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Original scientific paper

THE AUGMENTED DICKEY-FULLER TEST FOR THE STATIONARITY OF THE FINAL PUBLIC CONSUMPTION AND GDP TIME SERIES OF THE REPUBLIC OF NORTH MACEDONIA

Zoran Ivanovski[1]
Nadica Ivanovska

Abstract
In this paper, we present the results of an econometric analysis for the stationarity of the analyzed long-time series of GDP and final public consumption, carried out by Augmented Dickey-Fuller Test in order to apply vector auto-regression model VAR(p). We use quarterly data on the movement of GDP and Public consumption of the Republic of North Macedonia for the time interval 2000Q1 – 2019Q4. The analysis was performed by using Eviews statistical analysis software was used for data processing, in which the VAR model is developed. In fact, this is starting procedure for the use of vector auto-regression. The VAR model has proven to be especially useful for describing the dynamic behavior of economic and financial time series and for forecasting. It often provides superior forecasts to those from univariate time series models and elaborate theory-based simultaneous equations models. The regression from the unit root test with the ADF test that used 3 lags proved that the DLNGDP series is stationary after 3 lags.

Key words**:** VAR (p), Akaike criterion, Durbin-Watson statistics, unit root, stationarity

JEL Classification: C1,C32, C35

INTRODUCTION

Fiscal policy is a powerful instrument of economic policy with which governments try to act in a developmental, stabilizing or countercyclical manner on economic flows in the national economy. For this purpose, the fiscal policy can use different instruments, as well as different methods, and certainly one of them is public spending.

In order to make assessment of the impact of public consumption on the GDP of the Republic of North Macedonia, it is preferable to usie the VAR(p) model. The VAR model is useful for determining the mutual influence of time series. Before presenting the model, we will give an explanation of the time series we use in the research: GDP and public (budgetary) consumption.

Gross domestic product measures the total economic activity of a country and represents the sum of the value of the total goods produced in a country for a period of one year. The total quantities of goods and services are expressed in their market prices, thus obtaining the market value of the total production in the economy during the year. The measurement of GDP includes the final goods and services of the four sectors in the economy: the household sector, the enterprise sector, the state sector and the foreign trade sector.

[1] **Zoran Ivanovski**, **Ph.D,** Full Professor, University of Skopje, **Nadica Ivanovska,**, **Ph.D,** Head of Compliance at Central Cooperative Bank, Republic of North Macedonia.

Public consumption represents spending by the state and other private and public institutions that provide public goods. The limit that determines this spending is the size of the state as an economic force, i.e. its power by force of law to impose taxes on its residents, which in the form of public revenues flow into the state budget and represent a source of funds for financing public expenses. Through public consumption, i.e. through the spending of collected public revenues, certain macroeconomic goals are realized in modern states, primarily goals of economic and social policy, but also of other policies.

The main goal of this research is to test stationarity of data. The stationarity of the time series is necessary to ensure the predictability of the series (forecasting), as well as to ensure the accuracy of the model of the VAR(p). The use of vector autoregression for the analysis of dynamic relationships between variables is very common and is a consequence of the failure of previous time series models to fully capture the relationship of variables, which are, in principle, complex.

The VAR model implies that the variables are stationary, that is, a prerequisite for the vector autoregression model is that the series are stationary. If not, it is necessary to perform the development of stationary variables from non-stationary ones.

1. LITERATURE REVIEW

VAR models (vector autoregressive models) are used for multivariate time series. The structure is that each variable is a linear function of past lags of itself and past lags of the other variables.

In general, for a VAR(p) model, the first p lags of each variable in the system would be used as regression predictors for each variable. VAR models are a specific case of more general VARMA models. VARMA models for multivariate time series include the VAR structure above along with moving average terms for each variable. More generally yet, these are special cases of ARMAX models that allow for the addition of other predictors that are outside the multivariate set of principal interest.

Macroeconometricians do four things: describe and summarize macroeconomic data, make macroeconomic forecasts, quantify what we do or do not know about the true structure of the macroeconomy, and advise (and sometimes become) macroeconomic policymakers. In the 1970s, these four tasks- data description, forecasting, structural inference and policy analysis-were performed using a variety of techniques. These ranged from large models with hundreds of equations to single-equation models that focused on interactions of a few variables to simple univariate time series models involving only a single variable. But after the macroeconomic chaos of the 1970s, none of these approaches appeared especially trustworthy.

Two decades ago, Christopher Sims (1980) provided a new macroeconometric framework that held great promise: vector autoregressions (VARs). A univariate autoregression is a single-equation, single-variable linear model in which the cur rent value of a variable is explained by its own lagged values. A VAR is an n-equation, n-variable linear model in which each variable is in turn explained by its own lagged values, plus current and past values of the remaining n - 1 variables.

This simple framework provides a systematic way to capture rich dynamics in multiple time series, and the statistical toolkit that came with VARs was easy to use and to interpret. As Sims (1980) and others argued in a series of influential early papers, VARs held out the promise of providing a coherent and credible approach to data description, forecasting, structural inference and policy analysis. In this article, we assess how well VARs have addressed these four macroecono- metric tasks.' Our answer is "it depends." In data description and forecasting, VARs have proven to be powerful and reliable tools that are now, rightly, in everyday use. Structural inference and policy analysis are, however, inherently more difficult because they require differentiating between correlation and causation; this is the "identification problem," in the jargon of econometrics. This problem cannot be solved by a purely statistical tool, even a powerful one like a VAR. Rather, economic theory or institutional knowledge is required to solve the identification (causation versus correlation) problem.

What, precisely, is the effect of a 100-basis-point hike in the federal funds interest rate on the rate of inflation one year hence? How big an interest rate cut is needed to offset an expected half percentage point rise in the unemployment rate? How well does the Phillips curve predict inflation? What fraction of the variation in inflation in the past 40 years is due to monetary policy as opposed to external shocks? Many macroeconomists like to think they know the answers to these and similar questions, perhaps with a modest range of uncertainty. A reduced form VAR expresses each variable as a linear function of its own past values, the past values of all other variables being considered and a serially uncorrelated error term. Thus, in our example, the VAR involves three equations: current unemployment as a function of past values of unemployment, inflation and the interest rate; inflation as a function of past values of inflation, unemployment and the interest rate; and similarly for the interest rate equation. Each equation is estimated by ordinary least squares regression. The number of lagged values to include in each equation can be determined by a number of different methods, and we will use four lags in our examples. The error terms in these regressions are the "surprise" movements in the variables after taking its past values into account. If the different variables are correlated with each other-as they typically are in macroeconomic applications-then the error terms in the reduced form model will also be correlated across equations.

A recursive VAR constructs the error terms in each regression equation to be uncorrelated with the error in the preceding equations. This is done byjudiciously including some contemporaneous values as regressors.

A structural VAR uses economic theory to sort out the contemporaneous links among the variables (Bernanke, 1986; Blanchard and Watson, 1986; Sims, 1986). Structural VARs require "identifying assumptions" that allow correlations to be interpreted causally. These identifying assumptions can involve the entire VAR, so that all of the causal links in the model are spelled out, or just a single equation, so that only a specific causal link is identified. This produces instrumental variables that permit the contemporaneous links to be estimated using instrumental variables regression. The number of structural VARs is limited only by the inventiveness of the researcher.

2. DATA

We begin by analyzing the time series we use in the research. In the research, we use time series of data from 20 years, namely the quarterly data for the period 2000 to the last quarter of 2019, expressed in millions of denars. The following graphs show the time series for GDP and public consumption in the Republic of North Macedonia for the period 2000Q1 – 2019Q4:

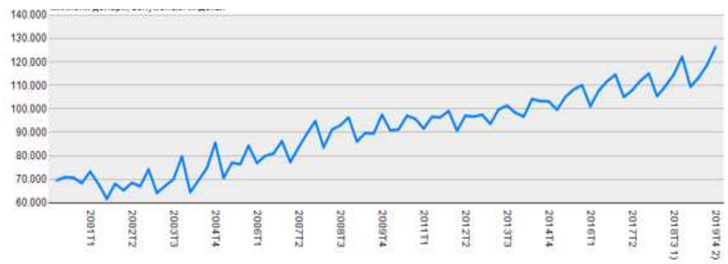

Chart 1. GDP quarterly by cost method
Source: State statistics of the Republic of North Macedonia

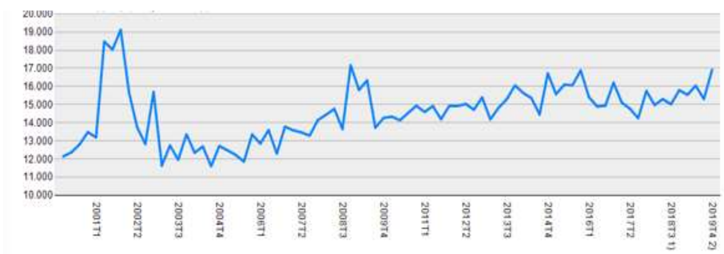

Chart 2 Final public consumption quarterly
Source: State statistics of the Republic of North Macedonia

From the graphic representation of the time series, it can be seen that the gross domestic product and public consumption in the Republic of North Macedonia have an increasing trend, but also that they have increased significantly in the last ten years. The minimum amount of GDP was in the third quarter of 2001 (during the military conflict in the Republic of North Macedonia), and the highest quarterly value of GDP was realized in the fourth quarter of 2019, when it amounted to 126,360 million denars.

The maximum amount of public spending of 19120 million denars was realized in the fourth quarter of 2001 (procurement of armaments in conditions of military conflict in the Republic of North Macedonia), and the minimum amount in the third quarter of 2004 (limited public spending before parliamentary elections). Next table shows GDP and public spending by quarter, as well as the rank.

Table 1 GDP and public spending by quarter and rank

Years	GDP	Rank GDP	Public Cons	Rank Public Cons
2000Q1	69617	70	12144	76
2000Q2	70967	65	12367	72
2000Q3	70743	66	12813	67
2000Q4	68467	72	13483	59
2001Q1	73289	64	13193	64

2001Q2	68059	74	18477	2
2001Q3	61742	80	18033	3
2001Q4	68122	73	19120	1
2002Q1	65391	77	15697	18
2002Q2	68527	71	13751	54
2002Q3	67072	76	12828	66
2002Q4	74273	63	15701	17
2003Q1	64254	79	11637	79
2003Q2	67256	75	12744	68
2003Q3	70098	68	11962	77
2003Q4	79773	57	13358	61
2004Q1	64540	78	12348	73
2004Q2	69659	69	12694	70
2004Q3	74784	62	11604	80
2004Q4	85550	51	12714	69
2005Q1	70626	67	12483	71
2005Q2	77089	59	12224	75
2005Q3	76410	61	11858	78
2005Q4	84322	52	13357	62
2006Q1	76991	60	12850	65
2006Q2	79988	56	13597	57
2006Q3	81024	55	12297	74
2006Q4	86289	49	13782	53
2007Q1	77365	58	13584	58
2007Q2	83626	53	13468	60
2007Q3	89439	48	13291	63
2007Q4	94855	38	14148	51
2008Q1	83620	54	14440	45
2008Q2	91196	43	14767	40
2008Q3	92996	40	13656	56
2008Q4	96367	36	17174	4
2009Q1	86104	50	15810	14
2009Q2	89708	46	16334	8
2009Q3	89512	47	13725	55
2009Q4	97549	29	14266	47
2010Q1	90878	44	14338	46

2010Q2	91270	42	14137	52
2010Q3	97119	30	14546	43
2010Q4	95795	37	14934	34
2011Q1	91638	41	14595	42
2011Q2	96665	34	14924	35
2011Q3	96417	35	14191	49
2011Q4	99117	26	14935	33
2012Q1	90713	45	14920	36
2012Q2	97105	31	15040	29
2012Q3	96710	33	14715	41
2012Q4	97558	28	15399	23
2013Q1	93617	39	14187	50
2013Q2	99844	24	14826	38
2013Q3	101440	22	15298	27
2013Q4	98362	27	16056	12
2014Q1	96746	32	15647	19
2014Q2	104229	19	15363	24
2014Q3	103324	20	14457	44
2014Q4	103236	21	16725	7
2015Q1	99679	25	15575	20
2015Q2	105177	17	16097	10
2015Q3	108275	13	16069	11
2015Q4	110118	10	16885	6
2016Q1	101100	23	15421	22
2016Q2	107841	15	14898	37
2016Q3	111758	9	14940	32
2016Q4	114605	6	16207	9
2017Q1	105084	18	15110	28
2017Q2	107915	14	14773	39
2017Q3	111969	8	14253	48
2017Q4	115045	4	15755	16
2018Q1	105440	16	14978	31
2018Q2	109714	11	15305	26
2018Q3	114645	5	15018	30
2018Q4	122183	2	15798	15
2019Q1	109446	12	15541	21

2019Q2	113443	7	16044	13
2019Q3	118781	3	15311	25
2019Q4	126360	1	16923	5

Source: State statistics of the Republic of North Macedonia and Authors' calculations

As for the ratio between public consumption and GDP, in the analyzed period, the lowest percentage value is in the third quarter of 2017 with a participation of 12.73%, while the highest participation of public consumption in GDP is in the third quarter of 2001 from 29.21%.

3. RESULTS AND DISCUSSION

In order to understand the character of the time series, we start the analysis with a graphic display of the series, i.e. we first perform a graph function to determine the relationship and character of the two variables, which will help us determine whether the time series are stationary (stationary).

The stationarity of the time series is necessary to ensure the predictability of the series (forecasting), as well as to ensure the accuracy of the model, and as non-stationary we consider the series that do not have a constant arithmetic mean, do not have a constant variance and those that have the character of seasonal movements (seasonality).

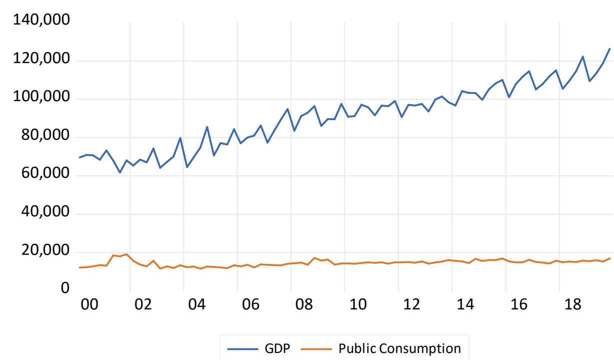

Chart 3 GDP and Public consumption of RNM 2001Q1-2019Q4
Source: Authors' calculations in Eviews

We can notice on the chart that GDP has an obvious growth trend over time and shows non-stationarity, due to the obvious fact that the arithmetic mean of the time series of GDP is not constant, and also the variance of the time series is not constant over time. On the other hand, the time series of public consumption generally shows stationarity, that is, public consumption has a weak growth, moves within limited frameworks and does not have large oscillations (variances).

The chart clearly shows big differences in the movement of the two time series despite the fact that both time series have growth, but it is more significant in GDP, while in public consumption it is weak. Therefore, we can conclude that the general tendency of the two series slightly overlaps. For a more detailed analysis of the time series, we will use descriptive statistics. The following table shows the results:

Table 2 Descriptive Statistics

	GDP	PUBLIC_CONS
Mean	90845.25	14548.91
Median	92317.00	14741.00
Maximum	126360.0	19120.00
Minimum	61742.00	11604.00
Std. Dev.	16245.81	1578.213
Skewness	-0.019277	0.292241
Kurtosis	2.024082	3.063507
Jarque-Bera	3.179672	1.152177
Probability	0.203959	0.562093
Sum	7267620.	1163913.
Sum Sq. Dev.	2.09E+10	1.97E+08
Observations	80	80

Source: Authors' calculations

We can see from the descriptive statistics the arithmetic mean (mean), the median (median), the minimum and maximum values in the time series, the standard deviation as a measure of the deviation of the numbers from the data set from its arithmetic mean.

Skewness and Kurtosis measures are numerical values for the shape of the data. We have got a negative value for the GDP indicating that the series is inclined to the left. In terms of Kurtosis, the normal distribution has a value of 3, which means that the public consumption data has a normal distribution, and the GDP data compared to a normal distribution has more skewed and thinner "tails" in the data distribution. The value for the Jarque-Bera statistic gives information on whether the data has a normal distribution. The probability is greater than zero, so we cannot reject the null hypothesis that the data do not have a normal distribution.

The VAR model implies that the variables are stationary, that is, a prerequisite for the vector autoregression model is that the series are stationary. The development of stationary variables from non-stationary ones, i.e. converting the quarterly data on GDP and public consumption in the Republic of North Macedonia expressed in millions of denars, is aimed at their use in time series, whereby they are converted into logarithmic variables. On the next table, the calculated values of logarithms of GDP and logarithms of public consumption are given, as follows:

Table 3 GDP and Public Consumption Logs

	LNGDP	LNPUBLIC_CON
2000Q1	11.1507640693712	9.404590499635412
2000Q2	11.16997025924329	9.422786913742056
2000Q3	11.16680887068128	9.458215559509576
2000Q4	11.13410715634581	9.509184911634074
2001Q1	11.20216580840056	9.487441664883778
2001Q2	11.12813025502894	9.824281994355154
2001Q3	11.03071969144142	9.799958691707272

2001Q4	11.12905549429865	9.858490186605392
2002Q1	11.08813991329662	9.661224890275208
2002Q2	11.13498310717338	9.528866827722945
2002Q3	11.11352194824066	9.459385560813045
2002Q4	11.21550277300765	9.661479683575522
2003Q1	11.07059925762893	9.361944956108078
2003Q2	11.11626151281513	9.452815851589884
2003Q3	11.1576495419452	9.389490237604502
2003Q4	11.28694038032136	9.499870735285582
2004Q1	11.07504046560595	9.42124938562205
2004Q2	11.15136718837624	9.448884719866416
2004Q3	11.22235923733859	9.359105145241294
2004Q4	11.35685627932034	9.450459027496354
2005Q1	11.16515362764054	9.432122997651052
2005Q2	11.25271587751809	9.411156511406302
2005Q3	11.24386885664161	9.380758024267314
2005Q4	11.34239808265898	9.499795870977106
2006Q1	11.25144381088757	9.461099090323365
2006Q2	11.28963190240489	9.517604459155686
2006Q3	11.30250068606379	9.417110609172446
2006Q4	11.36545740660683	9.531118671917154
2007Q1	11.25628976092377	9.516647908551129
2007Q2	11.33410975550552	9.508071780280965
2007Q3	11.40131210764664	9.494842393421332
2007Q4	11.46010468878664	9.557328550325372
2008Q1	11.33403800491055	9.577757412446818
2008Q2	11.42076631545144	9.600150240473774
2008Q3	11.44031176045772	9.521934264474278
2008Q4	11.47591909834107	9.75115189123243
2009Q1	11.36331114694413	9.668397930203519
2009Q2	11.40431523024618	9.701004103918222
2009Q3	11.40212797348756	9.526974266377732
2009Q4	11.48811009484546	9.565634362837982
2010Q1	11.41727322667057	9.570668634412818
2010Q2	11.42157742551092	9.556550752867032
2010Q3	11.48369230969995	9.585071320714485
2010Q4	11.46996577053009	9.611395771595648
2011Q1	11.4256013117985	9.588434283288216
2011Q2	11.4790066717666	9.610725934341048
2011Q3	11.47643781359878	9.560363239834536
2011Q4	11.50405624950116	9.61146273065021
2012Q1	11.41545595549073	9.610457873757752
2012Q2	11.48354814625955	9.618468597503832
2012Q3	11.47947208871101	9.596622660667574
2012Q4	11.48820235191472	9.642057851228414
2013Q1	11.44696726990568	9.560081331311986
2013Q2	11.51136424690327	9.604137675216665
2013Q3	11.52722276967105	9.635477379881812

2013Q4	11.4964098295923	9.683837890476174
2014Q1	11.4798442663681	9.658034484302058
2014Q2	11.5543456805206	9.639717300130662
2014Q3	11.54562496113324	9.578934005308442
2014Q4	11.54477290840935	9.724659884996429
2015Q1	11.50971030186823	9.653422343655654
2015Q2	11.56339992420376	9.686388198206229
2015Q3	11.59242956608283	9.684647229041752
2015Q4	11.60930779708653	9.734180932819669
2016Q1	11.52386540500856	9.643485495857658
2016Q2	11.58841319910017	9.608982254736222
2016Q3	11.62409109828038	9.611797458686809
2016Q4	11.64924671232847	9.69319852665812
2017Q1	11.56251530931022	9.623112055266786
2017Q2	11.58909915919307	9.600556469321609
2017Q3	11.62597732625071	9.564722689855032
2017Q4	11.65307863515363	9.664913054191376
2018Q1	11.56589734973633	9.614337736809312
2018Q2	11.60563225890444	9.635934851379514
2018Q3	11.64959567634509	9.61700476065983
2018Q4	11.71327519983913	9.667638628724365
2019Q1	11.60318655591497	9.651236971915612
2019Q2	11.63905578711444	9.683090226889944
2019Q3	11.68503674046016	9.636326803305096
2019Q4	11.74689025491602	9.736428922408086

Source: Authors' calculations

Below is a graphical representation of the logarithms of the variables:

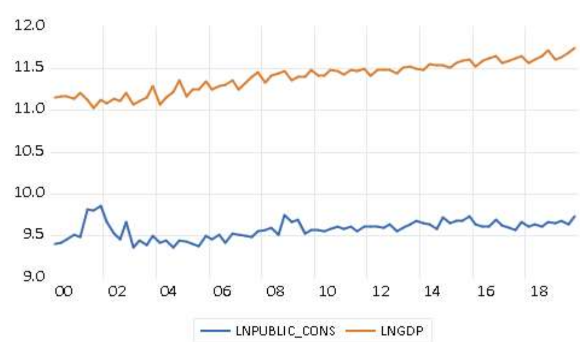

Chart 4 GDP and Public Consumption Logs
Source: Authors' calculation in Eviews

The graphical display is necessary to see if the series is stationary, due to the fact that if the series are non-stationary, the regression is spurious and the model is not correct. Stationarity means that the arithmetic mean, variance, and covariance of the variables are constant over time. From the graph, we can see that the logarithms of the GDP time series have a moderate growth trend, which suggests that their arithmetic mean is not constant over time, that is, that the series are non-stationary. In the case of public consumption, that trend is more moderate, which indicates the possibility that the time series of the logarithm of public consumption is stationary. For a more detailed analysis of the time series, we will use descriptive statistics. The following table shows the results:

Table 4 Descriptive statistics of logarithms of GDP and public consumption

	LNGDP	LNPUBLIC_CON
Mean	11.40057	9.579487
Median	11.43296	9.598386
Maximum	11.74689	9.858490
Minimum	11.03072	9.359105
Std. Dev.	0.183757	0.108255
Skewness	-0.278942	-0.001361
Kurtosis	1.986308	2.724268
Jarque-Bera	4.462681	0.253453
Probability	0.107384	0.880975
Sum	912.0454	766.3590
Sum Sq. Dev.	2.667576	0.925808
Observations	80	80

Source: Authors' calculations in Eviews

The probability is greater than zero, so we cannot reject the null hypothesis that the data for GDP logarithms and public spending logarithms have a normal distribution. For a more reliable determination of the stationarity of the series, we will use R squared and Durbin-Watson statistics, for which we develop an equation with the variables: lngdp, c and lnpub_cons. For this purpose, we use equation estimates, through the method of least squares (Least Squares). The results of the assessment are given below:

Dependent Variable: LNGDP
Method: Least Squares
Date: 03/28/20 Time: 12:22
Sample: 2000Q1 2019Q4
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.434692	1.605207	2.139720	0.0355
LNPUBLIC_CON	0.831555	0.167557	4.962836	0.0000

R-squared	0.239986	Mean dependent var	11.40057
Adjusted R-squared	0.230243	S.D. dependent var	0.183757
S.E. of regression	0.161221	Akaike info criterion	-0.787398
Sum squared resid	2.027394	Schwarz criterion	-0.727848
Log likelihood	33.49594	Hannan-Quinn criter.	-0.763523
F-statistic	24.62974	Durbin-Watson stat	0.261316
Prob(F-statistic)	0.000004		

Figure 1 Results from Method Least Squares
Source: Authors' calculation in Eviews

The main criterion for regression assessment is that if the coefficient of determination (R-squared) is greater than the Durbin-Watson statistics, it is a spurious regression. If we have such a regression, we cannot use it for hypothesis testing and prediction, that is, the result of such a regression is useless. The results of the assessment show that R-squared (0.2399) < Durbin-Watson statistics (0.2613), that is, that the variables enable application and use in the model, that is, one or both variables are not stationary. However, for a more accurate determination of the stationarity of the series, we will use the ADF (Augmented Dickey-Fuller Test) single root test.

Namely, the analysis of time series continues with the focus on unit roots, which are extremely important for the correct modeling of time series. If we have time series that have single roots, they are not stationary and we cannot apply typical autoregression models such as AR, ARIMA, VAR and others, that is, we need to make certain transformations to remove the single roots from the time series, and if we are not able to remove them, at least to be aware that the series have unit roots and to apply other methods of analysis. Unit roots are synonymous with the non-stationarity of time series or the term "free from" (random walk). Unit roots are tested in all time series models. For this purpose we will use data on logarithms of GDP and conduct an ADF unit root test. We will do the assessment by levels, using intercept and Akaike Info Criterion which automatically offers 11 lags. Based on the set parameters, the following results were obtained:

Augmented Dickey-Fuller Unit Root Test on LNGDP

Null Hypothesis: LNGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on AIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.477601	0.3382
Test critical values:	1% level	-4.085092	
	5% level	-3.470851	
	10% level	-3.162458	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDP)
Method: Least Squares
Date: 03/28/20 Time: 12:57
Sample (adjusted): 2001Q2 2019Q4
Included observations: 75 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP(-1)	-0.345644	0.139507	-2.477601	0.0157
D(LNGDP(-1))	-0.360129	0.160487	-2.243978	0.0281
D(LNGDP(-2))	-0.370061	0.145909	-2.536236	0.0135
D(LNGDP(-3))	-0.404481	0.130993	-3.087802	0.0029
D(LNGDP(-4))	0.331988	0.113934	2.913857	0.0048
C	3.839745	1.544982	2.485301	0.0154
@TREND("2000Q1")	0.002757	0.001088	2.534247	0.0136

R-squared	0.757201	Mean dependent var	0.007263
Adjusted R-squared	0.735777	S.D. dependent var	0.073085
S.E. of regression	0.037568	Akaike info criterion	-3.636661
Sum squared resid	0.095970	Schwarz criterion	-3.420362
Log likelihood	143.3748	Hannan-Quinn criter.	-3.550295

Figure 2 Results from ADF Unit Roots Test
Source: Authors' calculation in Eviews

The result has two parts, upper and lower. In the first, the null hypothesis is set, which reads: LNGDP has a single root. The ADF test used 4 lags out of a maximum of 11, based on the Akaike criterion. ADF results are expressed in t-statistics and p-value. ADF test statistics result for t-statistics is 0.0686 and is less than the critical values of the test

(test critical values) for 1%, 5% and 10%, which means that the null hypothesis cannot be rejected. Also, the p-value is greater than 5%, which means that the null hypothesis cannot be rejected. This means that this series has a single root. The lower part of the result is the regression from the unit root test, where it can be seen that the ADF test used 4 lags and where the p-value of the constant c is greater than 5%, because of which the null hypothesis cannot be rejected, that is, the series is non-stationary .

We continue the ADF test analysis by including trend and intercept in the test equation, and we will keep other parameters such as levels and Akaike criteria, as well as the maximum bor of 11 lags. Based on the set parameters, the following results were obtained:

Augmented Dickey-Fuller Unit Root Test on LNGDP

Null Hypothesis: LNGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on AIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.477601	0.3382
Test critical values:	1% level	-4.085092	
	5% level	-3.470851	
	10% level	-3.162458	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDP)
Method: Least Squares
Date: 03/28/20 Time: 12:57
Sample (adjusted): 2001Q2 2019Q4
Included observations: 75 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP(-1)	-0.345644	0.139507	-2.477601	0.0157
D(LNGDP(-1))	-0.360129	0.160487	-2.243978	0.0281
D(LNGDP(-2))	-0.370061	0.145909	-2.536236	0.0135
D(LNGDP(-3))	-0.404481	0.130993	-3.087802	0.0029
D(LNGDP(-4))	0.331988	0.113934	2.913857	0.0048
C	3.839745	1.544982	2.485301	0.0154
@TREND("2000Q1")	0.002757	0.001088	2.534247	0.0136

R-squared	0.757201	Mean dependent var	0.007263
Adjusted R-squared	0.735777	S.D. dependent var	0.073085
S.E. of regression	0.037568	Akaike info criterion	-3.636661
Sum squared resid	0.095970	Schwarz criterion	-3.420362
Log likelihood	143.3748	Hannan-Quinn criter.	-3.550295

Figure 3 Results from ADF Unit Roots Test
Source: Authors' calculation in Eviews

ADF test statistics score for t-statistics is 2.477 and is less than the critical values of the test (test critical values) for 1%, 5% and 10%, which means that the null hypothesis cannot be rejected. Also, the p-value is 33.82% and is greater than 5%, which means that the null hypothesis cannot be rejected. This means that this series has a single root. The lower part of the result is the regression from the unit root test, where it can be seen that the ADF test used 4 lags and where the p-value of the constant c and the trend are less than 5%, indicating that both variables are significant. for GDP. however, for the ADF test, the upper part of the result is important, because of which the null hypothesis cannot be rejected, that is, the series is non-stationary.

Testing continues using the first difference from lngdp, as can be seen from figure 31 in the text appendix, as well as the intercept and the Akaike criterion and 11 lags. Based on the set parameters, the following results were obtained:

Augmented Dickey-Fuller Unit Root Test on D(LNGDP)

Null Hypothesis: D(LNGDP) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on AIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.602170	0.0000
Test critical values:	1% level	-3.520307	
	5% level	-2.900670	
	10% level	-2.587691	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDP,2)
Method: Least Squares
Date: 03/28/20 Time: 13:01
Sample (adjusted): 2001Q2 2019Q4
Included observations: 75 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDP(-1))	-2.447148	0.436821	-5.602170	0.0000
D(LNGDP(-1),2)	0.802268	0.337489	2.377164	0.0202
D(LNGDP(-2),2)	0.230639	0.228671	1.008609	0.3166
D(LNGDP(-3),2)	-0.294661	0.116059	-2.538882	0.0133
C	0.016424	0.005345	3.072759	0.0030

R-squared	0.909560	Mean dependent var	-8.27E-05
Adjusted R-squared	0.904392	S.D. dependent var	0.125281
S.E. of regression	0.038737	Akaike info criterion	-3.599677
Sum squared resid	0.105042	Schwarz criterion	-3.445178
Log likelihood	139.9879	Hannan-Quinn criter.	-3.537987
F-statistic	175.9977	Durbin-Watson stat	1.883287
Prob(F-statistic)	0.000000		

Figure 4 Results from ADF Unit Roots Test for the first difference
Source: Authors' calculation in Eviews

The null hypothesis is: the first difference of the logarithm of GDP has a unit root. The test used 3 lags. ADF test statistics result for t-statistics is -5.602, but the absolute value is taken, which means that it is greater than the critical values of the test (test critical values) by 1%, 5% and 10%., which means that the null hypothesis is rejected. Also, the p-value is 0 and is less than 5%, which means that the null hypothesis: the first difference of the logarithm of GDP has a unit root, is rejected. This means that this series does not have a unit root, that is, using three lags, this series is stationary.

The lower part of the result is the regression from the unit root test, where it can be seen that the ADF test used 3 lags and where the p-value of the constant c is less than 5%, indicating that the variable is significant, and also R -squared is smaller than Durbin-Watson, because of which the null hypothesis can be rejected, that is, it is proved that the DLNGDP series is stationary after 3 lags. It can also be seen in the following graph, where the results are shown:

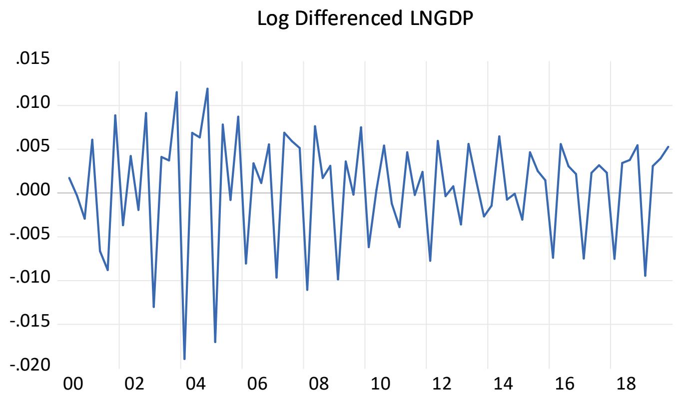

Chart 5 GDP – first difference
Source: Authors' calculation in Eviews

We can clearly see that the first difference series of the logarithm of GDP is stationary, that is, there is a clear reversion around the arithmetic mean (mean reversion), that is, it oscillates around 0.000. This fulfills the condition for the possibility to create the VAR model, which states that the model is created only if the series are stationary after the first difference.

CONCLUSION

The stationarity of the time series is necessary to ensure the predictability of the series (forecasting), as well as to ensure the accuracy of the model, and as non-stationary we consider the series that do not have a constant arithmetic mean, do not have a constant variance and those that have the character of seasonal movements (seasonality).

In this paper we present the whole methodology for testing stationarity of GDP data by using ADF (Augmented Dickey-Fuller Test) single root test, that provides an accurate determination of the stationarity of the series.

We need to make certain transformations to remove the single roots from the time series, and if we are not able to remove them, at least to be aware that the series have unit roots and to apply other methods of analysis. Unit roots are synonymous with the non-stationarity of time series or the term "free from" (random walk). Unit roots are tested in all time series models. For this purpose we use data on logarithms of GDP and conduct an ADF unit root test. We made the assessments by levels, using intercept and Akaike Info Criterion.

We proved that the first difference series of the logarithm of GDP is stationary, that is, there is a clear reversion around the arithmetic mean (mean reversion), that is, it oscillates around 0.000. This fulfills the condition for the possibility to create the VAR model, which states that the model is created only if the series are stationary after the first difference.

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