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AN EMPIRICAL INVESTIGATION FOR THE EURO AREA

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Abstract: This paper investigates the average impact of government debt on per-capita GDP growth in twelve euro area countries over a period of about 40 years starting in 1970. It finds a non-linear impact of debt on growth with a turning point—beyond which the government debt-to-GDP ratio has a deleterious impact on long-term growth—at about 90-100% of GDP. Confidence intervals for the debt turning point suggest that the negative growth effect of high debt may start already from levels of around 70-80% of GDP, which calls for even more prudent indebtedness policies. At the same time, there is evidence that the annual change of the public debt ratio and the budget deficit-to-GDP ratio are negatively and linearly associated with per-capita GDP growth. The channels through which government debt (level or change) is found to have an impact on the economic growth rate are: (i) private saving; (ii) public investment; (iii) total factor productivity (TFP) and (iv) sovereign long-term nominal and real interest rates. From a policy perspective, the results provide additional arguments for debt reduction to support longer-term economic growth prospects.

Keywords: Public debt, economic growth, fiscal policy, sovereign long-term interest rates

JEL Classification: H63, O40, E62, E43

Non-technical summary

The 2008-2009 crisis has put considerable strains on public finances in the euro area, in particular on government debt. Many euro area and EU countries are at high risk with regard to fiscal sustainability. Against this background, one important question refers to the economic consequences of a regime of high and potentially persistent public debt. While the economic growth rate is likely to have a linear negative impact on the public debt-to-GDP ratio, high levels of public debt are also likely to be deleterious for growth, but potentially after a certain threshold has been reached. It is precisely this relationship that the present paper seeks to investigate. From a policy perspective, a negative impact of public debt on economic growth strengthens the arguments for ambitious debt reduction through fiscal consolidation.

The literature, in particular the empirical part, on the relationship between government debt and economic growth is scarce. The theoretical literature tends to point to a negative relationship. The empirical evidence is primarily focused on the impact of external debt on growth in developing countries, while for the euro area, several studies analyse the impact of fiscal variables, including government debt, on long-term interest rates or spreads against a benchmark, as an indirect channel affecting economic growth.

This paper investigates the average relationship between the government debt-to-GDP ratio and the per-capita GDP growth rate in a sample of 12 euro area countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain) for a period of roughly four decades starting in 1970.

The basic empirical growth model is based on a conditional convergence equation that relates the GDP per capita growth rate to the initial level of income per capita, the investment/saving-to-GDP rate and population growth rate. The model is augmented to include the level of gross government debt (as a share of GDP). The basic estimation technique is panel fixed-effects corrected for heteroskedasticity and autocorrelation. Given the strong potential for endogeneity of the debt variable, especially reverse causation (low or negative growth rates of per-capita GDP are likely to induce higher debt burdens), we also use various instrumental variable estimation techniques. In addition, we find that the results remain robust when cyclical fluctuations in the dependent variable are eliminated by using the growth rate of potential or trend GDP.

The results across all models show a highly statistically significant non-linear relationship between the government debt ratio and per-capita GDP growth for the 12 pooled euro area

countries included in our sample. The debt-to-GDP turning point of this concave relationship (inverted U-shape) is roughly between 90 and 100% on average for the sample, across all models (the threshold for the models using trend GDP is somewhat lower). This means that, on average for the 12-euro area countries, government debt-to-GDP ratios above such threshold would have a negative effect on economic growth. Confidence intervals for the debt turning point suggest that the negative growth effect of high debt may start already from levels of around 70-80% of GDP, which calls for even more prudent indebtedness policies. We also find evidence that the annual change of the public debt ratio and the budget deficit-to-GDP ratio are negatively and linearly associated with per-capita GDP growth.

The channels through which government debt (level or change) is found to have an impact on the economic growth rate are: (i) private saving; (ii) public investment; (iii) total factor productivity (TFP) and (iv) sovereign long-term nominal and real interest rates. For the first three channels – private saving, public investment and TFP – a non-linear (concave) relationship also predominates across the various models used. As regards the channel of long-term sovereign interest rates, a strong and robust impact on nominal, as well as real, interest rates is found to come from the change in the debt ratio (first difference) and from the primary budget balance ratio. The level of the public debt ratio (in either linear or quadratic forms) is not found to be significant on average in determining long-term interest rates in our sample. The change in the public debt ratio and the primary budget balance prove to be highly statistically significant and remain robust even after controlling for short-term interest rates as a proxy for monetary policy effects.

Overall, a robust conclusion of our paper is that above a 90-100% of GDP threshold, public debt is, on average, harmful for growth in our sample. The question remains whether public debt is indeed associated with higher growth below this turning point. The additional evidence in this analysis, i.e. that (i) the debt turning points for the first two channels (private saving and public investment) seem to be much below the range of 90-100%; (ii) government budget deficits and the change in the debt ratio are found to be linearly and negatively associated with growth (and the long-term interest rates), may point to a more detrimental impact of the public debt stock even below the threshold.

The view is sometimes expressed [Professor Aba P. Lerner and Professor Domar] that a domestic national debt means merely that citizens as potential taxpayers are indebted to themselves as holders of government debt, and that it can, therefore, have little effect upon the economy […]. It is my purpose to refute this argument [and] to show that, quite apart from any distributional effects, a domestic debt may have far-reaching effects upon incentives to work, save, and to take risks.

J.E. Meade (1958), Oxford Economic Papers

1. Introduction

Government debt rose considerably over the past decades and this trend was generally accompanied by an expansion in the size of governments. For many industrial countries, the growth of general government expenditure was enormous in the 20th century. As shown in Tanzi and Schuknecht (1997), the average size of government for a group of thirteen industrial countries[4] increased from 12% of GDP in 1913 to 43% of GDP in 1990. At the end of the period, average public debt-to-GDP ratio was 79% for the big governments, 60% for medium-seized governments and 53% for small governments.[5]

The manner in which debt builds up can be important from the perspective of its economic impact, as well as of the subsequent exit strategy. Reinhart and Rogoff (2010) argue that war debts may be less problematic for future growth partly because the high war-time government spending comes to a halt as peace returns, while peacetime debt explosions may persistent for longer periods of time.

Before the 20th century, the accumulation of government debt was in general slow and occurred mainly in relation to wars. According to the Encyclopaedia Britannica, the national debt of England was initiated to finance the British participation in the war of the Grand Alliance with France during 1689-1697. In the United States, the newly-formed federal government assumed the debts of the states incurred during the American Revolution, all of which were pooled into a single debt issue in 1790. Government debt, especially at local levels, was contracted to a smaller extent also for other purposes. According to the same source, government borrowing in its modern form first occurred in medieval Genoa and Venice when the city governments borrowed on a commercial basis from the newly

[4] Australia, Austria, Canada, France, Germany, Ireland, Japan, New Zeeland, Norway, Sweden, Switzerland, United Kingdom and United States.

[5] Where big governments are defined as those with public expenditure-to-GDP ratio higher than 50%; medium-sized governments: between 40-50% and small governments: less than 40%.

developed banks. The US states incurred substantial debts in the early part of the 19th century, largely for public work improvements. France's debt increased substantially after 1878 as a result of public work expenditures and France's colonial expansion. According to some historians, England is considered to have been a leader in the modern era with respect to debt solvency and management techniques, while France is the country most violently disturbed by its national debt (Hamilton, 1947).

Economic and financial crises are also likely to contribute to the build-up of government debt, as shown in a recent paper analysing severe post-World War II financial crisis.[6] In this context, the 2008-2009 crisis has already put considerable strains on debt and, in general, on public finances in the euro area countries. The euro area government deficit ratio is projected to increase rapidly from 0.6% of GDP in 2007 to 6.6% of GDP in 2011, while the gross government debt ratio is expected to surge from 66.0% to 88.5% of GDP during the same period[7]. Overall, long-term fiscal sustainability in the euro area has deteriorated markedly and many expect that such effects would linger on in the medium and longer term. According to the latest European Commission's Sustainability Report, many euro area and EU countries (8 in the euro area and 13 EU countries) are now at high risk with regard to fiscal sustainability. This reflects large current fiscal deficits, high debt levels, an outlook of possibly subdued GDP growth, as well as the projected fiscal implications of population ageing which are considerable in some countries. The report calls the sustainability risks in the EU-27 so significant that "debt sustainability should get a very prominent and explicit role in the surveillance procedures" under the EU Stability and Growth Pact. This is also reflected in the work of the so-called Van Rompuy Task Force which is looking into ways to strengthen economic governance in the EU. Financial markets have reacted to the deterioration in the fiscal situation and outlook of individual countries with significant increases in sovereign yield spreads.

Against this background, one important question refers to the economic consequences of a regime of high and potentially persistent public debt. While the economic growth rate is likely to have a linear negative impact on the public debt-to-GDP ratio (a decline in the economic growth rate is, *ceteris paribus*, associated with an increase in the public debt-to-GDP ratio), high levels of public debt are likely to be deleterious for growth. Potentially, this effect is non-linear in the sense that it becomes relevant only after a certain threshold has

6 See Reinhart and Rogoff (2009)

7 According to the European Commission Spring Forecast as of May 2010.

been reached. It is precisely this non-linear relationship that the present paper seeks to investigate.

2. Literature Review

The literature, in particular the empirical part, on the relationship between government debt and economic growth is scarce. Most studies on this topic emphasize the impact of external debt and debt restructuring on growth in developing countries, while analyses across developed countries, particularly in the euro area, are virtually absent. Yet, such analyses become even more relevant as euro area governments are facing mounting fiscal pressures, with public debt-to-GDP ratios soaring following the financial and economic crisis and likely to remain at elevated levels in the medium term. Several studies that focus on the euro area analyse the impact of fiscal variables, including government debt, on long-term interest rates or spreads against a benchmark, as an indirect channel affecting economic growth.[8]

The ***theoretical literature*** on the relationship between public debt and economic growth tends to point to a negative relationship. Growth models augmented with public agents issuing debt to finance consumption or capital goods tend to exhibit a negative relationship between public debt and economic growth, particularly in a neoclassical setting.

Modigliani (1961), refining contributions by Buchanan (1958) and Meade (1958), argued that the national debt is a burden for next generations, which comes in the form of a reduced flow of income from a lower stock of private capital. Apart from a direct crowding-out effect, he also pointed out to the impact on long-term interest rates, possibly in a non-linear form "if the government operation is of sizable proportions it may significantly drive up [long-term] interest rates since the reduction of private capital will tend to increase its marginal product" (p. 739). Even when the national debt is generated as a counter-cyclical measure and "in spite of the easiest possible monetary policy with the whole structure of interest rates reduced to its lowest feasible level" (p. 753), the debt increase will generally not be costless for future generations despite being advantageous to the current generation. Modigliani considered that a situation in which the gross burden of national debt may be offset in part or in total is when debt finances government expenditure that could contribute

[8] A rather extended empirical literature deals with the impact of fiscal variables, such as taxes and government expenses, on economic growth, with somewhat controversial results, depending on factors such as the time span used, methodological approaches, sample heterogeneity etc. For a relatively recent study reviewing such issues, see inter alia, Hiebert et al (2002). The study finds a negative relationship between fiscal profligacy (government size) and trend economic growth among fourteen EU member countries for the period 1970-2000. It concludes that past improvements in the government budget position for the "old" EU countries have tended to support long-term economic growth.

to the real income of future generations, such as productive public capital formation.

Diamond (1965) adds the effect of taxes on the capital stock and differentiates between public external and internal debt. He concludes that, through the impact of taxes needed to finance the interest payments, both types of public debt reduce the available lifetime consumption of taxpayers, as well as their saving, and thus the capital stock. In addition, he contends that internal debt can produce a further reduction in the capital stock arising from the substitution of government debt for physical capital in individual portfolios.

Adam and Bevan (2005) find interaction effects between deficits and debt stocks, with high debt stocks exacerbating the adverse consequences of high deficits. In a simple theoretica model integrating the government budget constraint and debt financing, they find that an increase in productive government expenditure, financed out of a rise in the tax rate, will be growth-enhancing only if the level of (domestic) public debt is sufficiently low.

Saint-Paul (1992) and Aizenman et al. (2007) analyze the impact of fiscal policy, proxied *inter alia* by the level of public debt, in endogenous growth models and find a negative relation as well.

Several theoretical contributions have focused on the adverse impact of *external debt* on the economy and the circumstances under which such impact arises.[9] In this line of research Krugman (1988) coins the term of "debt overhang" as a situation in which a country's expected repayment ability on external debt falls below the contractual value of debt Cohen's (1993) theoretical model posits a non-linear impact of foreign borrowing on investment (as suggested by Clements et al. (2003), this relationship can be arguably extended to growth). Thus, up to a certain threshold, foreign debt accumulation can promote investment, while beyond such a point the debt overhang will start adding negative pressure on investors' willingness to provide capital.

In the same vein, the growth model proposed by Aschauer (2000), in which public capital has a non-linear impact on economic growth, can be extended to cover the impact of public debt Assuming that government debt is used at least partly to finance productive public capital, an increase in debt would have positive effects up to a certain threshold and negative effect beyond it.

The channels through which public debt can potentially affect economic growth are diverse.

[9] For more details on the literature review on this topic see Clements et al. (2003) and Schclarek (2004).

Meade (1958) was drawing attention to the fact that the removal of the "deadweight debt" would: (i) raise the incentive of households to save (the Pigou-effect)[10]; (ii) improve the incentives for work and enterprise; (iii) possibly allow for a decrease in income taxation at a later stage as a result of saving interest payments on the budget (improving even more the incentives for work and enterprise).

An important channel through which public debt accumulation can affect growth is that of long-term interest rates. Higher long-term interest rates, resulting from more debt-financed government budget deficits, can crowd-out private investment, thus dampening potential output growth. Indeed, if higher public financing needs push up sovereign debt yields, this may induce an increased net flow of funds out of the private sector into the public sector. This may lead to an increase in private interest rates and a decrease in private spending growth, both by households and firms (see Elmendorf and Mankiw, 1999). While the empirical findings on the relationship between public debt and long-term interest rates are diverse, a significant number of recent studies[11] suggest that high debt and deficits may contribute to rising sovereign long-term interest rates and yield spreads.

In Krugman's specification, the external debt overhang affects economic growth through private investment, as both domestic and foreign investors are deterred from supplying further capital. Other channels may be total factor productivity, as proposed in Patillo et al. (2004), or increased uncertainty about future policy decisions, with a negative impact on investment and further on growth, as in Agénor and Montiel (1996) and in line with the literature of partly-irreversible decision making under uncertainty (Dixit and Pindyck 1994).

The ***empirical evidence*** on the relationship between debt and growth is scarce and primarily focused on the role of external debt in developing countries.

Among more recent studies, several find support for a non-linear impact of external debt on growth, with deleterious effects only after a certain debt-to-GDP ratio threshold. Pattillo et al. (2002) use a large panel dataset of 93 developing countries over 1969-1998 and find that the impact of external debt on per-capita GDP growth is negative for net present value of debt levels above 35-40% of GDP. Clements et al. (2003) investigate the same relationship for a panel of 55 low-income countries over the period 1970-1999 and find that the turning point

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10 In Meade's arguments, because of the assumption of a capital levy to remove the debt, the net income of a citizen would remain the same, while his property value would decrease. The Pigou-effect consists in a citizen's net saving being higher (or his net dissaving lower), the lower is the ratio of his capital to his tax-free income.

11 See Ardagna et al. (2007) and Laubach (2009) for the long-term sovereign yields and Codogno et al. (2003); Schuknecht et al. (2009); Barrios et al. (2009), and Attinasi et al (2009), among others, for long-term sovereign bond yield spreads.

in the net present value of external debt is at around 20-25% of GDP. Other previous empirical studies that find a non-linear effect of external debt on growth include Smyth and Hsing (1995) and Cohen (1997). On the other hand, Schclarek (2004) finds a linear negative impact of external debt on per-capita growth (and no evidence of an inverted U-shape relationship) in a panel of 59 developing countries over the period 1970-2002.

Schclarek (2004) also investigates the relationship between gross government debt and per-capita GDP growth in developed countries. No robust evidence of a statistically significant relationship is found for a sample of 24 industrial countries with data averaged over seven 5-year periods between 1970 and 2002.[12] In contrast, a recent study by Reinhart and Rogoff (2010), which analyses (through simple correlation statistics) the developments of public (gross central government) debt and the long-term real GDP growth rate in a sample of 20 developed countries over a period spanning about two centuries (1790 - 2009), finds that: (i) the relationship between government debt and long-term growth is weak for debt/GDP ratios below a threshold of 90% of GDP; (ii) above 90%, the median growth rate falls by one percent and the average by considerably more. A similar change in the behaviour of GDP growth in relation to the debt ratio is also found by Kumar and Woo (2010).

3. Empirical model, data and results

3.1 Direct impact of public debt on growth

3.1.1 Results with the whole sample

We investigate the relationship between government debt-to-GDP ratio and per-capita GDP growth rate in a sample of 12 euro area countries, namely, Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. Data originates primarily from the European Commission AMECO database, covering the period 1970-2011 and thus including also the EC Autumn Forecast data for 2009-2011. (However, since for some control variables the forecast is not available, most of the models are estimated only up to 2008.) Using this relatively restricted cross-sectional sample also helps mitigating the issue of heterogeneity, which often turns problematic in standard growth regressions.

[12] The industrial countries used in the study are Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States. For the last period of time (2000-2002), data is averaged over 3 years only.

The empirical growth model is based on a conditional convergence equation that relates the GDP per capita growth rate to the initial level of income per capita, the investment/saving-to-GDP rate and the population growth rate. The model is augmented to include the level of gross government debt (as a share of GDP). Since we are interested in checking whether there exists a non-linear impact of government debt on growth, we use a quadratic equation in debt. Using debt in a linear form does not yield significant results.

Other control variables that we use in the estimation of the growth equation include: (i) fiscal indicators (i.e. a proxy for the average tax rate and the government balance, both in cyclically adjusted terms) to allow more extensively for the possibility of fiscal policy affecting economic growth; (ii) the long-term (sovereign) real interest rate, capturing the impact of inflation and the effects of the fiscal-monetary policy mix; (iii) indicators for the openness of the economy and external competitiveness (such as the sum of export and import shares in GDP; terms of trade growth rate; real effective exchange rate REER) to expand the model beyond a closed-economy form. Given the relatively small dimension of the country cross section and the need to control for country specific characteristics, the equation also contains country-fixed effects. The country dummies capture economic and social characteristics specific for each country that remain broadly unchanged over time. In addition, year dummies are included to control for common shocks across countries that occurred over the period of the analysis, as well as for economic and monetary regime changes, such as the creation of the monetary union and the introduction of the euro. A list of the variables used in the various regression models, as well as the sources of data, is presented in Appendix 1.

The basic estimation equation is as follows:

$$g_{it+k} = \alpha + \beta \ln(GDP/cap)_{it} + \gamma_1 debt_{it}^2 + \gamma_2 debt_{it} + \delta\ saving/inv.rate_{it} + \phi\ pop.growth_{it} + other\ controls\ (fiscal;\ openness;\ interest\ rate) + \mu_i + \nu_t + \varepsilon_{it} \quad (eq.1)$$

where g_{it+k} = the growth rate of GDP per capita, k = 1 or 5 (three different measures are used in the empirical estimation: annual growth rate g_{it+1}; 5-year cumulative overlapping growth rate $g_{it/t+5}$, where t takes annual values; and 5-year cumulative non-overlapping growth rate g_{it+5}, where t takes the values at the start of each half-decade);

$ln(GDP/cap)_{it}$ = natural logarithm of the initial level of GDP per capita

$debt_{it}$ = gross government debt as a share of GDP

$saving/inv.rate_{it}$ = saving or investment (gross capital formation) as a share of GDP (the

	variables are used in the empirical estimation in aggregated terms, total national saving/investment rate, as well as on a disaggregated basis, as public and private saving/ investment rate)
other controls	=> see description in the text above
μ_i	= country fixed effects
ν_t	= time fixed effects
ε_{it}	= the error term.

The basic estimation technique is panel fixed-effects corrected for heteroskedasticity and autocorrelation up to order 2 (for the annual growth rate and the cumulative 5-year non-overlapping growth rate) or 5 (for the cumulative 5-year overlapping growth rate). The results across various models are presented in Table 1 Appendix 2.

Given the strong potential for endogeneity of the debt variable, especially reverse causation (low or negative growth rates of per-capita GDP are likely to induce higher debt burdens), we use various instrumental variable estimation techniques (see results in Table 2 Appendix 2).

As stated in Hiebert et al. (2002), in a panel context, most studies on growth regressions have made use of the instrumental variable (IV) approach to deal with the issue of simultaneity bias. The estimators used in our paper are either 2-SLS (two-stage least square) or GMM estimators[13]. With the GMM estimator, we also correct for the heteroskedasticity and autocorrelation that may be present in the error structure by using the consistent estimator. The two-step GMM presents some efficiency gains over the traditional IV/2-SLS estimator derived from the use of the optimal weighting matrix, the overidentifying restrictions of the model, and the relaxation of the independent and identical distribution (i.i.d.) assumption, see Baum et al (2007).[14]

We instrument the debt variable for each country through either its time lags (up to the 5th lag) or through the average of the debt levels of the other countries in the sample. Both instruments are highly correlated with the instrumented variable, as shown by the first stage statistics, such as Shea partial R-square. While using lagged terms of regressors as instruments is relatively common practice with macroeconomic data, for the debt-to-GDP ratio, this may be more problematic given the high persistency of the debt stock variable.

[13] As implemented in Stata with the ivreg2 command developed by Baum et al. (2007).

[14] For an exactly identified model, the efficient GMM and traditional IV/2SLS estimators coincide.

Thus, we also calculate for every country and year in the sample the average public debt-to-GDP ratio of the other countries and use this variable as an instrument. As such, this instrument has the advantage of not having a direct causation effect on the growth rate, at least if one assumes that there are no strong spillover effects between debt levels in euro area countries and per-capita GDP growth rate in one specific country. The endogeneity problem is also mitigated in our specification by the fact that the explanatory variables are all lagged 1 or 5 years compared to the dependent variable.

When using the annual GDP growth rate we capture a short-term impact of debt on growth, while for the 5-year specifications, we capture the (more relevant) long-term impact of debt on growth. The latter will also be analysed by using the potential/trend GDP growth rate as a dependent variable (see below the robustness checks).

As summarized in Tables 1 and 2 of the Appendix 2,[15] the results across all models show a highly statistically significant non-linear relationship between the government debt ratio and the per-capita GDP growth rate for the 12 euro area countries included in our sample, starting from 1970 to present. The debt-to-GDP turning point of this concave relationship (inverted U-shape) is roughly between 90 and 100% on average for the sample, across all models. This means that, on average for the 12-euro area countries, government debt-to-GDP ratios above such threshold would have a negative effect on economic growth[16].

In addition, given the persistency of the government debt-to-GDP ratio, we also estimate the models using debt in first differences (in a linear form as the squared term is not significant). We find that the annual change in the government debt-to-GDP ratio is highly statistically significant and negatively associated with the economic growth rate. The negative impact on the annual growth rate of a 1 percentage point acceleration in the yearly change of government debt-to-GDP ratio stands at about -0.10 pp. See Table 3 in Appendix 2 for more details.

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15 Use of other control variables, mentioned above and not shown in the table models, does not change the results.

16 The debt turning points for individual countries are, of course, likely to differ. An estimation of the regression equation by country with the annual growth rate as the dependent variable and using SUREG, seemingly unrelated regression estimator, and small sample statistics, have also been performed. For several countries in the sample, the quadratic relationship is also unveiled. However, due to the fact that the number of observation is relatively small, i.e. a maximum of 41 observations by country using annual data, the results by country are subject to considerable uncertainty and, therefore, they are not reported.

3.1.2 Other robustness checks

a) Controlling for other potentially relevant variables

One additional variable to keep in mind when investigating the relationship between public debt and growth is the stock of private debt. The negative impact of public debt on growth could conceivably be stronger in countries with high private debt burdens. Unfortunately, data on the total private debt stock or at least private external debt[17] are not readily available in a consistent manner for the euro area countries for a longer time span. Instead, for this purpose, we use as an additional control in the growth equation the variable *total domestic credit to the private sector*,[18] the only available for our time span and the country selection, extracted from the World Development Indicators (WDI) database. However, we do not find the variable to be statistically significant in determining growth in our sample across any of our models and its inclusion does not modify significantly the results for public debt (see estimation results in Table 4 Appendix 2).

Implicit and contingent liabilities represent other factors related to public indebtedness, but not reflected in the government debt stock, which may affect economic performance through various channels. These are potential future obligations of the government related to ageing costs, liabilities of the private sector guaranteed by the government, other implicit or explicit obligations that the public sector may incur conditional on future uncertain events. Contingent liabilities become part of public debt once they are called, but markets (as a rule and depending on public availability of data) factor them in the debt premia requested for government borrowing. This may increase interest rates and thus slow down economic growth. Alternatively, high contingent liabilities related to population ageing, if not tackled adequately, may contribute to diverting resources from more productive purposes and thus reduce longer term growth perspectives, i.e. potential GDP growth. Data for contingent liabilities are not available in a consistent manner for the countries and the time span of our sample; consequently, we cannot account directly in our models for these factors. For the ageing-related burden, we account indirectly by using the variable *old dependency ratio* as an explanatory factor for the private saving rate; the variable is found to have a negative impact on private saving, which in turn is likely to contribute to slowing down future economic growth (for more details, see the results in the next chapter for the channel of private saving).

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[17] Data for external debt, total and disaggregated into public and private external debt, are available from the World Bank's WDI (World Development Indicators) database only for developing countries.

[18] The variable, averaged annually over the period 1970-2008, ranges from 40.8% of GDP in Greece to 103.7% of GDP in Luxembourg. The sample annual average is 77% of GDP.

b) Robustness of the polynomial functional form

In addition to the quadratic form of the public debt-to-GDP ratio, we also check for other polynomial functions. Since a linear debt form does not yield significant results, we start by using powers higher than one—in increments of 0.2—and check for polynomial degrees up to power 3. Using different polynomial forms does not change our conclusions: the relationship remains concave (see Chart 1 in Appendix 2) and the debt turning point remains roughly between 90 and 100% of GDP. Using lower powers yields slightly higher debt turning points and the vice versa. For instance, compared to the quadratic form under a basic fixed-effects model that yields a debt turning point of 99.8% of GDP, using a polynomial form with the maximum power of 1.2 yields a debt turning point of 103.9%, while for power 3 we obtain a turning point of 92.7% (see Table 5 in Appendix 2 for more details). As the power approaches 3, the coefficient of the higher-power term remains significant at the 1% level but it becomes very small converging towards zero as we increase the power. Including more than two debt terms in the regression equation (e.g. first, second, and third power) does not yield significant results.

c) Impact of government debt on potential/trend GDP growth rate

As an additional robustness check we investigate the impact of the government debt-to-GDP ratio on potential/trend GDP growth. In this way, we are able to: (i) capture more adequately a long-run impact and avoid cyclical fluctuations; (ii) mitigate the problem of endogeneity and especially reverse causation; (iii) test the robustness of the debt turning point.

We use potential and trend GDP as reported in the AMECO database (Autumn 2009 forecast vintage) based on the European Commission's methodology, and compute annual and 5-year growth rates. Results with the same instrumental variable-models as previously used for the growth rate of real GDP per capita are reported in Table 6 Appendix 2 for the potential GDP growth rate and in Table 7 (same Appendix) for trend GDP. Our conclusions remain robust: we find the same concave relationship, with the variables *debt* and *debt squared* highly statistically significant across all models and with debt turning points in a broadly similar range (the estimation models using the *growth rate of trend GDP* as a dependent variable seem to yield lower turning points at about 82-92% of GDP if 5-year non-overlapping growth rates are used).

d) Confidence intervals for the debt turning point

Estimating various estimated models, we are able to calculate inter-model debt turning points. Tables 2, 6 and 7 in Appendix 2 show that the inter-model simple average for the

turning points stands at about 94% for the GDP per capita growth rate across the instrumental variable models (97% across all models), and 95% and 91% for the potential and trend GDP growth rate, respectively.

In addition to the inter-model ranges, we also calculate confidence intervals for each model turning point.[19] Since the turning point is a non-linear combination (the ratio) of two estimated coefficients—debt and debt squared—multiplied by a scalar (-½), the normal distribution 95% confidence intervals (CI) estimated for each coefficient cannot be used to compute the CI for the turning point. We thus use two alternative approaches to assess the statistical uncertainty surrounding the turning point estimates: the delta method and bootstrapping. These methods are commonly applied to compute the standard error of non-linear functions for which it is too complex to analytically compute the variance[20] [21] (Vance, 2006). The results are reported at the bottom of the estimation tables.

The delta method basically expands a function of random variables (e.g. the ratio) about its mean using (usually a one-step) Taylor approximation, and then computes the variance. Its accuracy depends on the degree of linearity of the derivative function at the point that it is evaluated (Vance, 2006), i.e. it is a good Taylor approximation when the random variable has a high probability of being close enough to its mean. Therefore, the delta method assumes that the coefficients in the model are normally distributed, being influenced by the sample size (Hole, 2007). In our case, we expect the delta method[22] to be more accurate with the regressions using annual data (over 300 observations) than when 5-year averages are used (about 60-80 observations, depending on the model).

The bootstrap method is based on simulations by drawing a large number of samples (in our case, 1000) with replacements, each used to derive the coefficients and calculate the turning

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19 We thank the anonymous reviewer for suggestions in this direction.

20 The ratio of two normally distributed variables has a Cauchy distribution (hence variance is not defined) when the two variables are independent and have a zero mean. As we cannot consider that the distributions of our coefficients for debt and debt square are independent, or that they have a zero mean, the form of the ratio distribution is computationally very complex and not readily available.

21 A study (Hole 2007) comparing various approaches to estimating confidence intervals for the willingness to pay measures (based on the marginal rate of substitution as the ratio of the attribute coefficients) found them to be reasonably accurate and yielding similar results. The delta method was found to be the most accurate when the data is well-conditioned, while the bootstrap was considered more robust to noisy data and misspecification of the model. In addition to the delta and bootstrapping methods, the study also investigates the Fieller and the Krinsky Robb approaches, commonly applied in the willingness to pay literature. The simulation results in Hole (2007) were all based on the condition that a specific discrete choice model (i.e. logit) was the correct model specification. Although expected to yield similar results, further research was called in case of other models.

22 As implemented in Stata using the *nlcom* "Nonlinear combination of estimators" command

points. Confidence intervals are subsequently calculated based on the resulting distribution of the turning points. While bootstrapping relies on relatively few assumptions, the method is to be used with caution when the available sample is small (Vance, 2006). The default bootstrapping method[23] constructs symmetric 95% confidence intervals based on a normal distribution of the turning points. Non-symmetric confidence intervals based on the bias-corrected or percentile bootstrapping can also be obtained to reflect potential skewness in the sampling distribution of the turning points. In our case, the bias is relatively limited, but it is mostly negative so that it tends to skew the confidence intervals towards the lower bound, i.e. the negative effects of debt tend to start at a lower level. With certain models, however, especially with instrumental variables, the bootstrapping procedure, as implemented in Stata, either rendered unstable CI when the simulation was repeated or an estimation of the bootstrapped standard errors was not possible due to "lack of observations". In these cases, the results with the delta method are shown under the reservation that confidence intervals may actually start at a lower level of the lower bound (and may be non-symmetric). Either way, it seems that the resulting 95% confidence intervals for the debt turning point may start as low as 70-80% of GDP, which calls for even more prudent indebtedness policies.

3.2 Channels for the impact of public debt on growth

Another important question relates to the channels through which public debt is likely to have an impact on the economic growth rate. To this end, we investigate the impact of debt on: (i) private saving and private investment (gross fixed capital formation) rate; (ii) public investment (gross fixed capital formation) rate; (iii) total factor productivity (TFP); and (iv) sovereign long-term nominal and real interest rates. We find some evidence for the channels of private saving, public investment, TFP, and interest rates (see the regression results in Tables 1-5 in Appendix 3). For the first three channels – private saving, public investment and TFP – a non-linear relationship (concave) also predominates across the various models used.[24]

We analyse the channel of private saving ratio using the following regression equation:

[23] As implemented in Stata using the *bootstrap* command.

[24] The results appear less robust than in the case of the direct channel between debt and growth (under some specifications, especially the most restrictive ones, the debt term, linear or/and squared, loses significance). This is likely to reflect the fact that public debt may influence economic growth rate through several channels simultaneously.

$$priv.saving.rate_{it} = \alpha_0 + \alpha_1 priv.saving.rate_{it-1} + \gamma_1 debt_{it}^2 + \gamma_2 debt_{it} + other\ control\ variables\ (initial\ level\ GDP/cap;\ economic\ growth\ rate;\ population\ growth;\ tax\ rate;\ credit\text{-}to\text{-}GDP\ ratio;\ old\ and\ young\ people\ dependency\ ratio;\ LT\ interest\ rates;\ openness) + \mu_i + \nu_t + \varepsilon_{it} \qquad (eq.\ 2)$$

where the variable notations are explained above and/or in Appendix 1.

We use a dynamic panel model since the private saving rate is likely to be highly persistent (a similar model is also preferred for private and public investment). In addition to the lagged private saving ratio and the debt variable, the other control variables are the main determinants of saving usually employed in the literature (see for instance Masson et al., 1998, and Schclarek, 2004). Hence, the level of the private saving ratio is assumed to depend also on: (i) the level of income per capita; (ii) demographic shifts and structure as proxied by the growth rate of the population and the ratio of the non-working age population to the working age population, split between old and young dependency ratio; (iii) the level of taxation (proxied by total government revenue as a share of GDP); (iv) the depth of the financial system and other financial indicators, as proxied by the share of domestic private credit in GDP and the long-term interest rate; (v) indicators of openness of the economy to capture the possibility of foreign saving inflows or outflows.

The regression results[25] presented in Table 1 Appendix 3 broadly show a similar non-linear impact of public debt on private saving. Yet, now the turning point in the debt-to-GDP ratio is at lower levels, i.e. between 82% and 91%. Above this threshold range and holding other factors constant, the private sector seems to start dissaving, which may be counter-evidence to the Ricardian equivalence hypothesis. The results could be explained by the fact that private agents may anticipate inflationary pressures and/or troubles in the financial markets and/or transfer capital abroad. As in Masson et al. (1998), other factors that are found to have a robust impact on private saving are demographics (higher old dependency ratios in the euro area countries contribute to a decrease in the private saving rate) and the (lagged) economic growth rate (with a positive impact).

Turning to the channel of private investment, somewhat surprisingly, no (direct) impact of debt on private investment is found; rather the impact may be indirect through the channel of long-term interest rates (as will be shown below). The estimation equation for gross fixed

[25] With the exception of the more restrictive xtlsdv model (least square dummy variable model, a dynamic panel model estimated using the bias-corrected fixed-effects as in Bruno, 2005).

capital formation is as follows:

$$gfcf\_priv = \alpha_0 + \alpha_1 \mathrm{L}.gfcf\_priv + \gamma_1 debt^2 + \gamma_2 debt + \text{other controls (public investment; economic growth rate; initial level of GDP/cap; tax rate; private credit-to-GDP ratio; LT interest rates; openness indicators)} + \mu_i + \nu_t + \varepsilon_{it} \quad \text{(eq. 3)}$$

As shown in Table 2 Appendix 3, the results across various models are neither conclusive nor robust, the debt variables turning mostly insignificant.

Switching to public investment (government gross fixed capital formation), the following regression equation is proposed:

$$gfcf\_gov = \alpha_0 + \alpha_1 \mathrm{L}.gfcf\_gov + \gamma_1 debt^2 + \gamma_2 debt + \text{other controls (private investment; economic growth rate; initial level of GDP/cap; gov. budget balance; LT interest rates; openness indicators)} + \mu_i + \nu_t + \varepsilon_{it} \quad \text{(eq. 4)}$$

The results are broadly robust across various models and point to a similar concave relationship between public debt and public investment, yet with a turning point ranging from 45% of GDP to 68% of GDP. Above this threshold range, the negative association between public debt and public investment can be explained by the fact that, in their consolidation efforts, governments may tend to cut expenditure allotted for public investment, including maintenance of public infrastructure. Such a pattern is also documented in Chalk and Tanzi (2002).

As in Pattillo et al. (2002) and Schclarek (2004), we also analyse the impact of debt on total factor productivity (TFP), according to the following regression equation:

$$TFP = \alpha_0 + \alpha_1 \mathrm{L}.\mathrm{TFP} + \gamma_1 debt^2 + \gamma_2 debt + \text{other controls (lagged economic growth rate; population growth rate; old and young dependency ratio; private credit-to-GDP ratio; LT interest rates; openness indicators)} + \mu_i + \nu_t + \varepsilon_{it} \quad \text{(eq. 5)}$$

The estimation results, presented in Table 4 Appendix 3, point to a similar concave relationship between public debt and TFP, this time the turning point, beyond which debt affects TFP negatively, being higher, i.e. above 100% of GDP.

Finally, as regards the potential impact of public debt on long-term (LT) sovereign interest rates, the following regression equations are proposed for nominal and, respectively, real interest rates.

$$LT\_nom_i = \alpha_0 + \alpha_1 ST\_nom_i + \gamma_1 D.debt + \text{other controls (inflation rate; gov. primary balance; lagged economic growth rate; output gap; external balance and openness indicators)} + \mu_i + \nu_t + \varepsilon_{it} \quad \text{(eq. 6)}$$

The estimation equation for real LT sovereign interest rates is similar:

$$LT\_real_i = \alpha_0 + \alpha_1 ST\_real_i + \gamma_1 D.debt + \text{other controls (gov. primary balance; lagged economic growth rate; output gap; external balance and openness indicators)} + \mu_i + \nu_t + \varepsilon_{it} \quad \text{(eq. 7)}$$

While a non-linear impact of the public debt-to-GDP ratio is mostly unveiled for the first three channels, a strong and robust impact on sovereign long-term nominal as well as real interest rates is found to come from the change in the debt ratio (first difference) and from the primary budget balance ratio. The level of the public debt ratio (in either linear or quadratic forms) is not found to be significant on average in determining long-term interest rates in our sample. The change in the public debt ratio and the primary budget balance prove to be highly statistically significant and remain robust even after controlling for short-term interest rates (the latter variable, which is highly correlated with long-term interest rates, is included in the regression estimation in order to capture monetary policy effects). A one percentage point acceleration in the change of public debt ratio appears to determine on average an increase in the sovereign long-term real interest rate for our sample by about 7 basis points (see Table 5.1. in Appendix 3) and in nominal interest rates by 11 basis points (see Table 5.2. in Appendix 3). While the results regarding the relationship between public debt/government balance and the long-term interest rates need further investigation, they are broadly in line with conclusions of recent studies such as Ardagna et al. (2007) and Laubach (2009).

4. Conclusions and areas for further research

This analysis finds evidence for a non-linear impact of public debt on per-capita GDP growth rate across twelve euro area countries over a long period of time starting in 1970. It unveils a concave (inverted U-shape) relationship between the public debt and the economic growth rate with the debt turning point at about 90-100% of GDP. This means that a higher public debt-to-GDP ratio is associated, on average, with lower long-term growth rates at debt levels above the range of 90-100% of GDP. The long-term perspective is reinforced by the evidence of a similar impact of the public debt on the potential/trend GDP growth rate. From

an econometric perspective, the paper deals with the potential endogeneity problem, in particular with the issue of simultaneity or reverse causation, in various ways including: (i) using 1-year and 5-year forward growth rates, as well as the potential and trend GDP growth rates, to mitigate/eliminate the impact of the economic cycle; (ii) using a quadratic relationship in debt, while the linear one (which would be implied by the converse relation, i.e. lower economic growth induces, ceteris paribus, a higher debt-to-GDP ratio) is not found to be significant; (iii) using instrumental variable estimation models.

The public debt threshold of 90-100% of GDP is an average for the (12-country) euro area and its statistical confidence may go as low as 70% of GDP. This suggests that for many countries current debt levels already may have a detrimental impact on GDP growth, given that the euro area average debt-to-GDP ratio (estimated to increase from 78.7% in 2009 to 88.5% in 2011) is already above the lower threshold. This evidence constitutes an additional warning signal for policy-makers (this time from a long-term growth perspective).

Annual changes in the debt level (first difference of the debt ratio) are also found to be negatively associated with annual economic growth rate.

The channels through which public debt is likely to have an impact on economic growth rate seem to be private saving, public investment, total factor productivity, and sovereign long-term nominal and real interest rates.

The question remains whether public debt is indeed associated with higher growth below the 90-100% turning point. This is a relevant issue even in view of the additional evidence in this analysis, showing that the debt turning points for the first two channels (private saving and public investment) seem to be much below the range of 90-100%. A possible explanation for a positive impact of higher debt (i.e. accumulated past deficits) on growth would be if those deficits were used to finance productive public investment. However, empirically, a large part of the debt increases of the past decades are related to higher public consumption and transfers. Taking this into account, a potential link could lie in the extent of past absorption of adverse exogenous shocks by governments, which were not compensated by debt-reducing measures afterwards. If such shocks result in a lower growth potential, their absorption via higher deficits may arguably provide an explanation of the above results.

Yet, government budget deficits are found to be linearly and negatively associated with the growth rate of both real and potential output. The fact that the change in the debt ratio and the budget deficits are linearly and negatively associated with growth (and with the long-term interest rates) may point to a more detrimental impact of the public debt stock even below the threshold. Hence, targeting a higher debt level to support growth is not a policy option. Any

policy with such a target would reduce the leeway of governments before the debt burden has an unmistakably adverse growth impact.

In the current economic environment, the results represent an additional argument in favour of swiftly implementing ambitious strategies for debt reduction. If policy makers let high debt ratios linger for fear that fiscal consolidation measures will be unpopular with voters, this will undermine growth prospects and thus will put an additional burden on fiscal sustainability. This debt-based argument thus adds to the positive growth effects of fiscal deficit reduction found in the literature for the long term and frequently also in the short term.[26]

It should be noted that the econometric results and the economic interpretation rest on the analysis of the long time period since 1970. Thus they apply to what could be broadly called "normal" economic times, some short-term disruptions in past decades notwithstanding. Recent fiscal and financial market developments for some countries carry characteristics of crisis situations which call for emergency policy responses. While, ideally, the long-term economic relationships established in the literature should provide the basis also for such short-term policy strategies, their value for concrete policy decisions may be more limited.

[26] See Alesina and Ardagna (2009).

References:

Adam, C. S. and D. L. Bevan (2005), "Fiscal deficits and growth in developing countries", Journal of Public Economics, Vol. (4), pp. 571-597.

Agénor, P-R and P. Montiel (1996), Development Macroeconomics, Princeton University press.

Alesina, A. and S. Ardagna (2009), Large changes in fiscal policy: taxes versus spending, NBER Working Paper No 15438.

Aizenman, J., K. Kletzer and B. Pinto (2007), Economic growth with constraints on tax revenues and public debt: implications for fiscal policy and cross-country differences, NBER Working Paper 12750.

Ardagna, S., F. Caselli and T. Lane (2007) "Fiscal Discipline and the Cost of Public Debt Service: Some Estimates for OECD Countries," The B.E. Journal of Macroeconomics: Vol. 7: Iss. 1 (Topics), Article 28.

Aschauer, D. A. (2000). "Do states optimize? Public capital and economic growth." The Annals of Regional Science, 34(3), pp 343-363.

Attinasi, M. G., C. Checherita, C. Nickel (2009), What explains the surge in euro area sovereign spreads during the financial crisis of 2007-09?, ECB Working Paper no. 1131/2009.

Barrios, S., P. Iversen, M. Lewandowska and R. Setzer (2009), Determinants of intra-euro area government bond spreads during the financial crisis, European Economy. Economic Papers 388.

Baum, C. F., M. E. Schaffer, and S. Stillman (2007), ivreg2: Stata module for extended instrumental variables/2SLS, GMM and AC/HAC, LIML, and k-class regression. Boston College Department of Economics, Statistical Software Components S425401. Downloadable from http://ideas.repec.org/c/boc/bocode/s425401.html.

Bruno, G. (2005). "Approximating the bias of the LSDV estimator for dynamic unbalanced panel data models", Economics Letters 87(3), pp. 361-366

Buchanan, J. M. (1958), Public Principles of the Public Debt, Homewood, Illinois.

Chalk, N. and V. Tanzi (2004), "Public debt and economic growth. Channels of the long-term impact" in "The behaviour of fiscal authorities: stabilisation, growth and institutions", edited by M. Buti, J. von Hagen and C. Martinez-Mongay.

Clements, B., R. Bhattacharya and T. Q. Nguyen (2003), External debt, public investment, and growth in low-income countries, IMF Working paper 03/249.

Codogno, L., C. Favero, and A. Missale (2003), "Yield spreads on EMU government bonds", Economic Policy, October, pp. 505–532.

Cohen, D. (1993), "Low Investment and Large LDC Debt in the 1980s," American Economic Review, Vol. 83 (3), pp. 437–49.

Cohen, D. (1997), Growth and external debt: A new perspective on the African and Latin American tragedies, Centre for Economic Policy Research Discussion Paper No. 1753.

Diamond, P. (1965), "National Debt in a Neoclassical Growth Model", American Economic Review, 55 (5), pp. 1126-1150.

Dixit, A. and R. Pindyck (1994), Investment under uncertainty, Princeton University Press.

Elmendorf, D. and N. Mankiw (1999). "Government Debt", in Taylor, J. and Woodford, M. (eds.), Handbook of Macroeconomics, vol. 1C, 1615-1669, North-Holland.

European Commission (2009a), Sustainability Report 2009, European Economy, No. 9.

European Commission (2009b), European Economic Forecast Autumn 2009, European Economy, No. 10.

Hamilton, E.J. (1947), "Origin and Growth of the National Debt in Western Europe", The American Economic Review, Vol. 37(2), Papers and Proceedings of the Fifty-ninth Annual Meeting of the American Economic Association, pp. 118-130.

Hiebert P., A. Lamo, D. R. de Avila, and J. P. Vidal (2002), "Fiscal Policies and Economic Growth in Europe: An Empirical Analysis", Paper presented at the 2002 Banca d'Italia Public Finance Workshop on the Impact of Fiscal Policy.

Hole A. R. (2007), "A Comparison of Approaches to Estimating Confidence Intervals for Willingness to Pay Measures", Health Economics, Vol. 16, pp. 827–840.

Krugman, P. (1988), Financing vs. forgiving a debt overhang: Some analytical issues, NBER Working Paper No. 2486.

Kumar, M. and J. Woo (2010), Public Debt and Growth, IMF Working Paper 10/174.

Laubach, T. (2009), "New Evidence on the Interest Rate Effects of Budget Deficits and Debt", Journal of the European Economic Association, Vol. 7(4), pp. 858-885.

Masson, P. R., T. Bayoumi and H. Samiei (1998), "International Evidence on the Determinants of Private Saving", The World Bank Economic Review, Vol. 12 (3), pp. 483-501.

Meade, J. E. (1958), "Is the National Debt a Burden?" Oxford Economic Papers, New Series, Vol. 10(2), pp. 163-183.

Modigliani, F. (1961), "Long-Run Implications of Alternative Fiscal Policies and the Burden of the National Debt", Economic Journal, 71 (284), pp. 730-755.

Pattillo, C., H. Poirson, and L. Ricci (2002), External Debt and Growth, IMF Working Paper 02/69.

Reinhart, C. M. and K. S. Rogoff (2009), "The Aftermath of Financial Crisis", American Economic Review, Vol. 99(2), pp. 466-472.

Reinhart, C. M. and K. S. Rogoff (2010), "Growth in a Time of Debt", NBER Working Paper No. 15639.

Saint-Paul, G. (1992), "Fiscal policy in an Endogenous Growth Model", Quarterly Journal of Economics, No. 107, pp. 1243-1259.

Schclarek, A. (2004), Debt and Economic Growth in Developing Industrial Countries, mimeo.

Schuknecht, L., J. von Hagen and G. Wolswijk (2009), Government Bond Risk Premiums in the EU revisited: The Impact of the Financial Crisis, CEPR paper No. 7499.

Smyth, D. and Hsing, Y. (1995), "In search of an optimal debt ratio for economic growth", Contemporary Economic Policy, 13:51–59.

Tanzi, V. and L. Schuknecht (1997), "Reconsidering the Fiscal Role of Government: The International Perspective", The American Economic Review, Vol. 87, No. 2, Papers and Proceedings of the Hundred and Fourth Annual Meeting of the American Economic Association, pp. 164-168.

Vance, C. (2006), Marginal Effects and Significance Testing with Heckman's Sample Selection Model: A Methodological Note, RWI Essen: Discussion Papers no. 39.

Appendix 1

Table 1: Data description and sources

Variable abbrev.	Variable name/description	Source
gov_debt	Gross government debt (% GDP)	AMECO
gov_bal	Government budget balance (% of GDP)	AMECO
gov_primary_bal	Government budget primary balance (excl. interest payments; % of GDP)	AMECO
gov_cab	Cyclically adjusted gov. balance (% of GDP at market prices)	AMECO
gov_rev_ca	Cyclically adjusted gov. revenue (% of GDP at market prices)	AMECO
GDP_cap	GDP at 2000 market prices per head of population (1000 euro)	AMECO
PotentialGDP	Potential gross domestic product at 2000 market prices (bill. EUR)	AMECO
TrendGDP	Trend gross domestic product at 2000 market prices (bill. EUR)	AMECO
pop_growth	Total population - growth rate	AMECO
openness	Calculated as sum of exports and imports (% of GDP)	AMECO
CA_bal	Current account balance (% GDP)	AMECO
gfcf_total	Gross fixed capital formation: total economy (% GDP)	AMECO
gfcf_gov	Gross fixed capital formation: general government (% GDP)	AMECO
gfcf_priv	Gross fixed capital formation: private sector (% GDP)	AMECO
saving_total	Gross national saving: total economy (%GDP)	AMECO
saving_pub	Gross saving: general government (% GDP)	AMECO
saving_priv	Gross saving: private sector (% GDP)	AMECO
reer	Real effective exchange rate, based on ULC, relative to rest 23 industrial countries	AMECO
LT_nom_i	Nominal long-term (LT) interest rates, sovereign (mostly central government LT bond yields)	AMECO
LT_real_i	Real long-term interest rates, sovereign; deflator: GDP at market prices	AMECO
ST_nom_i	Nominal short-term (ST) interest rates (3M-EURIBOR after 1999)	AMECO
ST_real_i	Real short-term interest rates; deflator: GDP at market prices	AMECO
Inflation (GDPdefl.)	Annual rate of change in GDP deflator at market prices	AMECO
output_gap	Gap between actual and trend GDP at 2000 market prices/trend GDP	AMECO
old_dep_ratio	Age dependency ratio, old (% of population over 65 in working-age population)	WDI
young_dep_ratio	Age dependency ratio, young (% of population under 15 in working-age population)	WDI
credit_priv	Domestic credit to private sector (% of GDP)	WDI
TFP_g	Growth rate of Total Factor Productivity (TFP), calculated based on *TFP_index* (2000=100)	AMECO

Note: Sources of basic data are the European Commission's AMECO database and the World Bank's World Development Indicators (WDI)

In the regression tables presented in Appendix 2, the following symbols are also annexed to several variables: L. (denotes the first time lag of variable); ln (natural logarithm of variable); _sq (square term of variable); _g (annual growth rate of variable); _5yg (5-year overlapping growth rate of variable).

Appendix 2: Direct relationship between debt and per-capita GDP growth

Table 1: Fixed effects (FE) models

FE models	Annual growth rate		Cumulative 5 year overlapping growth rate		Cumulative 5 year non-overlapping growth rate	
Variables	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**	**model 6**
gov_debt	0.1198***	0.1291***	0.5236***	0.4066**	0.6462***	0.5032**
	(.0410)	(.0412)	(.1294)	(.1649)	(.1396)	(.2095)
gov_debt_sq	-0.0006***	-0.0006***	-0.0025***	-0.0020***	-0.0031***	-0.0026**
	(.0001)	(.0002)	(.0006)	(.0008)	(.0007)	(.0011)
gov_rev_ca	-0.0511	-0.094	-0.3112	-0.1906	-0.3297	-0.2227
gov_cab	0.2484***	0.3083***	1.1756***	0.9392**	1.3120***	1.1244
ln_GDP_cap	0.5403	-0.0036	-9.704	-20.5168**	-7.9847	-14.2007
pop_growth	-1.3086***	-1.1997**	-3.6186***	-2.7678*	-3.6534**	-3.9632*
gfcf_total	0.0087	-	-	-		-
gfcf_gov	-	0.3988***	0.6483	-	0.4319	-
gfcf_priv	-	-0.047	-0.4018**	-	-0.4034*	-
saving_pub	-	-	-	-0.4572		-0.4535
saving_priv	-	-	-	0.0601		0.0266
openness	0.0307**	0.0341**	0.1975***	0.1643***	0.1622*	0.1338
LT_real_i	0.0234	0.0017	0.1974	-0.1935	0.0758	-0.3489
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (36) (1971-2006)	Included (36) (1971-2006)	Included (7) (1975-2005)	Included (7) (1975-2005)
Country dummies	Included (12)	Included (12)	Included (12)	Included (12)	Included (12)	Included (12)
_cons	-0.8206	-0.0238	37.1960**	61.3611**	33.9344	46.2412
N	412	406	382	314	81	68
R2-within	0.62	0.62	0.73	0.76	0.84	0.85
AR correction	lag(2)	lag(2)	lag(5)	lag(5)	lag(2)	lag(2)
debt turning point	**97.8**	**103.1**	**104.5**	**99.9**	**104.6**	**98.2**
95% CI bootstrap						
- normal-based CI	**(75; 120)**	**(83; 124)**	**(94; 114)**	**(85; 114)**	-	-
- percentile CI	**(73; 116)**	**(81; 123)**	**(93; 114)**	**(83; 112)**	**(77; 149)**	-
- bias-corrected CI	**(70; 114)**	**(79; 121)**	**(72; 114)**	**(87; 114)**	**(73; 138)**	-
95% CI nlcom	**(76; 118)**	**(82; 123)**	**(86; 122)**	**(80; 118)**	**(85; 123)**	**(75; 121)**

Note: The dependent variable is the economic growth rate (annual; cumulative 5-year overlapping, and respectively, cumulative 5-year non-overlapping). The abbreviations for the explanatory variables are explained in Table 1, Appendix 1. Countries included in the analysis: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. The table shows the estimated coefficients and their significance level (*10%; **5%, ***1%). For the main variable of interest—government debt—and its square, standard errors (SE) are also shown in parentheses. The confidence intervals (CI) of the debt turning point are generated through bootstrapping based on (i) a normal distribution; (ii) percentile distribution; (iii) bias-corrected distribution. Where CI are not shown, the bootstrapping procedure rendered unstable CI or an estimation of the bootstrapped SE was not possible due to "lack of observations". The *nlcom* command implements the delta method to calculate CI.

Table 2: Instrumental variable (IVREG) models

IVREG models	Annual growth rate		Cumulative 5 year overlapping growth rate			Cumulative 5 year non-overlapping growth rate		
Variable	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**	**model 6**	**model 7**	**model 8**
Instruments/	Avg. gov debt(n-i)	L(1/5).gov debt	Avg. gov debt(n-i)	L(1/5).gov debt	Avg. gov debt (n-i)	Avg. gov debt(n-i)		L(1/2).gov
Estimator	2SLS	2SLS	2SLS	GMM	GMM (h.a.)	2SLS	GMM	2SLS
gov_debt	0.0535*	0.1194***	0.3141***	0.7552***	1.4400***	0.4104***	0.4104**	0.7959***
	(.0291)	(.0374)	(.0831)	(0.1168)	(.4928)	(.1575)	(.1684)	(.2918)
gov_debt_sq	-0.0003**	-0.0006***	-0.0016***	-0.0038***	-0.0076***	-0.0022***	-0.0022***	-0.0039***
	(.0001)	(.0002)	(.0003)	(0.0005)	(.0027)	(.0007)	(.0005)	(.0013)
gov_rev_ca	0.0687	0.0089	-0.1081	-0.5657***	-0.9871	-0.1544	-0.1544	-0.6953*
gov_cab	0.1830**	0.2320***	0.8760***	1.2778***	1.2469**	1.1135**	1.1135*	1.1392*
ln_GDP_cap	0.1817	2.2802	-23.693***	-13.2096**	-45.744***	-4.0697***	-4.0697***	-2.8750**
pop_growth	-1.8422***	-1.7004***	-3.0004***	-2.0007***	2.401	-3.9632***	-4.0596***	-2.8196**
saving_pub	-0.0178	-0.0071	-0.4773*	-0.4700*	0.2328	-0.5302	-0.5302	-0.2405
saving_priv	0.1469***	0.1168**	0.1082	-0.0897	-0.3331	0.0695	0.0695	-0.3459
openness	0.0201***	0.0169**	0.1642***	0.1374***	0.1433**	0.1344***	0.1344**	0.1192***
LT_real_i	-0.2295***	-0.2175***	-0.2353	-0.2353	0.3721	-0.3714	-0.3714	-0.4636
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (36) (1971-2006)	Included (36) (1971-2006)	-	Included (7) (1975-2005)	Included (7) (1975-2005)	Included (7) (1975-2005)
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)
_cons	-4.529	-8.7638*	67.8248***	55.1877***	140.0319***	54.6590**	54.6590**	35.5593
N	338	319	314	314	314	68	68	59
R2-adj	0.67	0.67	0.76	0.881	0.21	0.77	0.77	0.81
Shea partial R-sq	0.89	0.64	0.88	0.65	-	0.86	0.86	0.33
debt turning point	**81.2**	**93.1**	**96.7**	**99.8**	**94.5**	**95.2**	**95.2**	**99.8**
95% CI nlcom	**(49; 113)**	**(77; 108)**	**(80; 112)**	**(93; 106)**	**(83; 105)**	**(70; 119)**	**(72; 118)**	**(84; 118)**

Note: The variable *gov_debt* is instrumented for each country through either its time lags (up to the 5th lag; *L(1/5).gov debt*) or through the average of the debt levels of the other countries in the sample, *Avg. gov debt(n-i).*
Models 1, 2, 3, 6, 8 are estimated through 2SLS (two-stage least squares); Models 4 and 7 through the heteroskedastic-efficient two-step GMM (generalised method of moments) estimator; Model 5 through GMM with heteroskedasticity and autocorrelation-consistent statistics.

Table 3: Regression results with debt in first difference (FE models)

FE models (debt in first difference D1.)	Annual growth rate		Cumulative 5-year overlapping growth rate	Cumulative 5-year non-overlapping growth rate
Variables	**model 1**	**model 2**	**model 3**	**model 4**
D1.gov_debt	-0.1106** (0.0525)	-0.0950** (0.0410)	-0.2302* (0.1269)	-0.1178 (.0938)
D1.gov_debt_sq	0.0022		-	-
gov_rev_ca	-0.0156	-0.0174	0.1011	0.1861
gov_cab	0.0915	0.0944*	0.6058	0.9803
ln_GDP_cap	-4.2250***	-4.1936***	-31.6788***	-30.7624**
pop_growth	-1.3455***	-1.3436***	-3.1521**	-3.9527**
gfcf_gov	0.3179**	0.3177**	-	-
gfcf_priv	-0.0496	-0.0523	-	-
saving_pub			0.1580***	-1.1139
saving_priv			-0.247	0.2737
openness	0.0401***	0.0409***	0.1580***	0.1321
LT_real_i	0.0199	0.0227	-0.247	-0.4599
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (36) (1971-2006)	Included (7) (1975-2005)
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)
_cons	14.3755***	14.3649***	34.7731*	38.2277*
N	406	406	382	81
R2-within	0.60	0.60	0.74	0.83
AR correction	lag(2)	lag(2)	lag(5)	lag(2)

Robustness checks

a) Controlling for private credit

Table 4: Estimation results from regression equations controlling for variable *credit_priv*

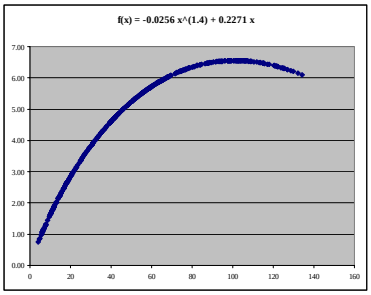
	Annual growth rate			
Variable	**model 1**	**model 2**	**model 3**	**model 4**
Instruments/ Estimator	- FE	L(1/5).govdebt 2SLS	Avg. govdebt(n-i) GMM (h.a.)*	Avg. govdebt(n-i) GMM (h.a.)*
Variable				
gov_debt	0.1263*** (0.0451)	0.1372*** (0.0488)	0.2093* (0.1163)	0.3327*** (0.1113)
gov_debt_sq	-0.0006*** (0.0002)	-0.0007*** (0.0002)	-0.0012* (0.0006)	-0.0018*** (0.0006)
credit_priv	-0.0021	0.0051	-0.0111	-0.0203*
ln_GDP_cap	0.1051	2.5697	-5.0043*	-3.7716*
gov_ca_rev	-0.0916	0.0116	-0.0306	-0.2646**
gov_cab	0.3029***	0.2114**	0.3697***	0.6557***
pop_growth	-1.1910**	-1.7718***	-0.957	-0.7651
gfcf_gov	0.3909**	-	-	0.8307***
gfcf_priv	-0.0479	-	-	-0.0344
saving_pub	-	0.0409	0.0491	-
saving_priv	-	0.1379***	0.2063*	-
openness	0.0343**	0.0155*	-0.0035	0.0098
LT_real_i	-0.0035	-0.2427***	-0.1989*	0.0524
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	-	-
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)
_cons	1.3521	-8.7638*		
N	400	313	332	400
R2-adj	0.67	0.64	-	-
Shea partial R-sq (1st stage)	-	0.64	0.89	0.89
debt turning point	**103.0**	**98.0**	**87.2**	**90.9**
95% CI nlcom	**(81; 124)**	**(80; 111)**	**(72; 101)**	**(80; 102)**

b) Robustness of the polynomial functional form

Chart 1: Plots of the economic growth rate as a function of public debt (various polynomial forms)

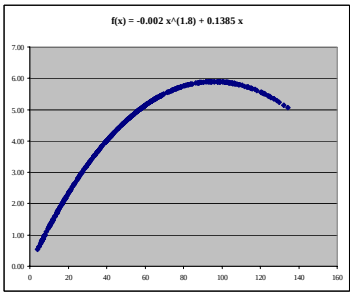
Power 1.4

$f(X) = -0.0256\ X^{1.4} + 0.2271\ X$



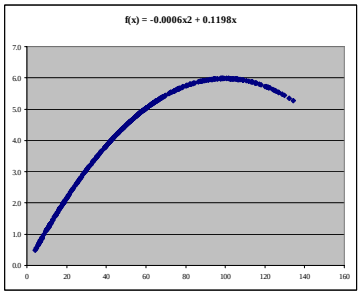
Power 1.8

$f(X) = -0.002\ X^{1.8} + 0.1385\ X$



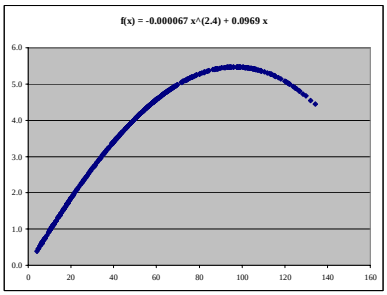
Power 2 (basic model)

$f(X) = -0.0006\ X^{2} + 0.1198\ X$



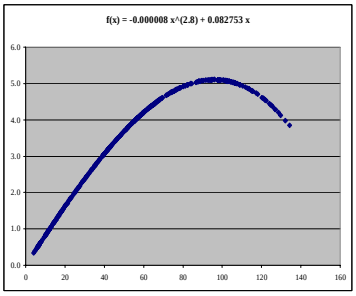
Power 2.4

$f(X) = -0.000067\ X^{2.4} + 0.0969\ X$



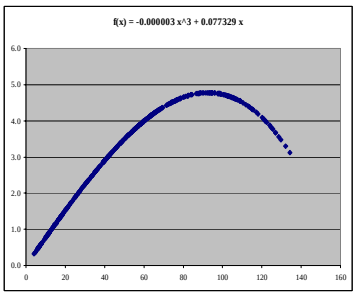
Power 2.8

$f(X) = -0.000008\ X^{2.8} + 0.0827\ X$



Power 3

$f(X) = -0.000003\ X^{3} + 0.077329\ X$



Note: The third plot (power 2) represents the basic model with estimated coefficients for debt and debt squared as in model 1 FE in Table 1, Appendix 2. The coefficients for the other functional forms are derived based on the same regression model. All graphs plot the annual economic growth rate against the government debt-to-GDP ratio for the pooled observations (412 in total; 12 countries over 1970-2009).

Table 5: Various functional forms and the resulting debt turning points

powers	turning point	coefficient power-term
1.2	103.9	-0.1315***
1.4	101.1	-0.0256***
1.6	98.7	-0.0067***
1.8	95.8	-0.0020***
2	**99.8**	**-0.0006*** **
2.2	97.1	-0.0002***
2.4	96.8	-0.0001***
2.6	96.2	-0.000023***
2.8	95.9	-0.000008***
3	92.7	-0.000003***

Note: The table shows various polynomial forms for the economic growth rate as a function of government debt-to-GDP ratio, as well as the resulting debt turning points and coefficients of the power-terms. The latter are the estimated regression coefficients according to model 1 FE in Table 1, Appendix 2. The significance level of the power-term coefficients is also indicated (***1%).

c) Estimation results with potential/trend GDP growth rate as dependent variable

Table 6: Results with potential GDP growth rate

IVREG models	Annual growth rate		Cumulative 5 year overlapping growth rate			Cumulative 5 year non-overlapping growth rate		
Variable	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**	**model 6**	**model 7**	**model 8**
Instruments/	Avg. govdebt(n-i)	L(1/5).govdebt	Avg. govdebt (n-i)	L(1/5).govdebt	Avg. govdebt (n-i)	Avg. govdebt(n-i)		L(1/2).govdebt
estimator	2SLS	2SLS	2SLS	GMM	GMM (h.a.)*	2SLS	GMM	2SLS
gov_debt	0.0967***	0.1631***	0.6145***	0.8185***	2.1360***	0.5526***	0.5526***	0.7817**
	(0.0158)	(0.0220)	(0.0745)	(0.1387)	(0.7369)	(0.1386)	(0.1388)	(0.3143)
gov_debt_sq	-0.0005***	-0.0008***	-0.0032***	-0.0042***	-0.0112***	-0.0031***	-0.0031***	-0.0041***
	(0.0001)	(0.0001)	(0.0003)	(0.0006)	(0.0039)	(0.0006)	(0.0006)	(0.0014)
gov_rev_ca	-0.2622	1.9585*	-0.5008***	-0.6714***	-2.0188**	-0.4538**	-0.4538**	-0.7185**
gov_cab	-0.0748***	-0.1221***	0.7100***	0.8880***	1.1670*	1.4134***	1.4134**	1.3432**
ln_potentialGDP	0.0566	0.0835*	-15.0818***	-7.3414	-44.7146***	-20.9597**	-20.9597**	-15.273
pop_growth	0.4997***	0.5932***	0.8701	1.3671	8.7907*	1.7362	1.7362	2.5970**
saving_pub	0.1652***	0.2229***	0.2762	0.3658	0.8647	-0.5625	-0.5625	-0.2647
saving_priv	0.0676***	0.0538**	-0.0084	0.064	-0.9003	-0.0748	-0.0748	-0.2751
openness	0.0145***	0.0107**	0.1675***	0.1306***	0.1731**	0.1779***	0.1779***	0.1512***
LT_real_i	-0.1296***	-0.1068***	-0.2922**	-0.1709	0.6557	-0.3886	-0.3886	-0.5796**
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (36) (1971-2006)	Included (36) (1971-2006)	-	Included (7) (1975-2005)	Included (7) (1975-2005)	Included (7) (1975-2005)
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)
_cons	2.5453	-14.2002**	82.9331***	47.6307	261.1700***	115.9797***	115.9797***	84.9594
N	338	319	314	295	314	68	68	59
R2-adj	0.76	0.75	0.85	0.81	-	0.82	0.82	0.84
Shea partial R-sq (1st stage)	0.90	0.60	0.89	0.60	-	0.89	0.89	0.25
debt turning point	**99.2**	**102.8**	**94.9**	**97.8**	**95.2**	**88.6**	**88.6**	**95.1**
95% CI nlcom	**(87; 110)**	**(95; 110)**	**(87; 103)**	**(90; 105)**	**(85; 104)**	**(70; 107)**	**(71; 106)**	**(76; 114)**

Note: The IVREG models are the same as the ones used in Table 2, Appendix 2.

Table 7: Results with trend GDP growth rate

IVREG models	Annual growth rate		Cumulative 5 year overlapping growth rate			Cumulative 5 year non-overlapping growth rate		
Variable	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**	**model 6**	**model 7**	**model 8**
Instruments/ estimator	Avg. govdebt(n-i) 2SLS	L(1/5).govdebt 2SLS	Avg. govdebt (n-i) 2SLS	L(1/5).govdebt GMM	Avg. govdebt (n-i) GMM (h.a.)*	Avg. govdebt(n-i) 2SLS	Avg. govdebt(n-i) GMM	L(1/2).govdebt 2SLS
gov_debt	0.0762***	0.1220***	0.4653***	0.8185***	2.2108***	0.4261***	0.4261***	0.7344***
	(0.0143)	(0.0195)	(0.0644)	(0.1169)	(0.8507)	(0.1149)	(0.1150)	(0.2616)
gov_debt_sq	-0.0004***	-0.0006***	-0.0026***	-0.0042***	-0.0115**	-0.0026***	-0.0026***	-0.0040***
	(0.0001)	(0.0001)	(0.0003)	(0.0005)	(0.0045)	(0.0005)	(0.0006)	(0.0012)
gov_rev_ca	-0.0671***	-0.0991***	-0.3543***	-0.6714***	-2.0871**	-0.4205**	-0.4205***	-0.6277**
gov_cab	0.1040**	0.1244***	0.8053***	0.8880***	1.2041*	1.3469***	1.3469**	1.4239***
ln_trendGDP	-0.8566	0.6673	-18.7782***	-7.3414	-46.3692***	-25.5530***	-25.5530***	-16.325
pop_growth	0.1939	0.2935**	-0.3864	1.3671	8.6807*	0.6659	0.6659	1.4199
saving_pub	0.0672	0.1010*	0.0734	0.3658	0.9191	-0.6358	-0.6358	-0.3794
saving_priv	0.0335	0.0215	0.0159	0.064	-1.0228	-0.1396	-0.1396	-0.2967
openness	0.0129***	0.0098**	0.1244***	0.1306***	0.1504	0.1595***	0.1595***	0.1286***
LT_real_i	-0.0939***	-0.0832***	-0.2836**	-0.1709	0.7961*	-0.2768	-0.2768	-0.4287*
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (36) (1971-2006)	Included (36) (1971-2006)	-	Included (7) (1975-2005)	Included (7) (1975-2005)	Included (7) (1975-2005)
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)	Included (11)
_cons	6.928	0.0259	100.6667***	47.6307	273.5729***	141.4961***	141.4961***	91.4312
N	338	319	314	295	314	68	68	59
R2-adj	0.76	0.76	0.86	0.81	-	0.82	0.82	0.84
Shea partial R-sq (1st stage)	0.91	0.62	0.90	0.60	-	0.89	0.89	0.25
debt turning point	**94.2**	**98.8**	**90.8**	**93.0**	**95.8**	**83.0**	**83.0**	**91.0**
95% CI nlcom	**(91; 107)**	**(90; 107)**	**(81; 100)**	**(84; 102)**	**(86; 105)**	**(64; 102)**	**(65; 101)**	**(73; 108)**

Note: The IVREG models are the same as the ones used in Table 2, Appendix 2.

Appendix 3: Analysis of channels through which public debt may influence economic growth

Table 1: The channel of private saving

DV: Private saving (% GDP)

Variable	model 1 (Abond)	model 2 (Abond)	model 3 (FE)	model 4 (xtlsdv)
L.saving_priv	0.3740***	0.4687***	-	0.8053***
L.gov_debt	0.1270***	0.1144***	0.0840*	0.0240
	(0.0246)	(0.0382)	(0.0445)	(0.0239)
L.gov_debt_sq	-0.0007***	-0.0007***	-0.0005**	-0.0001
	(0.0002)	(0.0003)	(0.0002)	(0.0001)
L.GDP_cap_g	0.2923***	-	0.3726***	0.2392***
L.ln_GDP_cap	-	-4.3723	-	-
L.gov_rev_ca	0.0257	0.1104**	-0.3691***	
L.pop_growth	0.9432***	0.2123	1.2480**	0.4413
L.credit_priv	-0.0171	-0.0166	-0.0284**	-0.0022
L.old_dep_ratio	-0.4826*	-0.4878**	-0.5091***	-0.2666**
L.young_dep_ratio	0.1002	-0.0099	0.3186***	0.0693
L.LT_real_i	0.0434	-0.0264	0.3600***	0.0771
L.openness	-0.0421**	-0.0263	0.0078	-0.0098
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)
Country dummies	-	-	Included (11)	Included (11)
_cons	19.4582***	27.4620*	46.2809***	
N	313	313	339	332
R-within	-	-	0.65	Bias correction up to order
AR correction	-	-	lag(2)	O(1/NT^2)
Instruments DV	Lag(2/6)	Lag(2/4)	-	-
ABond test for AR in first-differenced errors				
AR(1) test; p-value	0.0144	0.0166	-	-
AR(2) test; p-value	0.4210	0.2834	-	-
debt turning point	**92.8**	**81.1**	**80.0**	-
95% CI nlcom	**(53; 132)**	**(36; 125)**	**(42; 118)**	

Note for tables 1-5 of Appendix 3:
Abond denotes dynamic panel models estimated using the GMM Arellano-Bond estimator; xtlsdv denotes dynamic panel models estimated using the bias-corrected fixed-effects (least square dummy variable) as in Bruno (2005). All regression models use annual data. DV denotes *dependent variable.*

Table 2: The channel of private investment (gross fixed capital formation)

DV: Private gross fixed capital formation (% GDP)

Variable	**model 1 (Abond)**	**model 2 (Abond)**	**model 3 (FE)**
L.gfcf_priv	0.6490***	0.6036***	-
gfcf_gov	-0.5881***	-0.5064**	0.2665
L.gfcf_gov	0.3339***	0.1438	-0.0264
L.gov_debt	-0.0216	-0.0063	-0.0643*
	(0.0183)	(0.0214)	(0.0329)
L.gov_debt_sq	0.0001	0.0000	0.0004**
	(0.0001)	(0.0002)	(0.0002)
L.GDP_cap_g	0.2203***	-	0.1496**
L.ln_GDP_cap	-	2.5239	-
L.gov_ca_rev	-0.1816***	-0.1498***	-0.1656**
L.credit_priv	-0.0076	-0.0126**	0.0087
L.LT_real_i	-0.0994***	-0.1105***	-0.3186***
L.openness	0.0062	0.0188	-0.0167
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)
Country dummies	-	-	Included (11)
_cons	13.7089***	6.2523	30.1428***
N	313	313	339
R-within	-	-	0.51
AR correction	-	-	lag(2)
Instruments DV	Lag(2/6)	Lag(2/4)	-
ABond test for AR in first-differenced errors			
AR(1) test; p-value	0.014	0.0127	-
AR (2) test; p-value	0.2852	0.2854	-
debt turning point	-	-	-

Table 3: The channel of public investment (public gross fixed capital formation)

DV: Public gross fixed capital formation (% GDP)

Variable	**model 1 (Abond)**	**model 2 (FE)**	**model 3 (xtlsdv)**
L.gfcf_gov	0.7814***	0.8983***	0.9568***
gfcf_priv	-0.0467***	-0.0359	-0.0366***
L.gfcf_priv	0.0705**	0.0462*	0.0463***
L.gov_debt	0.0140	0.0059	0.0068*
	(0.0092)	(0.0045)	(0.0037)
L.gov_debt_sq	-0.0002**	-0.0001**	-0.00005**
	(0.0001)	(0.00002)	(.00002)
L.gov_bal	0.0315***	0.0314***	0.0347***
L.GDP_cap_g	0.0180*	0.0211*	0.0206**
L.LT_real_i	0.0166	0.0144	0.0101
L.openness	0.0041**	-0.0003	-0.0004
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)
Country dummies		Included (11)	Included (11)
_cons	-0.3749	-0.3295	
N	393	406	406
R-within		0.89	Bias correction up to order
AR correction		lag(2)	O(1/NT^2)
Instruments DV	Lag(2/6)	-	
ABond test for AR in first-differenced errors			
AR(1) test; p-value	0.0258		
AR (2) test; p-value	0.1639		
debt turning point	**46.9**	**54.9**	**69.6**
95% CI nlcom	**(19; 75)**	**(17; 93)**	**(36; 103)**

Table 4: The channel of total factor productivity (TFP growth)

DV: Total factor productivity (TFP) growth rate (%)

Variable	model 1 (Abond)	model 2 (FE)	model 3 (xtlsdv)	model 4 (Abond)
L.TFP_g	0.1881	-	0.3591***	-
L.TFP_5yg	-	-	-	0.9798***
gov_debt	0.1486***	0.0455**	0.0344*	0.1344***
	(0.0475)	(0.0189)	(0.0200)	(0.0464)
gov_debt_sq	-0.0007**	-0.0002**	-0.0002	-0.0005*
	(0.0003)	(0.0001)	(0.0001)	(0.0003)
L.GDP_cap_g	-0.4761***	-0.0684	-0.2684***	-0.3837***
pop_growth	-0.2178	-0.4758	-0.5432**	-0.7966
old_dep_ratio	-0.0538	-0.1398**	-0.1280*	0.1960
young_dep_ratio	-0.0416	-0.0329	-0.0456	-0.0313
credit_priv	-0.0102	-0.0016	-0.0034	0.0094
LT_real_i	0.0461	0.0486	0.0369	-0.0869
L.ToT_g	-0.0588***	-0.0543	-0.0299	0.1354**
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (36) (1971-2006)
Country dummies		Included (11)	Included (11)	
_cons	-0.3362	-0.6678		-5.7329
N	389	408	408	365
R-within	-	0.46	Bias correction up to order	-
AR correction	-	lag(2)	O(1/NT^2)	-
Instruments DV	Lag(2/6)	-	-	Lag(2/6)
ABond test for AR in first-differenced errors				
AR(1) test; p-value	0.0037	-	-	0.0076
AR (2) test; p-value	0.5674	-	-	0.3967
debt turning point	**109.3**	**107.7**	**-**	**137.2**
95% CI nlcom	**(52; 167)**	**(64; 151)**		**(62; 213)**

Table 5.1: The channel of sovereign long-term real interest rates

DV: Long-term real interest rate (sovereign; annual)

Variable	model 1 (FE)	model 2 (FE)	model 3 (FE)	model 4 (FE)
gov_debt	0.0032 (0.0075)	0.0026 (0.0192)	0.0002 (0.0092)	-
gov_debt_sq	-	0.0000 (0.001)	-	-
D1.gov_debt	-	-	-	0.0930*** (0.0268)
gov_primary_bal	-	-	-0.2030***	-
ST_real_i	0.7620***	0.7665***	0.6443***	0.7412***
L.GDP_cap_g	0.0656	0.033	0.0049	0.1227**
output_gap	-0.1056**	-0.1158**	-0.079	-0.1155**
CA_bal	-0.0055	-0.0166	-0.028	-0.0017
openness	-0.0084	-0.0138	-0.0084	-0.0167*
reer	0.0075	0.0020	0.0005	0.0038
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)
_cons	1.3315	4.5036	1.9354	1.9981
N	375	317	375	373
R-within	0.89	0.88	0.88	0.89
AR correction	lag(5)	lag(5)	lag(5)	lag(5)

Table 5.2: The channel of sovereign long-term nominal interest rates

DV: Long-term nominal interest rate (sovereign; annual)

Variable	model 1 (FE)	model 2 (FE)	model 3 (FE)	model 4 (FE)
gov_debt	-0.0106 (0.0081)	0.0116 (0.0164)	-	-
gov_debt_sq	-	-0.0000 (0.0001)	-	-
D1.gov_debt	-	-	0.0687*** (0.0241)	0.1067*** (0.0242)
gov_primary_bal	-0.1326***	-	-0.0760***	-
ST_nom_i	0.5229***	0.6224***	0.5166***	0.5907***
Inflation (GDPdefl.)	0.2665***	0.1245***	0.2925***	0.1517***
L.GDP_cap_g	-0.0431	-0.042	-0.0145	0.0435
output_gap	-0.0371	-0.0306	-0.0114	-0.0301
CA_bal	0.0316	0.0252	0.0425	0.0434
openness	0.0009	-0.012	0.0027	-0.0156*
reer	-0.0024	-0.0131	-0.0022	-0.0122
Year dummies	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)	Included (38) (1971-2008)
Country dummies	Included (11)	Included (11)	Included (11)	Included (11)
_cons	2.094	5.1252***	2.7342*	4.0901**
N	317	375	316	373
R-within	0.95	0.93	0.95	0.94
AR correction	lag(5)	lag(5)	lag(5)	lag(5)