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Modelling Economic Policy Issues

Persistence in sovereign debt during the past two centuries: Evidence for the US and the largest European economies

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ABSTRACT

This paper analyzes the persistence of the sovereign debt / GDP and sovereign debt / GDP per capita series for the five largest European economies and the US using fractional integration. We use historical data starting in 1800 for the US and the UK, in 1861 for Italy and in 1880 for Germany, France and Spain. The results indicate high degrees of persistence of debt-to-GDP and debt per capita ratios with clear evidence of no mean reversion in both debt indicators. We also find evidence of correlation with the primary deficit, supporting the idea that one of the causes of this debt persistence is precisely the primary deficit persistence. Empirical results support the need for a better coordination between fiscal and monetary policies to enhance debt control in the countries under examination.

1. Introduction

During the year 2023 we observed the largest growth in sovereign debt since World War II. The value of global debt increased from 285 trillion U.S. dollars in the first quarter of 2022 to 307 trillion U.S. dollars in the second quarter of 2023, approximately three times global GDP (Dyvik, 2023a), and at the end of 2023 public borrowing accounted for about 50 % of total indebtedness (Gaspar and Pazarbasioglu, 2022). In advanced economies, the public debt over GDP ratio grew from 71 % in 2007 to 112 % in 2023 (IMF, 2023a); while in emerging markets and developing economies it grew up from 35 % to 65 % (IMF, 2023b). However, during the same period, private debt was stable in advanced economies and underwent slight growth in the emerging economies. In particular, non-financial corporate (NFC) debt changed from 89 % to 93 % in advanced economies while increasing from 60 % to 98 % in emerging economies (Dyvik, 2023b). Thus, the increase of global debt was mainly generated by the growth of sovereign debt and emerging corporate growth.

The policy of cheap money that followed the Lehman financial crisis after 2013 generating low interest rates and the purchase of public debt by central banks favoured government indebtedness, together with the collapse of revenues due to the drop in economic growth. Thus, most Euro-countries “temporarily” exceeded the Maastricht agreement limiting sovereign debt to a 60 % Debt/GDP ratio. This ratio stands today at 84 % for EU members and 89 % for the Eurozone (IMF, 2023c).

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There are several explanations for these levels of indebtedness, and among them we should mention first the very low (close to zero or even negative) nominal interest rates, (e.g., the cases of Germany, Japan, Switzerland and Spain between 2014 and 2022) and second, that the real interest rate had been falling in the US and in the Eurozone below the GDP growth rate, so it seemed that implementing expansionary fiscal policies was not a problem due to these stimuli. As a consequence, after the Covid-crisis public debt in many advanced economies clearly exceeded the recommended threshold of 90 % of GDP.

According to [Niemann et al. \(2013\)](#), who examined the issue of debt and inflation persistence in the US, as public debt is issued in response to macroeconomic shocks, the optimal discretionary policies are the ones that generate persistent debt, and this persistence is carried over to inflation. In fact, after the Covid period, supply chain and energy bottlenecks in 2022 raised inflation in 2023 to levels that in some countries were double digit, pushing governments to seek a balance between public debt and inflation. As Central Banks changed their monetary policies to increase the price of money in order to reduce inflation, the cost of debt and its associated interest rates were suddenly raised, impacting on the public budgets, reducing growth-oriented public policies because of the higher payments of these interests. Therefore, today, it is essential to find a balance between fiscal and monetary policy that favours the reduction of inflation while maintaining some level of economic growth.

The two traditional levers that countries use to correct inflation are monetary and fiscal policies. As monetary policy tightens and Central Banks raise interest rates to correct inflation, the cost of debt will rise. Thus, fiscal policies should adapt these monetary measures accordingly to improve their effectiveness and reduce the impact on economic growth and hence employment. This mechanism is clear in the US where the Federal Reserve sets the monetary policy and the US government sets the fiscal agenda. However, in Europe, within the Euro-27 space, each country establishes a different fiscal policy which may or may not be in line with ECB policy.

[Reinhart and Rogoff \(2010\)](#) analysed public debt, inflation, and growth in 44 countries over two centuries. They concluded that debt levels above 90 % of GDP in developed and emerging countries lead to 1 % lower GDP growth than would have existed if the countries had remained below the 90 % GDP threshold. Thus, as countries approach the 90 % ceiling, the interest rate will rise forcing a painful adjustment that will negatively affect economic growth. However, this 90 % limit was recently discussed by [Herndon et al. \(2014\)](#), identifying some methodological errors in the study and showing empirical evidence of countries with debt/GDP ratios above 90 % that averaged 2.2 % of GDP growth in the 1946–2009 period. Therefore, there is no clear public debt threshold beyond which GDP growth will fall off sharply. In fact, for all the countries under study (except Germany), the debt/GDP levels are over 100 % but after the Covid recovery, they have all maintained positive GDP growth levels. Recently, [Reis \(2022\)](#) suggested that one of the factors impacting the limit of the Debt/GDP ratio might be a debt revenue term associated with the income generated when the debt is issued. Others such as [Willems and Zettelmeyer \(2022\)](#) underline the importance of the credibility of the Central Bank, which can be accumulated via prudent policies. These factors could explain the situation of Japan with a 2.5 debt/GDP ratio plus a negative interest rate policy.

In light of the above debate, the main purpose of this research is the examination of the statistical properties of the sovereign debt in the US and in the major European economies (Germany, the UK, Italy, France and Spain) over the long term (1800 to 2022), to analyse their degree of persistence with two main objectives: first, to extend the analysis conducted in previous papers and based on stationarity $I(0)$ and unit root $I(1)$ tests to the fractional $I(d)$ case, and second, to analyse if debt is corrected naturally, showing mean reversion properties in the long term. If there is lack of mean reversion, shocks will have a permanent nature and additional policy actions will be needed to recover the original long-term projections of the series.

For this purpose, fractional integration seems to be an appropriate technique since with a single parameter “ d ”, i.e., the order of integration of the series, we can determine the nature of the shocks (transitory if that value is smaller than 1, or permanent if it is equal to or higher than 1). Note that traditionally this question was solved by using stationarity or unit root tests: evidence of stationarity supported the transitory nature of shocks, while unit roots provided evidence of permanency of their effects; however, the use of fractional integration provides us with two main advantages. First, it allows a higher degree of flexibility in the dynamic specification of the series with potentially fractional degrees of differentiation and second, it avoids false unit roots results in cases when d is close to 1. Understanding the dynamics of the public debt evolution is a necessary key to assess the impact on a country’s economy, and thus, facilitate the design of appropriate government policies. Moreover, we extend the perspective of the debt analysis to the long term, with data starting in the 19th century and completing those studies on persistence that use data starting only after WWII. In addition, we introduce the perspective of debt per capita to complement the traditional debt to GDP perspective.

The rest of the paper is structured as follows: [Section 2](#) provides a brief literature review focused on sovereign debt and fractional integration studies; [Section 3](#) outlines the fractional integration model used for the analysis; [Section 4](#) describes the data and discusses the empirical results, while [Section 5](#) offers some concluding remarks.

2. Literature review

Regarding the persistence of sovereign debt with traditional unit root tests, [Antonini et al. \(2013\)](#) analysed the debt/GDP ratio in the EU10 countries for the period (1982 - 2009) with Augmented Dickey – Fuller tests (ADF, [Dickey and Fuller, 1979](#)). These authors found evidence of unit roots for all the countries under study, with the implication that shocks have long-run effects. [Camarero et al. \(2015\)](#) analysed 17 OECD countries, which also included the ones under this study, for the time period from 1970 to 2010, with various types of unit root tests. They concluded that debt/GDP ratio series were $I(1)$, pointing out to a weak fiscal sustainability, and a cointegrating relationship between deficit and debt. [Brady and Magazzino \(2017\)](#) analysed the long-term Italian sovereign debt as in this paper, linking their results with the public deficit (1862–2013), and using different sets of tests ([Dickey and Fuller ADF, 1979](#); [Phillips and Perron PP, 1988](#); [Kwiatkowski et al. KPSS, 1992](#); and [Elliot et al. ERS, 1996](#)). They found evidence of unit roots with and

without a trend for public debt, concluding that Italian public debt was non-stationary or I(1). Campos and Cysne (2022) investigated the Brazilian debt/GDP ratio with Dickey and Pantula (1987) tests, also finding support of first order differentiation or I(1) behaviour.

On the other hand, some authors have questioned the results based on simple unit root tests. In particular, Diebold and Rudebusch (1991) and Hassler and Wolters (1994) examined the properties of Dickey-Fuller unit root tests under fractionally integrated alternatives. Lee and Schmidt (1996) used KPSS tests with evidence of consistency only against stationary long memory alternatives or $0 < d < 0.5$. Caporale and Gil-Alana (2004, 2014) proposed that some stock series could be nonstationary or I(1) but fractionally cointegrated and exhibiting slow reversion to the mean. Thus, this duality between I(0) and I(1) can be very restrictive as many series might be long memory nonstationary though mean reverting if the differencing parameter is in the range [0.5, 1).

Some recent developments in time series analysis and forecasting are related to neural networks and learning machines that might improve the quality of the results. For instance, Xu et al. (2023) proposed Artificial Neural Networks as a way to improve the prediction of crude oil prices; Chang et al. (2023a,b) used dynamic econometric and artificial intelligence models to analyze renewable and green energy sources; Moshin et al. (2023) and Mohsin and Jamaani (2023a,b) used machine learning techniques to forecast green energies and future oil prices; in a similar way, Lazcano et al. (2023) used deep learning models applied to financial time series forecasting.

In this paper we analyze persistence in the long-term sovereign debt/GDP using fractional integration. In this specific line, Cuestas et al. (2014) analysed government debt dynamics following the Euro area integration (2000–2013) since its creation and during the financial crisis period. These authors found evidence of structural breaks in all countries around the period 2007 - 2008 except for France and Germany, which showed high persistence and no mean reversion. Caporale et al. (2021) analysed the private debt to GDP ratio in 43 OECD countries (including all G20 and BRICS) for the period 1951–2020. Their empirical results indicate that with the exception of Argentina, all the examined countries were found to be highly persistent with orders of integration around or above 1 (6 with unit roots or $d = 1$, and 37 with I(d) structures with $d > 1$).

In this paper we extend the literature on stationarity and unit root tests and even that based on cointegration models by allowing fractional degrees of differentiation. In doing so, we get a higher degree of flexibility in the models, allowing, for example, cases which are nonstationary but still display mean reversion. Cointegration is captured by examining the debt/GDP ratios, in this case studied by treating the observed data rather than the estimated values of a regression of debt on GDP, and still allowing for fractional degrees of differentiation.

3. Methodology

The methodology examined in this paper is based on long memory processes. In particular, we use a modelling approach denominated fractional integration and which is characterized due to the degree of dependence in the data, measured by the differencing parameter d , which is a fractional value. For our purposes we define a covariance stationary process $\{x_t, t = 0, \pm 1, \dots\}$ with mean μ as integrated of order 0, and denoted by I(0), if the infinite sum of the autocovariances, defined as $\gamma(u) = E[(x(t) - \mu)(x(t + u) - \mu)]$, is finite, that is:

$$\sum_{j=-\infty}^{\infty} |\gamma(u)| < \infty. \tag{1}$$

These types of processes, also known as short-memory, include not only white noise but also the stationary and invertible AutoRegressive Moving Average (ARMA) model, which is frequently employed with stationary series. By contrast, a process displays the property of long memory (so-named because of the relevance of observations in the distant past) if the infinite sum of its autocovariances is infinite:

$$\sum_{u=-\infty}^{\infty} \gamma_u = \infty. \tag{2}$$

There exist many mathematical models that satisfy the above property, and within them, one very common in time series analysis is that based on fractional integration or I(d) with $d > 0$. Thus, x_t is said to be integrated of order d and denoted as I(d) if it can be expressed as:

$$(1 - L)^d x_t = u_t, \quad t = 1 \ 2 \ \dots \tag{3}$$

where L is the lag operator and u_t is I(0) or short memory. Note that the polynomial in L on the left-hand side of (3) can be expanded in terms of its Binomial representation such that, for any real d ,

$$(1 - L)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j L^j = 1 - dL + \frac{d(d - 1)}{2} L^2 - \dots \tag{4}$$

and thus, Eq. (3) becomes:

$$x_t = dx_{t-1} - \frac{d(d - 1)}{2} x_{t-2} + \dots + u_t. \tag{5}$$

According to Eq. (5), if d is an integer value, x_t depends only on a finite number of previous observations; however, if it is non-integer, it will depend on all its past history. Moreover, the higher the differencing parameter d is, the higher the association is

between the observations and d can be taken as a measure of the degree of persistence (dependence) in the data. In this context, if d is smaller than 0.5, x_t is still covariance stationary; however, $d \geq 0.5$ indicates lack of it; in addition, x_t in (3) admits an infinite MA representation and values of d below 1 support the hypothesis of mean reversion with shocks having transitory effects, decaying hyperbolically slow to zero. On the other hand, if $d \geq 1$, there is lack of this property implying permanency of shocks.

The estimation of the differencing parameter, d , is based in this work on a frequency domain version of the Whittle function, using a simple version of a testing procedure developed in Robinson (1994) and widely used in empirical applications of fractional integration (Gil-Alana and Robinson, 1997). This method has numerous advantages with respect to other approaches. First, it is based on a testing procedure, testing the null hypothesis of $H_0: d = d_0$, in (3) for any real value d_0 , and thus, including values outside the stationarity region ($d_0 \geq 0.5$); second, it has a standard $N(0,1)$ limit distribution and this asymptotic regular behaviour holds whether or not deterministic terms are included in the model; it also allows for weak autocorrelation for the error term, and it is the most efficient method in the Pitman sense against local departures from the null. These arguments seem to be sufficient for choosing this approach in the empirical application carried out in the following section.

4. Data and results

According to Niemann et al. (2013), who examined the issue of debt and inflation persistence in the US, as public debt is issued in response to macroeconomic shocks, the optimal discretionary policies are the ones that generate persistent debt, and this persistence is carried over to inflation. In fact, after the Covid period, supply chain and energy bottlenecks in 2022 raised inflation in 2023 to levels that in some countries were double digit, pushing governments to seek a balance between public debt and inflation. As Central Banks changed their monetary policies to increase the price of money in order to reduce inflation, the cost of the debt and its associated interests were suddenly raised, impacting on the public budgets, reducing growth-oriented public policies because of the higher payments of these interests. Therefore, today, it is essential to find a balance between fiscal and monetary policy that favours the reduction of inflation while maintaining some level of economic growth; otherwise, the consequence will be an increase in the unemployment rate and economic recession.

The sovereign Debt/GDP and primary balance/GDP data has been taken from IMF e-library datasets, choosing the Historical Public Debt Database (1800–2015) and updating with Refinitiv-Eikon for the most recent data. Specifically, data starts in 1800 for the US and the UK, in 1861 for Italy and in 1880 for Germany, France and Spain. In addition, GDP per capita data has been taken from Prados de la Escosura (2017). These authors provide Geary-Khamis (current US\$ 2011) and GEKS (current US\$ 1990) estimates of yearly GDP output and population for nearly 600 years for Spain, France, the UK and Italy and for about 200 years for the United States and Germany. In addition, an estimation of Debt/capita has been implemented as the product of these two. All this information is described in Table 1, providing some descriptive statistics for the samples under examination.

Figs. 1–3 display the regression plots of these magnitudes. Fig. 1 compares GDP/capita and Debt/GDP for the selected countries, showing that peaks at Debt/GDP come at very low or very high income levels. However, the linear trend and the slope vary from country to country. Fig. 2 displays the GDP/Capita and Debt/capita relationship, and for this case the linear trend is positive for all the countries under study. However, the slope depends on the specific country under examination. Finally, Fig. 3 describes the Debt/Capita and Debt/GDP relationship, revealing a very high peak of the Debt/GDP at very low levels of Debt/Capita and positive trends in all cases. Thus, these figures show evidence that indebtedness measured in terms of Debt/GDP had been higher in the past, especially in times of poverty with low levels of GDP per capita; but also, during prosperous times with high levels of GDP per capita. The question that should be answered is regarding the sustainability of this financial leverage in public finances.

Table 1
Descriptive statistics of the dataset.

	SPAIN	ITALY	FRANCE	UK	US	GERMANY
Number of obs.	141	160	141	221	221	141
Starting date	1880	1861	1880	1800	1800	1880
i) DEBT / GDP						
Minimum val.	7.25	24.21	14.39	27.27	–	4.17
Maximum val.	161.72	159.72	237.03	269.80	134.50	81.00
Average	57.46	86.60	79.85	114.02	31.97	34.98
St. Dev.	32.64	32.91	49.22	66.66	30.75	18.12
St. Dev. / Av.	1.76	2.63	1.62	1.71	1.04	1.93
ii) DEBT / GDP per Capita						
Minimum val.	896.15	1087.96	2454.02	1890.75	–	296.16
Maximum val.	37,333.34	50,157.87	41,488.26	35,323.14	72,396.01	34,421.14
Average	6421.99	12,066.85	9871.46	9220.64	8622.34	8020.57
St. Dev.	8389.49	14,487.72	9484.62	7097.75	14,175.33	9892.58
St. Dev. / Av.	0.77	0.83	1.04	1.30	0.61	0.81
iii) GDP / GDP per Capita						
Minimum val.	1507.16	2547.10	1315.85	2549.08	2071.41	1983.73
Maximum val.	35,071.19	37,725.50	39,261.96	38,375.48	56,470.06	46,809.96
Average	8152.02	10,281.99	10,669.01	10,937.89	14,958.49	15,354.41
St. Dev.	9772.45	11,588.99	11,684.07	10,247.07	15,615.20	13,755.01
St. Dev. / Av.	0.83	0.89	0.91	1.07	0.96	1.12

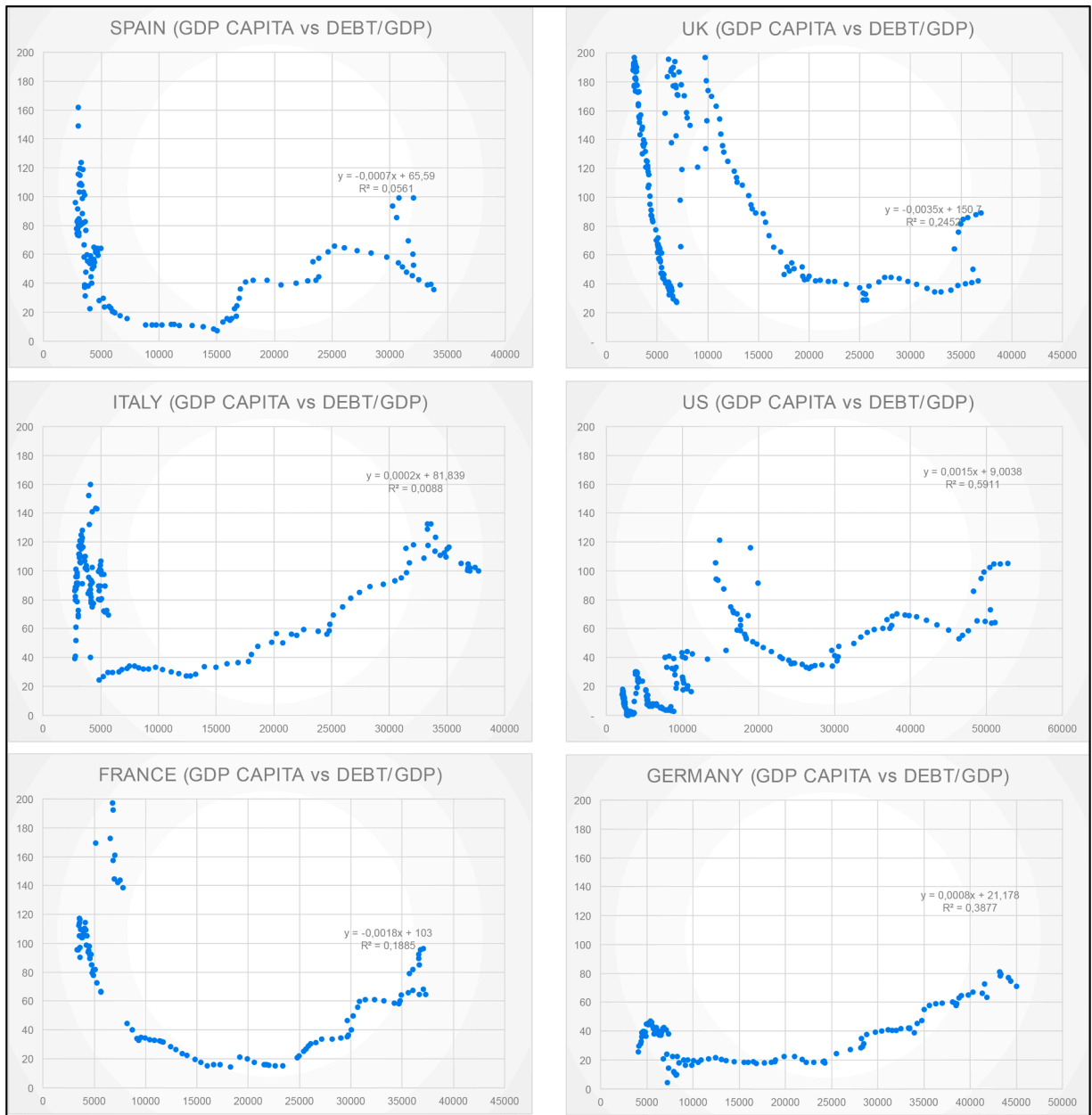


Fig. 1. Relationship between GDP/Capita (x) and Debt/GDP (y) for selected countries
 Scattered diagram between GDP/Capita (x) and Debt/GDP (y). It can be seen that higher levels of debt/GDP occurs at most poverty and richness levels.

Based on Eq. (3), we consider a model that allows for deterministic terms such as a constant and/or a linear time trend. Thus, the model under investigation is the following one,

$$y_t = \gamma + \delta t + x_t, (1 - L)^d x_t = u_t, \tag{6}$$

where y_t refers to the observed time series data (original values in case of the DEBT/GDP and logs for the DEBT/CAP); γ and δ are unknown coefficients corresponding to an intercept and a linear time trend respectively, and d is a real number and refers to the order of integration of the series. If this number is positive, the series displays the property of long memory, and values of d below 1 indicate support of mean reversion in the data. Based on the specification of x_t in the above equation, u_t is I(0) by construction and to allow for some (weak) dependence we suppose that it follows the exponential spectral model of Bloomfield (1973) that approximates AR structures in a non-parametric way.

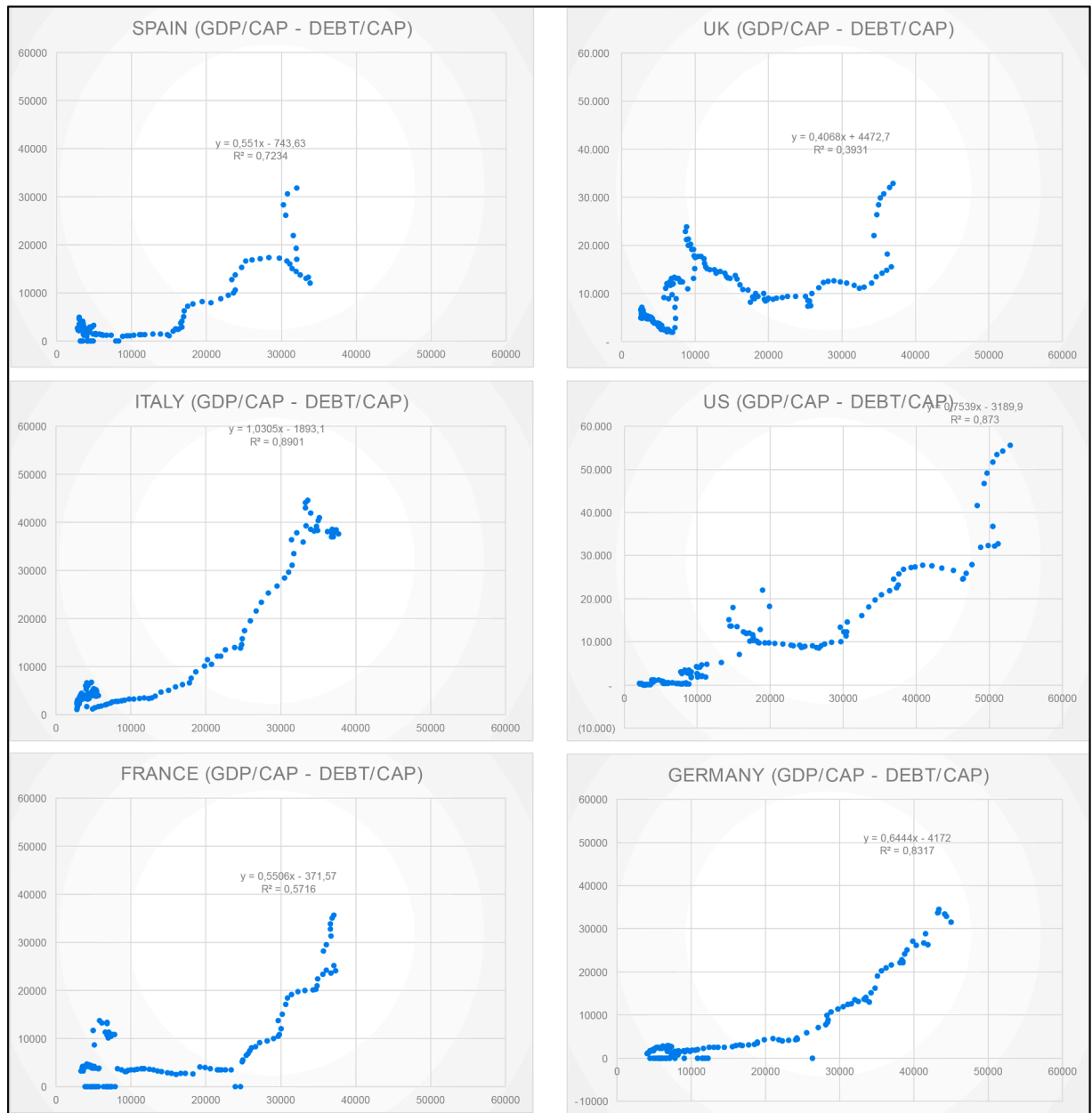


Fig. 2. Relationship between GDP/Capita (x) and Debt/capita (y) for selected countries
 Scattered diagram between GDP/Capita (x) and Debt/CAP (y). It can be seen a growing trend in all countries meaning that debt levels per capita are higher at richer levels.

As is also standard in the literature, we consider the three potential set-ups of i) no regressors in the first equality in (6) (results in terms of d and the 95 % confidence interval reported in the second column of Table 2), ii) with only an intercept (column 3), and iii) with an intercept and a linear time trend (column 4), the most appropriate model for each series being displayed in bold in the table. Table 3 displays the estimated coefficients for the selected models for each country and each series. This selection is based on the significance of the estimated coefficients in the d -differenced series, noting that the two equations in (6) can be expressed as

$\tilde{y}_t = \gamma \tilde{1}_t + \delta \tilde{t}_t + u_t, t = 1, 2, \dots$ where $\tilde{y}_t = (1 - L)^d y_t$, $\tilde{1}_t = (1 - L)^d 1_t$, and $\tilde{t}_t = (1 - L)^d t$, and since u_t is $I(0)$ by construction, standard t -tests apply on the γ and δ coefficients above.

Starting with DEBT/GDP, in the upper part of Tables 2 and 3, we observe that the time trend coefficient is statistically significant for the case of the US. In the remaining cases, the intercept is sufficient to describe the deterministic part of the model. The estimates of d are rather large in all cases. For two countries (Italy and the US) the estimated values of d are smaller than 1, though in both cases, the 95 % confidence interval includes the value of 1, implying lack of rejection of the unit root hypothesis. For the remaining cases the

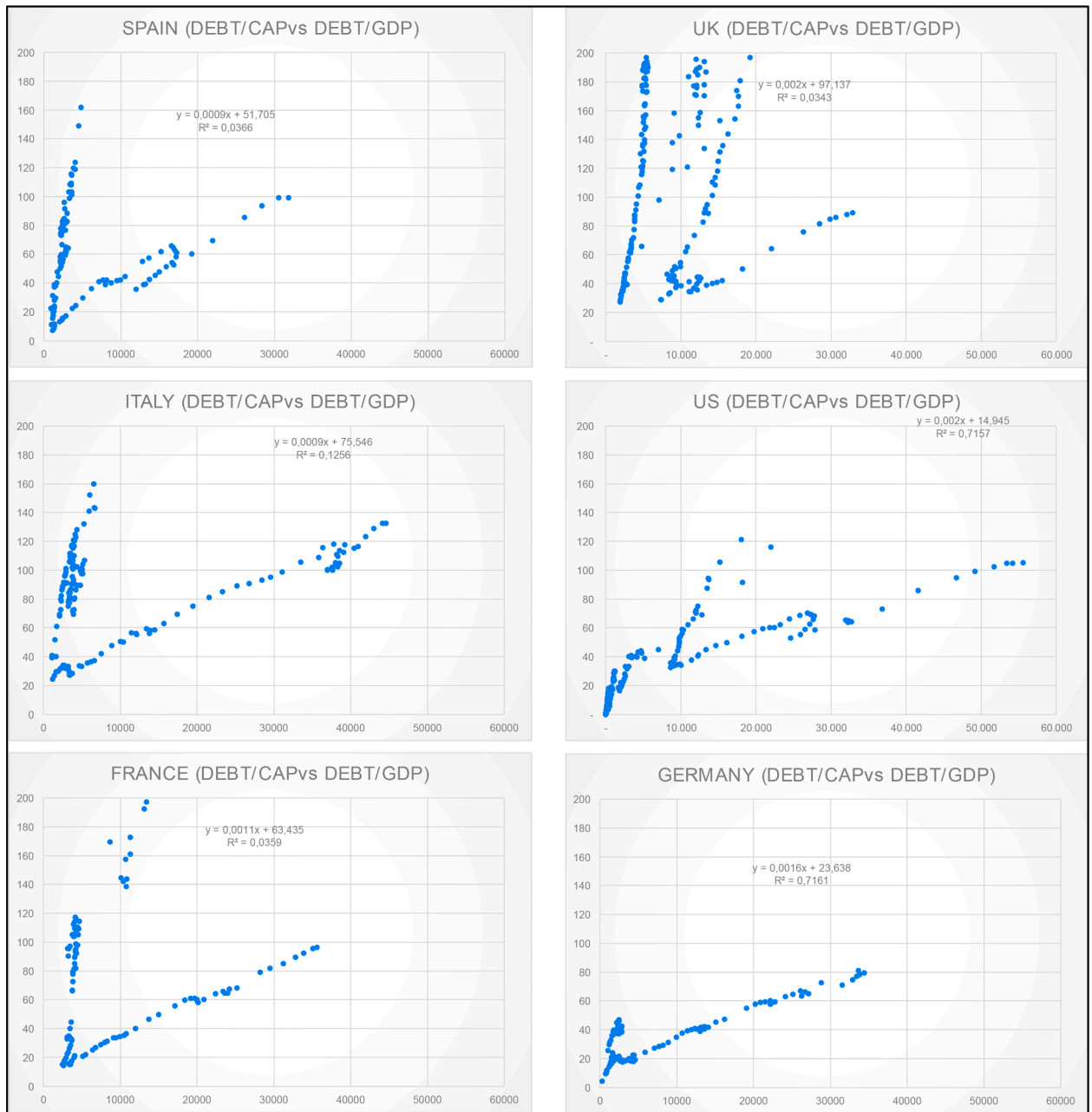


Fig. 3. Relationship between Debt/Capita (x) and Debt/GDP (y) for selected countries
 Scattered diagram between Debt/Capita (x) and Debt/GDP (y). It can be seen that highest levels of debt/capita occur at smaller levels of debt/GDP (i.e. with very low levels of GDP). However, there is a growing trend and with higher levels of GDP, debt/CAP also tends to grow.

estimates of d are above 1, but for Spain and Germany the unit root null cannot be rejected, this hypothesis being decisively rejected for the other two countries (UK and France) in favour of $d > 1$. Thus, we do not observe evidence of mean reversion in any single case.

Next, we look at DEBT/CAP (lower cases in Tables 2 and 3). The time trend is now required in the cases of Italy and the US, in both cases with positive time trend coefficients (Table 3). Focusing on d , the first thing we observe is that the values are now slightly smaller than in the previous cases. For the US, the estimate of d is 0.84, and the interval close its upper value at 0.99 indicating a rejection of the unit root and supporting a very slow reversion to the mean. For the remaining cases, the I(1) hypothesis cannot be rejected except for Spain where it is rejected in favour of $d > 1$ ($d = 1.20$ [1.03, 1.42]).

Thus, from an econometric perspective, the analysis of sovereign debt is controversial since, depending on the period considered and the span of the data used, the results obtained differ. The empirical results indicate continued growth of sovereign debt over time with a growing trend that is only cushioned in very short periods of time, usually by fiscal adjustments, as suggested by Bequiraj et al.

Table 2
Estimates of the differencing parameter, d.

i) DEBT / GDP			
Country	No terms	An intercept	A linear time trend
SPAIN	0.76 (0.63, 0.95)	1.05 (0.79, 1.38)	1.05 (0.81, 1.37)
FRANCE	1.12 (0.95, 1.38)	1.25 (1.02, 1.62)	1.25 (1.02, 1.62)
GERMANY	0.95 (0.82, 1.15)	1.09 (0.95, 1.35)	1.09 (0.95, 1.36)
ITALY	0.97 (0.83, 1.20)	0.93 (0.77, 1.16)	0.93 (0.77, 1.16)
UK	1.13 (0.97, 1.35)	1.23 (1.04, 1.54)	1.23 (1.04, 1.49)
USA	0.90 (0.75, 1.09)	0.94 (0.79, 1.18)	0.93 (0.77, 1.17)
ii) DEBT / GDP per CAPITA (in logs)			
Country	No terms	An intercept	A linear time trend
SPAIN	0.90 (0.75, 1.12)	1.20 (1.03, 1.42)	1.18 (1.03, 1.43)
FRANCE	0.96 (0.80, 1.19)	1.15 (0.99, 1.37)	1.16 (0.99, 1.38)
GERMANY	0.93 (0.76, 1.18)	1.05 (0.88, 1.31)	1.04 (0.88, 1.32)
ITALY	1.02 (0.84, 1.25)	1.09 (0.91, 1.33)	1.09 (0.92, 1.34)
UK	0.97 (0.84, 1.16)	1.12 (0.97, 1.31)	1.12 (0.97, 1.31)
USA	0.91 (0.73, 1.14)	0.84 (0.72, 1.01)	0.84 (0.69, 0.99)

In parenthesis, the 95 % confidence bands of the estimated values of d. In bold, the selected model for the deterministic terms of each series.

Table 3
Estimates of the differencing parameter, d.

i) Debt / GDP						
Country	d (95 % band)	Intercept (tv)	Time trend (tv)	D		
				Standard error	t-value	p-value (95 %)
SPAIN	1.05 (0.79, 1.38)	163.59 (22.85)	—	0.168	6.236	4.9822E-09
FRANCE	1.25 (1.02, 1.62)	95.396 (10.57)	—	0.189	6.622	7.0215E-10
GERMANY	1.09 (0.95, 1.35)	24.851 (10.57)	—	0.133	8.217	1.2612E-13
ITALY	0.93 (0.77, 1.16)	40.864 (4.92)	—	0.117	7.925	3.7526E-13
UK	1.23 (1.04, 1.54)	17.590 (22.90)	—	0.158	7.777	2.8422E-13
USA	0.93 (0.77, 1.17)	17.117 (4.29)	0.492 (2.59)	0.122	7.595	8.7130E-13
ii) Debt / GDP per Capita (in logs)						
Country	No terms	An intercept	A linear time trend	D		
				Standard error	t-value	p-value (95 %)
SPAIN	1.20 (1.03, 1.42)	8.524 (57.25)	—	0.112	10.691	7.1300E-20
FRANCE	1.15 (0.99, 1.37)	8.056 (93.12)	—	0.112	10.245	1.0010E-18
GERMANY	1.05 (0.88, 1.31)	6.912 (47.03)	—	0.133	7.915	6.8168E-13
ITALY	1.09 (0.92, 1.34)	6.951 (78.00)	0.0253 (2.36)	0.128	8.546	9.9920E-15
UK	1.12 (0.97, 1.31)	8.480 (132.15)	—	0.097	11.554	1.9180E-24
USA	0.84 (0.69, 0.99)	5.824 (19.10)	0.0247 (2.60)	0.087	9.685	1.0540E-18

In parenthesis, in column 2, the 95 % intervals of the differencing parameter; in columns 3 and 4, the intercept and the time trend with their corresponding t-values; the following three columns refer to the standard error, the t-value and p-value for the differencing parameter.

(2018). Therefore, the long-term trend in sovereign debt does not revert to the mean, except for the US and, in even in this case, at a very slow rate since the upper confident limit of d is very close to 1. On the other hand, [Bekaert and Harvey \(2003\)](#) [Reinhart and Rogoff \(2010\)](#) and [Panizza and Presbitero \(2012\)](#) found that mean reversion occurs, however, these authors consider shorter sample sizes and reversion to the mean occurs when a fiscal consolidation effort takes place.

To analyze the economic reasons of this persistence, some authors such as [Antonini et al. \(2013\)](#) rely on the characteristics of the shocks hitting the economy but also on the way government policy reacts to those shocks. Thus, [Aiyaguri and McGrattan \(1998\)](#), [Schmitt-Grohé and Uribe \(2004\)](#) and [Leith and Wren-Lewis \(2013\)](#) among others, proposed that governments look for a theoretical optimal debt policy that optimizes trade-offs in the general economy dynamics (consumption smoothing, crowding out, wealth redistribution or work disincentives) and the debt/GDP ratio should then be stationary around the optimum level. However, our empirical results show clear evidence of nonstationarity, with high persistence and no mean reversion properties in the long term in the countries under analysis.

Some older authors such as [Barro \(1979\)](#) proposed a Ricardian equivalence model where the optimal fiscal policy implies smoothing out intertemporally the burden of taxation. This would imply that the effect of a positive shock on government spending will generate a small but persistent increase in taxation rather than a higher pace of fiscal adjustment. Thus, the level of debt would be permanently higher to compensate this deficit, leading to persistence and unit root properties in the debt/GDP series. However, if this were true, debt/GDP would grow with no limits and there is a recognition that debt cannot grow without bounds ([Antonini et al.](#),

2013). Nevertheless, we believe that it would be a clear temptation for governments that after generating temporal deficits when completing expansionary cycles, if there were no pressure by bond holders or international organisms, not to react in the opposite way as this reverse policy would generate unpopular measures and could affect future elections.

When analyzing debt/GDP ratio, ECB (2011) groups debt accumulation according to three main underlying factors: i) the government primary balance in each period; ii) the “snowball” effect, which captures the joint impact of interest payments on the outstanding stock of debt and of real GDP growth and inflation rates on the debt ratio (through the denominator); and iii) the deficit-debt adjustment, which relates to those transactions or other factors that affect the outstanding stock of debt but are not recorded as part of the primary balance.¹ Looking for an empirical evaluation of these factors in the countries under study, we have also analysed persistence in the primary balance and its correlation with the variation of the DEBT/GDP ratio.

Starting with the direct relationship between deficit and debt, we have studied the Granger (1969) causality tests and their correlation between changes of debt and the primary balance for the countries under analysis. Table 4 shows evidence of this dependence in all countries in the short term (lag = 2), and in the long term (lag = 10). Additionally, Fig. 4 shows the cross correlograms between debt/GDP changes and primary balance/GDP ratio, showing an evident negative relationship in all cases as public deficits (or negative balances) are covered with positive debt that lasts for at least 2 - 3 lags. As for the Granger tests, the value of this correlation depends on the specific country under analysis. For instance, the US shows a very strong correlation factor of (−0.86), implying a clear relationship between public deficits and debt increases. On the other side, we see countries such as Spain (−0.34), France (−0.11) and especially Italy (−0.06) where this dependency appears to be weaker, implying that other factors such as interest spending, inflation and lower growth (snowball effect) might then be more important. For the specific case of Italy, Bastasin et al. (2019) indicate that for 127 out of the past 157 years, Italian level of DEBT/GDP largely exceeded that of today’s G7 ex-Italy, explaining the large level of interest payments to be paid. Other countries such as the UK (−0.57) or Germany (−0.51) show certain levels of dependency between the two factors.

Continuing with the primary balance statistical analysis, we estimate the differencing parameter d with both parametric and semiparametric methods, in Table 5, and we observe that the values are, in all cases, in the range (0.5, 1) with the exception of the UK where the differencing parameter is found to be significantly higher than 1. Thus, high levels of persistence are found in all cases, though evidence of mean reversion is also found with all three methods in the cases of Spain and Germany, and with some of them for France, Italy and the US. Nevertheless, the values are substantially smaller than those reported in previous tables, implying that some but not all the persistence of the debt ratios might be coming from the primary balance. In this respect, and following Barro (1979), as the primary balance is persistent, an increase in the government spending would persist and would be compensated with debt and taxes, leading to persistent debt behaviour.

To explain persistence transmission between primary balances and debt, Bequiraj et al. (2018) suggest that governments intervene with a new deficit and debt when the output gap is positive; however, they do not adopt a symmetrical correction when the situation is reversed, as politicians’ need to be re-elected and prefer not to adopt unpopular measures. We also believe that because of this, primary balance is persistent, and as there is a causal relation between primary balances and debt, part of this persistence might be transmitted to debt. However, as the debt is not adjusted unless bondholders do not perceive risk of default, this persistence is increased because debt is not reduced. Antonini et al. (2013) include an extra factor regarding the high level of interdependence between countries. This would explain why in countries that are closely integrated through trade, the cyclical fluctuations in one country would be reflected in those of the other countries. Then, fiscal responses to these fluctuations will be reflected in the debt/GDP ratios reinforcing the persistence effect.

Therefore, for some countries, the challenge nowadays might be the current policy followed by Central Banks of employing high interest rates to tighten inflation, because of existing debt levels. For instance, in a country with a debt/GDP ratio of 100 % with a general budget of 40 % of the GDP, a 4 % rise in the interest rate would require a budget adjustment of 10 % only due to interest payments. However, from a policy perspective the impact of a sovereign debt crisis may differ depending on the mandate of the monetary versus the fiscal authority in each case. The economies studied in this paper offer examples of three different situations: (i) the UK has an independent central bank and is not part of a monetary union; (ii) the US is a monetary union with a federal fiscal structure; and (iii) European countries are members of the Eurozone where each state maintains independent fiscal policies, which requires a greater coordination effort in the employment of fiscal rules. Bequiraj et al. (2018) points to this economic debate in his research, considering the optimal degree of fiscal policy responsiveness to rising public debt and changing macroeconomic conditions. In line with Bohn (1998), fiscal consolidation in the case of a rapid increase in public debt has been traditionally seen as a way to restore fiscal sustainability. Nevertheless, it is also important to consider the risk of fiscal fatigue from an excessive fiscal effort. Ghosh et al. (2013a,b) modelled the notion of fiscal space as the difference between the country’s current debt level and its debt limit, where this limit is the debt level beyond which fiscal solvency would fail. This limit would depend on factors such as market interest rates, output and government expenditure gap, inflation, political stability, trade openness and others. According to Eurostat data (2022), today the highest public debt in the European Union is concentrated in the southern countries, with Greece (171 %), Italy (144 %), Portugal (114 %) and Spain (113 %) showing the highest values. The US has a similar level of 119.5 % (St Louis FRED, 2023).

To complete the empirical analysis, we have included the results of Bai-Perron’s (2003) methodology (Table 6), testing for the presence of a structural break in the data. The empirical results show that these breaks occurred during World War periods. Consequently, the challenge that we are facing today is the growth of sovereign debt, the high price of money and the consequent associated

¹ One example of this third part or “other transactions” can be acquisitions of shares in companies by the government, which are recorded as financial transactions

Table 4
Granger causality tests between primary balance and debt variation.

Null Hypothesis:	Long Term (lag = 10)		Short Term (lag = 2)	
	F-Statistic	Prob.	F-Statistic	Prob.
PB_SPAIN does not Granger Cause SPAIN_D_VAR	2.785	0.0042	3.873	0.0232
SPAIN_D_VAR does not Granger Cause PB_SPAIN	0.490	0.8936	0.110	0.8956
PB_FRA does not Granger Cause FRA_D_VAR	4.776	0.0000	15.356	0.0000
FRA_D_VAR does not Granger Cause PB_FRA	19.152	0.0000	19.051	0.0000
PB_GER does not Granger Cause GER_D_VAR	0.519	0.3365	0.942	0.3924
GER_D_VAR does not Granger Cause PB_GER	1.144	0.8739	0.313	0.7319
PB_ITALY does not Granger Cause ITALY_D_VAR	0.714	0.7097	0.801	0.4506
ITALY_D_VAR does not Granger Cause PB_ITALY	1.040	0.414	0.456	0.6348
PB_UK does not Granger Cause UK_D_VAR	8.646	0.0000	22.494	0.0000
UK_D_VAR does not Granger Cause PB_UK	1.618	0.1057	2.527	0.0827
PB_US does not Granger Cause US_D_VAR	4.170	0.0000	12.158	0.0000
US_D_VAR does not Granger Cause PB_US	2.330	0.013	5.048	0.0072

PB means Primary Balance and D_VAR is Debt Variation.

fiscal imbalance. The stimulus policy of cheap money and the purchase of public debt followed by central banks after the 2008 financial crisis accelerated the level of indebtedness, the highest since World War II. Following a recent [IMF \(2024\)](#) post, as debt dynamics remained fairly benign for a long-time because real interest rates were significantly below growth rates, the pressure for fiscal consolidation was reduced and public deficits and public debt were allowed to drift upwards. Then, during the pandemic, debt increased even more as governments rolled out large emergency support packages and at the same time as we confront higher debt levels, the macroeconomic environment has become less favourable. Supply chain bottlenecks and energy concerns have raised inflation, and conversely real long-term interest rates that could generate significant challenges. In Europe, the European [Commission \(2023a\)](#) is conscious of this situation as it endeavours to face up to the seriousness of debt sustainability levels in many European countries. In particular, the EC decided in April 2023 to reactivate fiscal rules to control public spending in order to approve national budgets. The central objective of the proposals is to strengthen the sustainability of public debt and to promote sustainable and inclusive growth in all member states. These measures are aiming for debt to be placed on a credible path at prudent levels, and for the deficit to be maintained or reduced and kept below 3 % of GDP over the medium term ([European Commission, 2023b](#)). In [Table 7](#), we have checked cointegration of debt variations with primary balances with [Engel and Granger's \(1987\)](#) tests, finding evidence of a long run relationship between the two variables. This result would suggest debt sustainability in the long term according to [Trehan and Walsh \(1988\)](#); however, this hypothesis requires further investigation and is left for future work.

5. Conclusions

We have studied the persistence and mean reversion properties of the long-term sovereign debt and debt per capita series for the five largest European economies and the US. To this end, large data series at a yearly frequency have been used, starting in 1800 (for the UK and the US), in 1860 (for Italy) and in 1880 for the remaining countries.

The empirical results show that higher levels of debt in terms of debt/GDP had also occurred in the past, especially in times of poverty with low levels of GDP per capita; but also, during prosperous times with high levels of GDP per capita. Today, as the trend is positive and there is no evidence of mean reversion the question that should be answered is regarding the sustainability of this financial leverage in public finances. These results are in line with other studies such as [Antonini et al. \(2013\)](#), [Cuestas et al. \(2014\)](#), [Chen et al. \(2018\)](#) and [Caporale et al. \(2021\)](#) among others, but not with [Bekaert and Harvey \(2003\)](#), [Reinhart and Rogoff \(2010\)](#) or [Panizza and Presbitero \(2012\)](#) that found mean reversion and stationarity in debt using shorter samples.

Despite debt being always measured in terms of the debt/GDP ratio, sustainability would also depend on the fiscal policy and on the macroeconomic conditions, these being factors which might modify the threshold level ([Bohn, 1995, 1998](#); [Greiner et al., 2007](#); [Bequiraj et al., 2018](#), among others). The empirical evidence provided in this work on the nonstationarity and the persistent and non-mean reverting behaviour of sovereign debt in the countries under study suggest that a sustainability evaluation would require additional cointegration tests with the primary balance time series ([Trehan and Walsh, 1988](#)). In any case, the reduction of current debt levels must require the application of additional policies to ensure its reduction.

Economic reasons for the persistence of debt might rely on the characteristics of the shocks hitting the economy but also on the way government policy reacts to those shocks. Even though some authors proposed that a stationary debt/GDP optimum level should exist ([Aiyagui and McGrattan, 1998](#), [Schmitt-Grohé and Uribe, 2004](#), [Leith and Wren-Lewis, 2013](#), among others) our empirical results show evidence of nonstationarity, with high persistence and no mean reversion properties. We believe that when shocks occur, fiscal adjustments tend to be smaller but persistent, and budget gaps are compensated with debt ([Barro, 1979](#)). However, in the absence of pressure by bond holders or international entities, governments tend not to react in the opposite way as this reverse policy would generate unpopular measures leading to a persistent effect ([Bequiraj, 2018](#)). To support this hypothesis, we have also analysed the

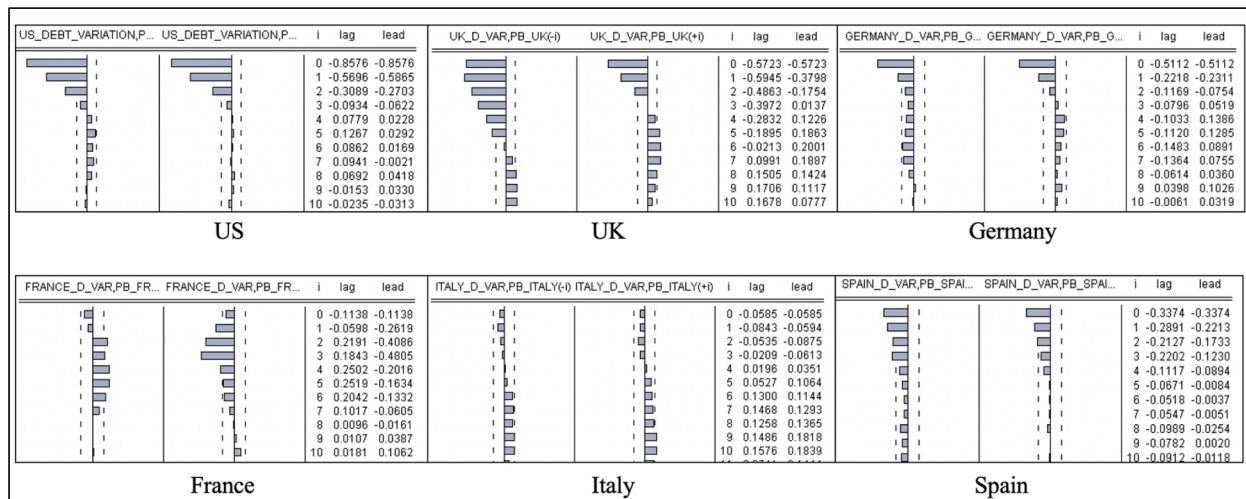


Fig. 4. Cross correlogram variation of debt/GDP vs primary balance/GDP ratios.

Table 5
Estimates of d for the Primary Balance over GDP ratio.

Country	Semiparametric	Parametric (W.N.)	Parametric (Autoc.)
SPAIN	0.80 (0.72, 0.88)	0.79 (0.66, 0.96)	0.51 (0.34, 0.75)
FRANCE	0.86 (0.73, 0.99)	0.90 (0.74, 1.09)	0.53 (0.29, 0.91)
GERMANY	0.54 (0.43, 0.65)	0.52 (0.38, 0.70)	0.45 (0.04, 0.71)
ITALY	0.92 (0.86, 0.98)	0.92 (0.78, 1.09)	0.67 (0.41, 1.00)
UK	1.36 (1.30, 1.42)	1.40 (1.17, 1.65)	1.46 (0.46, 1.89)
USA	0.84 (0.79, 0.88)	0.83 (0.64, 1.08)	0.78 (0.14, 0.93)

The values in parenthesis refer to the 95 % confidence bands for the differencing parameter.

Table 6
Analysis of Structural breaks following Bai & Perron (2003) methodology.

DEBT/GDP	Structural breaks	Sample starting	Structural breaks since 1900	Sample starting
US	1914, 1948	1800	1929, 1948	1900
UK	1915, 1947	1800	1921, 1947	1900
France	1901, 1922	1881	1922	1900
Germany	none	1883	None	1900
Italy	1920	1867	1921, 1941	1900
Spain	none	1880	None	1900

Table 7
Cointegration tests between primary balance and debt variation.

Country	Variables		Critical Values (McKinnon 2010)	
	Primary Balance	Debt Variation	$N = 1$	$N = 2$
Spain	-3.04	-6.15	-2.88	-3.85
France	-3.85	-4.45	-2.88	-3.85
Germany	-6.21	-7.75	-2.88	-3.85
Italy	-3.46	-9.57	-2.88	-3.84
UK	-5.99	-4.31	-2.88	-3.83
US	-8.88	-9.46	-2.87	-3.82

statistical properties of the primary balances and their relationship with debt variations. We found empirical evidence of persistence in all countries under analysis and correlations between primary deficits and debt variations. However, the strength of this dependency varies across countries and additional factors can be related with the GDP growth, real interest rates and associated debt snowball effects (ECB, 2011) and with globalisation and interdependence among countries (Antonini et al., 2013).

A high debt/GDP ratio hinders, among other things, the ability of governments to promote economic growth in their countries since it limits the application of expansionary fiscal policies to increase public spending or reduce taxes. This implies less capacity to respond to moments of uncertainty and economic recession which can prolong or exacerbate these periods. Further, servicing debt might become complicated if monetary policy is restrictive in an environment of high interest rates, which in turn can lead to a greater burden on taxpayers which, in turn, discourages saving and investment. As Willems and Zettelmeyer (2022) noted, in the past, government borrowing costs below growth rates generated a free lunch, depending on the credibility of the central bank, which can be accumulated via prudential policies.

As a final remark, as the time series are non-mean reverting, it is expected that debt will continue to grow. The lack of the gold standard or other balancing effects may lead to this growth to becoming a serious issue in the long run as there is no counterpart of this debt. Future lines of research should be oriented to the study of factors that affect this debt sustainability, especially the impact of natural resources and green economic sustainable technologies.

CRediT authorship contribution statement

Miguel A. Martin-Valmayor: Writing – review & editing, Writing – original draft, Resources, Data curation, Conceptualization.
Nieves Carmona-González: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization.
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Luis A. Gil-Alana: Writing – review & editing, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.eap.2024.06.012](https://doi.org/10.1016/j.eap.2024.06.012).

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