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PUBLIC DEBT AND ECONOMIC GROWTH IN EURO AREA COUNTRIES. A WAVELET APPROACH

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Abstract. In this paper we propose to analyze the dynamic of the relation between public debt and economic growth rate for Euro area countries by employing a wavelet approach, establishing thus both short-term and long-term correlations between these two variables. In this way we will present time-frequency dependencies between debt and economic growth and differentiate between short term and long-term effects. High levels of public debt have a negative impact on the economic output, because they entail concerns about debt sustainability. Non-linear analysis of the debt-growth nexus shows the existence of thresholds from which rising indebtedness can hamper economic growth. Using wavelet analysis, we demonstrate that there is a strong relation between public debt and economic growth, especially for high frequencies, public debt having a significant impact on economic growth in case of periods situated above 2 years for most Euro Zone member states.

High debt levels can cause serious effects on fiscal stability and therefore require fiscal consolidation in order to restore economic growth. Therefore, Euro Zone member states should implement prudent debt policies and establish clear limits for debt increase, in order to comply with fiscal sustainability and ensure conditions for preserving economic growth.

Keywords: growth-debt nexus, sustainability, Euro area sovereign debt crisis, fiscal consolidation, continuous wavelet transform, wavelet coherence.

JEL Classification: F36, H60, H87, O11.

Introduction

After the global financial crisis of 2007, the sustainability of high debt ratios emerged as a serious concern for states and governments, due to an impressive increase in public debt levels worldwide. Euro Zone (EZ) countries sovereign debt crisis (SDC), which followed the financial crisis, showed that public debt must be monitored more strictly, in order to avoid situations of payment incapacity or sovereign default.

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The sovereign debt crisis in EZ raised again the issue of the necessity to complete the European Monetary Union (EMU), implemented through a common currency area, with a Fiscal Union and a Banking Union. The lack of fiscal coordination among EZ countries has entailed serious consequences for the financial architecture of the European Union. Thus, common budgetary policies are as important as common monetary regulations in order to prevent negative consequences of financial crisis. The convergence of monetary and fiscal policies within Euro area is essential in order to ensure stability of the currency union.

In order to investigate the impact of the high levels of debt on macroeconomics, we study in this paper the relation between public debt and economic growth for EZ countries during 2000–2019, including both the financial crisis and the sovereign debt crisis. Public debt has increased substantially in the Euro area countries as a result of the last financial crisis, from 69% of GDP in 2000 to 86.4% of GDP in 2019. This significant increase is due to the necessity to find additional sources of financing for restoring growth levels to figures before the world financial crisis. Also, implementation of pro-cyclical fiscal policies is hampered by high debt levels, which makes countries with high debt experience more pronounced recessions (Checherita-Westphal & Rother, 2012).

Sustainability of public debt is closely related to the evolution of gross domestic product growth rate, as an excessive debt accumulation contributes to higher interest rates, which influences output and can trigger crisis. The relation between debt and growth is also determined by the destination of funds engaged as debt. Usually, most EZ countries resorted to debt in order to finance public expenditure and transfers during the crisis, in order to ensure a smooth functioning of the economy during contractions. If public debt is used to finance public investment, this has a positive effect on GDP growth. The recent crisis showed that debt buildup can be harmful for economic growth, especially after a certain threshold is reached.

Thus, as a result of the crisis, the relation between debt and growth started to be studied from the prospect of finding the optimal debt level which is not detrimental to growth. There have been identified several thresholds in the literature, from which public debt starts to impact negatively economic growth (Ash et al., 2017; Attard, 2019; Checherita & Rother, 2010; Eberhardt & Presbitero, 2013; Reinhart & Rogoff, 2010). Non-linearities in the relationship public debt-growth result from the fact that negative spillovers from debt to growth start once a certain threshold is exceeded. If debt goes beyond a certain limit, it becomes problematic to find resources for debt and interest repayment, leading to accumulation of deficits and resulting finally in lower economic growth.

The paper contributes to existing literature by proposing a new non-linear method for studying the interaction between debt and growth, respectively wavelet analysis. Most studies examining debt-growth nexus employ linear estimation techniques. We consider that our analysis fills thus an important gap, as, from our knowledge, there is yet no paper studying time-varying interaction between public indebtedness and output in EZ by using wavelet techniques. At the same time, there are few studies which concentrate on debt-growth nexus for EZ countries.

Using the wavelet methodology for assessing the relation between public debt and economic growth, we can discern the existence of both short-term and long-term effects between these two variables during the period analyzed, decomposing this relation between

variables in short, medium and long time intervals, in order to discern the potential effect of increasing debt on economic growth ratio. We consider that the application of wavelet methodology will provide new insights in order to analyze the relation between public debt and economic growth.

Our choice for Eurozone countries group is due to the fact that these countries form a monetary union, with a common currency, while they still lack fiscal and budgetary coordination. Therefore, the choice for this group could be suggestive for the whole European Union, analyzing the case of Euro area from the prospect of a possible future trajectory for the rest of EU countries. Public debt evolution in relation to output dynamics in EZ deserves closer investigation, regarding the characteristics of a Monetary Union within the European Union, taking into consideration that debt trajectory in EZ is not similar to other countries (Baum et al., 2012).

Our results show that public indebtedness has a significant impact on economic growth, especially at scales more than two years, which suggests the importance of debt evaluation in order to ensure public finances sustainability. Understanding the interaction between public debt and economic output provides also important insights for policymakers for proposing policies for monitoring the evolution of public finances and providing a sustainable economic growth.

Our article is structured as follows: Section 1 contains the literature review, in Section 2 we present some theoretical considerations regarding public debt sustainability, Section 3 introduces the method of continuous wavelet transform used in this paper, while Section 4 contains the results of the wavelet analysis for debt-economic growth nexus using quarterly data for the period 2000–2019 for Euro area member states and Section 5 robustness checks. The last section concludes.

1. Literature review

The relation between public debt and economic growth can be examined in order to find the impact of high public debt on output and also potential thresholds for public debt becoming significant in influencing growth ratio. An increase in public debt is usually causing concerns for future growth and for ensuring the financing resources to repay interest rates.

Public debt-economic growth nexus is analyzed using both linear and non-linear methods. We will focus especially on papers applying non-linear methods for assessing the relation between debt and growth, taking into account our choice for continuous wavelet transform analysis of the variables. Non-linear impact of debt on GDP growth can be represented as a concave inverted U-shape, with the threshold identified at 90 percent of GDP (Reinhart & Rogoff, 2010).

The "steady-state debt ratio" proposed by Blanchard et al. (1990) refers to the ratio of debt to GDP towards which the economy tends to converge on long-term, which implies debt stabilization. This steady-state ratio represents the maximum level of debt which governments can afford in order to comply with the intertemporal budget constraint. Also, the "natural debt limit" (Mendoza & Oviedo, 2004), for the case of emerging economies, is actually the maximum debt which the governments are capable of paying taking into consideration the worst case fiscal scenarios.

The literature usually takes into consideration the impact of debt on GDP growth rate and the channels through which debt can influence growth. Thus, the impact depends very much on the structure of the economy and country characteristics. The influence of high ratios of debt on economic output is manifested through several channels, such as private saving, public investment, total factor productivity and long-term interest rates (Checherita & Rother, 2010).

There is also significant cross-country heterogeneity regarding the debt-growth nexus: some economies have low levels of debt and yet reduced economic growth, while there are countries for which high levels of public debt do not exert any influence on GDP growth ratio. Therefore, it is not possible to establish a common threshold for debt influence on output, due to heterogeneity issues. Differences among countries regarding the behavior of the growth-debt nexus are related to institutional and macroeconomic conditions. Debt distress is a serious phenomenon affecting economies and can provoke macroeconomic imbalances at the level of each state if debt is not managed accordingly.

Non-linear analyses of the nexus public debt-economic growth propose specific thresholds, beyond which economic growth is negatively compromised. The identification of turning points in the debt-growth relation originated in the paper of Reinhart and Rogoff (Reinhart & Rogoff, 2010), which opened a new direction in the debates regarding the effect of public indebtedness buildup on output. The threshold from which high public debt influences output is established based on empirical models at 90% of GDP using a sample of 44 countries (emerging and advanced economies) for over two hundred years. Following Reinhart and Rogoff, many studies have tried to propose limits for public debt increase, so that economic growth should not be negatively influenced.

The threshold from which public debt starts to impact negatively economic growth was estimated at 50% of GDP for low-income economies by Clements, Bhattacharya and Nguyen (Clements et al., 2003). Debt can influence growth because of its effect on resource utilization, rather than through private investment reduction. The effect of government debt on economic growth in the case of advanced and emerging economies for the period 1970–2007 is explored, looking for potential non-linearities and threshold effects (Kumar & Woo, 2010). The paper confirms that on average a 10 percentage point increase in debt produces a further reduction in GDP growth ratio of 0.2 percentage points per year.

Other research confirms that debt has a negative effect on economic growth beyond a threshold, estimated at 85% of GDP (Cecchetti et al., 2011). The detection of the threshold was based on data for the level of government, non-financial corporate and household debt in 18 OECD countries during 1980–2010. The threshold for corporate debt was estimated at 90% and for household debt at 85% of GDP.

Public debt – economic growth nexus was analyzed, accounting for non-linearities, by means of a dynamic threshold panel methodology using yearly data for EZ countries (Baum et al., 2012). The estimations show that the relation between debt and GDP growth is positive, and identify a threshold of 67% beyond which the impact of debt on growth has values close to zero. When debt exceeds 95% of GDP, any additional debt has a negative influence on the rate of economic growth.

Different thresholds for public debt-economic growth nexus are established in a general multivariate growth framework with Bayesian model averaging and non-linearities are

dependent on the time and country dimension as well as data frequency (Balázs, 2012). At the same time, non-linearities seem to emerge especially in case of low levels of public debt, 20–60% of GDP.

Eberhardt and Presbitero (2013) have also looked for potential thresholds for public debt to have significant effects on economic growth, showing there is a negative non-linear relation between debt and growth both across and within countries, but no evidence for a debt threshold across countries. Regarding the heterogeneity of the relation between debt and growth, evidence for thresholds or high vulnerability regions is confirmed for countries with higher debt to GDP and lower growth ratios.

There are also attempts to identify thresholds beyond which debt becomes unsustainable, in the presence of non-linearities (Kourtellos et al., 2013). The debt-growth nexus is mediated by the quality of institutions, in case this quality is poor, then high debt can result in weak economic performance. Regarding the non-linear impact of debt on growth, specifically a concave relationship (an inverted U-shape curve), the turning point from which debt starts to negatively impact output is established at 80–94% of GDP for old EU member states, while for new member countries is 53–54% of GDP (Mencinger et al., 2014).

No single pattern of non-linearities for each country regarding debt-growth nexus can be identified, evidencing issues related to debt composition and country-specific characteristics (Eberhardt & Presbitero, 2015). The investigation of thresholds for developing, emerging and advanced economies from 1960 to 2012 is based on non-linear methods, showing the presence of a negative relationship between debt and long-term economic growth and no common threshold for all countries.

Other authors introduce the transmission mechanism when studying the causality from public debt to GDP growth rate (Ogawa et al., 2016). Long-term interest rate is used as a modality to transmit shocks for public debt and economic growth and the direction of causality is from GDP growth towards public debt.

Other results confirm a statistically significant threshold effect for countries with debt-to-GDP ratios exceeding 50% of GDP, and point to the importance of the debt trajectory, whether debt is increasing or decreasing. Using tests for threshold effects and dynamic heterogeneous panel data models with cross-sectionally dependent errors applied on advanced and developing economies, during 1965–2010, no clear debt-threshold is confirmed, while some advanced economies present evidence of a weak debt trajectory effect (Chudik et al., 2017).

Another investigation of non-linearities in the debt-growth nexus shows no threshold for indebtedness. There is a negative relation between debt and growth in the long run, while in the short and medium term, increasing public sector debt is found to have a positive effect on output (Mika & Zumer, 2017).

Choosing a sample of emerging and advanced economies, Bernardini and Forni (2017) show that public debt and private debt accumulation have a direct effect on the duration and intensity of financial crisis. The authors used a sample of AE and EME countries applying the Local Projection Method and find that debt accumulation leads to more severe recessions in EMEs and AEs and these effects are more pronounced in case of EMEs. The heterogeneity between EMEs and AEs also comes from fiscal policy.

High-debt countries confront with problems related to debt repayments and consequently rising interest rates, which impacts negatively economic growth, due to a reduction of interest spending. A one-standard-deviation decrease in the real GDP growth rate contributes to the increase of debt-to-GDP by 3.24 percentage points for high-debt countries and 1.04 percentage points for low-debt countries (Gómez-Puig & Sosvilla-Rivero, 2018).

Spillover effects between public debt and economic growth are analyzed using a vector autoregressive (GVAR) model for three groups of Euro area countries, including control variables (aggregate consumption and investment, budget balance, trade balance and long-term interest rates) which can function as possible transmission mechanisms between debt and growth. The results confirm the presence of common effects from an output increase impulse of one eurozone group to the other groups. Also, growth shocks are analyzed in relation to reducing public debt and lowering long-term real interest rates (Kempa & Khan, 2017).

Debt produces a significant long-term effect on the rate of economic growth. Bidirectional causality from debt to growth is not clearly confirmed. Thus, for countries with low levels of public debt there is a two-way causality, while in case of high-debt countries the relation of causality manifests only from debt to growth (Attard, 2019).

The relationship between debt and economic growth is studied in a panel of 72 countries using data for the period 1970–2014, in a VAR model. The paper finds that this relation is dependent on the sector holding debt (government, firms or households), the source of debt financing (internal or external) and also varies with countries having different development levels and exchange rate regimes (Kim & Zhang, 2020).

Although the relation between public debt and economic growth is very important from the prospect of macroeconomic stability, few papers have examined so far the nexus between these two variables for the case of Euro area countries. Usually this relationship is estimated using different econometric techniques in order to assess the effect of public debt increase on output in advanced and emerging economies (Table 1).

Table 1. Literature review, relation debt-economic growth

Authors	Method	Sample and period	Main findings
Clements et al. (2003)	The fixed effects and system GMM	55 low-income countries, during 1970–1999	The threshold from which public debt starts to impact negatively economic growth was estimated at 50% of GDP for low-income economies
Reinhard and Rogoff (2010)	Regression	44 emerging and advanced economies for 200 years	The threshold from which high public debt influences output is 90% of GDP
Kumar and Woo (2010)	Pooled OLS, robust regression, between estimator (BE), fixed effects (FE) panel regression, and system GMM (SGMM) dynamic panel regression	Advanced and emerging economies for the period 1970–2007	A 10 percentage point increase in debt reduces GDP growth ratio with 0.2 percentage points per year

Continue of Table 1

Authors	Method	Sample and period	Main findings
Cecchetti et al. (2011)	Growth regressions	18 OECD countries during 1980–2010	Debt has a negative effect on economic growth beyond a threshold of 85% of GDP
Baum et al. (2012)	Dynamic threshold panel methodology	Yearly data for EZ countries	A threshold of 67% beyond which the impact of debt on growth is close to zero. When debt is above 95% of GDP, any additional debt has a negative influence on economic growth
Balázs (2012)	General multivariate growth framework with Bayesian model	1960–2010	Non-linearities emerge in case of low levels of public debt, 20–60% of GDP
Eberhardt and Presbitero (2013)	Linear dynamic and asymmetric dynamic models	105 developing, emerging and developed economies during 1972–2009	There is a negative non-linear relation between debt and growth, but no evidence for a debt threshold
Kourtellos et al. (2013)	A structural threshold regression	Balanced 10-year period panel dataset for 82 countries in 1980–1989, 1990–1999, and 2000–2009	The debt-growth relation is mediated by the quality of institutions
Mencinger et al. (2014)	Non-dynamic baseline fixed effects panel regression	EU countries	Debt has negative impact on growth at 80–94% of GDP for old EU member states, and at 53–54% of GDP for new member countries
Eberhardt and Presbitero (2015)	Linear dynamic model	118 developing, emerging and advanced economies during 1960–2012	Negative relationship between debt and long-term economic growth
Ogawa et al. (2016)	Panel VAR model	31 EU and OECD countries, 1995–2013	The causality is from GDP growth towards public debt
Chudik et al. (2017)	Tests for threshold effects and dynamic heterogeneous panel data models with cross-sectionally dependent errors	Advanced and developing economies, during 1965–2010	Threshold effect for countries with debt-to-GDP ratios exceeding 50% of GDP, showing the importance of the debt trajectory
Mika and Zumer (2017)	Cross-country panel regressions and mean group estimations	EU countries during 1995–2015	A negative relation between debt and growth in the long run, and a positive relation in the short and medium term
Kempa and Khan (2017)	GVAR model for three groups of Euro area countries	Quarterly data for 11 EZ countries during 1991–2014	Common effects from an output increase impulse of one EZ group to the other groups

End of Table 1

Authors	Method	Sample and period	Main findings
Bernardini and Forni (2017)	Local Projection Method	A sample of AE and EME countries	Debt build-up has as result more severe recessions in EME and AEs and these effects are more pronounced in case of EMEs
Gómez-Puig and Sosvilla-Rivero (2018)	Autoregressive Distributed Lag (ARDL) bounds testing approach	Annual data, central and peripheral countries of the euro area during 1961–2013	A one-standard-deviation decrease in the real GDP growth rate results in the increase of debt-to-GDP by 3.24% for high-debt countries and 1.04% for low-debt countries
Attard (2019)	Panel time series autoregressive distributed lag model	25 European Union member states during 1996–2017	For countries with low levels of public debt there is a two-way causality, while in case of high-debt countries causality is only from debt to growth
Kim and Zhang (2020)	Vector Autoregressive Model	Panel of 72 countries	The nexus debt-growth depends on the sector holding debt, the source for financing debt and development level

In case of European Union and Euro Area countries, the relation between public debt and macroeconomics is extremely important, taking into account that keeping debt levels sustainable represents an ongoing preoccupation for governments. Public debt acts as an important trigger for economic growth, and in case of EU countries, the limit-values of debt and deficits are clearly defined within the Stability and Growth Pact and are monitored under a strict surveillance procedure. The financial crisis of 2007, followed by Euro zone countries crisis, has proved that a high level of public debt can produce negative consequences for economic growth and can determine a country enter in a situation of incapacity of payment. The case of Greece, which witnessed financial system collapse as a result of the high debt accumulated, represented an important lesson for European policymakers.

2. Theoretical considerations regarding economic growth and public debt sustainability

The relation between public debt and economic growth is still an issue to be clarified, although there are currently many studies which try to find different measures for public debt thresholds. Following Reinhart and Rogoff (2010), many papers propose limits for public debt increase, beyond which debt becomes detrimental for economic growth. There are also studies which show that there cannot be established a threshold for public debt (Ash et al., 2017).

The bidirectional causality between growth-debt can be analyzed from several perspectives: a low growth rate can produce a linear negative impact on debt, while high debt can hamper growth after a certain limit is reached (Checherita & Rother, 2010). According to the classic theory of public debt (Elmendorf & Mankiw, 1999), public debt can have a positive

effect on income, aggregate demand and output on short-term, while on long-term public debt can result in a decrease of GDP growth rate.

Regarding the definition of public debt sustainability, most authors start usually from the intertemporal budget constraint, according to which a government must keep the debt level stable in time. In this model a government borrows with an interest rate i_t, for a certain period of time t.

$$\left(1+i_t\right)D_{t-1}+G_t=D_t+T_t\,, \tag{1}$$

where D_t is total debt, G_t represents governmental expenses and T_t income from taxes. In order to preserve the condition of sustainability, it is important to keep under control the ratio of debt to GDP (Demaj, 2017).

Debt is engaged for the payment of deficits and new debt will serve the government operating purposes to ensure sufficient capital for its current expenses. Debt is sustainable as long as the government can generate future primary surpluses in order to be able to pay the future debts and accrued interest rates.

An important condition for debt sustainability, which results from the above equations, is that the rate of interest increase should not exceed the GDP growth rate.

From equation (1) we can infer the condition for public debt sustainability, respectively if we suppose the debt to remain constant, in order for debt to be sustainable, it is necessary that the growth rate of GDP should be greater than the growth rate of interest ratio.

$$d_t=d_{t-1}\left(\frac{1+i_t}{1+\ y_t}\right)+\ s_t\,, \tag{2}$$

where s_t is the primary surplus and y_t is the growth rate of GDP.

Therefore, the reaction of primary surplus to debt changes is an important factor in order to control for the stability of the public debt. The condition for the sustainability of public debt is that the present value of debt should be equal to zero, because governments cannot engage new debt in order to finance the old debt. Deficits financed through debt must be compensated by future surpluses. This condition is expressed by the following equation:

$$\sum_{t=1}^{\infty}\left(ps_t\prod_{p=1}^{t}\frac{1+i_t}{1+g_t}\right)+d_0=0, \tag{3}$$

where i_t is the interest rate, g_t is the GDP growth rate and d_0 is the ratio of debt to GDP. Also, equilibrium is reached when GDP growth rate tends to equal the interest rate (Albu, 2006).

The sustainability of fiscal policy is satisfied by respecting the conditions imposed through this equation. The International Monetary Fund uses the concept of Debt Net Present Value (NPV) in order to analyze debt sustainability. The concept of NPV is applied in order to calculate the real burden of debt, for low-income countries receiving loans, by using a formula through which debt payments are updated with the market interest rate in order to assess the real opportunity costs of loans (International Monetary Fund [IMF], 2003).

The legacy of public debts accumulated during years of the financial crisis and then during sovereign debt crisis represents an important concern for governments. The sovereign debt crisis of EZ states, which started in 2009, shifted the focus on issues concerning public

debt sustainability, due to increasing levels of indebtedness in order to sustain economic growth. The degree of contagion of this crisis manifested eventually for all EZ countries (Abel et al., 2011).

The crisis started due to the accumulation of public deficits in Greece, not declared officially, and rapidly spread to the other EZ countries, starting with Ireland, Spain, Portugal, Cyprus and Italy. High debt levels in Greece produced investors' serious doubts regarding the solvency of the state. The withdrawal of investors caused significant panic on financial markets, risk premiums went up and Greece was found in the situation of incapacity to service its debt obligations and international financial assistance was required.

The case of Greece shows that high levels of public debt can produce anytime a self-fulfilling crisis, due to multiple equilibria issues (Wyplosz, 2014). The sovereign debt crisis entailed a transformation of liquidity into solvency problems (Valiante, 2011).

The crisis drew attention to the role of the Stability and Growth Pact in keeping public debt and budget deficits within sustainable limits at the level of EZ countries. Fiscal indiscipline can be identified among the causes for the crisis (Wyplosz, 2014). Other causes of the crisis include the rapid accumulation of private debt in all EZ countries, which had as result debt buildup at governmental level as well (De Grauwe, 2010).

The sovereign debt crisis demonstrated that rising public indebtedness can have detrimental effects on growth and on financial stability. High debt-to-GDP ratios can be seen by investors as the product of inflationary or time-inconsistent policies, leading states to implement fiscal austerity programs, which produce as secondary effects a rise in unemployment, risk of deflation or economic contractions (Yener et al., 2014). The sovereign debt crisis in EZ entailed the implementation of large macroeconomic stabilization programs (Samarakoon, 2017).

High indebtedness can affect output on long-term, due to the rise in sovereign spreads and sovereign yields, financial intermediation and increase in future distortionary taxation (Burriel et al., 2020).

Usually high public debt build-up is associated with risks for the interest-growth differential to become positive and thus raise important concerns for public debt sustainability. The actual low-interest rate environment preserves public debt on a sustainable path, but in case interest rate will be lower than growth rate, this can result in debt non-sustainability (Mauro & Zhou, 2020). There have been formulated serious concerns regarding the evolution of the interest-growth differential, taking into consideration that historical evolutions show that we can have no guarantee for the fact that r-g will remain negative (Rogoff, 2020).

The response of the European Union to the public indebtedness increase was the setup of new financial institutions and regulations in order to provide help for countries facing severe debt sustainability problems and liquidity shortages, such as European Financial Stability Facility and the European Stability Mechanism. The sovereign debt crisis demonstrated that the actual fiscal framework of the EU must be completed in order to react better to future debt crisis.

The SDC was the result of inadequacy of the fiscal policies applied at the level of Euro area countries. Thus, countries such as Germany and northern countries should have stimulated growth by enforcing the right expansionary fiscal policies with tax cuts and increase

of expenses, while periphery EZ member states should have run restrictive fiscal policies (Frieden & Walter, 2017).

The debt crisis was amplified in the EZ due to the impossibility to resort to unconventional monetary policy tools by the European Central Bank, such as other national central banks, due to the existence of the common currency. On the other hand, price stability requires convergence of long-term interest rates to the average interest rate to satisfy the criteria for membership in EMU (Jiang et al., 2013).

3. Methodology

Taking into account that public debt is continuously increasing, both worldwide and in case of Euro Zone countries, reaching extremely high levels especially after the economic crisis of 2007 and the sovereign debt crisis, we will attempt in this paper to study the effect of the increasing public debt on economic growth in case of EA countries, by looking at this relation taking into account the time and frequency dimension by applying wavelet analysis.

Wavelet analysis allows us to study the dynamic of economic variables in both time and frequency domains, overcoming thus the limitations related to a time series analysis. One of the advantages of wavelet analysis is that it does not require stationarity of the data.

Wavelet transformation is a process of decomposition and superposition of information, in which both the time and frequency dimensions are considered together. The wavelet transform has certain characteristics, such as time resolution being adjusted to frequency. In case of high frequencies, the window width narrows, while in case of low frequencies the window width widens.

3.1. The continuous wavelet transform

The wavelet transform decomposes a time series $x(t)$ in terms of some basis wavelets $\psi^*_{\tau,\, s}(t)$ which are obtained by translation and dilation of the mother wavelet $\psi(t)$.

The continuous wavelet transform of a time series, represented as $W_x(\tau,\, s)$, consists in the application of a mother wavelet $\psi(t)$ to the time series $x(t)$. The mother wavelet is defined by the following formula:

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right), \tag{4}$$

where τ is the location or translation parameter, measuring the time position of the mother wavelet and is represented on the time axis, s is the scale or dilation parameter, which shows how the wavelet is stretched or dilated and can generate wave functions of different frequencies. A lower scale detects higher frequencies of the time series, while a higher scale will show the lower frequencies of the series.

For a times series $x(t)$ the continuous wavelet transform for a mother wavelet ψ is:

$$W_x(\tau,s) = \int_{-\infty}^{+\infty} x(t)\psi^*\left(\frac{t-\tau}{s}\right) dt; \tag{5}$$

$$W_x(\tau,\, s) = \int_{-\infty}^{+\infty} x(t)\psi^*_{t,\, s}(t)dt, \tag{6}$$

where * represents the complex conjugate.

We will work in this paper with the most used type of wavelet transform, respectively Morlett transformation. The Morlett transform of the mother wavelet represents the convolution of the time series $x(t)$ using wavelet-daughters generated by the mother wavelet by translation in time by τ and scaling by s.

In case of Morlett transformation, the mother wavelet is given by the following formula:

$$\psi(t) = \pi^{-1/4} e^{i\omega t}\ e^{-t^2/2}, \tag{7}$$

where ω represents the angular frequency and refers to the number of oscillations within a Gaussian envelope and is set to 6, the value usually used in the literature. The increase (decrease) of ω helps to obtain an improved (poorer) frequency localization with a worse (better) localization regarding time.

Wavelet power spectrum measures the local variance distribution of the time series $x(t)$ using both time and scale/frequency.

$$\left|W_x(\tau, s)\right|^2. \tag{8}$$

Cross wavelet spectrum measures the covariance between two series in the time-frequency space and is given by the following formula:

$$W_{xy}(\tau, s) = W_x(\tau, s)\ W_y^*(\tau, s), \tag{9}$$

where $W_x(\tau, s)$ is the wavelet transform of $x(t)$ and $W_y^*(\tau, s)$ is the wavelet transform of y.

Wavelet coherency is defined by the following formula:

$$Coherency = \frac{\left|sWave.xy\right|^2}{sPower.x \cdot sPower.y}. \tag{10}$$

The lead-lag relationship between the time series is shown by the wavelet phase difference. The wavelet phase difference represents the ratio between the imaginary part of the cross-wavelet transform and the real part:

$$\phi(\tau, s) = \tan^{-1}\left(\frac{\mathcal{I}\left(W_{xy}(\tau, s)\right)}{\mathcal{R}\left(W_{xy}(\tau, s)\right)}\right). \tag{11}$$

4. Results

We will use for our analysis a sample of 19 Euro area member states, for which we will calculate the relation between the real GDP growth rate and public debt for the period 2000–2019, using quarterly data. We have extracted quarterly data from Eurostat about public debt as a percentage of GDP and for GDP growth rate for Euro area countries during 2000–2019. The descriptive statistics of the data is presented in Table 2, with mean, maximum, minimum, standard deviation, skewness and kurtosis for the variables public debt and GDP growth ratio. We have applied the R package WaveletComp (Schmidbauer & Roesch, 2018) in order to compute the wavelet power spectrums of the two variables and the wavelet coherency, in order to measure the correlation between public debt and economic growth for Euro area member countries.

Table 2. Descriptive statistics

	EZ public debt	EZ GDP
Observations	79	79
Mean	79.63	0.33
Median	80.20	0.44
Maximum	94.00	1.23
Minimum	65.90	–3.16
Standard Deviation	10.14	0.60
Skewness	0.06	–2.99
Kurtosis	–1.78	14.02

4.1. Wavelet power spectrum: economic growth and public debt

In Figure 1 we have presented the wavelet power spectrums for public debt and economic growth for Euro area countries. On the horizontal axis time is represented as quarters, from 2000Q1 to 2019Q3, while the vertical axis shows the periods or scales for the wavelet transformation. Periods are represented starting from half a quarter, to 2, 4 and 16 quarters, referring to short, medium and long-term scale intervals. The red color suggests that the wavelet power spectrum is higher, while blue color refers to periods when the wavelet power spectrum is lower. Significant fluctuations of the wavelet power spectrum show a pronounced volatility of the series economic growth and public debt.

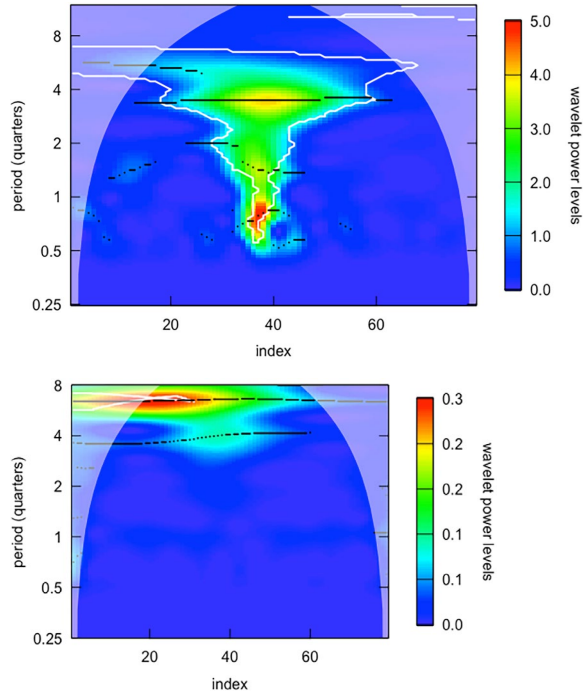

Figure 1. Wavelet power spectrum Euro area GDP growth rate and public debt

Analyzing the wavelet power spectrum for the series of economic growth of Euro zone, we can notice that the wavelet power spectrum is higher in the scale of 0.5 to 1 quarter, during the start of the economic crisis of 2007–2010. During the global financial crisis, EZ countries registered negative growth rates, respectively –8.9% in 2012 and –8.2% in 2013, starting to recover to positive ratios in 2014 (1.4%). The decrease of economic output may affect the long-term prospects for economic recovery for euro area countries even further.

For the series of public debt, the wavelet power spectrum is higher for the interval situated within 4–8 quarters, from 2000 until 2010. In the rest of the period, the fluctuations of the wavelet power spectrum are not significant for public debt or for the ratio of economic growth of the Eurozone. The 20% of GDP increase in public debt since the onset of the crisis is a significant drawback for EZ recovery, taking into consideration that public debt should be reduced to comply with Maastricht criteria. But the return to public debt levels, as well as economic growth ratios prior to the crisis will probably be a long and difficult process, taking into consideration that the crisis has contributed to a significant increase in the public and private debt, the stock of non-performing loans, as well as unemployment, poverty and inequality in Euro area.

4.2. The wavelet coherence analysis: public debt and economic growth

The wavelet coherence analysis shows the lead-lag relationships between debt and output growth in case of Euro area countries, presenting both the evolution in time and frequency of these variables, which allows us to grasp the degree of correlation between public debt and economic growth. The areas of blue color signify that the co-movement between the two series is lower, while red color indicates a strong correlation between them. The thick black contour shows the areas where the wavelet coherence is significant at 5% level against red noise estimated from 1000 Monte Carlo simulations using phase randomized surrogate AR(1) coefficients. The cone of influence includes the results which are not affected by edge effects.

As far as phase differences are concerned, these are graphically represented by arrows. When the direction of the arrow is pointed to the right, the two variables are completely synchronized. When the arrow is pointed to the left, the two variables move in anti-phase. When the arrow has the upside right and downside left direction, then the first variable is leading the second, while an arrow pointed downside right (or upside left) means that the second variable is leading and that the first is lagging.

In the case of Euro area, the correlation between public debt and economic growth for all countries is shown in Figure 2, in colors ranging from blue, signifying the lowest amount of correlation between the variables and red, showing a higher degree of correlation, closer to 1. The period, represented on the y-axis, shows the time frequencies used in our analysis, starting with business cycles of 0.5 quarter, to 2, 4, 8 and 16 quarters.

Empirical analysis confirms the persistence of a strong heterogeneity among EA countries regarding the relation between public debt and economic growth. Wavelet coherence analysis shows that public debt and economic growth have a high degree of correlation in the scale two to eight quarters, during 2004–2010, covering thus the period of the economic crisis of 2007 and the sovereign debt crisis.

The results for each country show the correlations among public debt and economic output for different frequencies (Figure 3). During the SDC, many EZ countries doubled their

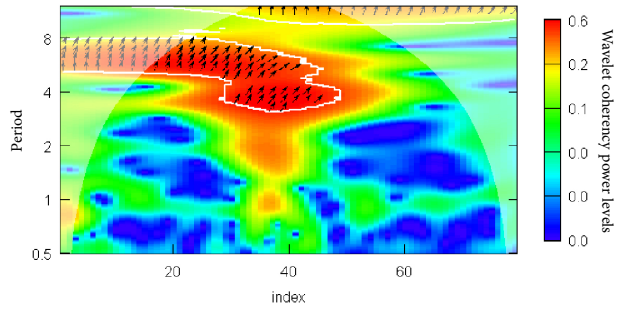

Figure 2. Wavelet coherence Euro area GDP growth rate and public debt

public debt-to-GDP ratios and registered negative growth. For most EZ countries included in our sample, public debt influences the evolution of GDP growth during the whole interval analyzed, 2000–2019, the direction of the lead-lag relations showing that public debt is significantly influencing the ratio of growth especially in case of high frequencies, above 2 years. These influences can be seen from the fact that the increase of public debt levels in most EZ countries following the crisis has had an impact on GDP growth ratios.

Thus, from 1999 until the onset of the global financial crisis, public debt decreased from 71.5% of GDP in 1999 to 65.9% in 2007 in the Euro area. Fiscal indicators during this period were mainly within Maastricht limits, with deficits not exceeding 3% of GDP and low interest rates. In 2007, Euro area GDP growth ratio was 3% and most EZ countries exceeded a growth ratio of 3% (only 4 EZ countries had GDP growth less than 3%, respectively Denmark, Germany, Italy and Portugal).

However, the period of the global financial crisis and the sovereign debt crisis was accompanied by a sharp increase in public debt levels in EZ, from 69.6% of GDP in 2008 to 92.8% of GDP in 2014. In 2007, many EZ countries exceeded the limits for debt ratios of 60% of GDP: Belgium (87.3% of GDP), Germany (64% of GDP), Greece (103.1%), France (64.5%), Italy (103.9%), Malta (62.3%), Portugal (72.7%) and Austria (65% of GDP). In 2009, EZ growth rate was negative, at –4.5%, while all Euro area countries registered negative growth ratios (Austria with a GDP growth of –3.76%, Belgium –2.02%, Finland –8.07%, Germany –5.70%, Greece –4.30%, Italy –5.28% and Portugal –3.12%). The effect of high debt levels on economic growth is thus manifest for most EZ countries on longer-time scales, debt producing economic growth decline at periods of more than 2 years.

In 2014, most euro area countries had high public debt levels, due to the deficits accumulated during the crisis in order to stimulate economic growth. Thus, the biggest values for public debt were registered in Greece – 178.9% of GDP, Italy – 135.4%, Portugal – 132.9%, Belgium – 107%, Cyprus – 109.2%, Ireland – 104.4% and Spain – 100.7%. The rapid deterioration of public finances indicators was due to the fiscal stimulus enforced during the GFC and SDC in order to support the economy. The fiscal expansionary measures applied in the EZ resulted in an increase of public deficits and consequently in the buildup of high public debts. In 2014 negative growth was registered only in Cyprus (–1.86%) and Finland (–0.36%), for the other EZ countries the decrease in debt levels compared to the peak from 2009 having an impact on GDP growth recovery as well.

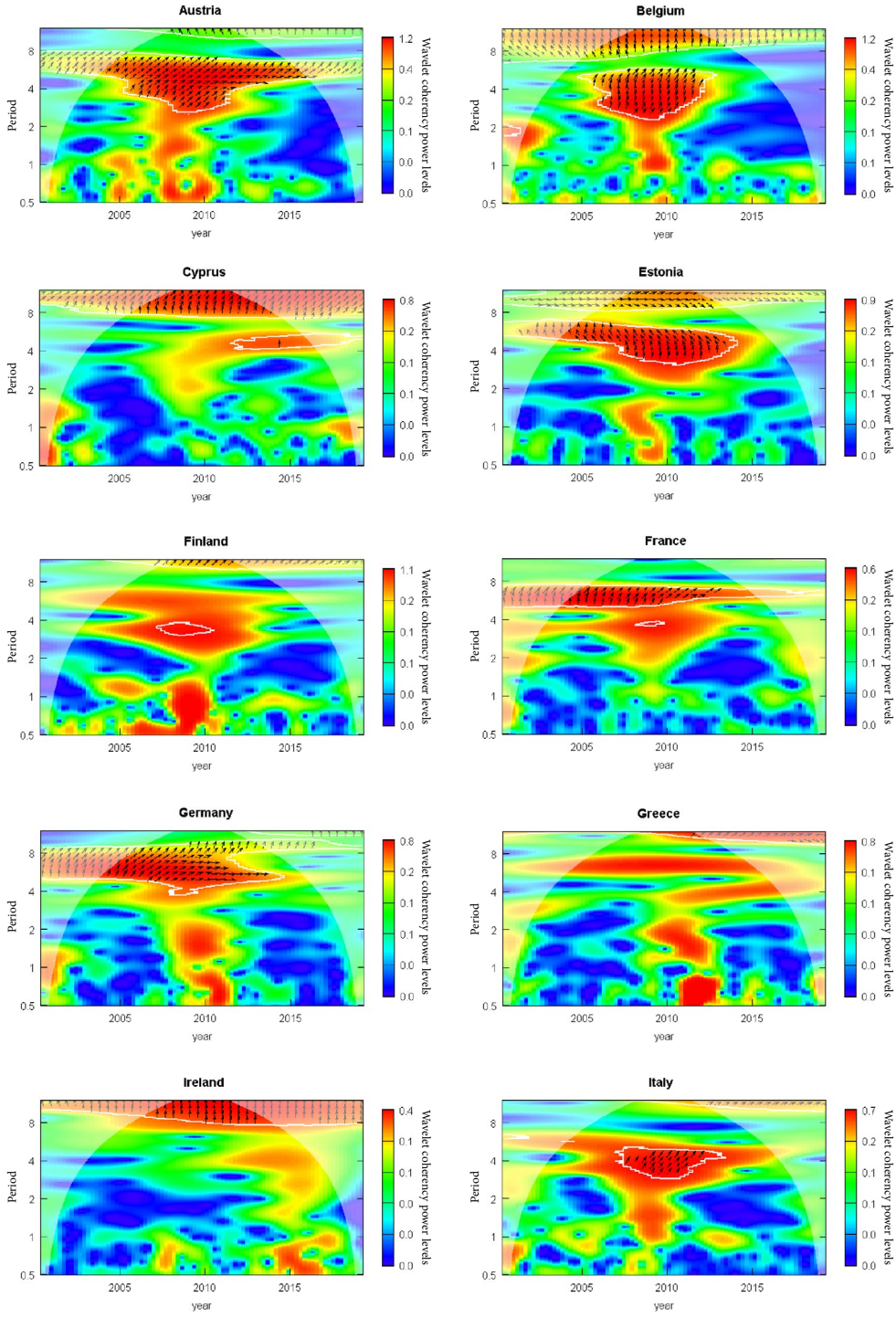

Figure 3. *To be continue*

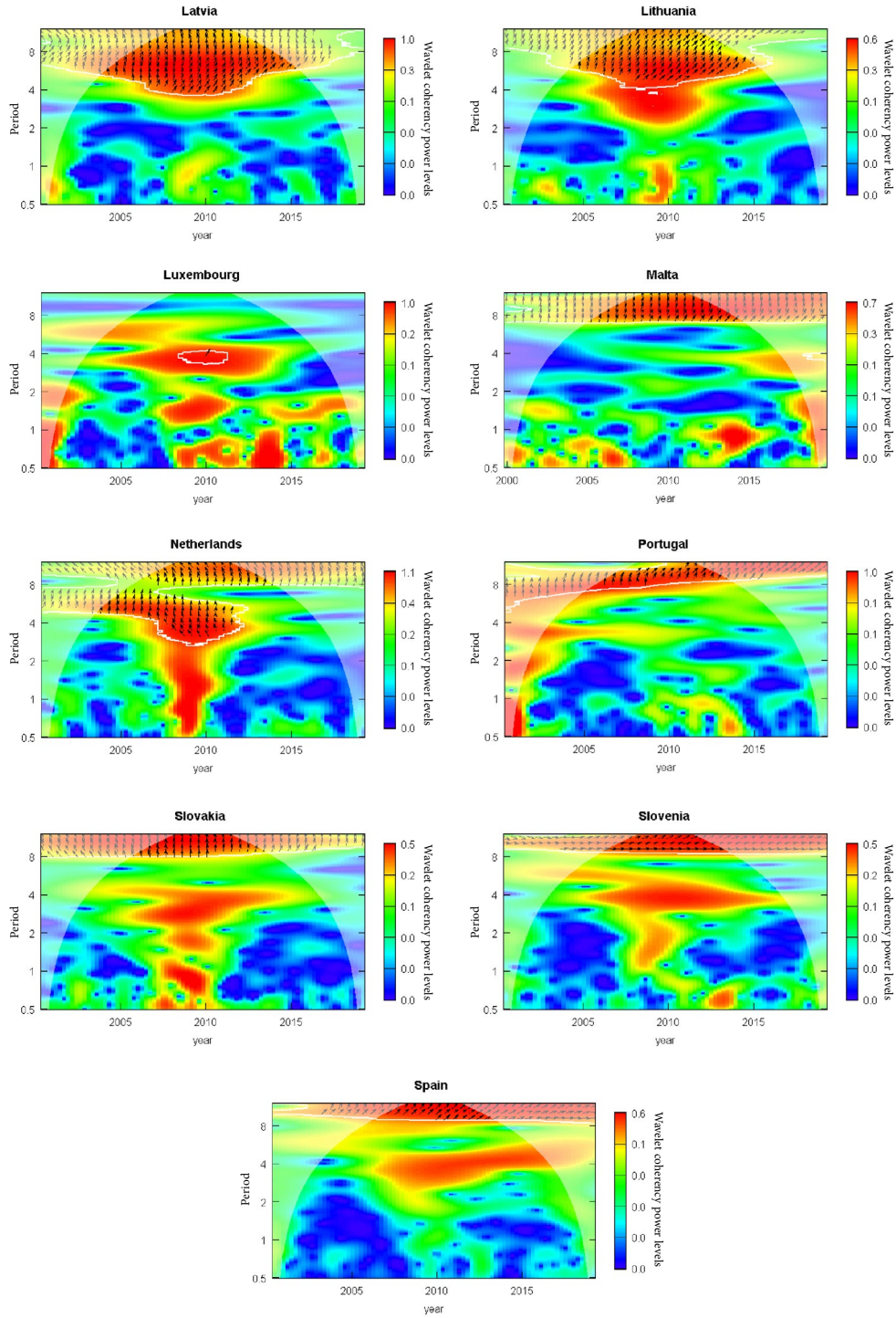

Figure 3. Wavelet coherence public debt-GDP growth for Euro Zone countries

Following the end of the crisis, the debt trajectory started to reduce in the Euro area, to 84.1 of GDP in 2019 (in 2019, GDP growth rate for Euro area was 1.28%) and in most EZ countries. In 2019, only three countries had debt ratios above 100% of GDP: Greece – 176.6% of GDP, Italy – 134.8% and Portugal – 117.7% of GDP.

Country-level wavelet coherence analysis shows that public debt and economic growth are correlated during the period analyzed, 2000–2019, with public debt influencing the ratio of GDP growth.

For Austria, wavelet coherence spectrum is showing that public debt and economic growth are highly correlated in case of high frequencies, respectively for periods between 3–8 quarters, during the whole period analyzed, respectively 2000–2019, while during the global financial crisis, 2007–2012, this relation is manifested also for shorter time scales, 2–4 quarters, and the leading variable is public debt for the whole period. Belgium presents a similar pattern, public debt and economic growth being highly correlated in case of long time scales (8 quarters) during 2000–2019. Another region of high correlation appears during 2007–2012, for scales of 2–6 quarters, with public debt influencing the level of economic growth.

In case of Estonia, the relation between public debt and output growth presents high correlation between 2000–2014, during the global financial crisis and SDC, at longer-time scales (3–8 quarters). The variables are in phase, with public debt influencing the rate of growth at scales 3–5 quarters, and out of phase for frequencies 5–7 quarters, with economic growth leading.

Cyprus is another country severely affected by the sovereign debt crisis, because debt distress was combined with the banking system collapse, forcing the country to request financial assistance from European Commission, ECB and IMF in 2012. Wavelet coherence analysis during 2000–2019 for Cyprus shows that public debt and growth are synchronized in case of longer-time scales, more than 2 years, with public debt as the leading variable, influencing the growth rate.

For Finland, Greece and Luxemburg, the co-movement debt-GDP growth is not significant at any frequencies. The SDC started with Greece, which increased the estimation for budget deficit from 6.7 to 12.7% of GDP in 2009, producing panic on financial markets. As a result of investors losing confidence in the sovereign bonds, the premium risks started to rise, and the cost of debt and interest substantially increased. Thus, Greece had to receive financial assistance from the European Central Bank and the IMF in order to save the country from default, the result being that Greece was imposed severe austerity programs.

In case of France and Germany, economic growth and public debt are synchronized, with public debt leading for high frequencies, 4–8 quarters during 2005–2012, covering the period of the financial crisis and sovereign debt crisis. In case of Italy, the relation between the two variables is significant in the scale of 3–6 quarters, during 2007–2014, during the world financial crisis and SDC. The two variables are in phase, with public debt leading and influencing the level of output growth.

Latvia and Lithuania show co-movement between public debt and economic growth in case of long-time scales, more than 4 quarters, during 2004–2016, with public debt influencing growth ratio. For Netherlands, public debt and economic growth are synchronized in case of high frequencies, 3–6 quarters, during 2005–2012, with both variables influencing each

other. In case of Malta, Ireland, Portugal, Slovakia, Slovenia, Spain, public debt and economic growth rate are correlated at very high frequencies, exceeding 8 quarters, during 2005–2015, with public debt influencing the level of economic growth.

The results of the wavelet coherence analysis show that the coherence among the variables is present especially in case of longer-time scales, 4–8 quarters, while on short-term there is a low amount of correlation between public debt and economic growth for EZ countries. The co-movement and synchronization between public debt and economic growth is demonstrated by areas of red color, which are especially present during the period 2005–2012, during the financial crisis and the SDC, demonstrating how high debt levels impact GDP growth on long-term for most countries analyzed.

Wavelet transformation analysis allows to reconsider the relation debt-economic output from the perspective of shorter and longer time horizons. Thus, our results show that this relation becomes more relevant in case of longer-time scales, specifically in case of periods longer than 1–2 years. In this situation, the phase-difference between these two variables shows that public debt and economic growth are correlated, with public debt influencing economic growth levels in most Euro area countries. This result is consistent with classical debt theory, according to which debt can stimulate demand and output in the short run, while in the long-term debt can contribute to a reduction in output and in the rate of growth (Barro, 1990; Elmendorf & Mankiw, 1999). Our estimations prove, in line with most existing literature, that debt is producing negative effects on economic growth ratios in the Euro Zone countries.

Regarding the situation of each member state of the Euro Area, the analysis of wavelet coherence shows that there are significant differences among countries regarding the relation between public debt and GDP growth ratio. The correlation between debt and growth is heterogeneous depending on country specific characteristics, and there is no single threshold or frequency for which public debt acts as a trigger on economic growth. Therefore, our results seem to suggest that the debt-to-GDP ratio at which public debt exerts the strongest negative impact on economic growth changes over time and across EA countries.

Some authors have explained the heterogeneities between EA countries regarding the debt-growth nexus as a result of differences in the production technologies (Eberhardt & Presbitero, 2013). Cross-country heterogeneity is due to the fact that capacity to overcome debt crisis is related to macroeconomic frameworks and there is no common procedure for coping with debt overhang for all countries (Reinhart & Rogoff, 2012).

Euro Area country analysis demonstrates the impact of the global financial crisis and sovereign debt crisis on rising debt levels and decline in growth ratios. The sovereign debt crisis in the Eurozone is evidenced starting with 2009, when member states were affected by increasing levels of public debt and incapacity of payment of financial obligations, as a result of the imbalances within their financial systems, due to the fact that public debt and deficits were not kept under strict monitoring.

The group of PIIGS countries (Portugal, Italy, Ireland, Greece and Spain), which were most severely affected by the crisis were characterized by high public debts before the onset of the crisis and also by running large current account deficits. The cause for the impressive explosion of debt after the GFC and SDC is that debt levels prior to the crisis were not sustainable. For instance, in 2006, debt was exceeding the 60% limit in Belgium, Greece,

Italy and Portugal. Thus, the macroeconomic and fiscal vulnerabilities accumulated for EZ countries during years preceding the crisis have produced this important build-up of public debt (Wyplosz, 2006).

5. Robustness checks

In order to verify the validity of the wavelet coherence results we have applied the wavelet coherence analysis to two groups of EZ countries. Thus, based on gross national income per capita in PPS, we have classified the countries of the Eurozone in two groups, high-income countries (with an income per capita above 28 in current prices PPS): Belgium, Germany, Ireland, Spain, France, Italy, Luxembourg, Netherlands, Austria, Finland and low-income countries (with an income per capita less than 28 in current prices PPS): Estonia, Greece, Cyprus, Latvia, Lithuania, Malta, Portugal, Slovenia and Slovakia.

We have estimated the relation between public debt and economic growth for these two groups of EZ countries using wavelet coherence analysis, in order to check whether our results are robust to this new classification. The results obtained confirm the validity of our models, showing that public debt and economic growth ratio are correlated also in case of high frequencies, in the scale of more than 2 years, with public debt influencing the rate of growth (Figure 4).

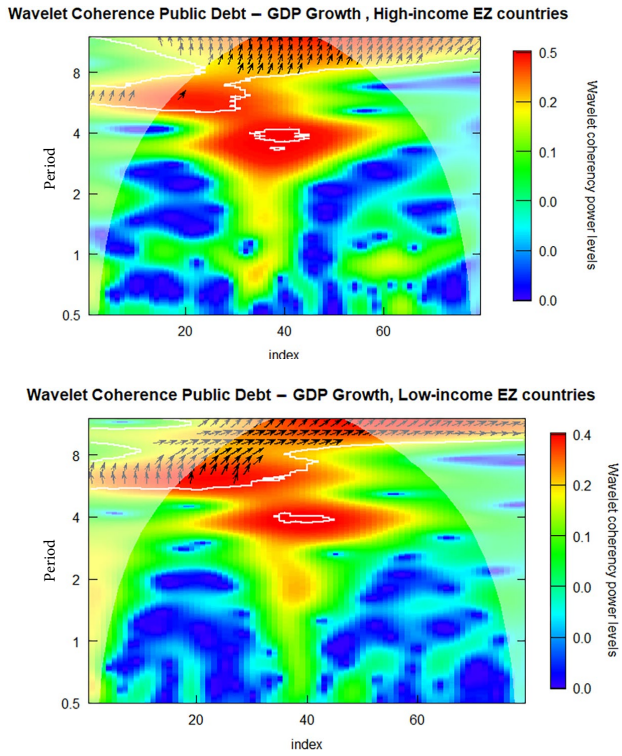

Figure 4. Wavelet coherence public debt-GDP growth for high-income Euro Zone countries and low-income Euro Zone countries

Thus, for the group of high-income EZ countries public debt and output are correlated at large scales, of more than 8 quarters, during 2005–2012, with public debt as the leading variable and economic growth as lagging variable, showing the influence of debt on economic output.

For the group of low-income EZ countries the results are similar, with the variables public debt and economic growth correlated in case of high frequencies, starting with 6–8 quarters, during 2005–2012, during the global financial crisis and the sovereign debt crisis. The direction of causality is from debt to GDP growth, high debt levels having a significant impact on economic growth.

Conclusions

Taking into account that public debt is continuously increasing, both worldwide and in case of Euro Zone countries, reaching extremely high levels especially after the economic crisis of 2007 and the sovereign debt crisis, we have attempted in this paper to study the effect of the increasing public debt on economic growth in EZ countries during 2000–2019. The novelty which is brought about by the technique of wavelet analysis is the possibility to study the relation and co-movement between economic variables at different time horizons, using short-time, medium time and long-time scales. By applying this method to the study of public debt - economic growth nexus, we can thus present time-varying characteristics which could not be showed by other non-linear methods.

Our choice for this method is due to the fact that wavelet techniques offer a new insight in analyzing our data because of the possibility to decompose the time series at very low and high frequencies and to inspect their characteristics in both time and frequency domains. Our argument for using the continuous wavelet transform is related to the opportunity of studying how the variables relate at different frequencies and how this relation has evolved during time. Thus, we can investigate new dimensions about the evolution of public debt and economic growth in the EZ.

The results of our study show that public debt and economic growth have a positive co-movement during the period analyzed, 2000–2019, for most Euro Zone countries, and correlate especially at long-run frequencies, more than two years. This confirms the classical theory of public debt, according to which debt can stimulate output on short-term, while higher debt will impact negatively economic growth on long term, demonstrating the importance of keeping debt levels within sustainable limits. Our results are in line with most of empirical literature searching for thresholds in the relation debt-growth, proving that public debt is harmful for growth, especially after long-time intervals, exceeding 2 years.

Thus, our paper draws attention to the necessity of preserving sustainable debt limits, in order to prevent recessions or defaults. Public indebtedness buildup represents an important concern for European decision-makers regarding the efficiency of the monitoring procedures contained within the Treaty for Growth and Stability, and other European fiscal regulations. The actual fiscal framework in EU, characterized by the persistence of high levels of public debt, accrued during the financial crisis from 2007 and sovereign debt crisis, has to improve regulations in order to prevent further excessive debt accumulation.

As directions for further research, we consider that the present analysis could be extended in order to study public debt-GDP growth nexus in core and periphery euro area countries, as well as for the two main groups of European Union member states – old member states and new members, taking into account that these groups of countries share more similarities and thus common trajectories could be identified in order to propose fiscal rules and policies for ensuring debt sustainability.

At the same time, the present study could be completed taking into account the impact of the actual Covid-19 crisis. The pandemic will produce a new increase in debt levels accompanied by low economic growth in the Euro area, and this situation is unprecedented due to the potential dimensions of this new debt crisis.

Taking into account that public debt has detrimental effects on economic growth, the importance of debt reduction in order to sustain economic output should be carefully considered. In order to decrease the negative impact of the crisis and to prevent the emergence of new future crisis, the European Union is permanently improving actual fiscal regulations in order to ensure a more adequate supervision of debt and deficits evolution. Thus, the relation debt-growth can be studied from the perspective of fiscal rules enforced in order to prevent debt buildup. Establishing limits and rules regarding public debt and deficits could provide the fiscal space necessary in case of future economic crisis and also for coping with the actual Covid-19 pandemic.

Author contributions

Lucian-Liviu Albu wrote the final version of the paper and was responsible for wavelet analysis. Ada-Cristina Albu prepared the article and interpreted the wavelet results.

Disclosure statement

We acknowledge that we do no have any competing financial, professional, or personal interests from other parties.

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