Non-linearities in Fiscal Policy: Evidence from the Eurozone

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This version: September 2017

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Abstract: This paper investigates the existence and the policy implications of non-linear fiscal reaction functions for Eurozone countries from 1978 to 2015, focussing on differences between countries under pressure during the sovereign debt crisis (periphery) and the ones that were not (core). We use a novel method within the fiscal reaction function literature to determine an endogenous threshold in the presence of regressor endogeneities, and find that non-linear specifications fits the fiscal reaction functions of EMU countries best in some dimensions. More specifically, core EMU countries tend to follow a counter-cyclical fiscal policy with regard to changes in the output gap which is stronger when the output was negative. This allowed the automatic stabilisers to operate more effectively. The stabilisation response of their periphery counterparts on the contrary is found to be pro-cyclical and linear. This required a stronger response to debt than in core EMU countries, which is found to be stronger when debt reaches very high levels. This strong response of fiscal policy to debt variations for the periphery during the crisis is independent from any market pressures as captured by spreads.

Keywords: Fiscal reaction function, Sustainability, Stabilisation, Rolling window, Dynamic panel data, Threshold effects.

JEL: H60, E62, C33

Acknowledgements: we thank Eric Leeper, Jordi Gali, Elias Tzavalis, Andros Kourtellos, Barbara Roffia, Dieter Gerdesmeier for their very helpful suggestions and input. We also thank the participants at an ECB seminar, the 2017 Banca d'Italia Fiscal Policy Workshop, the 2017 Rimini Macro Worhshop and in particular Cristina Checherita-Westphal, Jacopo Cimadomo, George Hondroyiannis, Christophe Kamps, Steffen Osterloh and Thomas Warmedinger for their comments and discussions. Panagiotis Politsidis gratefully acknowledges the Fiscal Policies Division of the ECB for its hospitality. The views expressed in this paper are those of the authors and do not necessarily reflect those of the ECB or the Eurosystem.

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1. Introduction

The sovereign debt crisis, followed by an intensive consolidation period in many countries, and the double-dip recession in the Eurozone in 2012 led to debates on the size and the timing of the necessary adjustment as well as on the desirability and possibility of a counter-cyclical fiscal stance. These debates can be considered to be two sides of the same coin. The European sovereign debt crisis points to insufficient attention to fiscal sustainability before the crisis, while the subsequently necessary consolidation effort restricted the possibility for fiscal policy to contribute to stabilising output, in an environment when monetary policy hit the lower-bound.

In principle, stabilisation and sustainability can be compatible objectives for a prudent fiscal policy by pursuing the reduction of debt in good times and also creating buffers to be used for macroeconomic stabilisation in bad times. The experiences over the past few years raise the question what fiscal stance actually has been pursued by various euro area countries. In particular, is there a difference between the countries that came under market scrutiny and pressure and those that did not? Secondly, are there differences over time or different regimes, for example when government debt-to-GDP becomes alarmingly high for instance in the presence of the 2009-2010 crisis?

To address these issues, we focus on the estimates of linear and non-linear version of fiscal reaction functions (FRFSs) for 15 euro and non-euro area countries over the 1978-2016 period. Our estimates suggest that the periphery counties pursued a linear and pro-cyclical fiscal stance, and needed to respond stronger to increasing debt for debt-to-GDP ratios above 95%. In contrast, the (mildly) counter-cyclical stance pursued by core EMU countries allows them to let the automatic stabilisers operate when the output gap was negative and also allowed for a more moderate (and linear) response to debt.

Fiscal policy reaction functions are usually examined to investigate whether fiscal policy is driven by efforts towards debt stabilisation and/or macroeconomic stabilisation (see inter alia Bohn, (1998); Reicher (2014); Weichenrieder et. al., (2014); Nerlich et. al., (2015); Checherita-Westphal and Ždarek, (2017))[2]. Recently, there has been a focus to non-linear versions of FRFs. These extensions refer either

[2] Fiscal policy reaction functions have been employed for analytical projects not directly related to fiscal policy. Claeys (2006) examines the interaction between the fiscal and monetary policy setting by augmenting the fiscal

to typical ex ante imposed nonlinear versions of FRFs, i.e. polynomial functions (see Bohn, (2005); Gosh et. al., (2011), (2013); Medeiros, (2012)), regime-switching models (see Fournier et. al., (2015); Legrenzi et. al., (2013)) and only few studies employ a non-linear impact analysis assuming exogenously imposed debt thresholds (see Celasun et. al., (2007), Cimadomo, (2012), Lukkezen & Rojas-Romagosa (2012), Lukkezen & Teulings (2013)).

Fiscal reaction functions quantify the response of fiscal policy (usually measured as change in the (cyclically-adjusted) primary balance) to cyclical conditions (measured by the output gap) and fiscal conditions (measured by the lagged (cyclically-adjusted) primary balance and debt-to-GDP ratio). A positive response of fiscal policy to fiscal conditions is regarded as a "weak condition" for debt sustainability (Bohn (1998; 2005)).

A positive response of the cyclically-adjusted primary balance to output gap indicates a discretionary fiscal policy oriented towards countercyclical stabilisation, whereas a negative response indicates a pro-cyclical response. The primary balance includes the effect of automatic stabilisers and is therefore expected to respond stronger to improvements on the output gap than the cyclically-adjusted primary balance. With the budgetary semi-elasticity to the output gap averaging at 0.53 for the EU (Mourre et al 2013), a rule of thumb for a-cyclical policy would be a coefficient around 0.5 for primary balance. However, budgetary semi-elasticities range widely across countries, as indexation rules, significant tax deductions and earmarking rules for revenues can automatically stimulate public spending during boom times and dampens revenues in bad times (see IMF (2015)).

We estimate fiscal reaction functions with both the primary balance and cyclically-adjusted primary balance, and considering a coefficient around 0.5, respectively a coefficient around zero for the case of cyclically adjusted balance, as an indication of an a-cyclical fiscal stabilisation response.

To the best of our knowledge, our paper adds to the literature in a number of ways:

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reaction function with the short term interest rate. Celasun et. al. (2006) examine primary surplus behaviour and risks to fiscal sustainability in emerging market economies accounting for factors that are likely to be important drivers of primary balances such as, the real oil price, institutional quality, sovereign default status, commitment to an IMF program. Tangalakis (2011) investigates the links between financial market movements and fiscal policy outcomes.

First, our paper focuses to cross-country heterogeneities in fiscal policy among EMU members over a period of almost four decades, while focussing on possible changes since 2010-12 sovereign debt crisis**.** We investigate possible differences between core euro area countries and periphery countries by estimating FRF using dummies that disentangle for the effects from both country blocks.[3] Core countries are defined as those that did not come under severe market pressure during the crisis (Austria, Belgium, Finland, France, Germany and the Netherlands), while periphery countries are those that ended up with an EU/IMF programme or which had sovereign spreads in excess of 500 basis points before the introduction of OMT in 2012 (Ireland, Spain, Italy, Cyprus and Portugal).[4]

Second, our analysis departs from previous non-linear methods by employing an endogenous threshold in the reaction of fiscal policy regarding government debt and to output gap. The endogeneity of government debt and output gap threshold is relevant in order to capture the inherent underlying macro and fiscal interactions arising from the dependence of primary balance with output gap and lagged values of debt (Medeiros (2012). We employ this non-linear version of FRF in a dynamic generalised method of moments (GMM) context making use of benign instruments scrutinised with appropriate econometric methods. Recent econometric findings (Yu, 2013) point that failure to capture endogeneity in the threshold variable lead to biased and inconsistent estimators of the standard least squares (CLS) threshold estimator of Hansen (2000) used in the literature so far. In the same context we also account for any endogeneities in other variables by carefully introducing a number of instruments.

Thirdly, similar to the study of thresholds within the context of the debt-growth nexus literature (in Reinhart and Rogoff (2010)), and rather than treating non-linearities as a statistical artefact, we provide a deeper analysis of the underlying fiscal policy implications arising from these non-linearities. Moreover, as we are particularly interested in the recent crisis period and the implications to

[3] Baldi and Staehr (2015) also consider differences in fiscal reaction functions between Eurozone countries during the crisis, based on quarterly data for the pre-crisis period 2001–2008 and for the crisis period 2009–2014. They refer to heterogeneities by breaking the panels across different group of countries reducing sizeably the number of observations in their estimates. They conclude that after the crisis there is much more feedback from the debt stock while differences refer mostly to the persistence and cyclical reaction to output variations.

[4] This division of EMU in periphery and core countries follows a number of other studies, e.g. Argyrou et. al. (2012), Afonso et. al. (2015), Palaiodimos and Tzavalis. (2015).

sustainability we investigate also the effects of other channels i.e. pressure for consolidation through sovereign spreads.

Even-though this analysis is backward looking, our findings have important policy implications for the future conduct of fiscal policy and also may provide a narrative for introducing non-linearities in relevant more complicated euro area wide general equilibrium models with analytical fiscal rules in place. Our analysis proves that conclusions usually drawn from the total number of EMU countries may mask significant heterogeneities between countries regarding the use of fiscal rules.

According to our results, periphery EMU countries follow a pro-cyclical fiscal policy regarding output stabilisation, without discernible differences across different states of the economy. While the operation of automatic stabilisers gained some importance during the crisis period, in the periphery policy remained pro-cyclical. They are also found to react stronger to (high) debt than core countries, which is the flip side of the pro-cyclical stabilisation reaction as high debt levels eventually require a stronger reaction. We find an endogenous debt threshold of 96% of GDP for periphery countries, which are more responsive to debt changes when in the high debt regime.

Our findings for core countries mirror those of the periphery. Core countries pursued a broadly a-cyclical fiscal policy with regard to output stabilisation, but we do not find support of a threshold for responses to debt. An output gap threshold is found for core EMU countries for negative output gaps, with strong counter-cyclical policy when the output gap is negative and more limited, but still mildly counter-cyclical policy when the output gap is positive.

The remainder of this paper is organized as follows. Section 2 presents our baseline and threshold fiscal policy rule. Section 3 describes our dataset. Section 4 provides estimates of the model and discusses the results. Section 5 concludes.

2. Methodology

2.1. A baseline linear fiscal reaction function to address endogeneity issues

Traditionally the fiscal policy mix between effort to sustainability and the stabilisation has been based on the seminal work of Bohn (1998; 2005) that takes the following formal definition:

$$d_k = -\lim_{T\to\infty} \sum_{t=k+1}^{T} s_t \cdot \left[\frac{1+i}{(1+\beta)(1+\pi)}\right]^{-t}. \quad (1)$$

Equation (1) states the condition for a sustainable fiscal policy i.e. the value of the initial debt-to-GDP ratio $(d_k)$is be equal to the negative present discounted value of all future primary deficits $\{s_{K+1}, s_{K+2}, \dots, s_{K+T,\dots}\}$.

Based on this model-based approach a sustainable fiscal policy requires that governments react to changes in sovereign debt by adjusting their primary balance. In its simplest form, this approach postulates a linear relationship between the level of lagged public debt, the output gap and the government's primary surplus at any given period, or:

$$s_t = \beta' X_t + \varepsilon_t = \alpha_d \cdot d_{t-1} + \alpha_y \cdot y_{it} + \alpha_m \cdot m_t + \gamma' \cdot \Omega_t + \varepsilon_t \quad (2)$$

$s_t$is the fiscal variable (i.e.at this stage of the analysis the ratio of primary balance to aggregate income (GDP) at time t), d_t is the ratio of public debt to aggregate income, y_t is the output gap, Ω_t is a set of other determinants of the primary surplus and ε_t is the error term. To capture fiscal financial inter linkages, we augment specification (2) with a monetary policy variable m_t aimed at reflecting the monetary policy stance.

In a panel context, fiscal rule takes the following form:

$$Pb_{it} = a_{i,t} + \alpha_b \cdot Pb_{it-1} + \gamma_d \cdot D_{it-1} + \delta_y \cdot OG_{it} + \alpha_m \cdot mon_{it} + \alpha_{y\_US} \cdot OG_{US_{it-1}} + a_{ir} \cdot IIR_{it} + n_i + \lambda_t + \varepsilon_{it}\,,\ for\ country\ i\ (i = 1,\dots,N)\ and\ period\ t\ (t = 1,\dots,T) \quad (3)$$

where Pb_{it} stands for the primary balance as a percent of GDP (current prices). D_{it-1} is the lagged general government consolidated gross debt (as a percent of GDP). OG_{it} denotes the gap between actual and potential gross domestic product at 2010 reference levels in percentage points of potential gross domestic product (constant prices). mon_{it} captures the monetary stance and is defined by the deviation of the interest rate implied by the Taylor-rule from the prevailing 3-month real interest rate[5]. $OG_{US_{it-1}}$is the lagged US output gap (constant prices) whileIIR_{it} stands for the implicit interest

[5] Monetary policy is approximated by the deviation of the real interest rate from its value as implied by the Taylor (1993) rule, with a negative (positive) value of this variable capturing the monetary excesses (shortages) resulting from the adoption of an expansionary (contractionary) monetary policy stance (see among others Clarida et. al., 1998; Taylor, 2009).

rate on government debt[6]. n_i and λ_t stand for unobserved country and time effects and lastly ε_{it} is the random component, which could be perceived as reflecting the non-systematic policy response or the fiscal policy shocks, which are independent across countries.

In the presence of a lagged dependent variable we follow Celasun et. al. (2006)[7], Candelon et. al. (2010), Golinelli and Momigliano (2009), Medeiros (2012) and employ two-step GMM estimator accounting for possible endogeneities between the output gap with contemporaneous and lagged fiscal shocks (past values of primary balance) and lagged debt. Following Roodman (2009), Eq. (3) is augmented with a collapsed version of instrumental variables to avoid over-parameterisation of our endogenous variables and the weakening of Hansen test of instrument validity[8].

In our specification we use as instruments in most cases the second to third and the three or fourth to fifth lags of the endogenous variables, i.e. the output gap (OG_{it}) respectively, the debt to GDP ratio (D_{it-1}), together with implicit interest rate (IIR_{it}), lagged US output gap ($OG_{US_{it-1}}$) and the monetary stance (mon_{it})**.** Our decision on the subset of instruments depends on the test of instrument validity i.e. Sargan, Hansen and Difference in Hansen for level and subset of equations and takes also into account the absence of second order autocorrelation in first difference errors (i.e. that moment conditions are valid).[9]

Our analysis mainly focuses to the coefficients that are relevant for fiscal policy analysis and these are denoted as γ_y and δ_d and express the effort towards sustainability and stabilisation as described in specification (3).

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[6]Following Candelon et. al. (2010) and Debrun et. al. (2016) we incorporate in our fiscal reaction function model one lag values of the US output gap and the implicit interest rate defined as the interest payments divided by the previous period public debt.

[7]In addition, as pointed out by Celasun and Kang (2006) "if other regressors in the fiscal reaction function such as the output gap are potentially endogenous to contemporaneous primary balance shocks and would need to be instrumented", then the GMM estimators are "the best performing estimator for the coefficients of the endogenous variables".

[8] We make use of the Stata command xtabond2.

[9] According to Bond (2002) and Roodman (2009) omitting the more distant lags of instruments might not lead to significant loss of information.

2.2. A non-linear fiscal reaction function with an endogenous threshold

There are reasons to expect that varying levels of debt and output prompt policy makers to pursue a different policy mix regarding stabilisation of government debt and/or the business cycle. Hence, a non-linear specification can contain valuable information about the state-dependent nature of the interaction between the government budget balance, on the one hand, and its macro and fiscal determinants, on the other. We augment our fiscal reaction function with a threshold parameter to distinguish between different fiscal policy regimes.

We use the structural threshold regression (STR) model of Kourtellos et. al. (2016) which is a recent addition in the threshold regression literature. Unlike the threshold regression models that divide the sample in two regimes depending on the exogenous threshold value, the STR model allows the estimation of an endogenous[10] threshold value to the variable of interest in a dynamic GMM panel approach, accounting also for regime specific heteroskedasticity. This is quite relevant, as following this approach in this paper we account for the endogeneity of the threshold for the output gap and the level of public debt due to the underlying fiscal macro linkages. Failure to capture this aspect leads to biased and inconsistent estimators of the standard least squares (CLS) threshold estimator of Hansen (2000) and Caner and Hansen, 2004 (see Yu, 2013).[11]

The threshold variable q_{it} - in our case the debt-to-GDP ratio and the output gap interchangeably –is splitting observations in two regimes according to the following indicator function:

$$I(q_{it} \leq \gamma) = \begin{cases} 1 & \text{iff } q_{it} \leq \gamma\text{: Regime 1} \\ 0 & \text{iff } q_{it} > \gamma\text{: Regime 2} \end{cases} \quad (4)$$

with $I(q_{it} > \gamma) = 1 - I(q_{it} \leq \gamma)$.

[10] Correlation at this point reflects contemporaneous correlation of the variable of interest with the error term in Equation (3).

[11] Unlike the existing fixed-effect literature, we address potential sources of endogeneity bias by using a GMM dynamic panel approach along the lines of Kourtellos et. al. (2013; 2016) and Kazanas et. al. (2015) and Seo et. al. (2016). This endogeneity refers to the contemporaneous correlation of the output gap to persistent fiscal policy shocks (ε_{it}) as well as the dependence of lagged debt to past values of primary balance. According to Medeiros (2012), "countries generating higher primary balances on average - reflected in the higher values of the fixed-effects coefficient - will tend to have a lower level of public debt; if this correlation is not taken into account, the negative correlation between debt levels and the unobserved country fixed-effects would exert a downward bias on the response of the primary surplus to lagged debt. The remaining sources of endogeneity may come from the correlation of the lagged debt with the country-specific and time-invariant determinants of primary surpluses as well as the persistence of errors making lagged debt endogenous.

In contrast to sample selection models used in the previous literature where the threshold variable (allowing the division of observations into different regimes) is taken to be latent or given, here the threshold variable is treated as an estimable parameter.

Following Kourtellos et. al. (2016) the general form of equation (2) in two regime form is given as below:

$$s_{it} = \beta_{X1}' \cdot X_{it} \cdot I(q_{it} \leq \gamma) + \beta_{X2}' \cdot X_{it} \cdot I(q_{it} > \gamma) + \kappa \cdot \Lambda_{it}(\gamma) + \varepsilon_{it} \, , \quad (5)$$

which can be also expressed as:

$$s_{it} = \beta' \cdot X_{it} + \delta' \cdot X_{it} \cdot I(q_{it} \leq \gamma) + \kappa \cdot \lambda_{it}(\gamma) + \varepsilon_{it} \, , \quad (6)$$

where $\mathrm{E}(\varepsilon_{it} - Z_{it}) = 0$.

In this equation λ_{it} is a scalar variable that involves an inverse Mills ratio term for each of the two regimes in order to restore the conditional mean zero property of the error ε_{it} and defined as follows:

$$\lambda_{it}(\gamma) = \lambda_{1it}(\gamma) I(q_{it} \leq \gamma) + \lambda_{2it}(\gamma) I(q_{it} > \gamma) \quad (7)$$

with $\lambda_1(\gamma - Z_{it}'\pi_q) = -\frac{\varphi(\gamma - Z_{it}'\pi_q)}{\Phi(\gamma - Z_{it}'\pi_q)}$ and $\lambda_2(\gamma - Z_{it}'\pi_q) = -\frac{\varphi(\gamma - Z_{it}'\pi_q)}{1-\Phi(\gamma - Z_{it}'\pi_q)}$ while $\varphi(\cdot)$ and $\Phi(\cdot)$ indicate the normal probability density function and cumulative density function respectively.

By defining the criterion $S_n(\gamma) = S_n(\widehat{\varepsilon_{it}}) =$

$$= \sum_{i=1}^{n} \left(s_{it} - \widehat{\beta_{X1}'} \cdot X_{it} \cdot I(q_{it} \leq \gamma) - \widehat{\beta_{X2}'} \cdot X_{it} \cdot I(q_{it} > \gamma) - \hat{\kappa}(\gamma) \cdot \hat{\lambda}_{it}(\gamma)' \right)^2$$

the value of γ can be estimated by minimizing the CLS criterion: $\underset{\gamma}{\operatorname{argmin}} \, S_n(\gamma)$. [12]

Finally, contrary to previous literature, rather that accepting ex-ante the existence of non-linearities and a threshold, we test for its existence extending Kazanas et. al. (2015) bootstrap methodology in a panel context.[13] This allows us to test the null hypothesis that the fiscal policy rule is given by the linear representation of Equation (3), against its alternative of a non-linear specification of Equation (6), formally $H_0: \delta' = 0$.

[12] The consistency and asymptotic distribution of the threshold parameter γ is nonstandard as it involves two independent standard Wiener processes with two different scales and two different drifts, while the construction of confidence intervals is based on the inversion of the likelihood ratio test (see Kourtellos et. al., 2016). In technical annex A, we describe the threshold location in the case of variable endogeneity in a GMM dynamic panel data context.

[13] The procedure is analysed in more detail in the Appendix as a technical annex.

3. Data

The dataset consists of annual data on primary budget balance, primary cyclically-adjusted government balance, government debt, and the output gap from the European Commission's AMECO database for the period 1978-2015. Our sample consists of 15 countries, based on data availability: 12 EMU countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Portugal and Spain), as well as Denmark, Sweden and the UK. Our dataset is based on the new European System of National and Regional Accounts (ESA 2010), which only covers the period starting in 1995. Therefore, to obtain a consistent series of historically primary balance data from 1979 onwards, we extend the ESA 2010 dataset backwards by using the annual growth rate of the primary balance as calculated according to the European System of Integrated Economic Accounts (ESA 79).

4. Empirical analysis

Our analysis consists of the following steps. First, we estimate a (linear) baseline model of FRFs for the complete sample. We illustrate differences between group of countries by plotting the sensitivity of the estimated coefficients over time using rolling windows and splitting our sample to the core and periphery country blocks. Secondly, we provide a thorough investigation of any possible differences between two country blocks introducing a relevant dummy in the linear model and assessing how these differences evolved during the recent crisis. Thirdly, we investigate possible non-linearities in fiscal policy by estimating endogenous thresholds of output gap and debt thresholds based on the structural threshold approach (STR) of Kourtellos et. al. (2016). Fourthly, where non-linearities are found to be significant, their policy implications are analysed by introducing threshold dummies at the country block-level to our model. Finally, we undertake a number of robustness checks to confirm the validity of our findings. This robustness refers to the impact of electoral cycle and market pressure especially to the periphery group of countries during the sovereign crisis.

4.1.1. Results from the benchmark fiscal policy model

Table (1) presents the baseline estimations of the fiscal reaction function in eq. (4) for the full period and sample of countries under examination, with alternative specifications referring to difference and system generalized methods of moments (GMM). Output gap and debt (as percent of GDP) are treated as endogenous employing as collapsed instruments their lagged values and first differences in the first difference and level equations, respectively.[14] As seen in columns 1-4, across different estimators (One-step and two-step versions of difference and system GMM estimator) the primary balance reacts positively to the lagged debt and the contemporaneous output gap, with the estimated coefficients being statistically significant and ranging between 0.03 and 0.07 in the first case and between 0.55 and 0.66 in the latter case.

It should be noted that estimates for the lagged debt and the output gap are higher than the estimates found in the literature in which case these variables are treated as strictly exogenous processes (e.g. Tangalakis (2011), Medeiros (2012), Weichenrieder et. al. (2014), Checherita et. al. 2015, Debrun et. al. (2016)). For comparison, we report in table 1 also estimates when debt and output gap are treated as exogenous variables (columns 5-6). In this case, the estimated coefficients are lower and comparable with those obtained in the literature.

Estimates for the remaining variables broadly have the expected sign, but are not always significant. One and two lags of the primary balance (Pb_{it-1} and Pb_{it-2}) have also a significant positive impact, and an insignificant impact respectively. The coefficients ~~on~~ of the implicit interest rate (IIR) are positive but not significant.[15]Also, no evidence of a significant direct link is found between fiscal policy in EMU and the ECB's monetary policy, while the lagged US output gap, as an indicator of global economic conditions has a negative and significant effect on the primary balance in a number of specifications (col. 2-4).

[14] In most cases the 3rd or 4th to 5th lags are employed as collapsed GMM instruments for the case of lagged debt-to-GDP ratio and the 2nd to 3rd lags for the case of output gap.

[15] Debrun et. al. (2016) find that high and rising borrowing costs and interest payments lead to a more aggressive fiscal consolidation strategy.

Results from the Sargan (1958) and the Hansen (1982) test of instrument validity indicate that the hypothesis that the employed instruments are valid is not rejected. As noted by Roodman (2009), in the system GMM context, the difference-in-Hansen test for the full set and subset of instruments point again to the validity of instruments used, while in all cases the number of instruments used is less that the number of cross section of our sample (following Bowsher (2002)). Lastly, tests on the existence of 1st and 2nd order autocorrelation to the levels and the first difference of residuals indicate the absence of autocorrelation of our specifications (i.e., all moment conditions are valid).

4.1.2. Intuition behind differences in the fiscal policy mix between core and periphery EMU

In this part of the paper we consider possible country heterogeneities of the fiscal policy mix over time within EMU and re-estimate equation (4) for a series of 15 year wide, rolling windows both for the full sample and for the core and the periphery EMU country blocks. Each estimation is performed by including and excluding respectively the financial assistance provided by governments to the financial sector from 2007 onwards (financial assistance measures or FAM).[16] These time-varying estimates aim to plot the country specific time variation of the trade-off between sustainability and stabilisation.[17] Figure 1 exhibit the time-varying coefficients for the reaction to (one period lagged) debt. While the average responses of primary balance to debt tend to move in the same direction in both EMU country blocks, heterogeneities are observed over time. For the windows before the start of EMU, signs of a parallel response can be seen in both core and periphery countries, with sustainability efforts increasing in the period before qualification for EMU, followed by a milder response after the launch of the euro

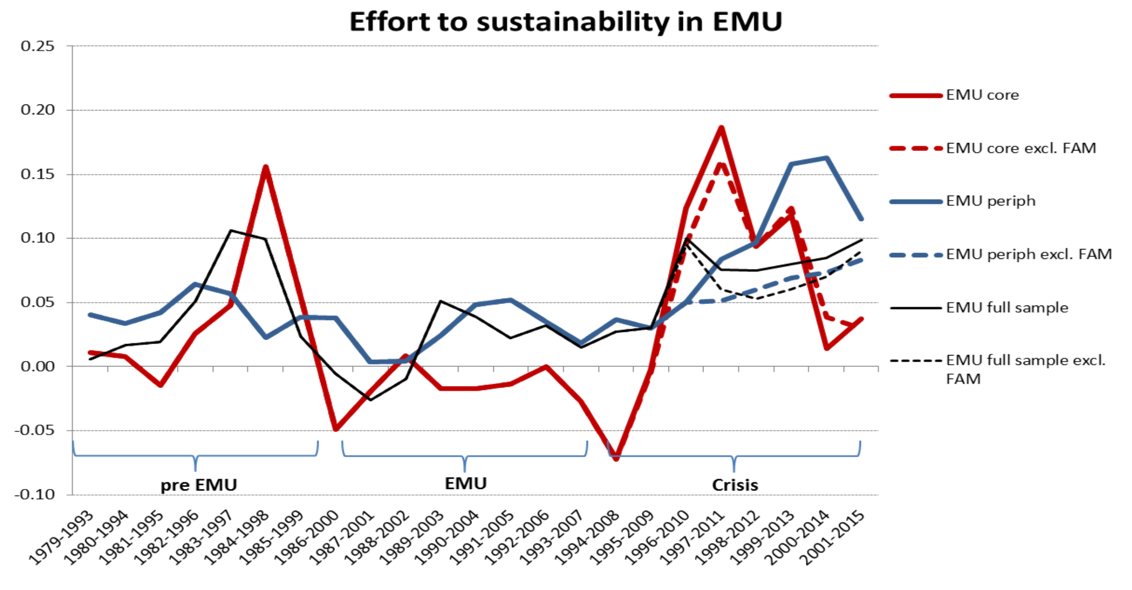
[16] The support provided by governments to their financial sector during and after the crisis in 2008 had a considerable impact to both deficit and debt in EMU countries. For example, the Irish government deficit in 2010 was 32.1% of GDP, of which 21.3 percentage points was on account of support to the financial sector. Based on Eurostat supplementary tables for government interventions to support financial institutions: http://ec.europa.eu/eurostat/web/government-finance-statistics/excessive-deficit/supplemtary-tables-financial-crisis, we correct the primary balance (adjusted for "net revenue/cost for general government") and the debt ratio ("general government liabilities").

[17] For brevity reasons we report in this part only the system GMM estimates. For all country groups (core, periphery and total) the rolling window estimates are chosen based on acceptance from the Sargan and the Hansen test as well as the test for 1st and 2nd order autocorrelation. Using the difference GMM estimator points to similar results.

and the related convergence of interest rates, which for some windows become zero (periphery) or even negative (core).[18]

The inclusion of the crisis years increases the heterogeneity between the periphery and the core. An important source of heterogeneity is the support provided by governments to their financial sector, which affected in particular the periphery countries. Excluding the effect of FAM, the sustainability effort of periphery countries while on gradually increasing path stays initially below that in core countries when the crisis years are included in the sample. On the other hand, the strong response in core countries is proved to be transitory as it falls strongly once years after 2012 (the peak in the consolidation effort) are included in the rolling windows, and fall below the coefficient for the periphery.[19]

Figure 1. Fiscal reactions towards sustainability/Two-step system GMM estimates (15 years)



Note: Endogenous variables (Debt as % of GDP, output gap) are included in the specification. Pre-EMU, EMU and Crisis period refer to 1979-2000, 2001-2008 and 2009-2015.

Regarding the stabilising role of fiscal policy, heterogeneities between country blocks become even more profound (see figure 2). The response of the primary balance to the output gap is consistently above 0.5 for the full sample and for the core countries for almost all windows, which indicates a

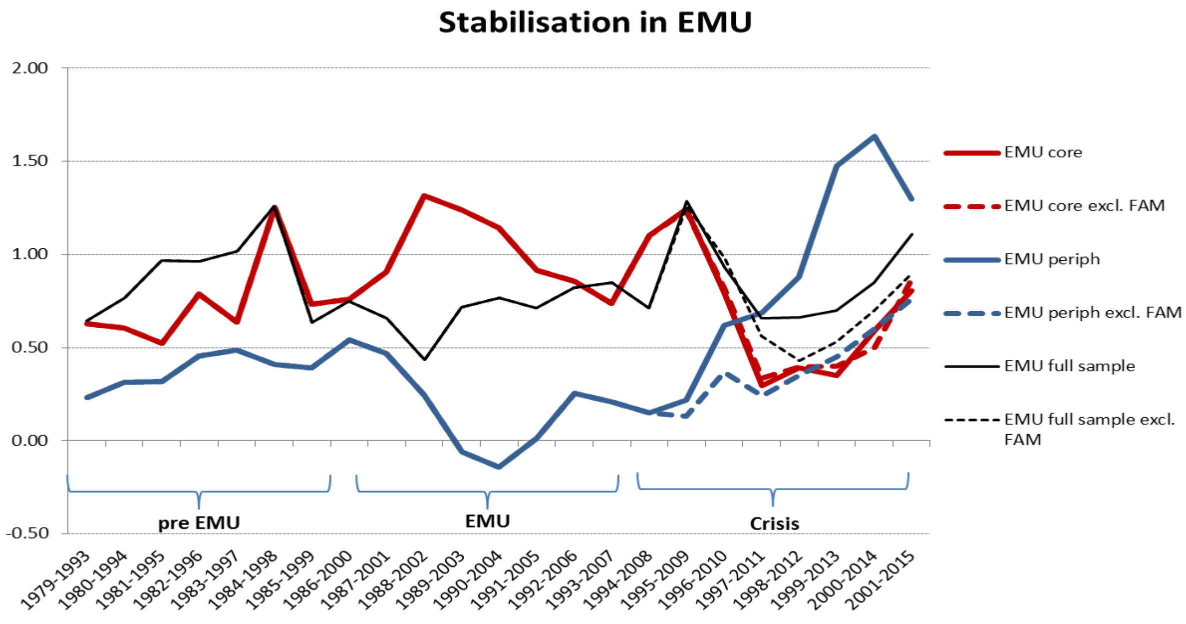
[18] While a negative coefficient would signify non-compliance with Bohn's (weak) condition for debt sustainability, it needs to be considered that during this period, the debt ratio in most of the core countries was either falling or stable.

[19]In the following sections, our estimates are based on the data excluding FAM in order to make out analysis more and findings more tractable.

counter-cyclical fiscal stance. However, the coefficient for peripheral countries is estimated to vary between 0 and 0.5 for all windows until 2010, which signals a fiscal stance that was at best a-cyclical and frequently pro-cyclical in the period before the crisis.

When the crisis years enter the recursive estimates, a considerable change is found in the fiscal stance in the periphery. Including the support to the financial sector, the fiscal stance is found to be strongly counter-cyclical. When corrected for the support to the financial sector, the stabilisation coefficients gradually increase from 0.4 to 0.9 when more crisis years are included, which represents an a-cyclical to counter-cyclical response[20]. For windows including crisis years, the coefficients for the core countries are similar to the periphery, which in their case represents a move from a clearly counter-cyclical to a-cyclical stabilisation response (and below the average response of primary balance to output gap for the core EMU countries of 0.8).

Figure 2. Fiscal reactions towards stabilisation /Two-step system GMM estimates (15 years)



Note: Endogenous variables (Debt as % of GDP, output gap) are included in the specification. Pre-EMU, EMU and Crisis period refer to 1979-2000, 2001-2008 and 2009-2015.

[20]These findings confirm IMF analysis on the stabilising properties of fiscal policy (Fiscal Monitor (2015), p. 28) based on which … *fiscal stabilization tends to operate mostly during recessionary episodes and is virtually absent during expansions (Figure 2.8, in the report)*.

4.2. An extended fiscal reaction function capturing cross EMU country differences

In this section, following an alternative model version, we investigate possible heterogeneities of fiscal between the core and the periphery of EMU. Rather than splitting the sample, an extension of 'equation (4) is employed using country block dummies. More specifically, the following version of our fiscal reaction model is estimated:

$$Pb_{it} = a_{i,t} + \alpha_1 \cdot Pb_{i,t-1} + \alpha_2 \cdot Pb_{i,t-2} + \alpha_3 \cdot OG_{US_{i,t-1}} + \alpha_4 \cdot mon_{i,t} + \alpha_5 \cdot IIR_{i,t} +$$

$$\{\zeta_X \cdot X_{it} + \zeta_{X\_P} \cdot X_{it} \cdot periph_{i,t} + \zeta_{X\_C} \cdot X_{it} \cdot core_{i,t}\} + n_i + \lambda_t + \varepsilon_{i,t}, \text{ i=1-15, t=1978-2015} \quad (8)$$

Where X_{it} denotes the policy objective (variable) of interest i.e.. OG_{it} and D_{it-1} while $periph_{i,t}$ and $core_{i,t}$ refer to dummies equal to 1 if country i belongs to the EMU periphery or core bloc and 0 otherwise. Similar to Sections 4.1.1 and 4.1.2, the instruments for ~~to~~ the endogenous variables i.e. OG_{it} and D_{it-1} are collapsed to the t-2 to t-3 lags of output gap and the t-3 to t-5 lags or t-4 to t-5 lags of debt. Coefficients of interest are denoted as: ζ_{X_P}, ζ_{X_C} and ζ_X with the first one referring to the additional effect for the periphery countries, while the second one the equivalent coefficient for the core EMU countries.

In an attempt to detect potential changes of the fiscal policy stance during the crisis years we report three separate estimates. The first two refer to the pre-crisis period (1978-2008) and a sample ending in the peak consolidation year for most countries (1978-2012), while the third refers to the full time sample (1978-2016). For brevity reasons, system GMM estimators are reported followed by the difference-in Hansen tests (in line with Roodman (2009) approach of reporting GMM estimates).

Since the reaction of the primary balance includes both the effect of automatic stabilisers and discretionary policy by the government, it is not a priori clear to what extent the difference in the fiscal stance between the core and periphery is due to discretionary policy or to the functioning of the automatic stabilisers. To decompose for these differences arising from the discretionary and the automatic stabiliser parts of fiscal policy, the extended equation (8) is re-estimated with the cyclically-adjusted primary balance as the dependent variable. Comparing coefficients from both estimates allows for capturing the operation of the automatic stabilisers.

4.2.1 Empirical results

When introducing country block dummies for the core and periphery, the response of the primary balance to previous year's debt increases is found to be positive, but only weakly statistically significant for all countries in our sample (ζ_d). The additional effect for the periphery (ζ_{d_p}) and the core countries (ζ_{d_c}) negates most of the overall effect before in the sample ending in 2008, but is not significant for samples including the crisis years (see table 2, col. 1-3).

Discretionary fiscal policy is found to respond to debt with the coefficient for all countries varying between 0.08 for the pre-crisis sample and 0.11 for the sample ending in 2012 (see columns 4-6 in Table 2). For the pre-crisis period, the periphery dummy is significantly negative, and negates most of the overall response For the core EMU, dummy estimate(ζ_{d_C}) is negative and significant when crisis years are included in the sample, which compensates for the strong overall response to debt found for the rest of countries (ζ_d). The country block dummy for the periphery is not significant for the samples including the crisis years. As more crisis years come in, the overall and the discretionary response for both group of countries becomes weaker, thereby providing some support of fiscal fatigue.

These findings are robust to the use of instruments, since the Sargan, the Hansen test and the Difference in Hansen test return benign p-values. Tests for autocorrelation reject autocorrelation in all our specifications.

When conducting an analogous analysis for output stabilisation, we also find strong heterogeneities between the two EMU country blocs. The reaction of the primary balance to the output gap for all countries varies between 0.5 and 0.8 across time samples, indicating a counter-cyclical policy (see columns 1-3 of Table 3). For the core countries, there is no difference from the findings for the overall reaction, as the coefficient of the country-block dummy ($\zeta_{OG\_C)}$ is insignificant. However, for the EMU periphery the coefficient of the country block dummy (ζ_{OG_P}) is negative and significant. The sum of the coefficients ζ_{OG_P} and ζ_{OG} indicates pro-cyclical policy as it varies over time, but remains well below the 0.5 value that would indicate an a-cyclical policy stance of the primary balance.[21]

The discretionary reaction to changes in the output gap, as measured by the cyclically-adjusted primary balance, is positive and significant for all countries (ζ_{OG}), with the coefficient ranging between 0.56 and 0.69, consistent with a counter-cyclical discretionary fiscal policy (columns 4-6 in Table 3). The insignificance of the coefficient of the country block dummy indicates no different reaction in the core countries. However, the coefficient of the periphery country block dummy (ζ_{OG_P}) is significantly negative across all time samples, with values ranging between -0.63 and -0.75. This puts the sum of the overall coefficient and periphery country block dummy coefficient around or even below 0, which indicate an a-cyclical, or pro-cyclical discretionary fiscal stance.[22]

Finally, our estimates suggest the effective operation of the automatic stabiliser as measured by the difference between the coefficients for the primary and cyclically–adjusted balances, which remains close but lower than (0.4) the value that would be expected on the basis of average budgetary elasticities in OECD countries (0.5). However, the difference is slightly higher for the sample ending in 2012, which suggests a stronger operation of the automatic stabilisers during the recessionary phase of the crisis than normal times and also some reforms undertaken during the crisis to improve their effectiveness (see Figure 1 in the annex).

[21] Other studies based on the full sample of EMU countries report evidence of pro-cyclicality for EMU on average, especially in good times and following the introduction of the SGP in 1999 (Cimadomo 2005; Candelon, Muysken, and Vermeulen 2010; Deroose, Larch, and Schaechter 2011). In contrast, Gali and Perotti, (2003) and Tangalakis (2011) in their work provide evidence of countercyclical policy in the EMU before the crisis and attribute this fiscal response to: a global trend for Governments towards more prudent fiscal policies, the necessity to abide by the rules of the Stability and Growth Pact and concerns about the long term sustainability of fiscal balances. Other papers support the view for procyclicality when real time data is used suggesting that there could be a difference between the ex-ante intentions of governments and ex post outcomes (Forni and Momigliano 2005; Cimadomo 2012; Golinelli and Momigliano 2006).

[22] Buti and Van den Noord (2004); and Fatás and Mihov (2009) also find evidence of an a-cyclical fiscal policy for the euro area before the financial crisis.

4.3 Endogenous thresholds

The existence of a threshold in the EMU fiscal reaction functions is tested following a two-stage approach. In the first stage, the methodology of Kourtellos et. al. (2016) is employed to estimate one endogenous threshold to the variable of interest (i.e., debt and output gap). The second stage refers to the non-parametric bootstrapping approach of Hansen (1996) and Kazanas & Tzavalis (2015) used in a dynamic panel GMM context to test the existence of one threshold of our model.[23] Using this two-stage approach we address: firstly, endogeneity bias that yields inconsistent threshold estimates and coefficients between the two regimes[24] (addressed also by Seo et. al., 2016) and secondly the goodness of fit of a non-linear fiscal reaction function in our data.

Following our baseline specification (equation (4)) we test separately the stability of the sustainability and the stabilisation coefficients by means of a Wald test (Wald-Stat) of the following hypotheses:

$$H_0: \delta_{i,\_H} = \delta_{i\_L} \text{ against its alternative } H_1: \delta_{i\_H} \neq \delta_{i\_L}$$

$$H_0: \gamma_{i,\_H} = \gamma_{i\_L} \text{ against its alternative } H_1: \gamma_{i\_H} \neq \gamma_{i\_L}$$

where γ_{i_H} and δ_{i_H} depict the relevant sustainability and stabilisation coefficients in the High regime (H) (i.e., above the threshold (H)) and γ_{i_L} and δ_{i_L} when being in a Low regime (L) (i.e., below the threshold (H)). To test the robustness of our findings we also test a non-linear fiscal policy rule when discretionary fiscal policy is involved. In this respect, we test for the existence of a threshold when cyclically-adjusted primary balance is considered as the dependent variable. Moreover, we follow the

[23] Based on the non-parametric bootstrap simulation procedure, significance levels (probability values) of statistic Wald-Stat are obtained (see, for example, Hansen 1996) from the following steps. First, based on the GMM procedure linear model (4), which assumes no regime switching under the above null hypothesis is estimated. Then values are drawn from the saved residual series with replacement. These are added to the fitted values of dependent variable based on the parameter estimates of the threshold model (Data Generating Process) to obtain a new series. This series is then used to estimate threshold parameter q and then calculate the value of test statistic Wald-Stat. The above procedure is repeated 5000 times so that the sampling distribution does not depend on the threshold estimate and coefficient estimate. The obtained 5000 values of q and Wald-Stat are used to estimate the p- value of Wald-Stat reported in Table 4.

[24] Hansen (2000) and Seo and Linton (2007) in their panel method of selecting thresholds assume exogeneity of covariates. Caner and Hansen (2004) relax this requirement by allowing for endogenous regressors but the threshold variable is still exogenous. See also Hansen (2011) for an extensive survey. According to Kourtellos et. al. (2016) *"if the threshold variable is an endogenous variable, the above approaches will yield inconsistent slope coefficients for the two regimes".*

same collapsed methodology with the t-2 and t-3 lags of output gap and the t-3 or t-4 to t-5 lags of debt (as % GDP) as instruments.

Estimates from the Kourtellos et. al. (2016) methodology of estimating endogenous thresholds for the debt-to-GDP ratio and the output gap are presented in table 4 of the annex. For the full time sample (1978-2016), the debt threshold for the core country sample is estimated approximately at 50% of GDP when the primary and the cyclically-adjusted primary balance are employed. For the periphery the estimated threshold is higher, around 95% of GDP for both dependent variables. To check the robustness of our estimates in the case of the periphery EMU group, we exclude one country at a time and re-estimate the thresholds. It is concluded that for the periphery EMU countries no significant effect comes from a specific country, as excluding each country interchangeably results in threshold estimate mostly between 95 and 100% of GDP.

For the output gap, the threshold estimates found for the core group support the existence of a different regime when the output gap is negative (-0.60 for the case of the primary balance and -0.20 for the case of the cyclically-adjusted primary balance). For the periphery countries, the estimated output gap threshold is significantly lower compared to the EMU core (-3.2 for the primary balance and -3.6 for the cyclically-adjusted primary balance). Broadly speaking these latter estimates are suggestive of a relatively more active (in terms of frequency) response of core countries towards stabilisation compared to the periphery countries.

To check the fitness of non-linear models related to the thresholds estimated, we report in the same table results from the bootstrap simulation (p-value on Wald test statistics). For the peripheral EMU countries, evidence of a non-linear version of a fiscal reaction function related to a significant debt threshold as the relevant null hypothesis is strongly rejected for both dependent variables (p-value equal to 0.04). On the other hand, the null hypothesis of a linear stabilising effort cannot be rejected as p-value varies between 0.2 and 0.4. For the core countries, only the existence of a threshold regarding fiscal responses to the output gap can be supported. The simulated p-value ranges between 0.017 and 0.002, and strongly reject the null hypothesis of a linear fiscal policy rule regarding output gap as described in equation (4). However, the debt threshold debt is rejected for core countries as p-values are found to vary between 0.5 and 0.6 for the primary or cyclically adjusted primary balance.

4.4 Policy implications from non-linearities for the core and the periphery EMU

In the last part of our analysis, we employ an augmented structural threshold regression (STR) model aimed to investigate the fiscal policy implications of the thresholds we previously estimated for the periphery and core countries. We quantify the effect of the debt threshold for the EMU periphery by introducing dummies denoted as $I(D_{i,t} > \gamma)$ and $I(D_{i,t} < \gamma)$ respectively. In the high debt regime, the dummy is equal to 1 if debt in the EMU periphery is above the threshold and 0 if below the threshold. In the low regime, the dummy is equal to 1 if debt is below the threshold and 0 in case it is higher. This dummy specification allows the use of the entire data span for all EMU countries, avoiding the case of a sample split that reduces the number of observations of our sample. Equation (11) below follows the baseline specification of Equation (4) , allowing the high and low regime dummies to interact with lagged debt using the same endogenous and collapsed version of instrumental variables including the dummy interaction terms.

$$\mathrm{Pb}_{\mathrm{it}} = \mathrm{a}_{\mathrm{i,t}} + \alpha_1 \cdot \mathrm{Pb}_{\mathrm{i,t-1}} + \alpha_2 \cdot \mathrm{Pb}_{\mathrm{i,t-2}} + \alpha_3 \cdot \mathrm{OG}_{\mathrm{US}_{\mathrm{i,t-1}}} + \alpha_4 \cdot \mathrm{mon}_{\mathrm{i,t}} + \alpha_5 \cdot \mathrm{IIR}_{\mathrm{i,t}} + \{\gamma_{\mathrm{d}} \cdot \mathrm{D}_{\mathrm{i,t-1}} + \gamma'_{\mathrm{d}} \cdot \mathrm{I}(\mathrm{D}_{\mathrm{i,t}} > \gamma) \cdot \mathrm{D}_{\mathrm{it-1}} + \gamma''_{\mathrm{d}} \cdot \mathrm{I}(\mathrm{D}_{\mathrm{i,t}} < \gamma) \cdot \mathrm{D}_{\mathrm{it-1}}\} + \mathrm{n}_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{i,t}},\ \text{i=1-15, t=1978-2015} \quad (11)$$

Based on the previous specification, coefficients of interest are coefficients γ_{d} ,γ'_{d} *and* γ''_{d} (Equation (11) eq. 11). An analogous STR specification is also followed to investigate the output gap thresholds obtained for the core countries (-0.6% for the primary balance and -0.2% for the cyclically-adjusted primary balance). Same wise, dummies are denoted as $I(OG_{i,t} > \gamma)$ and $I(OG_{i,t} < \gamma)$ respectively.[25] In the positive output gap regime, the dummy is equal to 1 if the output gap in the EMU core is above the threshold and 0 if below the threshold value. In negative output regime, dummy is equal to 1 if

[25] In the case of a negative output gap threshold as is the caser for core countries, a High (H) regime for output stabilisation (i.e. $\mathrm{I}(\mathrm{OG}_{\mathrm{i,t}} < \gamma)$) refers to periods of negative output gaps. The case of Low (L) output stabilisation regime (i.e., $\mathrm{I}(\mathrm{OG}_{\mathrm{i,t}} > \gamma)$) refers to relatively "good economic conditions" in which output gaps are closing to zero or positive.

output gap in the EMU core is below the threshold and 0 if above the threshold value. Using the same specification for the endogenous and the instrumental variables, coefficients of interest refer to δ_{OG}, δ'_{OG} and δ''_{OG}.

More specifically:

$$\mathrm{Pb_{it}} = \mathrm{a_{i,t}} + \alpha_1 \cdot \mathrm{Pb_{i,t-1}} + \alpha_2 \cdot \mathrm{Pb_{i,t-2}} + \alpha_3 \cdot \mathrm{OG_{US_{i,t-1}}} + \alpha_4 \cdot \mathrm{mon_{i,t}} + \alpha_5 \cdot \mathrm{IIR_{i,t}} + \{\delta_{OG} \cdot \mathrm{OG_{i,t}} + \delta'_{OG} \cdot \mathrm{I}(\mathrm{OG_{i,t}} > \gamma) \cdot \mathrm{OG_{i,t}} + \delta''_{OG} \cdot \mathrm{I}(\mathrm{OG_{i,t}} < \gamma) \cdot \mathrm{OG_{i,t}}\} + \mathrm{n_i} + \lambda_t + \varepsilon_{i,t}, \text{ i=1-15, t=1978-2015} \quad (12)$$

Table 5 reports the estimated (from eq. 11) high and low regime coefficients for debt sustainability for in the periphery EMU countries.[26] Comparing these estimates (i.e., γ'_d and γ''_d) it appears that in the low debt regime, periphery countries exhibit a lower effort to stabilise debt as the coefficient for the low debt regime is statistically significant and negative. In the high debt regime, the coefficient for the periphery dummy is insignificant, meaning that the reaction to debt is not different to the coefficient for the full sample which is significantly higher as pointed from table 5. This means that periphery countries when being in the high debt regime (debt level above the 96% threshold) respond more actively increasing their effort to stabilise debt compared to the low debt regime. This means that in the low debt regime for the periphery, the average fiscal response in the form of an increase in the (cyclically adjusted) primary balance as a percent of GDP is on average between 0.1 and 0.2 per 10 percentage point increase of public debt. In the high debt regime, these responses increase from 0.3 (for the primary balance) to 0.5 (for the cyclically-adjusted balance).

Similar to the periphery, we differentiate between the positive and negative output gap regimes in the core countries by reporting estimates of Equation (12) in table 6.[27] The coefficients of the negative output gap regime is positive and statistically significant, and varies between 0.5-06 for the cyclically-adjusted primary balance and 0.7-0.8 for the primary balance. On top of the coefficient found for the

[26] As a robustness check, we employ the same estimation method for core EMU countries by applying the specification of equation (11) with threshold dummies for the estimated core country debt thresholds γ =50 (% of GDP). We find no support for core EMU countries of an endogenous threshold to debt stabilisation as high and low regime coefficients are insignificant in this estimation. These results are available from authors upon request.

[27] As a robustness check, we also applied threshold dummies for the estimated output gap thresholds for periphery countries (γ=-3.2 for the PB and -3.7 for CAPB), but found them to be insignificant. These results are available from authors upon request.

sample as a whole, this points to a stronger counter-cyclical stance in relative ‘bad economic conditions’ when the output gap is negative, compared to a milder counter-cyclical response of the (cyclically-adjusted) primary balance when the output gap is positive. In the positive output gap regime, the additional stabilisation effect on top of the overall counter-cyclical response is not significant. The implicit measure of the automatic stabilisers provided by the difference of the primary balance and cyclically-adjusted primary coefficients is around 0.3 in the positive output gap regimes, but increases to around 0.5 in the negative output gap environment (comparison of estimates for columns 1-2 vs 3-4 in table 6).

Overall, estimates from a non-linear version of our fiscal reaction function suggest that the periphery counties, as a result of their linear and pro-cyclical stance and late response to increasing debt, face the need for an additional fiscal effort when being in a regime of elevated debt values. In contrast, the counter-cyclical stance of the core countries allows them to let the automatic stabilisers operate in “bad economic conditions” (i.e., when the output gap is negative) and also allows a more moderate (linear) response to debt.

4.5 Robustness

To ensure that our results are robust across a range of specifications, we conduct a series of additional robustness tests (for the whole sample). More specifically, we are interested to see whether the non-linear fiscal effort towards sustainability and a pro-cyclical fiscal policy for the case of the periphery EMU countries are driven by the electoral cycle following the literature of Nordhaus (1975), Lindbeck (1976) and Allesina, Roubini, Cohen (1997). Secondly, we test if the increased fiscal effort regarding sustainability in the periphery countries above 96% of GDP threshold reflects market pressures. To capture these effects we re-estimate the linear and non-linear version of our fiscal reaction functions incorporating an electoral dummy denoted by $elect_{i,t}$ which takes the value of 1 for country i if t is an election year and 0 if not. We also include the 10y spread of national bonds against the German bund $spread_{i.t}$ (benchmark).

Starting from the linear estimation of the effort to sustainability for the period 1978-2016 (annex II, table 7), the inclusion of an election dummy has a significant and expected negative sign implying an expansionary effect for the EMU public finances, while the coefficient for the overall response to debt is slightly higher compared to table 2. At the same time the inclusion of spreads does not imply an additional contribution for our estimated fiscal rule. Same as in table 2, for case of primary balance, there no longer is a significant difference between the debt responses of both country blocks. However, for the cyclically-adjusted balance, the discretionary response of the periphery to debt is found to be stronger for the periphery than for the core for the full sample (1978-2016) and the sample ending in 2012 which is the peak of the crisis. For the sample ending in 2008, the coefficient of the periphery country block dummy is negative and significant, indicating a lower discretionary debt response (column 4) than the core but this finding is not confirmed in the full specification (column 12).

The non-linear estimation of the debt response of the periphery countries with the inclusion of election dummies confirms the stronger debt response when debt is above the 96% threshold (see table 8). The additional inclusion of the spreads is not robustly significant for the non-linear reaction function, which we interpret as pointing to the contribution from the EU/IMF assistance (bail in) programmes to the periphery countries that were temporarily facing difficulties in their market access and allowed them to sterilise from the market stress conditions.

Finally, table 9 in annex II presents robustness results for the stabilisation efforts for the core and the periphery of EMU with the inclusion of election dummies. Again the a-cyclical stance of the periphery is confirmed providing similar estimates as the case of table 3, both for the primary and cyclically adjusted primary balance. This a-cyclical stance is due to the pro-cyclicality of the periphery relative to the full sample of the rest of the countries of our sample. The election dummy again exhibits the same expansionary effect both for primary and cyclically adjusted primary balance (coefficients vary between 0.45 to 0.60).

5. Conclusions

Fiscal consolidation has been one of the main themes in the economic policy debate in Europe since the onset of the financial and sovereign debt crises, as well as the contribution of fiscal policies to output stabilisation. These debates raise the question if the countries that came under market pressure during the crisis and those that did not did pursue different policies before the crisis.

Adding to the existing literature on linear fiscal reaction functions, we assess fiscal policy in EMU across time, focusing on heterogeneities between core and periphery EMU counties and employ both linear and non-linear versions of fiscal reaction functions. A key issue when employing these fiscal policy rules is the endogeneity bias of fiscal policy relevant variables, i.e. the level of debt and output gap due to the interlinkages between fiscal and macro variables. In this respect, we employ endogenous regressors and instruments that accounts for these possible endogeneities and interlinkages and apply a novel non-linear empirical approach to estimates endogenous thresholds.

We find significant heterogeneities between core and periphery EMU countries. Periphery EMU countries followed a pro-cyclical fiscal policy with regard to output stabilisation, without a discernible differences across different states of the economy. They are also found to react stronger to debt than core countries, which is the flip side of the pro-cyclical stabilisation reaction as high debt levels eventually require a stronger reaction. When we test the thresholds found by our nonlinear model by a bootstrap approach, we find that periphery countries respond stronger to debt above a debt threshold around 95% of GDP. For core countries, our findings are a mirror image. They are found to have pursued a counter-cyclical fiscal policy with regard to output stabilisation, which is stronger counter-cyclical when the output gap is negative. For the core countries, we do not find evidence of non-linearities in the response to debt. During the crisis, we provide evidence based on which fiscal policy in the periphery seems not to be affected by market pressure. This important finding underlines the positive impact that the EU/IMF adjustment programs had for the financing of these stressed economies during the crisis period.

According to our findings, differences in country experiences during the crisis are rooted in different fiscal reactions before the crisis, which should inform policy conclusions based on estimates applying to all EMU countries. These findings can provide important policy implications for the future conduct of fiscal policy and also may provide an argument for introducing non-linearities to relevant theoretical models.

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Annex I

Table 1: Baseline estimates (Eq. 4) for the period 1978-2016

A. Dependent variable: Primary balance as a % of GDP ($Pb_{i,t}$)

Estimator: Difference and System GMM. One step and two-step incorporating the Windmeijer (2005) correction.

Variables	*Two-step estimator Difference GMM*	*One step estimator Difference GMM*	*Two-step estimator System GMM*	*One step estimator System GMM*	*Two-step estimator Difference GMM*	*Two-step estimator System GMM*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
$Pb_{i,t-1}$	0.495**	0.457**	0.682***	0.618**	0.101	0.547***
	(0.252)	(0.188)	(0.188)	(0.312)	(0.0700)	(0.0932)
$Pb_{i,t-2}$	-0.0192	-0.0148	-0.125	-0.0592	-0.0934**	0.0109
	(0.190)	(0.161)	(0.145)	(0.213)	(0.0433)	(0.0411)
$\mathbf{D}_{i,t-1}$	0.0661***	0.0645**	0.0522***	0.0342***	0.0253***	0.0153***
	(0.0222)	(0.0275)	(0.0118)	(0.0103)	(0.0125)	(0.00515)
$\mathbf{OG}_{i,t}$	0.600***	0.616***	0.566***	0.547***	0.389***	0.397***
	(0.131)	(0.121)	(0.0935)	(0.178)	(0.0970)	(0.116)
$mon_{i,t}$	-0.0253	-0.0183	0.0102	0.0127	-0.0167*	0.0113
	(0.0179)	(0.0139)	(0.0145)	(0.0159)	(0.0100)	(0.0116)
$OG\_US_{i,t-1}$	-0.196	-0.182**	-0.250***	-0.228**	0.0663	-0.131**
	(0.123)	(0.0857)	(0.0898)	(0.0939)	(0.0493)	(0.0569)
$IIR_{i,t}$	0.274	0.269	0.0378	0.0346	0.0154	-0.0212
	(0.206)	(0.252)	(0.0515)	(0.0464)	(0.114)	(0.0425)
$\alpha_{i,t}$	-	-	-0.716	-1.350	-	-0.358
	-	-	(0.879)	(0.882)	-	(0.593)
Observations	504	504	519	519	504	504
Number of Country_id	15	15	15	15	15	15
Number of instr.	8	8	11	11	Output gap and Debt treated as strictly exogenous	Output gap and Debt treated as strictly exogenous
Residuals 1st order AR (p_value)	0.181	0.179	0.262	0.149	-	-
Residuals 2nd order AR (p_value)	0.591	0.547	0.801	0.670	-	-
Sargan [(a)] test of overidentifying restrictions (p_value)	0.133	0.133	0.411	0.411	-	-
Hansen test of joint validity of instruments (p_value)	0.200	0.200	0.754	0.754	-	-
Difference-in-Hansen test of exogeneity of instrument subsets (p_value):						
- All GMM instruments for level eq.	0.200	0.200	0.879	0.879	-	-
- Those based on lagged Output gap for 1st difference eq.	-	-	0.603	0.603	-	-
- Those based on lagged debt for 1st difference eq.	-	-	0.754	0.754	-	-
- Those based on lagged difference of Output gap for level eq.	-	-	0.618	0.618	-	-
- Those based on lagged differences of debt for level eq.	-	-	0.679	0.679	-	-
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-3 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-3 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-3 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-3 to t-5 lags of debt*	-	-
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference	-	-

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

(a) Not robust, but not weakened by many instruments, (b) a collapsed instrument set was used following Rodman (2009b),

Table 2: Effort to sustainability for the period 1978-2016

A. Dependent variables: Primary balance as a % of GDP ($Pb_{i,t}$) (col. 1-3) & Cyclically adjusted primanry balance as % of trend GDP ($capb_{i,t}$) (col. 4-6)

Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	$Pb_{i,t}$	$Pb_{i,t}$	$Pb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Variables	*1978-2008*	*1978-2012*	*1978-2016*	*1978-2008*	*1978-2012*	*1978-2016*
$Pb_{i,t-1}$	1.155***	0.435	0.866	-	-	-
	(0.327)	(0.340)	(0.592)	-	-	-
$Pb_{i,t-2}$	-0.645**	0.221	-0.291	-	-	-
	(0.291)	(0.354)	(0.351)	-	-	-
$capb_{i,t-1}$	-	-	-	0.891***	0.739**	0.399
	-	-	-	(0.271)	(0.296)	(0.355)
$capb_{i,t-2}$	-	-	-	-0.381	-0.0895	0.334
	-	-	-	(0.222)	(0.211)	(0.246)
$D_{i,t-1}$	0.0963*	0.189**	0.0712**	0.0788*	0.108***	0.088***
	(0.0467)	(0.0832)	(0.0324)	(0.0398)	(0.0335)	(0.0301)
$D_{i,t-1}$*Periphery	-0.0959*	-0.0219	-0.0245	-0.0603***	-0.0413	-0.0401*
	(0.0530)	(0.0464)	(0.0306)	(0.0180)	(0.0257)	(0.0220)
$D_{i,t-1}$*Core	-0.0858*	-0.0785*	-0.0213	-0.0566*	-0.0671***	-0.0518***
	(0.0435)	(0.0416)	(0.0311)	(0.0301)	(0.0199)	(0.0194)
$OG_{i,t}$	0.360*	0.675***	0.417	0.236	0.314**	-0.0206
	(0.172)	(0.215)	(0.256)	(0.148)	(0.115)	(0.119)
$mon_{i,t}$	-0.0116	-0.0535	-0.000579	-0.00601	-0.0200	-0.0125
	(0.0268)	(0.0454)	(0.0297)	(0.0413)	(0.0361)	(0.0249)
$OG\_US_{i,t-1}$	-0.202*	-0.187	-0.254	-0.107	-0.166*	-0.0369
	(0.103)	(0.120)	(0.156)	(0.102)	(0.0817)	(0.100)
$IIR_{i,t}$	-0.216	-0.125	-0.0754	-0.0449	-0.153**	0.347
	(0.131)	(0.0986)	(0.0844)	(0.217)	(0.0695)	(0.219)
$\alpha_{i,t}$	0.626	-6.730	-1.012	-1.420	-2.508	-6.732**
	(1.787)	(4.507)	(1.194)	(1.445)	(1.883)	(2.873)
Observations	414	474	519	414	474	519
Number of Country_id	15	15	15	15	15	15
Number of instr.	16	16	16	16	16	16
Residuals 1st order AR (p_value)	0.637	0.549	0.295	0.572	0.561	0.683
Residuals 2nd order AR (p_value)	0.276	0.357	0.741	0.957	0.598	0.719
Sargan [(a)] test of overidentifying restrictions (p_value)	0.478	0.218	0.635	0.451	0.240	0.549
Hansen test of joint validity of instruments (p_value)	0.545	0.543	0.514	0.567	0.441	0.929
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are instroduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). (a) Not robust, but not weakened by many instruments, (b) a collapsed instrument set was used following Rodman (2009b). (c) Cross product of debt with the country group dummy is treated as endogenous with the same lag structure as debt.

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Effort to stabilisation for the period 1978-2016

A. Dependent variables: Primary balance as a % of GDP ($Pb_{i,t}$) (col. 1-3) & Cyclically adjusted primanry balance as % of trend GDP ($capb_{i,t}$) (col. 4-6)

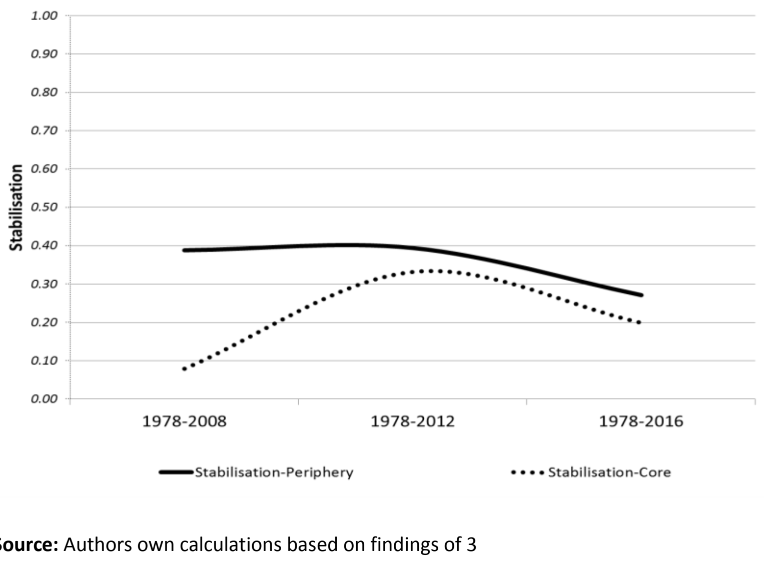
Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	Pb i,t	*Pb i,t*	*Pb i,t*	*capb i,t*	*capb i,t*	*capb i,t*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Variables	*1978-2008*	*1978-2012*	*1978-2016*	*1978-2008*	*1978-2012*	*1978-2016*
$Pb_{i,t-1}$	0.908***	0.731***	0.897***	-	-	-
	(0.258)	(0.345)	(0.249)	-	-	-
$Pb_{i,t-2}$	-0.397	-0.158	-0.260	-	-	-
	(0.445)	(0.425)	(0.184)	-	-	-
$capb_{i,t-1}$	-	-	-	0.814***	0.731***	0.672***
	-	-	-	(0.238)	(0.124)	(0.141)
$cab_{i,t-2}$	-	-	-	-0.0982	0.153	-0.0630
	-	-	-	(0.231)	(0.268)	(0.141)
OG i,t	0.747***	0.817***	0.544**	0.685***	0.588***	0.559***
	(0.113)	(0.180)	(0.220)	(0.0980)	(0.121)	(0.0717)
OG i,t*Periphery	-0.427***	-0.462***	-0.344***	-0.753***	-0.627***	-0.630***
	(0.108)	(0.162)	(0.131)	(0.159)	(0.140)	(0.115)
OG i,t*Core	-0.149	-0.152	0.0540	-0.429*	-0.220	-0.220
	(0.308)	(0.250)	(0.115)	(0.235)	(0.182)	(0.220)
$D_{i,t-1}$	-0.00550	0.0249***	0.0196***	0.00697	0.0503*	0.00983
	(0.0228)	(0.00406)	(0.00558)	(0.0193)	(0.0274)	(0.00621)
$mon_{i,t}$	0.0339	0.0108	0.0110	0.0143	-0.00766	0.0320***
	(0.0274)	(0.0224)	(0.0158)	(0.0369)	(0.0321)	(0.00994)
$IIR_{i,t}$	-0.190	-0.203*	-0.076	-0.150	-0.180*	-0.016
	(0.142)	(0.109)	(0.0904)	(0.0935)	(0.0907)	(0.0511)
$OG\_US_{i,t-1}$	0.0305	-0.0240	-0.00894	0.140	0.0886	0.0622
	(0.136)	(0.0914)	(0.0538)	(0.0826)	(0.0555)	(0.0443)
$\alpha_{i,t}$	0.658	-0.990	-0.820	-1.152	-3.423*	-0.574
	(2.004)	(2.516)	(0.489)	(1.433)	(1.920)	(0.461)
Observations	414	474	519	414	474	519
Number of Country_id	15	15	15	15	15	15
Number of instr.	16	16	16	16	16	16
Residuals 1st order AR (p_value)	0.275	0.297	0.178	0.371	0.455	0.226
Residuals 2nd order AR (p_value)	0.577	0.993	0.697	0.818	0.221	0.413
Sargan [(a)] test of overidentifying restrictions (p_value)	0.368	0.498	0.796	0.209	0.587	0.389
Hansen test of joint validity of instruments (p_value)	0.378	0.380	0.673	0.253	0.365	0.840
Difference-in-Hansen - test of exogeneity of instrument subsets (p_value):						
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are instroduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). (a) Not robust, but not weakened by many instruments, (b) a collapsed instrument set was used following Rodman (2009b). (c) Cross product of Output gap with the country group dummy is treated as endogenous with the same lag structure as output gap.

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Figure 1: Estimated effect of implicit automatic stabilisers during the crisis



Source: Authors own calculations based on findings of 3

Table 4: Threshold estimates employing Kourtelos et. al. (2013) threshold-GMM approach (endogenous variables: Debt to GDP , Output Gap)

	(1)	(2)	(3)	(4)
Period:	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*
Dependent variable:	$Pb_{i,t}$	$Capb_{i,t}$	$Pb_{i,t}$	$Capb_{i,t}$
Threshold variable:	$D_{i,t}$	$D_{i,t}$	$OG_{i,t}$	$OG_{i,t}$
Total country sample				
Threshold estimate (q)*	0.4700	0.7238	-2.6014	-2.1783
J-stat	2.66E-18	4.03E-19	1.22E-19	2.22E-19
CI	[0.46021 0.51668]	[0.38907 0.98616]	[-2.7466 1.8654]	[-2.7466 1.8654]
Boot p_value	0.124	0.163	0.131	0.067
Fstat	9.81	9.98	7.77	10.24
Core				
Threshold estimate (q)*	0.4951	0.5075	-0.6058	-0.1994
J-stat	2.66E-18	1.95E-18	3.44E-21	1.25E-20
CI	[0.38174 0.92277]	[0.38901 0.50746]	[-1.9068 1.6829]	[-1.9068 1.6829]
Boot p_value	0.514	0.601	0.017	0.0021
Fstat	1.66	1.49	32.34	36.66
Periphery				
Threshold estimate (q)*	0.9660	0.9549	-3.2633	-3.6808
J-stat	2.49E-20	4.10E-19	6.25E-17	1.27E-18
CI	[0.41565 1.0739]	[0.41565 1.0832]	[-3.8243 2.3264]	[-3.8243 2.3264]
Boot p_value	0.042	0.037	0.371	0.203
Fstat	16.67	17.63	2.09	2.36
Threshold estimate for the periphery (q*) excluding:				
Portugal/CI	0.99324 [0.42284 0.99324]	).98921 [0.38907 1.0944]	-3.3773 [-3.8354 2.2861]	-3.6322 [-3.6498 2.2861]
Spain/CI	0.99239 [0.39186 0.99506]	l.05446 [0.5112 1.6621	-3.1532 [-3.8243 2.1811]	-3.5203 [-3.9561 2.2593]
Italy/CI	1.01485 [0.41746 1.1125]	).96187 [0.38465 1.0287]	-3.3563 [-4.0792 2.487]	-3.3963 [-4.1992 2.6797]
Ireland/CI	0.99668 [0.3496 1.1444]	).94369 [0.33369 1.14369	-3.9161 [-3.9161 2.3164]	-3.9779 [-3.6671 2.3374]
Greece/CI	0.95261 [0.40286 1.0511]	).95261 [0.42316 1.3331]	-2.6206 [-3.8564 2.2861]	-3.9633 [-3.8564 2.8210]
Replacing Greece with Belgium/CI	0.96661 [0.42324 1.1438]	).97761 [0.41124 1.1088	-2.8816 [-3.3923 2.1091]	-3.4491 [-3.6664 2.4637]

Note: The table reports GMM threshold estimates of non linear model (7) following Kourtelos et. al. (2013) approach using the same endogenous and collapsed instrumental variables of linear model (4) as well as the non parametric bootstrap test statistics (Fstat and p_value) for the existence of a threshold. CI(q) denotes the heteroscedasticity corrected asymptotic confidence interval of the threshold parameter following the same approach. J-stat stands for Sargan's overidentifying restrictions test statistic implied by the GMM estimation procedure. A robustness check has been also performed with the use of dummies to capture a) the crisis impact, b) possible EMU accession effects and c) electoral effects providing almost the same estimates.

Table 5: Effort to sustainability for the EMU periphery during the period 1978-2016

A. Dependent variables: Primary balance as a % of GDP ($pb_{i,t}$) (col. 1-2) & Cyclically adjusted primanry balance as % of trend GDP ($capb_{i,t}$) (col. 3-4). Threshold variable: Debt as % C

Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	$Pb_{i,t}$	$Pb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$
	(1)	(2)	(3)	(4)
Variables	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*
$Pb_{i,t-1}$	0.741***	0.716**	-	-
	(0.355)	(0.359)	-	-
$Pb_{i,t-2}$	-0.115	-0.114	-	-
	(0.219)	(0.221)	-	-
$capb_{i,t-1}$	-	-	0.560***	0.538***
	-	-	(0.242)	(0.231)
$capb_{i,t-2}$	-	-	-0.0432	-0.0399
	-	-	(0.163)	(0.163)
$OG_{i,t}$	0.529**	0.572***	0.200	0.223
	(0.178)	(0.154)	(0.143)	(0.130)
$\mathbf{D_{i,t-1}}$	0.0491**	0.0340**	0.0366**	0.0291***
	(0.0223)	(0.0115)	(0.0156)	(0.00721)
$\mathbf{D_{i,t-1} * I(q_{i,t}<96)}$	-0.0292***	-0.0277**	-0.0193**	-0.0184**
	(0.0128)	(0.0091)	(0.0092)	(0.0072)
$\mathbf{D_{i,t-1} * I(q_{i,t}>96)}$	-0.0178	-	-0.00927	-
	(0.0152)	-	(0.0131)	-
$mon_{i,t}$	0.00716	0.0142	0.0182	0.0220*
	(0.0153)	(0.0133)	(0.0129)	(0.0111)
$OG\_US_{i,t-1}$	-0.136	-0.153	-0.0716	-0.0786
	(0.114)	(0.114)	(0.0648)	(0.0630)
$IIR_{i,t}$	-0.00119	0.0152	0.0409	0.0490
	(0.0747)	(0.0646)	(0.0648)	(0.0628)
$\alpha_{i,t}$	-1.969	-1.346	-1.703*	-1.388*
	(1.412)	(0.984)	(0.913)	(0.661)
Observations	519	519	519	519
Number of Country_id	15	15	15	15
Number of instr.	16	13	16	13
Residuals 1st order AR (p_value)	0.271	0.281	0.187	0.189
Residuals 2nd order AR (p_value)	0.887	0.849	0.480	0.463
Sargan [a] test of overidentifying restrictions (p_value)	0.765	0.757	0.761	0.720
Hansen test of joint validity of instruments (p_value)	0.681	0.612	0.622	0.695
Difference-in-Hansen - test of exogeneity of instrument subsets (p_value):				
- All GMM instruments for level eq.	0.781	0.661	0.822	0.795
- Those based on lagged Output gap for 1st difference eq.	0.424	0.637	0.314	0.553
- Those based on lagged differences of Output gap for level eq.	0.867	0.803	0.723	0.691
Instruments [b]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [c]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [c]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [c]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [c]
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are instroduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). [a] Not robust, but not weakened by many instruments, [b] a collapsed instrument set was used following Rodman (2009b). [c] Cross product of Debt with the threshold dummy is treated as endogenous with the same lag structure as lagged debt.

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Effort to stabilisation for the EMU core during the period 1978-2016

A. Dependent variables: Primary balance as a % of GDP ($Pb_{i,t}$) (col. 1-3) & Cyclically adjusted primanry balance as % of trend GDP ($capb_{i,t}$) (col. 4-6). Threshold variable: Output gap.

Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	$Pb_{i,t}$	$Pb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$
	(1)	*(2)*	*(3)*	*(4)*
Variables	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*
$Pb_{i,t-1}$	-0.0249	-0.0237	-	-
	(0.0860)	(0.0650)	-	-
$Pb_{i,t-2}$	0.249**	0.237***	-	-
	(0.0860)	(0.0650)	-	-
$capb_{i,t-1}$	-	-	1.006***	0.464*
	-	-	(0.239)	(0.223)
$capb_{i,t-2}$	-	-	-0.332*	-0.0430
	-	-	(0.176)	(0.165)
$OG_{i,t}$	0.642***	0.610***	0.269**	0.307***
	(0.281)	(0.181)	(0.115)	(0.149)
$OG_{i,t}*I(q_{i,t}<-0.61)$	0.824**	0.724***	-	-
	(0.337)	(0.252)	-	-
$OG_{i,t}*I(q_{i,t}>-0.61)$	-0.290	-	-	-
	(0.361)	-	-	-
$OG_{i,t}*I(q_{i,t}<-0.19)$	-	-	0.602***	0.526**
	-	-	(0.277)	(0.252)
$OG_{i,t}*I(q_{i,t}>-0.19)$	-	-	-0.115	-
	-	-	(0.250)	-
$D_{i,t-1}$	0.0458**	0.0375***	0.0137**	0.0230***
	(0.0166)	(0.00875)	(0.00595)	(0.00695)
$mon_{i,t}$	0.0297*	0.0386**	0.0206*	0.0316***
	(0.0183)	(0.0171)	(0.0114)	(0.0100)
$OG\_US_{i,t-1}$	-0.0121	-0.0474	-0.190**	-0.0958
	(0.0757)	(0.0577)	(0.0852)	(0.0579)
$IIR_{i,t}$	-0.0360	-0.00447	0.192	0.0178
	(0.123)	(0.102)	(0.201)	(0.0545)
$\alpha_{i,t}$	-1.804	-1.529**	-0.334	-0.931**
	(1.039)	(0.551)	(0.360)	(0.384)
Observations	519	519	519	519
Number of Country_id	15	15	15	15
Number of instr.	16	13	16	13
Residuals 1st order AR (p_value)	0.600	0.622	0.578	0.781
Residuals 2nd order AR (p_value)	0.299	0.34	0.527	0.978
Sargan [(a)] test of overidentifying restrictions (p_value)	0.608	0.491	0.178	0.818
Hansen test of joint validity of instruments (p_value)	0.590	0.914	0.222	0.146
Difference-in-Hansen - test of exogeneity of instrument subsets (p_value):				
- All GMM instruments for level eq.	0.807	0.610	0.248	0.857
- Those based on lagged Output gap for 1st difference eq.	0.572	0.909	0.412	0.947
- Those based on lagged debt for 1st difference eq.	0.697	0.705	0.222	0.692
- Those based on lagged differences of Output gap for level eq.	0.811	0.792	0.195	0.955
- Those based on lagged differences of debt for level eq.	0.664	0.622	0.559	0.958
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [(c)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [(c)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [(c)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt* [(c)]
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are introduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). [(a)] Not robust, but not weakened by many instruments, [(b)] a collapsed instrument set was used following Rodman (2009b). [(c)] Cross product of Output gap with the threshold dummy is treated as endogenous with the same lag structure as output gap.

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Annex II (robustness)

Table 7: Effort to sustainability for the period 1978-2016 including election and sovereign spread effects

A. Dependent variables: Primary balance as a % of GDP ($Pb_{i,t}$) (col. 1-3) & Cyclically adjusted primanry balance as % of trend GDP ($capb_{i,t}$) (col. 4-6)

Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	$Pb_{i,t}$	$Pb_{i,t}$	$Pb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$	$Pb_{i,t}$	$Pb_{i,t}$	$Pb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Variables	*1978-2008*	*1978-2012*	*1978-2016*	*1978-2008*	*1978-2012*	*1978-2016*	*1978-2008*	*1978-2012*	*1978-2016*	*1978-2008*	*1978-2012*	*1978-2016*
$Pb_{i,t-1}$	0.943**	0.507	0.954	-	-	-	0.449	1.157	0.342	-	-	-
	(0.347)	(0.381)	(0.681)	-	-	-	(1.471)	(1.468)	(0.469)	-	-	-
$Pb_{i,t-2}$	-0.258	0.136	-0.297	-	-	-	0.119	-0.646	-0.128	-	-	-
	(0.364)	(0.354)	(0.375)	-	-	-	(1.140)	(1.041)	(0.215)	-	-	-
$capb_{i,t-1}$	-	-	-	0.683*	0.739	0.367	-	-	-	0.753	0.393	0.667
	-	-	-	(0.340)	(0.565)	(0.311)	-	-	-	(0.543)	(1.105)	(0.494)
$cab_{i,t-2}$	-	-	-	-0.189	0.0710	0.373	-	-	-	0.0716	0.291	-0.178
	-	-	-	(0.255)	(0.506)	(0.223)	-	-	-	(0.463)	(0.485)	(0.353)
$\boldsymbol{D_{i,t-1}}$	0.0685	0.173*	0.0474	0.121**	0.143**	0.110***	0.0511	0.141***	0.00458	0.104**	0.148***	0.129***
	(0.0560)	(0.0820)	(0.0386)	(0.0473)	(0.0522)	(0.0291)	(0.0566)	(0.0140)	(0.0249)	(0.0500)	(0.0139)	(0.0187)
$D_{i,t-1}$*Periphery	-0.0446	-0.0724	-0.0272	-0.0827**	-0.0298	-0.0611*	-0.0650	-0.114	0.0390	0.00961	-0.109	0.0146
	(0.0739)	(0.0464)	(0.0309)	(0.0420)	(0.0211)	(0.0327)	(0.0975)	(0.0616)	(0.0272)	(0.0454)	(0.164)	(0.0246)
$D_{i,t-1}$*Core	-0.0189	-0.0626	-0.0228	-0.0626**	-0.0654***	-0.0431**	0.110	-0.0215	0.0262	0.0910	-0.1067**	-0.0598***
	(0.0690)	(0.0415)	(0.0324)	(0.0290)	(0.0243)	(0.0213)	(0.102)	(0.022)	(0.0221)	(0.104)	(0.0486)	(0.0150)
$OG_{i,t}$	0.536**	0.698***	0.215	0.213*	0.212	-0.0193	1.011	0.150	0.765***	0.561*	0.0919	0.451**
	(0.244)	(0.201)	(0.594)	(0.116)	(0.250)	(0.115)	(0.852)	(1.686)	(0.169)	(0.290)	(0.713)	(0.159)
$mon_{i,t}$	-0.00590	-0.0446	-0.0128	-0.0257	-0.0434	-0.0144	0.350	-0.172	0.0569*	0.258	0.0792	0.115***
	(0.0319)	(0.0366)	(0.0430)	(0.0341)	(0.0372)	(0.0209)	(0.209)	(0.418)	(0.0302)	(0.196)	(0.189)	(0.0286)
$OG\_US_{i,t-1}$	-0.217**	-0.209	-0.204	-0.0873	-0.158	-0.0366	-0.401	-0.564	-0.177	-0.382	0.336	-0.168
	(0.0968)	(0.138)	(0.164)	(0.0959)	(0.0998)	(0.0975)	(0.559)	(0.495)	(0.313)	(0.285)	(0.287)	(0.343)
IIRi,t	0.233	-0.0749	-0.0644	-0.0833	-0.0665	0.344*	-0.665	-0.110	0.0241	-0.262	-0.0465	-0.0418
	(0.366)	(0.153)	(0.0799)	(0.166)	(0.102)	(0.189)	(0.711)	(0.310)	(0.124)	(0.456)	(0.188)	(0.124)
$spread_{i,t}$	-	-	-	-	-	-	1.639	-0.393	-0.0841	0.835	0.779	0.156
	-	-	-	-	-	-	(1.130)	(2.198)	(0.115)	(0.720)	(0.696)	(0.294)
$Elect_{i,t}$	-0.435**	-0.592**	-0.610***	-0.675**	-0.587	-0.522***	-0.694**	-0.243**	-0.295**	-0.685**	-0.418**	-0.406**
	(0.258)	(0.286)	(0.253)	(0.255)	(0.431)	(0.163)	(0.342)	(0.121)	(0.142)	(0.291)	(0.161)	(0.145)
$\alpha_{i,t}$	-4.041	-6.190	-0.796	-2.769	-4.311	-6.690**	3.831	1.791	0.168	0.377	-5.002	-0.435
	(3.141)	(3.830)	(1.689)	(1.908)	(3.508)	(2.400)	(4.213)	(3.694)	(1.632)	(1.514)	(8.045)	(2.886)
Observations	414	474	519	414	474	519	235	295	340	235	295	340
Number of Country_id	15	15	15	15	15	15	15	15	15	15	15	15
Number of instr.	17	17	17	17	17	17	18	18	18	18	18	18
Residuals 1st order AR (p_value)	0.0886	0.185	0.656	0.137	0.485	0.606	0.799	0.373	0.470	0.328	0.818	0.272
Residuals 2nd order AR (p_value)	0.838	0.600	0.536	0.750	0.675	0.0767	0.845	0.510	0.941	0.912	0.555	0.751
Sargan [(a)] test of overidentifying restrictions (p_value)	0.0954	0.486	0.269	0.685	0.143	0.191	0.529	0.151	0.829	0.830	0.232	0.499
Hansen test of joint validity of instruments (p_value)	0.705	0.511	0.714	0.273	0.367	0.834	0.885	0.524	0.994	0.986	0.757	0.848
Difference-in-Hansen - test of exogeneity of instrument subsets												
- All GMM instruments for level eq.	0.359	0.842	0.281	0.412	0.251	0.888	0.255	0.384	0.289	0.587	0.613	0.911
- Those based on lagged Output gap for 1st difference eq.	0.376	0.471	0.409	0.318	0.771	0.892	0.795	0.278	0.663	0.847	0.416	0.112
- Those based on lagged differences of Output gap for level eq.	0.311	0.323	0.228	0.246	0.35	0.633	0.503	0.397	0.559	0.962	0.639	0.516
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are instroduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). (a) Not robust, but not weakened by many instruments, (b) a collapsed instrument set was used following Rodman (2009b). Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Effort to sustainability for the EMU periphery during the period 1978-2016

A. Dependent variables: Primary balance as a % of GDP ($pb_{i,t}$) (col. 1-3) & Cyclically adjusted primanry balance as % of trend GDP ($capb_{i,t}$) (col. 4-6). Threshold variable: Debt as % GDP.

Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	Pb i,t	*Pb i,t*	*Pb i,t*	*Pb i,t*	*capb i,t*	*capb i,t*	*capb i,t*	*capb i,t*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Variables	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*	*1978-2016*
$Pb_{i,t-1}$	0.652**	0.725***	0.556***	0.673**	-	-	-	-
	(0.348)	(0.352)	(0.207)	(0.311)	-	-	-	-
$Pb_{i,t-2}$	-0.106	-0.105	-0.140	-0.214	-	-	-	-
	(0.216)	(0.220)	(0.230)	(0.153)	-	-	-	-
$capb_{i,t-1}$	-	-	-	-	0.498*	0.476**	-0.622***	-0.503***
	-	-	-	-	(0.251)	(0.240)	(0.273)	(0.215)
$capb_{i,t-2}$	-	-	-	-	-0.0382	-0.0363	0.455	0.373
	-	-	-	-	(0.168)	(0.168)	(1.291)	(1.244)
$\mathbf{D_{i,t-1}}$	0.0532**	0.0365***	0.0562**	0.0351**	0.0388**	0.0303***	0.0451***	0.0394***
	(0.0241)	(0.0118)	(0.0279)	(0.0165)	(0.0159)	(0.00711)	(0.0276)	(0.0104)
$\mathbf{D_{i,t-1} * I(q_{i,t}<96)}$	-0.0270***	-0.023***	-0.0275**	-0.0233**	-0.0198***	-0.0177***	-0.0188**	-0.0191*
	(0.0104)	(0.0111)	(0.013)	(0.0131)	(0.0081)	(0.0098)	(0.0098)	(0.0117)
$\mathbf{D_{i,t-1} * I(q_{i,t}>96)}$	-0.0198	-	-0.0223	-	-0.0105	-	-0.0167	-
	(0.0165)	-	(0.0281)	-	(0.0131)	-	(0.0364)	-
$OG_{i,t}$	0.526***	0.572***	0.628***	0.620***	0.189	0.213	0.190	0.245
	(0.173)	(0.149)	(0.157)	(0.155)	(0.135)	(0.125)	(0.585)	(0.541)
$mon_{i,t}$	0.00358	0.0115	0.0152	0.0168	0.0144	0.0188*	0.0762	0.0857
	(0.0156)	(0.0129)	(0.0341)	(0.0267)	(0.0131)	(0.0106)	(0.0587)	(0.0490)
$Elect_{i,t}$	-0.449***	-0.439***	-0.333**	-0.263*	-0.563***	-0.553***	-0.364**	-0.327**
	(0.134)	(0.125)	(0.163)	(0.148)	(0.147)	(0.143)	(0.143)	(0.113)
$spread_{i,t}$	-	-	0.166***	0.0926*	-	-	0.233	0.191
	-	-	(0.0513)	(0.0507)	-	-	(0.138)	(0.217)
$OG\_US_{i,t-1}$	-0.143	-0.162	-0.206	-0.363	-0.0850	-0.0930	0.593	0.479
	(0.109)	(0.108)	(0.528)	(0.274)	(0.0659)	(0.0649)	(1.622)	(1.535)
$IIR_{i,t}$	0.00250	0.0203	-0.0405	-0.0182	0.0478	0.0558	0.0284	0.0196
	(0.0744)	(0.0636)	(0.0915)	(0.0840)	(0.0615)	(0.0597)	(0.237)	(0.238)
$\alpha_{i,t}$	-2.103	-1.414	-1.559	-0.659	-1.752*	-1.394*	-1.244	-0.478
	(1.471)	(0.993)	(1.884)	(0.811)	(0.941)	(0.668)	(2.671)	(1.706)
Observations	519	519	340	340	519	519	340	340
Number of Country_id	15	15	15	15	15	15	15	15
Number of instr.	17	15	18	16	17	15	18	16
Residuals 1st order AR (p_value)	0.257	0.268	0.376	0.212	0.182	0.183	0.864	0.879
Residuals 2nd order AR (p_value)	0.927	0.886	0.889	0.608	0.568	0.550	0.662	0.695
Sargan [(a)] test of overidentifying restrictions (p_value)	0.982	0.986	0.773	0.866	0.857	0.814	0.836	0.794
Hansen test of joint validity of instruments (p_value)	0.992	0.994	0.837	0.862	0.950	0.922	0.912	0.888
Difference-in-Hansen - test of exogeneity of instrument subsets (p_value):								
- All GMM instruments for level eq.	0.802	0.834	0.857	0.862	0.850	0.822	0.712	0.888
- Those based on lagged Output gap for 1st difference eq.	0.431	0.333	0.623	0.522	0.554	0.603	0.713	0.655
- Those based on lagged differences of Output gap for level eq.	0.718	0.522	0.738	0.613	0.777	0.702	0.838	0.455
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt [(c)]*
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are instroduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). [(a)] Not robust, but not weakened by many instruments, [(b)] a collapsed instrument set was used following Rodman (2009b). [(c)] Cross product of Debt with the threshold dummy is treated as endogenous with the same lag structure as lagged debt.

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Effort to stabilisation for the period 1978-2016 including election effects

A. Dependent variables: Primary balance as a % of GDP ($Pb_{i,t}$) (col. 1-3) & Cyclically adjusted primary balance as % of trend GDP ($capb_{i,t}$) (col. 4-6)

Estimator: System GMM with two-step incorporating Windmeijer (2005) correction.

	$Pb_{i,t}$	$Pb_{i,t}$	$Pb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$	$capb_{i,t}$
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*1978-2008*	*1978-2012*	*1978-2016*	*1978-2008*	*1978-2012*	*1978-2016*
$Pb_{i,t-1}$	0.872**	1.062***	0.704***	-	-	-
	(0.343)	(0.276)	(0.213)	-	-	-
$Pb_{i,t-2}$	-0.393	-0.569	-0.168	-	-	-
	(0.262)	(0.337)	(0.152)	-	-	-
$capb_{i,t-1}$	-	-	-	0.881***	0.880***	0.657***
	-	-	-	(0.283)	(0.119)	(0.165)
$cab_{i,t-2}$	-	-	-	-0.108	0.0436	-0.0648
	-	-	-	(0.258)	(0.245)	(0.173)
$OG_{i,t}$	0.639***	0.755***	0.681***	0.535***	0.631***	0.588***
	(0.312)	(0.358)	(0.190)	(0.111)	(0.149)	(0.0927)
$OG_{i,t}$ *Periphery*	-0.572**	-0.665***	-0.442**	-0.603***	-0.637***	-0.614***
	(0.251)	(0.337)	(0.212)	(0.193)	(0.167)	(0.166)
$OG_{i,t}$ *Core*	-0.135	0.142	-0.00205	-0.420	-0.361	-0.283
	(0.163)	(0.122)	(0.103)	(0.264)	(0.209)	(0.187)
$D_{i,t-1}$	-0.00818	-0.0242	0.0211***	0.0213	0.0459*	0.0113
	(0.0115)	(0.0443)	(0.00488)	(0.0277)	(0.0244)	(0.00674)
$mon_{i,t}$	0.0364**	0.0289	0.0224	-0.00984	-0.0179	0.0264*
	(0.0167)	(0.0171)	(0.0141)	(0.0401)	(0.0264)	(0.0132)
$OG\_US_{i,t-1}$	-0.227***	-0.286***	-0.215**	-0.184	-0.268**	-0.180**
	(0.0728)	(0.0461)	(0.0756)	(0.117)	(0.0993)	(0.0619)
$IIR_{i,t-1}$	0.00951	-0.00441	-0.0107	0.134	0.0891	0.0591
	(0.0917)	(0.0568)	(0.0426)	(0.0784)	(0.0656)	(0.0429)
$Elect_{i,t}$	-0.587***	-0.441***	-0.476***	-0.805***	-0.630***	-0.589***
	(0.178)	(0.0729)	(0.101)	(0.240)	(0.162)	(0.134)
$\alpha_{i,t}$	1.321	2.105	-0.626	-0.971	-2.433	-0.108
	(0.858)	(2.664)	(0.466)	(1.875)	(1.585)	(0.363)
Observations	414	474	519	414	474	519
Number of Country_id	15	15	15	15	15	15
Number of instr.	17	17	17	17	17	17
Residuals 1st order AR (p_value)	0.134	0.0823	0.0818	0.191	0.0974	0.0942
Residuals 2nd order AR (p_value)	0.350	0.251	0.912	0.981	0.411	0.577
Sargan [(a)] test of overidentifying restrictions (p_value)	0.896	0.631	0.826	0.517	0.449	0.445
Hansen test of joint validity of instruments (p_value)	0.721	0.996	0.951	0.178	0.367	0.736
(p_value):						
- All GMM instruments for level eq.	0.767	0.992	0.945	0.566	0.237	0.387
- Those based on lagged Output gap for 1st difference eq.	0.646	0.955	0.909	0.333	0.445	0.731
- Those based on lagged debt for 1st difference eq.	0.918	0.892	0.933	0.122	0.139	0.332
- Those based on lagged differences of Output gap for level eq.	0.671	0.772	0.882	0.258	0.985	0.737
- Those based on lagged differences of debt for level eq.	0.623	0.673	0.735	0.442	0.551	0.522
Instruments [(b)]	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*	*the t-2 to t-3 lags of Output gap and the t-4 to t-5 lags of debt*
Instruments used for level equation	1st difference	1st difference	1st difference	1st difference	1st difference	1st difference

Note: Cross product variables are introduced in the system GMM as exogenous to avoid the increase of instruments. In any case as a rule of thumb the instrument count is kept below cross section (Bowsher (2002) and Roodman (2009). (a) Not robust, but not weakened by many instruments, (b) a collapsed instrument set was used following Rodman (2009b).

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Technical Annex:

Threshold location in the case of variable endogeneity in a GMM dynamic panel data context (Kourtellos et. al. 2015)

In the case where the slope variables are also endogenous and therefore X_{it} is not a subset of Z_{it}, then X_{it} can be expressed as:

$$X_{it} = \Pi_X' \cdot Z_{it} + v_{Xit} ,$$

and the STR model can be written as follows:

$$s_{it} = \beta_{X1}' \cdot \Theta_{Xit} \cdot I(q_{it} \le \gamma) + \beta_{X2}' \cdot \Theta_{Xit} \cdot I(q_{it} > \gamma) + \kappa \cdot \Lambda_{it}(\gamma) + \varepsilon_{it}^* ,$$

where $$\varepsilon_{it}^* = \beta_{X1}' \cdot v_{it} \cdot I(q_{it} \le \gamma) + \beta_{X2}' \cdot v_{it} \cdot I(q_{it} > \gamma) + \varepsilon_{it}$$

with $E(\varepsilon_{it}^* | F_{i-1}) = 0$.[28]

As stated above the STR model treats the sample split value γ as an unknown parameter to be estimated. Hence, to facilitate the estimation, we follow Kourtellos et al. (2016) and first estimate the reduced form parameters π_q and Π_X by least squares (LS) to obtain $\hat{\pi}_q$and $\hat{\Pi}_X$, respectively. The fitted values are then given by $\hat{q}_{it} = \hat{\pi}_q' z_{it}$and $\hat{X}_{it} = \hat{\Theta}_{Xit} = \hat{\Pi}_X' z_{it}$, along with the first stage residuals, $\hat{v}_{Xit} = X_{it} - \hat{X}_{it}$ and $\hat{v}_{qi} = q_{it} - \hat{q}_{it}$, respectively.

The threshold parameter γ is estimated by employing the predicted values of the endogenous regressors $\hat{X}_{it}$ and the predicted inverse Mills ratio term $\hat{\Lambda}_{it}(\gamma)$ by concentration. Conditional on γ, the estimation problem is linear in the slope parameters $\psi = (\beta_{X1}' , \beta_{X2}' , \kappa)'$, yielding conditional 2SLS or GMM estimator $\hat{\psi}(\gamma) = (\hat{\beta}_{X1}(\gamma)', \hat{\beta}_{X2}(\gamma)' , \hat{\kappa}(\gamma))'$ by regressing s_{it} on $\hat{X}_{it}(\gamma)$ and instruments $\hat{Z}_{it}(\gamma)$. Then, by defining the criterion

$$S_n(\gamma) = S_n\left(\gamma, \hat{\psi}(\gamma)\right) =$$

$$= \sum_{i=1}^{n} \left(s_{it} - \hat{\beta}_{X1}(\gamma)' \cdot \hat{\Theta}_{Xit} \cdot I(q_{it} \le \gamma) - \hat{\beta}_{X2}(\gamma)' \cdot \hat{\Theta}_{Xit} . I(q_{it} > \gamma) - \hat{\kappa}(\gamma) \cdot \hat{\Lambda}_{it}(\gamma)\right)^2$$

the value of γ can be estimated[29] by minimizing the CLS criterion $\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}} S_n(\gamma)$.

[28] Here F_{i-1} is the sigma field generated by $\{z_{it-j},\ \chi_{it-1-j},\ q_{it-1-j}, \varepsilon_{it-1-j} : j \ge 0\}$.

[29] The consistency and asymptotic distribution of the threshold parameter $\gamma$is nonstandard as it involves two independent standard Wiener processes with two different scales and two different drifts, while the construction of confidence intervals is based on the inversion of the likelihood ratio test.