Financial Stability Facility (EFSF) with the purpose of providing cheap credit to troubled member countries at the condition of structural adjustment as well as an agreement by which banks accepted a 53.5% write-off of Greek sovereign debt. In March 2012, the member states of the European Union, except the United Kingdom and the Czech Republic, agreed on the Treaty on Stability, Coordination and Governance in the Economic and Monetary Union, also known as the European Fiscal Compact (EFC), which requires structural deficits of governments not to exceed 0.5% and, for countries with low debt-GDP ratios, 1% of GDP, respectively. The EFC can be seen as a tightening and extension to non-EMU EU members of the Euro Convergence Criteria introduced in 1997 which, among other things, require member countries to limit their annual budget deficit to 3% of GDP and to reduce the debt-GDP ratio to 60%.

The optimal policy response depends essentially on the question whether governments are illiquid or insolvent. As argued by Lucke and Wurzel (2011), a deteriorating access to international capital markets caused by worsening bond holders' expectations can be restored by sufficiently high short-term international assistance, as the EFSF has been designed for. Yet, such measures will prove ineffective if the fundamentals imply the government not being able to meet its debt obligations in the long run and merely postpone sovereign default. In this case, the EFC is intended to re-establish a sustainable sovereign debt policy by imposing stricter requirements on fiscal consolidation.

The aim of the present paper is to assess the fundamentals of debt sustainability in the EMU, i.e. the question whether bond holders have a reason to expect that the troubled EMU countries will not service their debt in the long run. In particular, we study whether the implementation of tighter rules on fiscal consolidation such as the Euro Convergence Criteria are associated with stronger evidence for debt sustainability. Moreover, we analyze whether the relationship between the pricing of risk as captured by bond yields and debt sustainability differs between EMU countries and stand-alone countries as argued by De Grauwe (2011). To this end, we also analyze the effect of the recent economic crisis on debt sustainability in different groups of countries.

[1] Between 2007 and 2011, the gross government debt normalized by GDP increased from 71.8% to 95.6% in the Euro Area (15 countries) with Ireland, Greece, Portugal and Spain experiencing the strongest increases. For OECD countries, the ratio increased from 73.3% to 101.6% in the same period (OECD 2012).

We define sustainability as the validity of the inter-temporal budget constraint (IBC) of the government derived from a stochastic general equilibrium model. Along the lines of Bohn (1995, 1998), we test a sufficient condition for the validity of the IBC: the response of the government's primary surplus to a one-unit change in sovereign debt has to be positive. We call the development of a net sovereign debt-GDP ratio over time *sustainable* if it is consistent with this condition and *non-sustainable* if not.[2]

We analyze sustainability using quarterly data of 9 EMU countries as well as 6 non-EMU countries from 1981:1 to 2010:4.[3] To study the questions posed above, we utilize the bounds testing approach suggested by Pesaran et al. (2001) for analyzing the long-run relationship between the primary surplus and sovereign debt for each country. To obtain robust results in the estimation of long-run relations for sub-groups of countries and for the sub-periods of interest we use the mean-group and pooled mean-group estimators proposed by Pesaran and Smith (1995) and Pesaran et al. (1999).

We obtain the following main results: On average, the Euro Convergence Criteria seem to be associated with a stronger evidence for debt sustainability. Yet, splitting the Euro Area into countries with high response coefficients and countries with low response coefficients reveals that the Convergence Criteria failed to establish sustainability in the latter group. Further, while the yield spreads suggest the debt crisis to be a problem of the southern Euro countries, we find evidence for debt sustainability for ESP and ITA but not for FRA, GRE and POR raising the question why FRA enjoys better terms of debt refinancing than ESP and ITA. Similarly, the crisis adversely affected primarily stand-alone countries rather than troubled EMU countries. Nevertheless, yield spreads increased more in the southern EMU countries than in stand-alone countries. Our results support the view put forward by De Grauwe (2011) and De Grauwe and Ji (2012) that countries within a monetary union are more prone to investor sentiments than stand-alone countries.

Our empirical study is complementary to De Grauwe and Ji (2012) who employ linear regressions to study the relationship between yield spreads and the fundamentals of debt-sustainability for selected EMU and non-EMU countries. They find evidence that, in the Euro Area, the pricing of sovereign default risk tends to be driven by investors' sentiments rather than fundamentals, whereas such bubbles are not observed in stand-alone countries. As a proxy for fundamentals they use debt-GDP ratios. According to economic theory, however, investors are concerned with the validity of the IBC of the government and there is no obvious relationship between the IBC and debt-GDP ratios.

Therefore, we approach the questions posed by De Grauwe and Ji (2012) from an angle

[2]We use the term *non-sustainable* instead of *unsustainable* since a positive response coefficient is a sufficient but not necessary condition for debt sustainability. Hence failure to find evidence for sustainability does not imply that debt is *unsustainable*.

[3]The EMU countries are Austria (AUT), Belgium (BEL), Spain (ESP), France (FRA), Germany (GER), Greece (GRE), Italy (ITA), the Netherlands (NLD) and Portugal (POR). As non-EMU countries we consider Australia (AUS), Canada (CAN), Denmark (DNK), the United Kingdom (GBR), Japan (JPN) and the United States (USA). We do not consider Finland, Norway and Sweden since they ran persistent primary surpluses and accumulated net assets. Therefore, the question of debt sustainability is not interesting for these countries.

which is consistent with economic theory. We seek to contribute to the body of empirical literature motivated by Bohn (1995) and Bohn (1998) which tests the sustainability of sovereign debt and, in an open economy setting, external debt. Methodologically, the present analysis is closely related to Schoder et al. (forthcoming) who study the sustainability of current account imbalances between EMU countries using the pooled mean-group estimator es well as non-parametric techniques. However, they do not assess the accumulation of sovereign debt–a gap which the present study seeks to close.

In a related contribution, Ballabriga and Martínez-Mongay (2005) follow the Bohn (1998) approach and test the validity of the IBC of the government for 16 EMU and non-EMU countries from 1977 to 2002 using annual data. They also analyze structural breaks caused by the introduction of the Euro. They find that the Maastricht criteria, in general, reinforced the sustainability of debt accumulation. Yet, the robustness of their results may be questionable due to a low number of degrees of freedom.

Greiner et al. (2006), Greiner et al. (2007) and Fincke and Greiner (2011) also assess debt sustainability with respect to the validity of the IBC. The first contribution analyses debt accumulation in Germany from 1960 to 2003 using annual data and finds evidence for sustainability. In the second paper, the authors study sustainability for Italy, France, Germany and Portugal as well as the US since the 1960s using annual data and find evidence for debt sustainability in all countries considered. The third study analyses debt sustainability for France, Germany, Ireland, Portugal, Spain, Greece and Italy using annual data. Time varying coefficients are obtained by penalized spline estimations in order to analyze sustainability over time. The find (at least some) evidence of sustainability for all countries except Greece. None of these three studies, however, addresses explicitly the question of how the sustainability of sovereign debt changed after the introduction of the EMU or compare EMU counties to non-EMU countries, systematically.

The paper proceeds as follows. Section 2 motivates the testable condition for debt sustainability used in the empirical analysis. In section 3, the data set is discussed. Section 4 discusses the results of the single-country ARDL sustainability tests intended to give some guidance on how to pool countries. The results of pooled regressions for different groups of countries are then discussed in section 5. Section 6 concludes the paper.

2 A test of sustainability

In order to motivate the criterion for sovereign debt sustainability, we follow Bohn's (1995, 1998) analysis of fiscal debt in a stochastic Lucas (1978)-type of fruit-tree economy with a government sector and complete capital markets.[4] Let s_t and h_t denote the state of the world in period t and the history of realized states up to t, respectively, where $h_t \in \mathbb{H}_t$, $s_t \in \mathbb{S}(h_{t-1})$ and h_0 represents the initial history.

The representative agent receives a stochastic stream of dividends of a good, Y_t, which is assumed to have a finite present value. The good is perishable and cannot be stored. It

[4]This section draws from Schoder et al. (forthcoming).

can be used for private or government consumption. The agent's problem is to choose an optimal consumption path through all t and all $h_t \in \mathbb{H}_t$ such as to maximize expected utility,

$$\sum_{t=0}^{\infty} \beta^t \sum_{h_t} \pi(h_t) U\big(C(h_t)\big) \tag{1}$$

$$s.t. \quad A(h_t) + Y(h_t) - T(h_t) = C(h_t) + \sum_{s_{t+1}} Q(s_{t+1} \mid h_t) A(s_{t+1} \mid h_t), \tag{2}$$

where $U(\cdot)$ is strictly increasing and concave, and $\beta > 0$. $\pi(h_t)$ is the probability of the event h_t to occur and $Q(s_{t+n} \mid h_t)$ is the period t world-market price of an Arrow-Debreu security, $A(s_{t+n})$, that yields one unit of the consumption good in state s_{t+n} at $t+n$ and zero units otherwise. $T(h_t)$ and $C(h_t)$ are lump-sum taxes and private consumption given h_t. Equation (2) is the budget constraint for the agent in time t with realized history h_t.

The stochastic path of government consumption, G_t, is financed by lump-sum taxes and borrowing on financial markets. Taxes are not understood as a transfer of the physical good but as an appropriation of claims by the government. Hence, the Lucas (1978) model including the government typically allows for taxes exceeding the exogenous income of goods, in which case the representative agent has to finance its consumption by borrowing from the government as can be readily seen from (2). The resource constraint is $G_t + C_t \leq Y_t$ and the feasibility constraints are $G_t \leq Y_t$ and, hence, $C_t \leq Y_t$. The government's budget equation is

$$B(h_t) + G(h_t) - T(h_t) = \sum_{s_{t+1}} Q(s_{t+1} \mid h_t) B(s_{t+1} \mid h_t), \tag{3}$$

where $B(h_t) = -A(h_t)$ is government debt given history h_t. Assuming that the representative agent cannot run Ponzi schemes against the government, Bohn (1995) has shown that

$$\lim_{N \to \infty} \sum_{h_{t+N}} Q(s_{t+N} \mid h_t) B(h_{t+N} \mid h_t) = 0. \tag{4}$$

The first-order condition of the optimization problem described by (1) and (2) implies $Q(s_{t+N} \mid h_t) = \pi(h_{t+N} \mid h_t) u_{t,n}$ with $u_{t,n}$ being the stochastic discount factor, which substituted into (4) implies, after applying the expectations operator and noting that $\sum_{h_{t+N}} \pi(h_{t+N} \mid h_t) = 1$, that (4) can be rewritten as the *transversality condition* (TC),

$$\lim_{N \to \infty} E_t[u_{t,N} B(h_{t+N} \mid h_t)] = 0 \tag{5}$$

Using $B(h_t) = -A(h_t)$ and applying the expectations operator, we can derive the *intertemporal budget constraint* (IBC) for the stochastic open economy from (2) and (4) as

$$B_t = \sum_{n \geq t} E_t[u_{t,n} S(h_{t+N} \mid h_t)], \tag{6}$$

where $S(h_t) \equiv T(h_t) - G(h_t)$ denotes the government's primary surplus.

Further, by using $\sum_{s_{t+1}} Q(s_{t+1} \mid h_t)\big(1 + R(s_{t+1} \mid h_t)\big) = 1$ resulting from the Euler equations, where $R(s_{t+1} \mid h_t)$ is the return of an asset in state s_{t+1}, dividing by Y_t and dropping the state and history indices for notational convenience, the budget identity given by (2) can be rewritten as

$$b_{t+1} = \frac{1 + R_{t+1}}{1 + \gamma_{t+1}}(b_t - s_t) \tag{7}$$

where γ_t is the growth rate of output from $t-1$ to t, s_t now denotes the primary surplus-GDP ratio (and not the state) and b_t is the sovereign debt-GDP ratio.

Following Bohn (1998) and the subsequent empirical literature on fiscal debt sustainability, we suppose a linear relationship between the primary surplus and sovereign debt of the form

$$s_t = \varrho b_t + \mu_t \tag{8}$$

where ϱ is a parameter and μ_t a stochastic process. Substituting (8) into (7) and iterating forward yields

$$b_{t+n} = (1 - \varrho)^n \prod_{k=1}^{n} \frac{1 + R_{t+k}}{1 + \gamma_{t+k}} b_t - \sum_{l=1}^{n} (1 - \varrho)^{n-l} \prod_{k=1}^{n} \frac{1 + R_{t+k}}{1 + \gamma_{t+k}} \mu_{t+l-1} \tag{9}$$

Using the straightforward relationships $b_t = \frac{B_t}{Y_t}$ and $Y_{t+n} = \prod_{k=1}^{n}(1 + \gamma_{t+k})Y_t$ as well as the result of the Euler equations which apply to all financial claims that $E_t[u_{t,n} \prod_{k=1}^{n}(1+R_{t+k})] = 1$, substituting (9) into the TC in (5) and re-arranging yields

$$\lim_{N \to \infty} (1 - \varrho)^N b_t - \sum_{l=1}^{N} (1 - \varrho)^{N-l} E_t \left[u_{t,l-1} \prod_{k=1}^{l-1} (1 + \gamma_{t+k}) \mu_{t+l-1} \right] = 0. \tag{10}$$

The assumption of a finite present value of all future income, $\lim_{N \to \infty} Y_t \sum_{l=1}^{N} E_t[u_{t,l} \prod_{k=1}^{l}(1+\gamma_{t+k})]$, requires that each summand of it converges to zero. This implies for (10) that the second term equals zero in the limit leading to

$$\lim_{N \to \infty} (1 - \varrho)^N b_t = 0 \tag{11}$$

A sufficient condition for a positive initial stock of debt to converge to zero in present value terms is thus that $\varrho > 0$.[5] An external debt process consistent with (11) meets the transversality condition and shall therefore be referred to as *sustainable* in the following.

The Bohn test is widely used in the empirical literature due to its simplicity, theoretical appeal and consistency with stochastic economies. Yet, one weakness should be noted: With taxes understood as an appropriation of claims rather than physical goods, which therefore

[5] A formal proof of the proposition that a positive ϱ is a sufficient condition for the TC and IBC to hold is provided in the unpublished appendix of Bohn (1998).

may exceed current income, an unbounded primary surplus-GDP ratio is technically feasible. In this case, the validity of the TC is a weak sustainability criterion since unbounded debt-GDP ratios may also be consistent with the TC. This is because future taxes can be raised without limits. In fact, as shown by Bohn (2007), any debt process which is integrated of finite order is consistent with the TC in a stochastic setting with lump-sum taxation. For this reason, Bohn (2007) suggests to impose stronger conditions for a debt accumulation process to be sustainable, such as boundedness of the debt-GDP ratio. As shown by Bohn (1991) for a stochastic economy and by Greiner and Fincke (2009, ch. 2) for a deterministic economy, the introduction of income-constrained taxation generates an upper bound on the surplus-GDP ratio and, therefore, also on the debt-GDP process being consistent with the accordingly modified TC. Given income-constrained taxes, a sustainable debt policy implies a mean-reverting debt-GDP process even though the persistence may be high.[6] In the present paper, however, we would like to follow Fincke and Greiner (2011) and argue that the debt-GDP processes observed for the countries considered in our study can be expected to have been below these upper bounds as there has typically been plenty of room for increasing taxes despite political resistance. Hence, the fact that taxes are constrained by income may well be argued to be negligible for empirical analysis of Western economies. In this case, the Bohn test is valid and a positive response coefficient, ϱ can be interpreted as evidence for debt sustainability even if a (locally) unbounded process is the best econometric approximation of the observed debt-GDP process.

3 Data

For all countries considered, we use quarterly data on government primary surpluses, net sovereign debt as well as nominal and real GDP. The data cover the period from 1980:1 to 2010:4. Quarterly data on GDP have been obtained from the OECD Economic Outlook 89 database. Since this database does not provide time series on primary surpluses and net sovereign debt for all countries considered, these data have been constructed combining different sources such as the OECD, the IMF and Eurostat. We employed the Chow and Lin (1971) procedure to interpolate the annual debt series by using variations in the quarterly series of the accumulated government net lending–which for some countries had to be approximated–to estimate a quarterly series. For some countries, this procedure has been

[6] To analyze the stationarity properties of the debt-GDP process, Bohn (2007) suggests to interpret the size of the response coefficient, ϱ. Assuming a constant save interest rate, R, and a constant GDP growth rate, γ, $\varrho > R - \gamma$ implies the debt-GDP process to be stationary. If $0 < \varrho \leq R - \gamma$ the debt-GDP process will be unbounded. In our study, however, we do not interpret our coefficients along these lines as the assumption of constant interest and growth rates seems inappropriate to us for empirical analysis. In a related contribution, we have additionally considered an *operational* criterion of debt sustainability defined as stationarity of the debt-GDP process (cf. Schoder et al. forthcoming). Yet, we do not test this criterion in the present paper since the power of unit root tests is notoriously weak, especially if time series are subject to smooth structural breaks such as the step-by-step unification of the European monetary system.

used to distribute annual observations of the primary surplus across quarters.[7] Since using quarterly data is one of the innovative contributions of our study, the construction of our data set is discussed in detail in Appendix A and B.

Figure 1 plots the government primary surplus-GDP ratio in percent, s_t, and the sovereign debt-annualized GDP ratio, $b_t/4$, in percent for all countries investigated. The following stylized facts can be observed: First, the net debt-GDP ratio differs considerably between countries. The lowest ratios are to be found in AUS and DNK which managed to reduce net debt considerably since the mid 1990s. The highest ratio can be observed in GRE, ITA and BEL with around 90%. Note that the troubled southern EMU countries do not face much higher debt-GDP ratios than other countries that are considered rather save such as the USA, JPN and BEL.

Second, apart from the level of the debt-GDP ratio its evolution over time is of interest. Countries such as AUS, BEL, CAN, DNK, ESP and NLD managed to reduce their debt-GDP ratio since the mid 1990s. Others, in particular AUT, FRA, GBR, GRE and ITA more or less stabilized the ratio in that time, whereas GER, JPN and POR experienced an increase in the debt ratio.

Third, the recent economic crisis caused huge primary deficits and a considerably rise in net public debt in all countries except BEL, GER, DNK and ITA.

The quarterly bond spreads defined as the difference of a country's interest rate on long-term government bonds and the German interest rate are plotted in Figure 2 for EMU and non-EMU countries since 1980. Note the convergence of interest rates due to the centralization of monetary policy after the introduction of the Euro. Despite the monetary union, the spreads rose considerably for southern EMU countries, i.e. GRE, POR, ESP and ITA, since 2009.

The next section discusses the econometric methodology applied and presents our estimation results. We estimate (8) for various sub-samples to analyze how the Euro Convergence Criteria as well as the financial crisis affected debt sustainability. We start with discussing single country estimation results to justify the pooling of countries in the subsequent subsection.

4 Single country ARDL sustainability tests

Equation (8) describes a long-run relationship between s_t and b_t. In the short run, s_t may deviate from the long-run equilibrium value due to demand stabilizing considerations of fiscal policy. It is thus natural to represent the policy reaction function as an error correction model (ECM). Including an index for country i and lags of order p and q for $b_{i,t}$ with parameters $\theta_{i,k}$ for $k = 0, \ldots, p$ and for $s_{i,t}$ with parameters $\psi_{i,k}$ for $k = 1, \ldots, q$, respectively, we thus

[7] Since the constructed debt series comprises end-of-period values, we define its first lag as B_t. All *R* and *STATA* scripts as well as the dataset can be obtained from the author upon request.

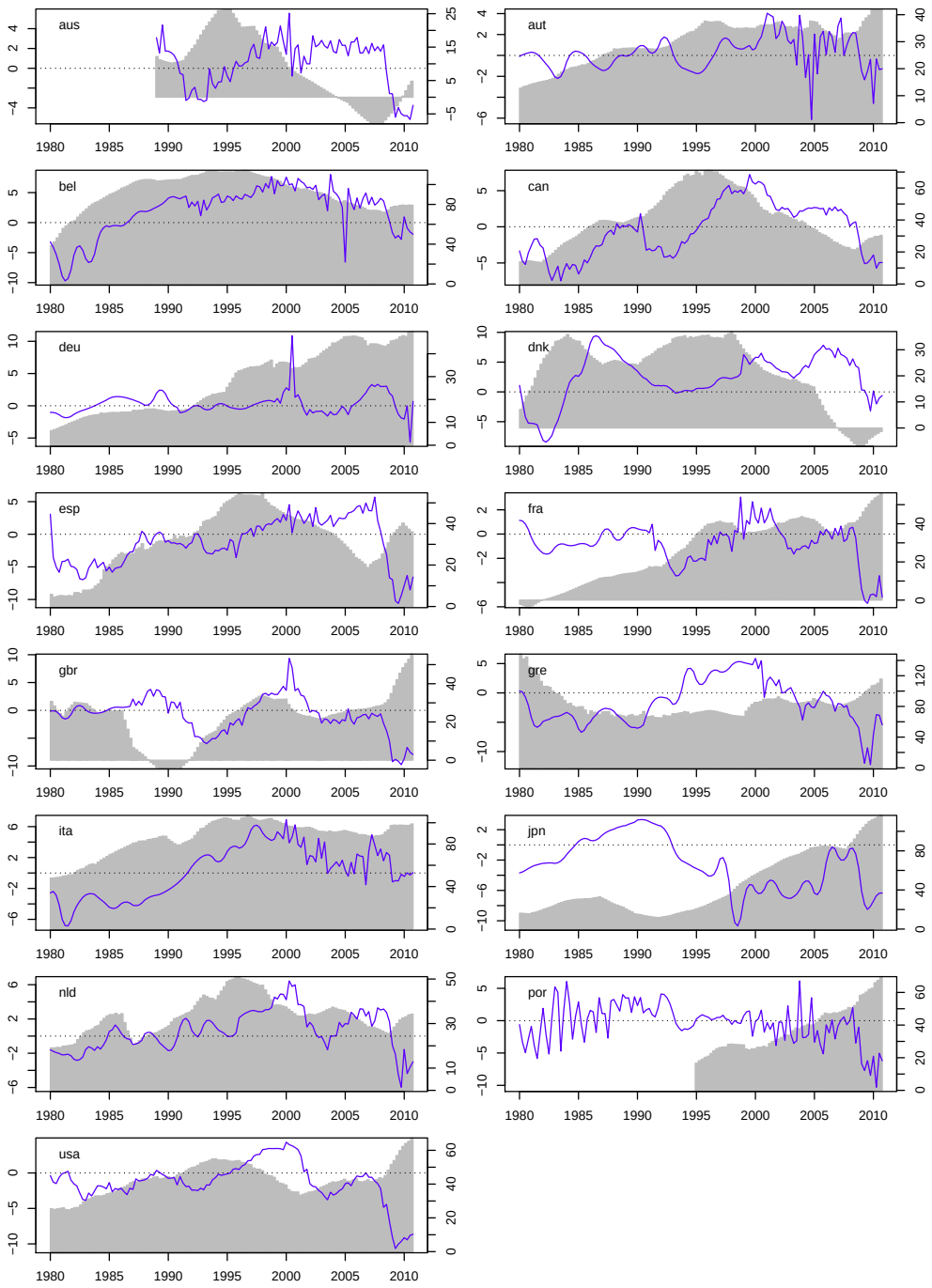

Figure 1: The net sovereign debt-annualized GDP ratio (bars, right axis) and the primary surplus-GDP ratio (solid line, left axis) from 1980:1 to 2010:4. Sources: OECD, IMF, Eurostat and own calculations (see Appendix A and B)

restate (8) as an Auto-Regressive Distributed Lag (ARDL) model of the form

$$s_{i,t} = \sum_{k=0}^{p} \theta_{i,k} b_{i,t-k} + \sum_{k=1}^{q} \psi_{i,k} s_{i,t-k} + \varepsilon_{i,t}, \tag{12}$$

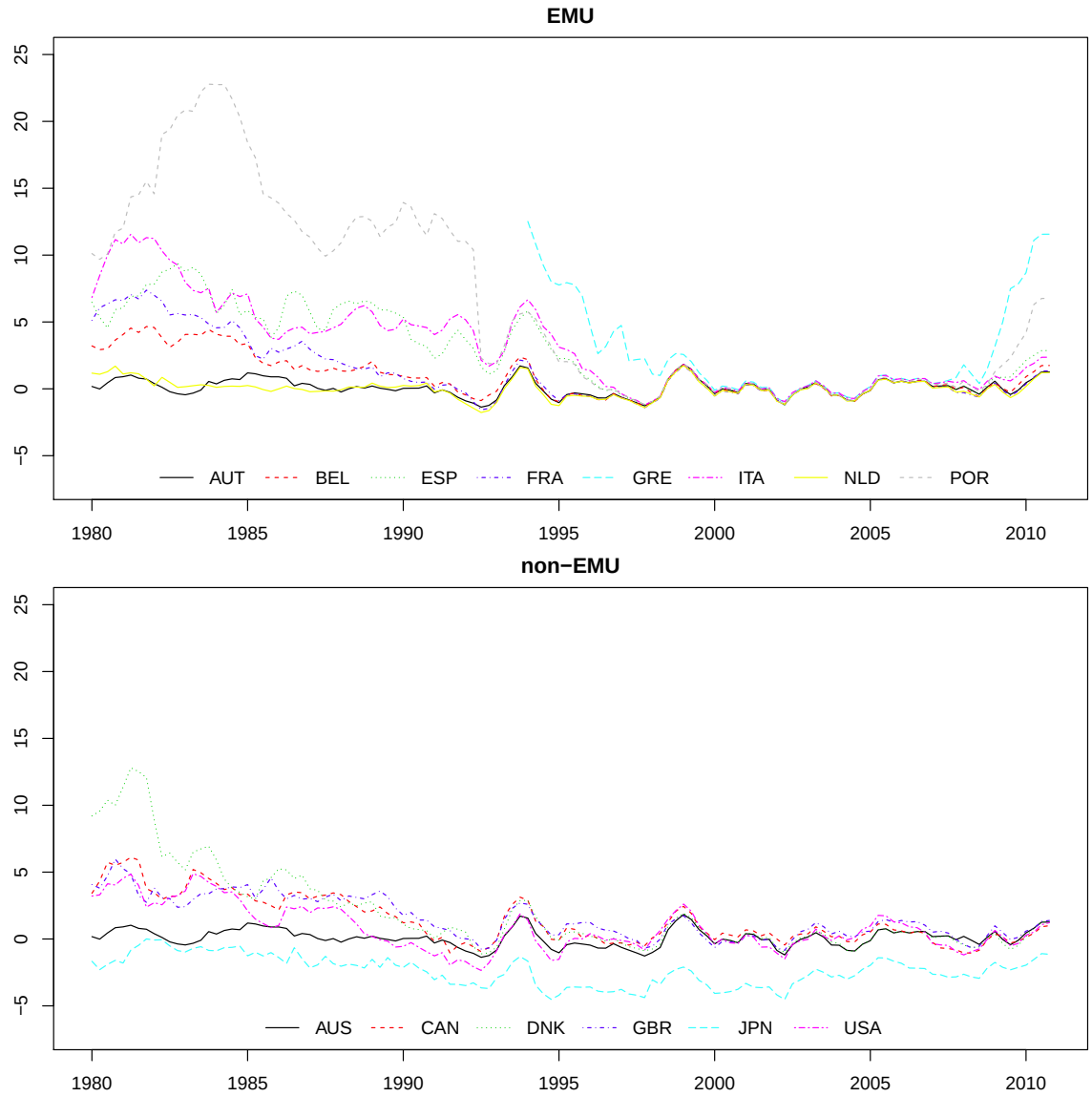

Figure 2: The spreads of interest rates on long-term government bonds relative to Germany from 1980:1 to 2010:4. Source: OECD EO 89

where $\sum_{k=1}^{p} \theta_{i,k} b_{i,t-k} + \sum_{k=1}^{q} \psi_{i,k} s_{i,t-k} + \varepsilon_{i,t} = \mu_{i,t}$. $\varepsilon_{i,t}$ is an i.i.d disturbance term with mean zero. Some manipulation yields the corresponding error correction representation,

$$\Delta s_{i,t} = \phi_i (s_{i,t-1} - \varrho_i b_{i,t}) + \sum_{k=0}^{p-1} \theta_{i,k}^{s} \Delta b_{i,t-k} + \sum_{k=1}^{q-1} \psi_{i,k}^{s} \Delta s_{i,t-k} + \varepsilon_{i,t} \tag{13}$$

where $\theta_{i,k}^{s} = -\sum_{j=k+1}^{p} \theta_{i,j}$ and $\psi_{i,k}^{s} = -\sum_{j=k+1}^{q} \psi_{i,j}$. The parameter $\varrho_i = -\phi_i^{-1} \sum_{k=0}^{p} \theta_{i,k}$ is the long-run relationship between s_t and b_t where $\phi_i = -(1 - \sum_{k=1}^{q} \psi_{i,k})$ measures the speed of adjustment of s_t after a change in b_t.

Table 1: ARDL bounds tests of a long-run relationship between s_t and b_t

	AUS	AUT	BEL	CAN	DNK	ESP	FRA	GBR
p	1	1	1	4	2	3	1	1
q	4	4	2	1	4	2	3	4
F-statistic	5.94	7.24	9.01	0.29	9.7	8.48	2.41	0.33
$\hat{\varrho}$	0.005	0.004	0.008***	-0.004	0.028***	0.003	-0.007	-0.012
	(0.008)	(0.003)	(0.001)	(0.021)	(0.006)	(0.005)	(0.005)	(0.031)
$\hat{\phi}$	-0.330***	-0.384***	-0.301***	0.028	-0.126***	-0.167***	-0.120***	-0.038
	(0.095)	(0.100)	(0.070)	(0.037)	(0.028)	(0.040)	(0.054)	(0.046)
# of obs.	84	120	122	119	120	120	121	120

	GER	GRE	ITA	JPN	NLD	POR	USA
p	1	1	1	1	1	1	1
q	4	1	2	4	4	4	4
F-statistic	7.64	2.03	2.04	10.55	3.54	1.02	1.63
$\hat{\varrho}$	0.004	-0.008	0.005	-0.001	0.007	-0.015	-0.006
	(0.003)	(0.006)	(0.005)	(0.004)	(0.005)	(0.013)	(0.006)
$\hat{\phi}$	-0.355***	-0.059**	-0.065**	-0.059***	-0.120***	-0.231	-0.060*
	(0.090)	(0.029)	(0.032)	(0.013)	(0.045)	(0.160)	(0.033)
# of obs.	120	122	122	120	120	62	120

Notes: p and q are the lag lengths of the debt-GDP ratio and the primary surplus-GDP ratio, respectively, in (13). The null hypothesis of the F-test is that the level variables in the ECM specification are jointly zero. The critical values for I(0) and I(1) variables are 2.44 and 3.28 for the 90% confidence level, 3.15 and 4.11 for the 95% confidence level and 4.81 and 6.02 for the 99% confidence level (Pesaran et al. 2001). $\hat{\varrho}$ and $\hat{\phi}$ are the long-run response of the surplus-GDP ratio to a one unit change in the debt-GDP ratio and the error correction coefficient, respectively. Standard errors are in parenthesis. *, **, and *** denote the significance level at 10%, 5%, and 1%, respectively.

Since s_t and b_t may not be integrated of order one but covariance stationary, we apply the ARDL bounds testing approach to analyzing long-run relationships proposed by Pesaran et al. (2001). Unit root tests have notoriously low power against the alternative hypothesis of covariance stationarity, especially in small samples. The advantage of the bounds testing approach is that it also applies to stationary variables.

The test proceeds as follows: The ARDL(p, q) model in (12) is estimated for various p and q with a maximum lag length of 4 in order to determine the optimal lag lengths p^* and q^* according to the AIC. The resulting model is transformed into first differences including s_{t-1} and b_t in levels and an F-test of the null of no long-run relationship is performed. Since the distribution of the test statistic is non-standard, Pesaran et al. (2001) provide the relevant critical values for I(0) and I(1) variables. Next, the ARDL(p^*, q^*) model is estimated and the long-run coefficient ϱ_i as well as its standard errors are computed. The disequilibrium term, $s_{i,t-1} - \hat{\varrho}_i b_{i,t}$, is computed and substituted into (13) which is finally estimated to obtain an estimate of the speed of adjustment parameter, ϕ_i.

The estimation results are reported in Table 1. Interpreting the F-test, we can reject the null of no long-run relationship between s_t and b_t for AUS, AUT, BEL, GER, DNK, ESP, JPN and NLD on a reasonable significance level, but not for CAN, FRA, GBR, GRE, ITA, POR and USA. The following observations are worth to note:

First, whereas the estimates for the speed of adjustment parameters, $\hat{\phi}$, are typically highly significant, the response coefficients $\hat{\varrho}$ are usually not statistically significant. This may be due to the low number of observations for each country. Hence, we pool countries with similar response coefficients in the next section.

Second, as expected countries with falling debt-GDP ratios tend to exhibit positive response coefficients (AUT, BEL, GER, ESP, ITA, NLD as EMU countries and AUS and DNK as non-EMU countries), whereas negative coefficients have been estimated for countries with rising debt-GDP ratios (FRA, GRE, POR as EMU countries and GBR, JPN, USA as non-EMU countries).[8]

Third, surprisingly there is no robust difference between the troubled southern EMU countries and the countries considered save by bond holders in terms of our debt sustainability criteria: For FRA, GBR, JPN and USA no evidence for sustainability can be found. Yet, ESP and ITA exhibit positive but insignificant response coefficients. Bond spreads, however, rose especially in the latter countries. The other countries behave as expected, i.e. response coefficients are positive in the other northern countries and negative in the other southern countries. These results suggests that bond holders pricing of risk may be driven by market sentiments rather then fundamentals as argued by De Grauwe (2011).

Our findings are only partly consistent with the related literature. Yet, the robustness of the previous results may be questioned since annual data have been employed allowing only for a low number of degrees of freedom. In their benchmark specification, Ballabriga and Martínez-Mongay (2005) find positive point estimates of the response parameter for AUT, BEL, DNK, ESP, FRA, GBR, GER, GRE, ITA, NLD, POR and USA but not for JPN. Greiner et al. (2007) find evidence of debt sustainability for all countries they consider, i.e. GER, FRA, ITA, POR and USA, whereas our estimates yield negative point estimates of the response coefficient for FRA, POR and USA. The difference may be due to the adverse impacts of the crisis on the latters' debt policies. Our results also deviate slightly from Fincke and Greiner (2011) who, using non-parametric estimation techniques, find evidence of sustainability for GER, FRA, IRE, ESP, and POR, partly for ITA and not for GRE. Again, the years of crisis have been excluded for all countries which may contribute to the inconsistency of the results. Moreover, their samples typically include the 1970s while our sample starts in 1980. It is worth to note that Fincke and Greiner's 2011 evidence of debt sustainability is not too strong for FRA and POR as, for both countries, zero lies just below the confidence intervals of the time-varying coefficients estimated.

Due to the generally low statistical significance of ϱ and failure to find evidence of a long-run relationship for a considerable number of countries, the results presented above have to be interpreted as preliminary. The main purpose is to identify countries with similar response coefficients in order to reduce heterogeneity in the pooled estimations.

[8] An exception is CAN which the point estimate of ϕ is positive.

5 Pooled regressions

By pooling countries we can study how sustainability changed in different groups after the introduction of the Euro Convergence Criteria as well as after the financial crisis while still getting robust results due to a high number of observations. We utilize panel estimation approaches which pool heterogeneous groups but allow for flexibility in the specification of the short-run dynamics.

For pooling heterogeneous countries, two alternative estimation techniques seem appropriate: the *mean-group* (MG) estimator and the *pooled mean-group* (PMG) estimator suggested by Pesaran and Smith (1995) and Pesaran et al. (1999), respectively. The former estimates independent ECMs for each country and computes the mean of the country-specific coefficients and statistics. However, the MG estimator is inefficient if the long-run coefficients such as ϱ_i are the same in every country i. In this case, the PMG estimator, which restricts $\varrho_i = \varrho \; \forall \; i$ but allows short-run parameters including the error correction parameter to vary across countries, is preferable. A Hausman test of the null that $\varrho_i = \varrho \; \forall \; i$ indicates which estimator is to be preferred.

Tables 2 to 4 report the estimation results for different sub-samples. We report either the MG or PMG estimates according to the result of the Hausman test. As a general rule, the lag order has been selected according to the BIC with a maximum lag length of 4 in each variable.[9] As a robustness check, we estimated (13) extended by including the cyclical element of the HP-filtered log of real GDP capturing the cyclical fluctuations of the primary surplus as an additional covariate. Yet, since the results are qualitatively the same as the estimates of the baseline model, we report only the results derived from the more parsimonious specification.

5.1 Sustainability and the Euro Convergence Criteria

To analyze the effect of the Euro Convergence Criteria on sovereign debt sustainability, we estimate (13) for groups of EMU and non-EMU countries for the periods before and after the introduction of the Euro Convergence Criteria in 1997:1. Table 2 presents the estimation results.Splitting the sample reduces the heterogeneity in the response coefficient and the PMG estimator becomes the preferred one for all samples considered here. Although we find evidence for debt sustainability in both sub-periods pooling all countries together, it is worth to note that the estimated response parameter, $\hat{\varrho}$, decreased from 0.041 to 0.011 suggesting that, on average, countries faced tighter constraints to service their debt. Splitting the samples into EMU (AUT, BEL, ESP, FRA, GER, GRE, ITA, NLD, POR) and non-EMU countries (AUS, CAN, DNK, GBR, JPN, USA) reveals that $\hat{\varrho}$ did not decrease remarkably in the group of EMU countries (0.037 and 0.030) but considerably in the group of non-EMU countries for which the coefficient turned insignificant in the second period (0.032 and 0.005). The decline in the average response coefficient is, therefore, caused by non-EMU countries

[9] If the iterative MLE procedure ran into identification issues, the maximum lag length was decreased as long as the problem persisted.

Table 2: Pooled mean-group estimation of (13) for EMU and non-EMU countries

	All		EMU		non-EMU	
	1980:1-1996:4	1997:1-2010:4	1980:1-1996:4	1997:1-2010:4	1980:1-1996:4	1997:1-2010:4
$\hat{\varrho}$	0.041***	0.011***	0.037***	0.030***	0.032***	0.005
	(0.004)	(0.004)	(0.004)	(0.007)	(0.005)	(0.004)
$\bar{\phi}$	-0.101***	-0.211***	-0.082*	-0.284***	-0.223***	-0.084
	(0.028)	(0.056)	(0.043)	(0.054)	(0.079)	(0.123)
# of obs.	894	840	534	504	336	336
H	0.16	0.75	0.97	0.62	0.93	2.08

Notes: $\hat{\varrho}$ and $\bar{\phi}$ are the long-run response of the surplus-GDP ratio to a one unit change in the debt-GDP ratio and the error correction coefficient, respectively. H is the Hausman test statistic with the null hypothesis that the difference between the MG and PMG estimators are not systematic. Standard errors are in parenthesis. *, **, and *** denote the significance level at 10%, 5%, and 1%, respectively.

rather than EMU countries which suggests that the Convergence Criteria contributed to a more sustainable development of sovereign debt in the EMU. This finding is highly consistent with Ballabriga and Martínez-Mongay (2005).

5.2 Is debt accumulation less sustainable in southern EMU countries?

The yield spreads plotted in Figure 2 suggest debt sustainability problems in the southern EMU countries. Yet, the single-country estimates reported in Table 1 indicate a positive response coefficient for ITA and ESP and a negative coefficient for FRA. To analyze the robustness of this result, we form groups based on the estimated response coefficients for single countries. We pool EMU countries with a positive point estimate of the response coefficient referred to as *sustainable* countries (AUT, BEL, ESP, GER, ITA, NLD) as well as EMU countries with negative coefficients referred to as *non-sustainable* countries (FRA, GRE, POR).[10] Notice that the classification into *sustainable* and *non-sustainable* countries is based on the point estimates rather than statistical significance. This is because the single-country estimations in section 4 are only preliminary and provide a rough guide for pooling countries such that parameter heterogeneity is minimized. If the remaining heterogeneity was too high, the Hausman test would indicate so.

The obtained estimation results for *sustainable* and *non-sustainable* EMU countries are then contrasted to the findings for the groups of northern EMU countries (AUT, BEL, FRA, GER, NLD) and southern EMU countries (ESP, GRE, ITA, POR). For our purpose, this is an interesting exercise since deviations between *sustainable* and northern countries and *non-sustainable* and southern countries, respectively, may indicate that the widely applied north-south divide in terms of sovereign debt sustainability may not be justified.

[10]Note that we include CAN in the group of *sustainable* non-EMU countries even though the estimated ϱ is negative. This is because of two reasons: First, the single country estimate does not make much economic sense since the estimated error correction parameter is negative. Second, CAN has successfully reduced its debt-GDP ratio since 1995 and is therefore more similar to AUS and DNK rather than GBR, JPN and USA.

Table 3: Pooled mean-group estimation of (13) for northern and southern as well as sustainable and non-sustainable EMU countries

	North	Sustainable	South	Non-sustainable
$\hat{\varrho}$	0.026***	0.027***	0.026***	-0.006
	(0.003)	(0.003)	(0.006)	(0.005)
$\bar{\phi}$	-0.278***	-0.291***	-0.133**	-0.217**
	(0.101)	(0.075)	(0.053)	(0.104)
# of obs.	590	708	412	294
H	0.76	0.79	2.39	2.82
	1980:1-1996:4		1997:1-2010:4	
	North	Sustainable	North	Sustainable
$\hat{\varrho}$	0.030***	0.030***	0.036***	0.031***
	(0.004)	(0.003)	(0.009)	(0.007)
$\bar{\phi}$	-0.137	-0.185**	-0.359***	-0.373***
	(0.092)	(0.076)	(0.057)	(0.042)
# of obs.	310	372	280	336
H	0.70	2.00	0.21	0.52
	1980:1-1996:4		1997:1-2010:4	
	South	Non-sustainable	South	Non-sustainable
$\hat{\varrho}$	0.061***	0.010	0.013	-0.029***
	(0.017)	(0.011)	(0.010)	(0.01)
$\bar{\phi}$	-0.006	-0.061	-0.205***	-0.350*
	(0.040)	(0.044)	(0.074)	(0.196)
# of obs.	204	135	224	168
H	1.06	2.70	0.70	0.00

Notes: $\hat{\varrho}$ and $\bar{\phi}$ are the long-run response of the surplus-GDP ratio to a one unit change in the debt-GDP ratio and the error correction coefficient, respectively. H is the Hausman test statistic with the null hypothesis that the difference between the MG and PMG estimators are not systematic. Standard errors are in parenthesis. *, **, and *** denote the significance level at 10%, 5%, and 1%, respectively.

Estimation results are reported in Table 3. For the whole sample period considered, there is no difference between northern and *sustainable* EMU countries with a $\hat{\varrho}$ of 0.026 and 0.027, respectively, indicating debt sustainability in both groups. Yet, while we find evidence of debt sustainability for the southern EMU countries with a $\hat{\varrho}$ of 0.026, the estimated response coefficient is -0.006 for the group of *non-sustainable* EMU countries. The difference can be explained by noticing that ESP and ITA historically seem to have adjusted their surpluses sufficiently to increases in debt whereas the same does not hold for FRA. Note that this is not reflected by the yield spreads which are much higher for the former than for the latter.

Table 3 also presents the estimation results for the periods before and after the introduction of the Convergence Criteria.[11] No significant differences can be observed between the groups of northern and *sustainable* EMU countries, nor between the two sub-periods for any of the two groups. For each of these sub-samples, we obtain a significantly positive response coefficient. For the group of southern EMU countries we estimate a positive ϱ in

[11]The results for northern and southern countries for the first sub-periods have to be interpreted with caution since the error-correction coefficients are not significant.

Table 4: Pooled mean-group estimation of (13) for EMU and non-EMU countries excluding and including the years of crisis

	EMU: sustainable		non-EMU: sustainable	
	1980:1-2006:4	1980:1-2010:4	1980:1-2006:4	1980:1-2010:4
$\hat{\varrho}$	0.026***	0.027***	0.035***	0.037***
	(0.003)	(0.003)	(0.007)	(0.007)
$\bar{\phi}$	-0.285***	-0.291***	-0.152***	-0.189***
	(0.079)	(0.075)	(0.032)	(0.0317)
# of obs.	636	708	282	318
H	0.06	0.79	2.19	1.49
	EMU: non-sustainable		non-EMU: non-sustainable	
	1980:1-2006:4$^{(i)}$	1980:1-2010:4	1980:1-2006:4	1980:1-2010:4
$\hat{\varrho}$	-0.006	-0.006	0.037***	-0.001
	(0.005)	(0.005)	(0.013)	(0.053)
$\bar{\phi}$	-0.451	-0.217**	-0.110**	-0.024
	(0.314)	(0.104)	(0.045)	(0.361)
# of obs.	258	294	318	354
H	65.25***	2.82	—$^{(ii)}$	0.02

Notes: $\hat{\varrho}$ and $\bar{\phi}$ are the long-run response of the surplus-GDP ratio to a one unit change in the debt-GDP ratio and the error correction coefficient, respectively. H is the Hausman test statistic with the null hypothesis that the difference between the MG and PMG estimators are not systematic. Standard errors are in parenthesis. *, **, and *** denote the significance level at 10%, 5%, and 1%, respectively.
$^{(i)}$ MG estimator
$^{(ii)}$ The asymptotic assumptions of the Hausman test are not met. The results obtained from the MG estimator, however, are qualitatively the same.

both periods, even though it decreases and turns insignificant in the second.[12] For the group of *non-sustainable* countries, however, we do not find evidence of debt sustainability in any of the two periods. Hence, in terms of debt sustainability a division of the EMU countries into north and south cannot be justified.

It is also interesting to note that the estimated response coefficient did not change for the *sustainable* EMU countries after the introduction of the Convergence Criteria but considerably for the *non-sustainable* EMU countries. This suggests that the Convergence Criteria may have been more effective for the former group than for the latter. This result contradicts Ballabriga and Martínez-Mongay (2005) who find that the Euro reinforced sustainability for FRA and left it unchanged for GRE and POR.

5.3 How did the financial crisis affect debt sustainability?

How did the recent economic crisis affect the fundamentals of debt sustainability in different groups of countries? Some insights into this question can be gained by estimating (13) for samples excluding the years of crisis and comparing the estimates to the corresponding results obtained from the full sample.

Table 4 reports the estimation results for EMU and non-EMU countries for the period

[12] Adding a control for the business cycle to the regression implies a significantly positive response coefficient for the south also in the second period.

from 1980:1 to 2007:4 and restates the estimates for the respective groups over the entire period for the sake of comparison. Excluding the years of crisis does not change the results for *sustainable* EMU nor *sustainable* non-EMU countries with coefficients of 0.026 vs. 0.027 and 0.035 vs. 0.037, respectively.[13] Also for *non-sustainable* EMU countries, we do not find a difference between the pre-crisis period and the entire sample. For both, we are unable to find evidence of debt sustainability.

The most striking finding we obtain is for *non-sustainable* non-EMU countries: Debt accumulation seems to have been sustainable until the crisis. The response coefficient is significantly positive for the period excluding the crisis but not for the period including the crisis (0.031 vs. -0.001).

In the *non-sustainable* EMU countries, the crisis does not seem to have deteriorated the debt servicing practices which, on average, were already problematic before 2007. *Non-sustainable* non-EMU countries, however, experienced a tightening of debt servicing constraints during the crisis which was strong enough to make a significantly positive response coefficient negative by just adding the four years to the sample.[14] Judging on the basis of fundamentals, one should have expected high risk premia on the government bonds for GRE, POR and FRA since the introduction of the Euro and not such a tremendous rise in yields for GRE, POR, ITA and ESP after the financial crisis as observed empirically. According to our findings, complete capital markets should have predicted a considerable rise in the yields of GBR, JPN and USA government bonds which cannot be observed empirically, however.

5.4 Why did the yield spreads not follow the fundamentals?

How can the low yield spreads for government bonds of GRE, POR and FRA after 1997 be justified despite the lack of evidence for sustainable debt accumulation? Why did spreads spike for GRE, POR, ITA and ESP after the financial crisis but not for GBR, JPN and the USA? Interesting insights can be gained by comparing the response coefficients to the average primary surplus, an exercise proposed by Bohn (2011). Note first that the IBC in (6) can be rewritten as

$$B_t = \sum_{n \geq t} E_t[u_{t,n}] E_t[S_{t+n}] + \sum_{n \geq t} Cov_t[u_{t,n}, S_{t+n}], \tag{14}$$

where $E_t[u_{t,n}]$ has the interpretation of the price of a safe n-period bond and captures systematic risk. Hence, the IBC can hold even if primary surpluses are negative on average as long as the covariance term, i.e. the value of safety attached to government bonds, is high enough. Hence, comparing the average primary surplus with the estimated response coefficient allows us to assess the value investors attach to the safety of government bonds.

Table 4 reports the average primary surplus-GDP ratios as well as the estimated response coefficients, $\hat{\varrho}$, for different groups of countries. Between 1980 and 1996, the average primary

[13] The results for northern and southern EMU countries do not change considerably by excluding the crisis from the sample.

[14] Note that this result is not driven by demand stabilizing considerations of fiscal policy since it is robust to including our business cycle measure as an additional covariate.

Table 5: Sample means for the primary surplus-GDP ratio and response coefficients for different groups of countries

	1980:1-1996:4		1997:1-2010:4	
	$\bar{s}$	$\hat{\varrho}$	$\bar{s}$	$\hat{\varrho}$
sustainable EMU	-0.75	0.030	1.66	0.031
non-sustainable EMU	-0.88	0.010	-0.95	-0.029
sustainable non-EMU	-0.63	0.032	2.35	0.044
non-sustainable non-EMU	-0.75	0.029	-2.45	0.006

Notes: $\bar{s}$ is the mean of the primary surplus-GDP ratio. $\hat{\varrho}$ is the PMG estimate of the long-run response of the surplus-GDP ratio to a one unit change in the debt-GDP ratio.

surplus-GDP ratio was roughly the same in all groups considered. Yet, while the groups of *sustainable* EMU and non-EMU countries managed to raise their average surpluses substantially between 1997 and 2010, the ratio declined for the groups of *non-sustainable* countries, especially non-EMU countries. Comparing the change of these averages with the change of the sustainability indicator, $\hat{\rho}$, reveals the following: For *sustainable* EMU and non-EMU countries, the positive response coefficients imply (14) to hold in both periods even though the average primary surpluses were negative in the first period. Therefore, the IBC was satisfied in the first period due to the high covariance terms, i.e. the high value bond holders attached to safety of government bonds. Moreover, for *non-sustainable* EMU countries, $\hat{\varrho}$ is lower than for non-EMU countries, even though the former's average primary surplus is considerably higher. This suggests that bond holders perceive government bonds issued by *non-sustainable* non-EMU countries significantly saver than bonds issued by *non-sustainable* EMU countries.

Our findings are therefore highly consistent with De Grauwe (2011) and De Grauwe and Ji (2012). Troubled countries within a monetary union are more susceptible to bubble-driven bond holders' sentiments then stand-alone countries. Our findings support the view that in monetary unions investors tend to neglect foul fundamentals and under-price the sovereign default risk during good times. In bad times, however, they seem to overestimate the risk of default.

6 Concluding remarks

We study the sustainability of sovereign debt accumulation in 15 EMU and non-EMU countries using quarterly data from 1980 to 2010. We analyze how and in what countries debt sustainability changed after the commencement of the Euro Convergence Criteria in 1997 as well as after the economic crisis 2007 and discuss why the borrowing costs for governments increased more for troubled EMU countries than for non-EMU countries after the recent crisis. We define *sustainability* as the validity of the inter-temporal budget constraint of the government. Following Bohn (1998), we motivate a positive response of the primary surplus-GDP ratio to an increasing debt-GDP ratio as a sufficient condition for sustainability and

test it using single-country and pooled regressions.

Our results suggest that, on average, the Euro Convergence Criteria requiring member states to limit government net borrowing to 3% of GDP and to reduce the gross sovereign debt to 60% of GDP contributed to keeping debt accumulation on a sustainable path in the EMU. In the EMU, debt accumulation has been *sustainable* in the periods before and after the implementation of the Euro whereas in non-EMU countries debt accumulation turned *non-sustainable* in the second period. Yet, splitting the Euro Area into countries with high response coefficients and countries with low response coefficients reveals that the Convergence Criteria failed to establish sustainability in the latter group comprising France, Greece and Portugal. The reasons for this failure are beyond the scope of this paper. This result suggests, however, that a mere tightening of the rules for fiscal consolidation might be insufficient to establish debt sustainability in troubled countries.

Contrary to what the yield spreads suggest, debt accumulation is not less *sustainable* in the average southern EMU country than in the average northern EMU country. We find no significant difference between the sustainability measure for northern and southern EMU countries. Single country estimation indicate that countries with significantly positive response coefficients tend to have managed to stabilize their debt-GDP ratio, whereas the others have not. Pooling EMU countries according to their average response coefficients reveals robust results. Debt accumulation has been *sustainable* in the group of Austria, Belgium, Germany, Spain, Italy and the Netherlands. No evidence of sustainability can be found for the group including France, Greece and Portugal. Therefore, the high (low) interest rates on Spanish and Italian (French) bonds cannot be justified by debt sustainability considerations alone. This observation is highly consistent with the view that the pricing of borrowing risks are driven by liquidity considerations rather then fundamentals as argued by De Grauwe (2011) and De Grauwe and Ji (2012).

Unsurprisingly, the crisis seems to have adversely affected the sustainability of debt accumulation. As suggested by pooled regressions, the response coefficients of EMU and non-EMU countries for which we do not find evidence of sustainability over the entire period have decreased enormously during the crisis, while countries with high average response coefficients over the entire sample have not been affected very much. In particular the United Kingdom, Japan and the United States experienced a considerable deterioration of debt sustainability during the crisis with a *sustainable* accumulation of debt until the crisis, but not over the entire sample. At the same time, no evidence of debt sustainability can be found for France, Greece and Portugal for any of the two periods. This finding suggests that investors under-estimated the risk of sovereign default during good years and over-estimated it during the crisis and is therefore highly consistent with De Grauwe (2011).

Finally, we obtain the implicit result that bond holders perceive the average bond issued by the United Kingdom, Japan and the United States saver than the average bond issued by France, Greece and Portugal. As argued by Bohn (2011), the United States benefits considerably from the perception of its government bonds to be safe assets. Using this line of argument implies for the EMU that commonly issued bonds would increase the safety of these assets which, ceteris paribus, would allow lower average primary surpluses to be

consistent with the inter-temporal budget constraint, i.e. debt sustainability.

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A Data

For our empirical study, we use quarterly data on the primary surplus of the general government, net sovereign debt of the general government, nominal and real GDP as well as bond spreads from 1980:1 to 2010:4 for 15 countries considered in the analysis. The following discusses how the data set used for the regression analysis has been computed.

A.1 Primary surplus-GDP ratio

For AUS, CAN, GBR, JPN and USA quarterly seasonally adjusted data has been taken from the OECD Economic Outlook 89.

For AUT, FRA, GER, ITA, GRE and NLD the series consists of two parts: The first is computed as the seasonally adjusted primary surplus taken from the OECD Economic Outlook 79 database which is the last edition providing these data for these countries over seasonally adjusted GDP taken from the OECD Economic Outlook 89. The second is the seasonally adjusted primary surplus-GDP ratio taken from Eurostat. For each country the break point is the quarter in which Eurostat data become available.

For BEL, DNK, ESP and POR no quarterly data on primary surpluses is available before 1991, only annual data. We computed the series the following way: For the quarters available the seasonally adjusted primary surplus-GDP ratio is taken from Eurostat. For the previous quarters, the primary surplus has been estimated applying the procedure outlined by Chow and Lin (1971) and discussed in greater detail in Appendix B. Annual observations of the primary surplus taken from the OECD EO 89 have been distributed to quarterly data using quarterly data of seasonally adjusted unemployment rates and inferring from the correlation between annual primary surpluses and annual unemployment rates. Finally, the estimated primary surplus has been normalized by GDP taken from the OECD Economic Outlook 89.

A.2 Sovereign debt-GDP ratio

For AUS, CAN, JPN and USA quarterly seasonally adjusted data on the general government's net debt-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 first is the discontinued data on net debt of the general government taken from the OECD EO 79. The second is interpolated 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. 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.

A.3 Business-cycle measure

For all countries considered, we measure the business cycle by the cyclical element of a Hodrick-Prescott filter ($\lambda = 1600$) applied on the logarithmized real GDP obtained from the OECD EO 89 database.

B Chow-Lin

To compute the primary surplus-GDP ratio as well as the debt-GDP ratio some series have to be interpolated and distributed 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

$$Y = X\beta + u, \tag{15}$$

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

$$Y. = CY = CX\beta + Cu = X.\beta + u., \tag{16}$$

with C being a $n \times 4n$ transformation matrix with the $[i, 4i-3]$-th element being 1 for $i = 1, \ldots, n$ and the others being zero for an interpolation problem and with the $[i, 4i-3]$-th, $[i, 4i-2]$-th, $[i, 4i-1]$-th and $[i, 4i]$-th elements being $1/4$ for $i = 1, \ldots, n$ and the others being zero for a distribution problem. Assuming that the quarterly residuals follow a first-order autoregressive 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

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

where

$$V = \begin{bmatrix} 1 & a & a^2 & \ldots & a^{4n-1} \\ a & 1 & a & \ldots & a^{4n-2} \\ a^2 & a & 1 & \ldots & a^{4n-3} \\ & & & \ldots & \\ a^{4n-1} & \ldots & a^2 & a & 1 \end{bmatrix} \frac{\sigma^2}{1-a^2} \tag{18}$$

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 from a polynomial $\frac{\sum_{j=1}^{4}\sum_{i=5}^{8} V[i,j]}{\sum_{j=1}^{4}\sum_{i=1}^{4} V[i,j]} - q = 0$ in a distribution 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.

B.1 Distribution of primary surplus

The primary surplus-GDP ratio for BEL, DNK, ESP and POR has been computed using an estimate of the primary surplus for a part of the sample. Since the primary surplus is a flow we apply the procedure for a distribution problem. The matrix X includes a constant, a time trend and the unemployment rate as explanatory variables. For the relevant countries, Figure 3 plots the annual primary surplus series as well as the annualized estimated quarterly series.

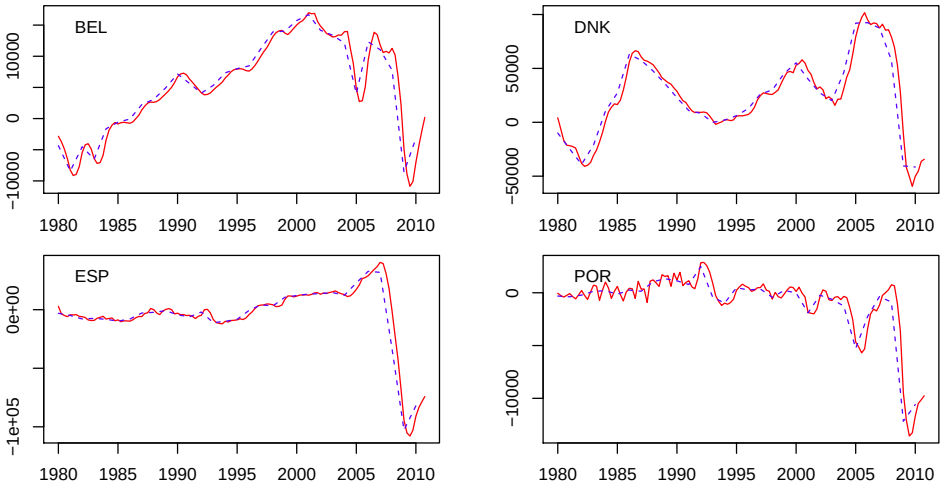

Figure 3: Annual primary surplus (dashed line) and annualized distributed quarterly primary surplus (solid line) from 1980:1 to 2010:4

B.2 Interpolation and extrapolation of net sovereign debt

The net debt series for BEL, DNK, ESP, GBR, NLD and POR 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 GRE, the debt series has been interpolated and extrapolated using annual data on net debt taken from the OECD EO 89 and the cumulated seasonally adjusted government net lending. Since for annual debt data is not available prior to 1995, the quarters before have been extrapolated using a cumulated estimated net lending series.

For the countries mentioned in the last two paragraphs, 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 from Eurostat.

For BEL and ESP as well as NLD and GRE net lending 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.

For POR, 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). 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 (and for GRE also extrapolated) net debt series as plotted in Figure 4 together with the annual net debt.

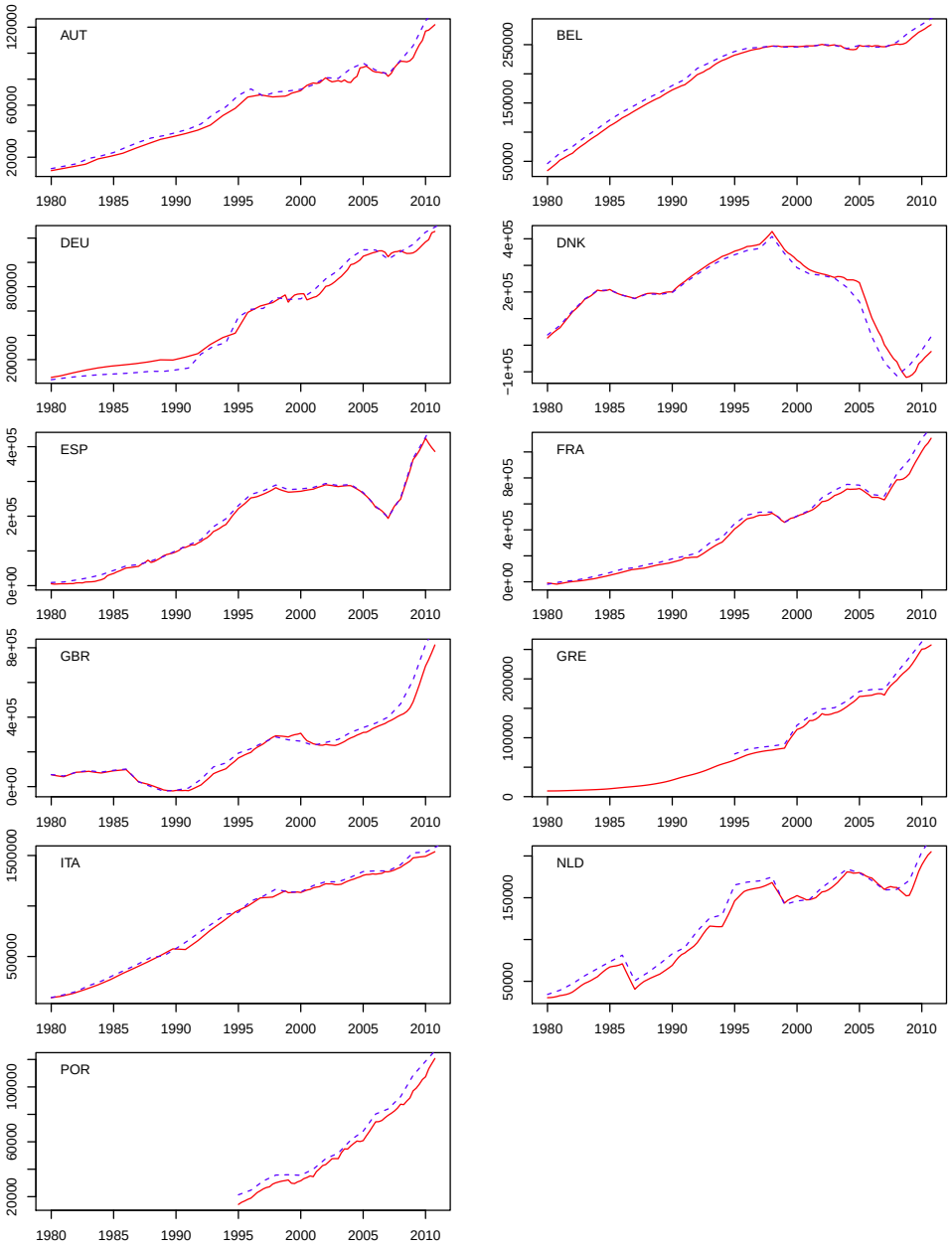

Figure 4: Annual net sovereign debt (dashed line) and interpolated/extrapolated quarterly net sovereign debt (solid line) from 1980:1 to 2010:4

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