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EUROPEAN UNION PUBLIC DEBT IN THE CONTEXT OF RECENT DEVELOPMENTS

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ABSTRACT
In the context of recent crises at the level of Europe, the public debt also calls into question the need to detect possible adverse effects over time. The increase in public debt may raise the question of the sustainability of this debt. Thus, the article aims to develop an appropriate model to predict, based on time series, the evolution of public debt in the EU27 (implicitly in the euro area and in several countries selected for example). Thus, the paper uses Eurostat quarterly data for gross government debt for the period 2000 q1 to 2021 q1, the forecast being made by 2028 quarter 1. The model is used Box Jenkins ARIMA methodology, comparing the information criteria Akaike, Schwartz and Hannan-Quinn, the ACF (autocorrelation function) and PACF (partial autocorrelation function) correlograms are analyzed, including for ARIMA residues, so as to verify the selected ARIMA model. The appropriate models for the forecast of gross public debt expressed as a percentage of GDP are for the EU - ARIMA (1,1,1), for the Euro Zone - ARIMA (1,1,1), for Romania - ARIMA (1,1,1) for France ARIMA (1,1,10), for Finland ARIMA (4,1,9), for Greece ARIMA (26,1,26). The forecasted developments further suggest for the European Union, the euro area and the analyzed countries (Romania, France, Finland and Greece) the possibilities for a dramatic increase in public debt, requiring a more careful analysis, especially in the context of discussions on debt sustainability.

KEYWORDS: Public debt forecasting, time series, ARIMA models, PACF.

1. INTRODUCTION
For fiscal-budgetary sustainability, analyzing the public debt-to-GDP ratio that a country can sustain over the short to medium term is an important element for policy makers. For this reason, the evolution of public debt, but also other additional factors can contribute to shaping the overall picture of the health of present and future public finances.

Debt forecasts and debt sustainability are made mainly by the world's leading international institutions and less by specialized studies.

The prediction model used in this article is of the ARIMA Box-Jenkins type, knowing that for the time series forecast, the Auto-Regressive Integrated Moving Average (ARIMA) models are widely used. These models undergo constant methodological updates and are used to predict many micro and macroeconomic indicators, ranging from the evolution of the prices of some products and raw materials to the evolution of GDP (Bowman & Husain, 2004, Shil et al., 2013, Abonazel & Abd-elftah, 2019, Cortez et al., 2018 etc.).

Thus, in order to be able to formulate ARIMA-type models for predicting data from univariate time series (Chris Brooks, 2008), the data used for the model should be stationary. Thus, we can start from various statistical tests to verify the stationary of the series and in this case it has been used an ADF test (augmented Dickey – Fuller).

2. LITERATURE REVIEW

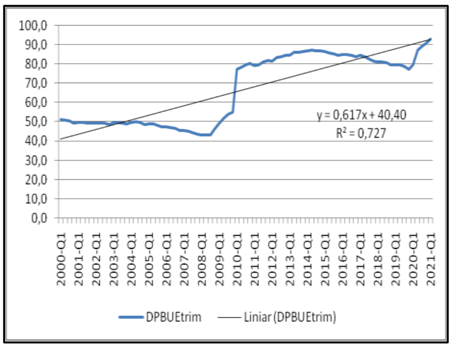
Education, infrastructure, trade support, health care, defense, state industry and institutions are just a few areas that require public spending that can be problematic in relation to budget revenues. In this respect, either reducing minor expenditures, or increasing taxes, or widening the tax base, or issuing currency or issuing public debt are a few solutions to meet budgetary needs. The issuance of public debt is accepted as long as it does not jeopardize the sustainability of public debt. This means avoiding the increasing structural deficits and complying with fiscal rules (e.g. Treaty of Maastricht and Stability and Growth Pact etc.) so that, in time, the in daftness must converge to its initial level (Keynes, 1923; Buiter, 1985; Corsetti and Roubini, 1991, Blanchard,1990 etc). But continuous government borrowing results in rising public debt, ant its' servicing will require higher and higher taxes and other fiscal constraints, finally conducing to even reach the situation of sovereign default (Domar, 1944). Thus, sustainability of public debt isn't an easy topic; most of the studies concerning public debt are using as investigation method: - unit-root tests (usually, Augmented Dickey-Fuller test, for the stationarity assessment of time series), - cointegration tests (for the influences between revenues and expenditures), -fiscal rule tests (comparing the primary balance with the primary balance which stabilize public debt) and fiscal reaction function tests (to explain the evolution of the public debt according to the evolution of the primary balance and vice versa). When considering forecasting, along with studies for this area (e.g. Stoian, 2008, which estimates budgetary revenues considering its own past values), for public debt, the institutional reports of IMF, World Bank, European Commission, European Central Bank and Eurostat are the main sources of reliable forecast. Generally, studies show that, given the low credibility of medium-term fiscal and budgetary programs and adjustments, public debt trajectories at world and European level will exceed pre-pandemic levels.

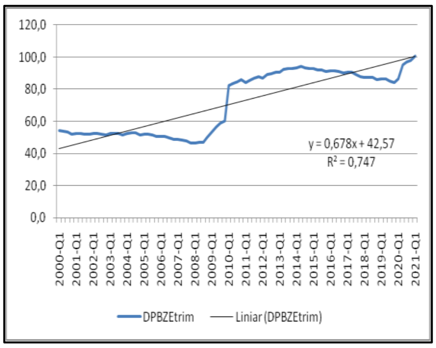
3. METHODOLOGY

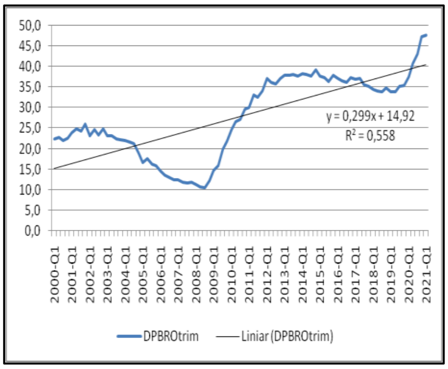
Given the concerns for future developments in macroeconomic parameters, regarding public debt, the present article aims to develop an appropriate model to predict, based on time series, the evolution of public debt in the EU27. Thus, the paper uses Eurostat quarterly data for general government gross debt for the period 2000q1 to 2021q1, the forecast being made by 2028q1. The model used is Box-Jenkings ARIMA.

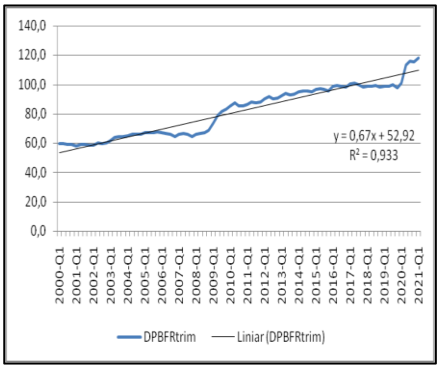
In general, Box-Jenkins (1970) models contain three stages of elaboration: identification, estimation and diagnosis, and prediction (D'Amico, 2020). For the identification stage, in this paper, it has been used corelograms for the Automatic Correlation Function (ACF) and the Partial Automatic Correlation Function (PACF). In the case of non-stationary time series differentiation of the first order is used for the series to become stationary.

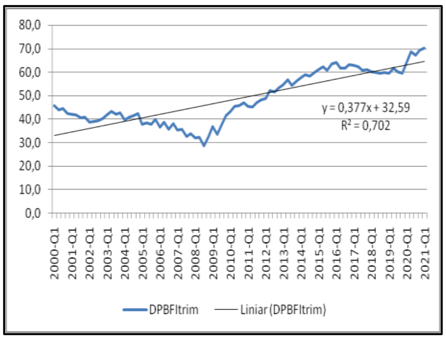
This is also necessary in our case, the graphs showing the existence of the trend for all the regions analyzed during the period involved in the analysis (2000 trimester or quarter 1 - 2021 trimester1). The choice of EU countries was made based on regional typologies (North, South, East and West), being selected: Romania (for East region of EU27), France (for West), Finland (for North) and Greece (for South).

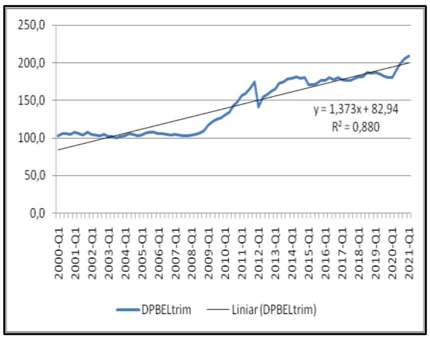












Source: Eurostat quarterly data, own representation. Notes: DPBUEtrim, DPBZEtrim, DPBROtrim, DPBFItrim, DPBELtrim – are general government gross debt, or rather quarterly consolidated government gross debt for the EU, euro area, Romania, France, Finland and Greece

Figure 1: Evolution of General government gross debt (% of GDP) for EU27, EA19, Romania, France, Finland and Greece for the period 2000q1-2021q1

According to the theory (e.g. Glen, S.; Hyndman & Athanasopoulos, 2018), in the autoregressive process (AR), the independent values will be the past values of the dependent variable, and the general form of the autoregressive model will be as follows:

$$yt = a_0 + a_1 y_{t-1} + \cdots + a_p\, y_{t-p} + \varepsilon_t \qquad (1)$$

The above equation is the general representation of the model AR (p), where a0,a1 …ap are the constants and yt-1...yt-p are the past values of the dependent variable. Regarding the moving average (MA), the general form of the equation is formulated as follows:

$$yt = a_0 + a_1 y_{t-1} + \cdots + a_p\, y_{t-p} + \varepsilon_t \qquad (2)$$

In the above equation, a0,b1, ..bq are constants and εt,εt-1… εt-q, are the past values of the error terms. The combined process of the AR and MA process is ARMA. Thus, the equation obtained after combining the above equations is the general representation of the ARMA model (p, q).

$$yt = a_0 + a_1 y_{t-1} + \cdots + a_p\, y_{t-p} + \varepsilon_t + b_1 \varepsilon_{t-1} + \cdots + b_q\, \varepsilon_{t-p} \qquad (3)$$

The above equations are valid for stationary series; in the case of non-stationary series, the first order difference is taken into account.

4. RESULT

From the previous graphs it is clear that the analyzed time series are non-stationary, so we will take into account the first difference. In this case, the ARMA model becomes an ARIMA type. See for stationary ADF unit root test in the table below.

In the appendix it has been present the correlograms for the autocorrelation function (ACF) and the partial autocorrelation function (PACF) for all the countries involved in analysis. Correlograms are used to correctly choose the p, q, and d values for models and to identify the terms of the AR and MA process. Thus, series of alternative models are built for the estimation process, being rather an art in establishing the most suitable ARIMA model.

Thus, in the estimation phase, we must follow the significance of the AR and MA components, which must have a p-value below 0.05. At the same time, we should compare the information criteria Akaike, Schwartz and Hannan-Quinn, preferring the model with the smallest three informational values (D'Amico, 2020). Also log-likelihood must have the highest value. From the tabulation of these values, we can decide which is the most suitable model, without claiming that it is perfect, but that it is the best possible model to choose for the EU, the euro area, Romania, France, Finland and Greece for public debt forecasting

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Table 1: Augmented Dickey - Fuller Unit Root Stationary Test for Gross Public Debt for the European Union27, Eurozone19, Romania, France, Finland and Greece

Serial label	Level	Critical Value		The first difference	Critical Value	
	Constant & Trend	5%	1%	Constant	5%	1%
DPBUEtrim	-1.5555	-3.4642	-4.0710	-7.5482	-2.8968	-3.5113
	0.8021*			0.0000*		
DPBZEtrim	-1.5536	-3.4642	-4.0710	-7.5596	-2.8968	-3.5113
	0.8028*			0.0000*		
DPBROtrim	-2.2010	-3.4662	-4.0753	-3.1019	-2.8972	-3.5123
	0.4824*			0.0303*		
DPBFRtrim	-3.2674	-3.4670	-4.0769	-3.8520	-2.8977	-3.5133
	0.0792*			0.0037*		
DPBFItrim	-2.1401	-3.4642	-4.0710	-10.8804	-2.8968	-3.5113
	0.5160*			0.0001*		
DPBELtrim	-2.1598	-3.4642	-4.0710	-10.3687	-2.8968	-3.5113
	0,5052*			0,0000*		

Source: Own research, using annual Eurostat data and Eviews11 software. Note: Numbers with * indicate critical unilateral p values of the ADF test (obtained from MacKinnon, 1996).

Table 2: Result of ARIMA estimates and selection of the appropriate ARIMA model for gross public debt (% of GDP) for the EU27

Models (AR, first difference, MA)	(1,1,1)	(1,1,3)	(1, 1,5)	(1,1,2)	(1,1,21)
R2	0.0519	0.0447	0.0428	0.0353	0.0409
R2 ajustat	0.0163	0.0089	0.0069	0.0008	0.0049
AR p-value	0.0389	0.2545	0.1640	0.2843	0.2106
MA p-value	0.0156	0.3846	0.1226	0.7261	0.7842
Log-likelihoodod	-200.2267	-200.5367	-200.6374	-200.9298	-200.7733
Akaike info criterion (AIC)	4.8625	4.8699	4.8723	4.8793	4.8756

Schwarz criterion (SC)	4.9783	4.9857	4.9885	4.9950	4.9913
Hannan-Quinn critererion (HQC)	4.9091	4.9165	4.9189	4.9258	4.9221

Table 3: Result of ARIMA estimates and selection of the appropriate ARIMA model for gross public debt (% of GDP) for the Eurozone19

Models (AR, first difference, MA)	(1,1,1)	(1,1,3)	(1,1,5)	(3,1,1)	(3,1,3)
R2	0.0538	0.0507	0.0440	0.0468	0.0303
R2 ajustat	0.0183	0.0151	0.0082	0.0111	0.0060
AR p-value	0.0173	0.3062	0.1827	0.2142	0.9885
MA p-value	0.0108	0.2244	0.4271	0.4268	0.9157
Log-likelihoodod	-202.5548	-202.6949	-202.9988	-202.8606	-203.5838
Akaike info criterion (AIC)	4.9180	4.9213	4.9285	4.9253	4.9425
Schwarz criterion (SC)	5.0337	5.0371	5.0443	5.0410	5.0582
Hannan-Quinn critererion (HQC)	4.9645	4.9678	4.9751	4.9718	4.9890

Table 4: Result of ARIMA estimates and selection of the appropriate ARIMA model for gross public debt (% of GDP) for Romania

Models (AR, first difference, MA)	(1,1,1)	(1,1,2)	(1,1,3)	(1,1,4)	(1,1,5)
R2	0.2058	0.1952	0.0810	0.1155	0.0828
R2 ajustat	0.1761	0.1650	0.0465	0.0824	0.0484
AR p-value	0.0000	0.1251	0.1613	0.1205	0.0645
MA p-value	0.0001	0.0007	0.2947	0.0952	0.3093
Log-likelihoodod	-137.4044	-137.9092	-143.3805	-141.8614	-143.3196
Akaike info criterion (AIC)	3.3668	3.3788	3.5091	3.4729	3.5076
Schwarz criterion (SC)	3.4825	3.4945	3.6248	3.5889	3.6234
Hannan-Quinn critererion (HQC)	3.4133	3.4253	3.5556	3.5194	3.5541

Table 5: Result of ARIMA estimates and selection of the appropriate ARIMA model for gross public debt (% of GDP) for France

Models (AR, first difference, MA)	(1,1,1)	(1,1,1)	(1,1,10)	(3,1,1)	(3,1,4)
R2	0.1490	0.1888	0.2107	0.1488	0.0875

R2 ajustat	0.1171	0.1584	0.1811	0.1169	0.0533
AR p-value	0.5584	0.0006	0.0395	0.5590	0.7957
MA p-value	0.0102	0.1501	0.0426	0.0000	0.2953
Log-likelihoodod	-164.9949	-163.3130	-162.9492	-165.0155	-168.0518
Akaike info criterion (AIC)	4.0237	3.9836	3.9750	4.0242	4.0965
Schwarz criterion (SC)	4.1394	4.0994	4.0907	4.1399	4.2122
Hannan-Quinn critererion (HQC)	4.0702	4.0302	4.0215	4.0707	4.1430

Table 6: Result of ARIMA estimates and selection of the appropriate ARIMA model for gross public debt (% of GDP) for Finland

Models (AR, first difference, MA)	(4,1,4)	(4,1,9)	(4,1,15)	(4,1,19)	(4,1,28)
R2	0.1282	0.1682	0.1517	0.1708	0.2055
R2 ajustat	0.0956	0.1477	0.1198	0.1397	0.1757
AR p-value	0.1102	0.0004	0.0020	0.0014	0.0021
MA p-value	0.6242	0.0190	0.1142	0.0751	0.0542
Log-likelihoodod	-171.7898	-170.1223	-170.8577	-170.1880	-169.1067
Akaike info criterion (AIC)	4.1855	4.1143	4.1633	4.1473	4.1216
Schwarz criterion (SC)	4.3012	4.2112	4.2790	4.2631	4.2373
Hannan-Quinn critererion (HQC)	4.2320	4.1592	4.2098	4.1939	4.1681

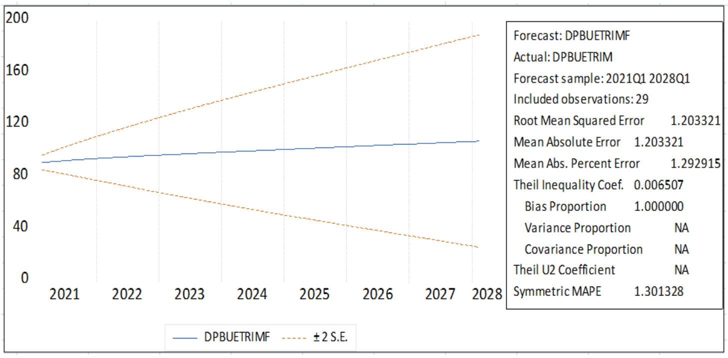
Table 7: Result of ARIMA estimates and selection of the appropriate ARIMA model for gross government debt (% of GDP) for Greece

Models (AR, first difference, MA)	(1,1,1)	(33,1,33)	(26,1,26)	(26,1,33)	(26,1,1)
R2	0,0250	0,1720	0,1681	0,2280	0,0456
R2 ajustat	0,0116	0,1409	0,1369	0,1990	0,0098
AR p-value	0,5081	0,5639	0,0193	0,3429	0,6754
MA p-value	0,6435	0,9999	0,0854	0,9996	0,1554
Log-likelihoodod	-257,4784	-257,1841	-257,0262	-266,8625	-256,8665
Akaike info criterion (AIC)	6,2257	6,2187	6,2105	6,4491	6,2111
Schwarz criterion (SC)	6,3414	6,3344	6,3262	6,5649	6,3269
Hannan-Quinn critererion (HQC)	6,2722	6,2652	6,2607	6,4956	6,2576

Source: for Tables from 2 to 7, own calculations, Eurostat source, quarterly data, gray color - selected model

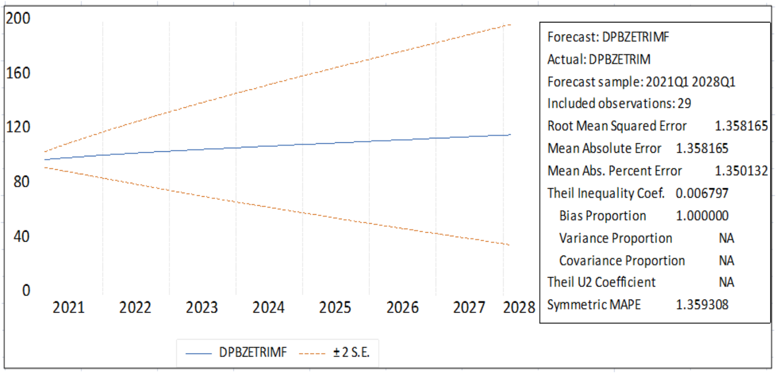
After choosing the model, in the diagnostic phase we will check if the residues are white noise, then we will check if the roots are inside or outside the circles, both for the MA and for the AR roots.

The roots of the MA indicate whether the process is reversible, and the roots of the AR give indications that the process is stationary, so for both (AR and MA) they must be inside the circle (see Annex). If the AR and MA roots are inside the circle, we can perform the forecasting process. The results are shown in the figures below.



Source: *own calculations, Eurostat source; quarterly data.*

Figure 2: General government gross debt (% of GDP) forecast for the EU27 according to the ARIMA model (1,1,1)



Source: *own calculations, Eurostat source; quarterly data.*

Figure 3: General government gross debt (% of GDP) forecast for euro area according to the ARIMA model (1,1,1)

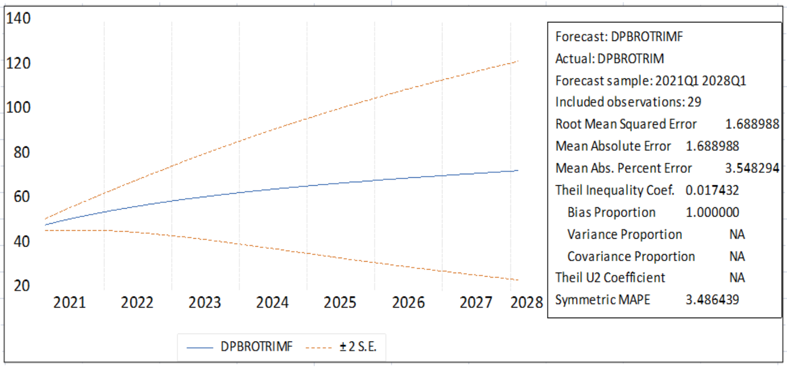


Figure 4: General government gross debt (% of GDP) forecast for Romania according to the ARIMA model (1,1,1)

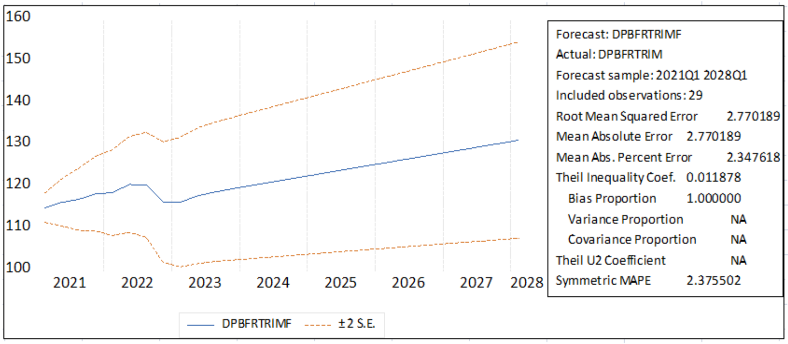


Figure 5: General government gross debt (% of GDP) forecast for France according to the ARIMA model (1,1,10)

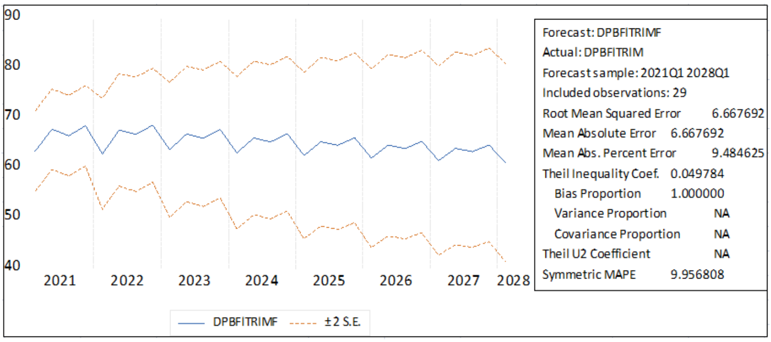


Figure 6: General government gross debt (% of GDP) forecast for Finland according to the ARIMA model (4,1,9)

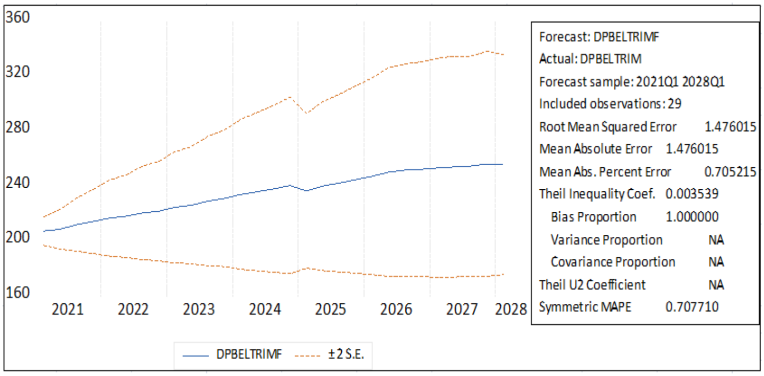


Figure 7: General government gross debt (% of GDP) forecast for Greece according to the ARIMA model (26,1,26)

5. CONCLUSION

This article aims to develop an appropriate forecast model for gross government debt for the period 2021 quarter 2 -2028 quarter 1. Using the ACF and PACF correlograms, we have identified a number of possible models for selected EU regions, euro area, Romania, France, Finland and Greece.

From the Box - Jenkins methodology estimates for all tentative models, the ARIMA (1,1,1) (for EU27), ARIMA (1,1,1) (for ZE19), ARIMA (1,1,1) (for Romania), ARIMA (1,1,10) (for France), ARIMA (4,1,9) (for Finland), ARIMA (26,1,26) (for Greece) can be considered as appropriate models for the general government gross debt forecast.

This type of forecasting model can help us understand possible future developments in government debt and can help policymakers to take appropriate action to limit the upward trend in government debt.

6. OBSERVATION OR NOTE AND POSSIBLE FUTURE APPROACHES

The article represents a partial capitalization of the study "From sustainable public debt to public debt for sustainable development - theoretical and empirical approaches in the context of COVID-19" (coord. Ailincă, A.G., unpublished volume) of the 2021 annual research program of Center for Financial and Monetary Research "Victor Slăvescu". Distinct topics were extracted from the volume which were published as articles but which do not overlap with this article.

At the same time, the preoccupations regarding the development of the forecasts related to the evolution of the public debt will be oriented in the future also towards the use of models of the artificial neural network (ANN) type.

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