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Granger Causality Analysis between Energy Consumption in Industry and Gross Domestic Product in Romania

Alexandru MANOLE

"ARTIFEX" University of Bucharest

Correspondence: Alexandru MANOLE, "ARTIFEX" University of Bucharest, Economu Cezărescu street, no. 47, 6th sector, Bucharest, Romania, Email: *alexandru.manole@gmail.com*

Abstract

In this paper, the author develops on the correlation, studied as Granger causality, between energy consumption in industry, separated as thermal and electrical energy, and Gross Domestic product in Romania. Upon assessing the stationary properties of the variables, the Toda-Yamamoto approach was considered for the causality analysis. All data are taken from a single (official) statistical data source. No causality was demonstrated, and the characteristics of the model allowed the application of the Wald test only for the thermal energy consumption vs. GDP. The variables are not integrated of the same order either, which limited the choice for acceptable models.

Key words Gross Domestic Product, energy, consumption, Granger causality, stationarity

JEL Codes: E03, E60, H30, H60, O11

Introduction. Literature review

The Gross Domestic Product (GDP) is one of the most important indicators in the national economy. It measures, at the highest level, the output of the economy. GDP, apart from becoming "(…) widely used as a reference point for the health of national and global economies." (Callen, 2008), can also be used for effecting international comparison and cross-country analyses.

The availability of data regarding different dimensions related to GDP structure and values allows for various analyses based on comparable data. As industry is one of the factors that contribute directly to the formation of GDP, and considering that activity in industry (including constructions) involves a consumption of electrical and thermal energy, this paper considers the possible existence of a Granger-type causality between GDP and energy consumption. Consumption of energy carries along the side effects of pollution, and it must be known if there is any causality in relation to the economic growth. The literature in the field produces mixed results regarding the presence and characteristics of causality relationships similar to the one evaluated in this paper. Hussin et al. (2017) have studied the causality between energy consumption and Gross Domestic Product for the case of Malaysia, by applying "unit root, cointegration and Granger causality tests". Their conclusion states that regarding causality, GDP causes price, and not vice versa at the same time. Campo and Sarmiento (2013) develop on the property of elasticity of the "long-run relationship between energy consumption and GDP", their study involves data regarding ten countries in Latin America, they outline the importance of having accurate knowledge on the effects posed by energy consumption on the GDP, at least from the perspective of the policy makers.

Al-mulali et al. (2013) have studied the "long run relationship between renewable energy consumption and GDP growth", for countries characterized as "upper middle income, lower middle income, and high income", by using the fully modified OLS, outlining, for a noticeable majority (79%) of countries, a "positive bi-directional long run relationship between renewable energy consumption and GDP growth", while for 19% of countries the neutrality hypothesis was validated and the conservation hypothesis is visible for 2% of the countries.

The study of Caraiani et al. (2015), on a panel of five countries, analyzed the causality relationship between primary energy consumption per capita. Their results show that most cases stood on the neutrality hypothesis.

1. Research methodology and data

The objective of this paper is to assess the existence of Granger Causality between the Gross Domestic Product achieved in industry and the energy consumption.

Given the fact that the variables are expected to be non-stationary, the standard application of the Granger Causality might lead to spurious results (Sims et al., 1990, cited by Hatemi-J et al., 2019). Therefore, we resorted to the Toda-Yamamoto methodology (Toda and Yamamoto, 1995) for estimating Granger Causality. The method is described by Giles (2011**),** and it was implemented in E-Views®, by applying the following steps:

a) Test for unit roots. Three tests have been applied for each variable:
   a. The Augmented Dickey-Fueller test, both for *Intercept* and *Trend and intercept*, for a maximum of four lags, automatic selection based on the Schwarz Info Criterion;
   b. Philips-Perron test, with default spectral estimation method and automatic selection based on the *Newey-West* bandwidth, both for *Intercept* and *Trend and intercept* options;
   c. Kwiatkowski-Phillips-Schmidt-Shin test, with the same settings as the PP.

   Where the tests offered contradictory results, if two tests let two the same conclusion, it has been accepted. At the end of this step, the maximum order of integration d_{max} between the two variables was established.
b) Estimation of the VAR model. The optimum lag length is chosen according to the majority rule: the value indicated by most of the tests. If no majority is reached, the Schwarz criterion is preferred because, according to Chirilă and Chirilă (2017), it is more suitable for models involving a small number of parameters. The model in this paper has only two parameters, therefore it fits this criterion.
c) Application of specification tests on the VAR model:
   a. *Roots of Characteristic Polynomial* for stability;
   b. Autocorrelation LM test. *Null Hypothesis: no serial correlation at lag order h*;
   c. For the normality test: *Orthogonalization: Cholesky (Lutkepohl), Null Hypothesis: residuals are multivariate normal*;
   d. For the heteroskedasticiy test: *VAR Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)*.

   If the model fails either of the first two tests, the lag length is extended by unit, as suggested by Giles (2011). If heteroskedasticity or normality occurs, the model will be considered not suitable for further testing (Hatemi-J., 2004)
d) Update of the VAR model with the d_{max};
e) Application of the Wald modified test. Interpretation of the test value against the critical step.

The data are extracted from the online database of the Romanian statistical authority (the National Institute of Statistics), regarding three indicators relevant for the analysis:

- GDP: the indicator representing the Gross Domestic Product computed on the basis of the expenses method, represented in comparable prices, according to SEC 2010. The definition included in the metadata is: "(…) *sum of gross added values for various institutional sectors of various activity branches, to which taxes are added and from which product-related subsidies are deducted (those not distributed on sectors and branches of activity). Also, it represents the balance of the production account of the total economy*(…)". (http://statistici.insse.ro/)
- ECI: the final consumption of electrical energy in industry (including constructions). The definition of the indicator is "(…) *the sum of the quantities of electrical energy used in various activities in industry, with the exception of the activities under the category consumption in the energetical sector*" (http://statistici.insse.ro/).
- TCI: the final consumption of thermal energy in industry (including constructions), defined as "*(…) the sum of the quantities of thermal energy used in various activities in industry, with the exception of the activities under the category consumption in the energetical sector*" (http://statistici.insse.ro/).

The dataset covers the interval 1996-2017, annual series. Regardless of the presence of unit roots and the degree of integration, all data were processed in their levels.

2. Results and discussions

2.1. Evolution of the three indicators between 1996 and 2017

The evolution of the data series for the three indicators over the interval 1996-2017 is presented in the figure no. 1, under the shape of two ratios between each of the two energy indicators (TCI and ECI) and the Gross Domestic Product, ratios defined as percentages.

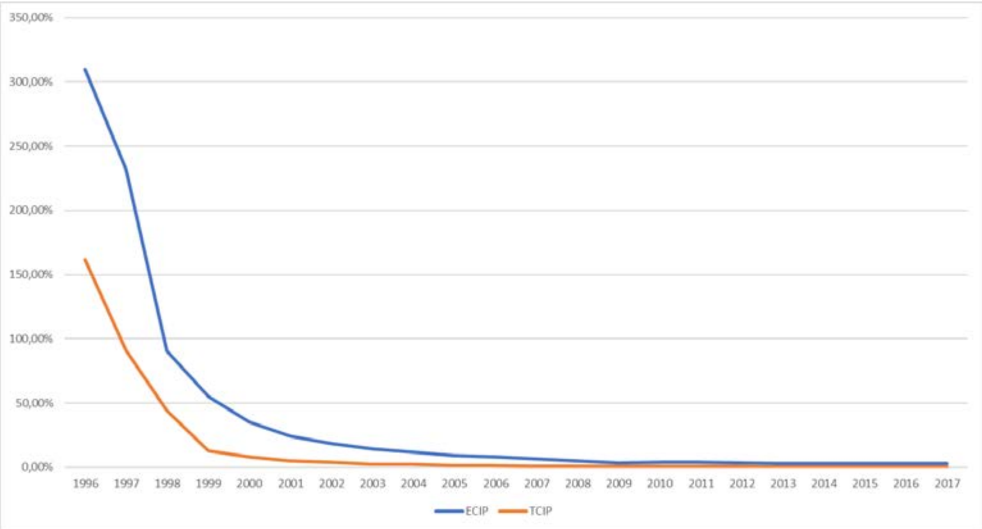

Figure no. 1. Evolution of the TCI and ECI relative to the GDP

The figure indicates clearly that the energy consumption in industry, both considered as electrical or thermal, has increased way slower than the Gross Domestic Product. Also, ECI evolved between a minimum of 18183 and a maximum of 25257 mil. kWh, while TCI varied between 2374 and 12774 thousands of giga-calories. Observation on the evolution of the individual series leads to the conclusion that ECI might be stationary, while TCI shows a descending trend (figure no. 2).

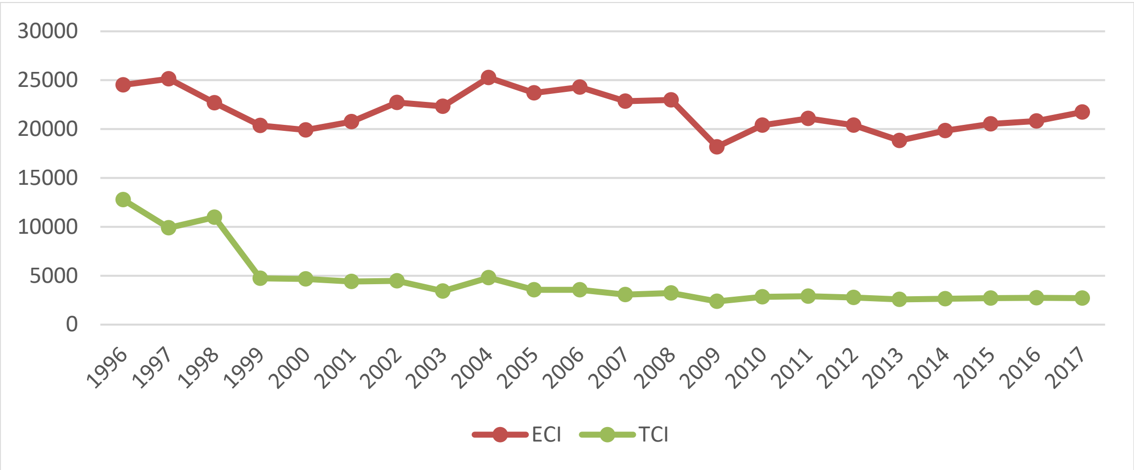

Figure no. 2. Evolution of the TCI and ECI in absolute values

2.2. Granger Causality analysis

2.2.1. Unit roots test

The application of the unit root tests produced the results presented in table no. 1 (the test values are presented on the first row in the respective cell, while the *p-value* is enclosed within round brackets, in the second row). The values marked with italic characters outline the tests that testify for stationarity.

For this study, the acceptable *p-level* was chosen at 0.05.

Table 1. Unit root tests for the two variables - level

Variable	ADF test		PP test		KPSS test	
	Intercept	Trend and intercept	Intercept	Trend and intercept	Intercept	Trend and intercept
Test for levels						
GDP	1.864112 (0.9995)	-2.602360 (0.2827)	1.500609 (0.9986)	-2.585930 (0.2891)	0.652915	*0.115765*
ECI	-2.438189 (0.1440)	-2.427208 (0.3565)	-2.412006 (0.1505)	-2.426691 (0.3567)	*0.329804*	*0.066409*
TCI	*-3.893273 (0.0084)*	-2.715228 (0.2412)	*-6.740949 (0.0000)*	*-4.220994 (0.0164)*	0.514786	0.156562
Test for 1st differences						
GDP	-2.441102 (0.1439)	-2.633310 (0.2709)	-2.238387 (0.1999)	-2.529046 (0.3122)	*0.308316*	*0.124137*
ECI	*-5.142842 (0.0006)*	*-5.162409 (0.0027)*	*-5.128792 (0.0006)*	*-5.143634 (0.0028)*	*0.077261*	*0.056030*
TCI	*-3.498840 (0.0224)*	*-6.704656 (0.0003)*	*-6.341428 (0.0000)*	*-7.580485 (0.0000)*	*0.408599*	*0.056426*
Test for 2nd differences						
GDP	*-4.653334 (0.0018)*	*-4.493982 (0.0108)*	*-5.718466 (0.0002)*	*-5.371822 (0.0020)*	*0.320653*	0.321564
ECI	NA	NA	NA	NA	NA	NA
TCI	NA	NA	NA	NA	NA	NA

Source: Author's processing, based on the source datasets.

As it can be observed from table 1, given the fact that GDP is I(2) and the other two variables are I(1), the maximum degree of integration, for both analyses, is 2. The calculation of the differences for the three series and further analyses based on the differenced values is considered not practical, as it might lead to loss of information upon application of differences (2nd difference is necessary in order to have a stationary GDP). However, a 1st difference would be acceptable (it can allow to measure the relationship specific to the acceleration of the variables, instead of the actual values). This fact prevents the use of methods designed for stationary variables (a similar crossroad was found by Caraiani et.al., 2015, for some variables they used).

2.2.2. Definition of the VAR models and specification tests

Two models are defined, one including GDP and ECI, and the other one based on GDP and TCI, both as unrestricted VAR. initially, the lag length of 2 is kept, as proposed by the analysis software. Then, the models were tested for optimum lag (out of a maximum of four) and the following models resulted:

- for ECI and GDP:

$ECI = C(1,1)*ECI(-1) + C(1,2)*ECI(-2) + C(1,3)*ECI(-3) + C(1,4)*GDP(-1) + C(1,5)*GDP(-2) + C(1,6)*GDP(-3) + C(1,7)$

$GDP = C(2,1)*ECI(-1) + C(2,2)*ECI(-2) + C(2,3)*ECI(-3) + C(2,4)*GDP(-1) + C(2,5)*GDP(-2) + C(2,6)*GDP(-3) + C(2,7)$

- for TCI and GDP:

$GDP = C(1,1)*GDP(-1) + C(1,2)*GDP(-2) + C(1,3)*TCI(-1) + C(1,4)*TCI(-2) + C(1,5)$

$TCI = C(2,1)*GDP(-1) + C(2,2)*GDP(-2) + C(2,3)*TCI(-1) + C(2,4)*TCI(-2) + C(2,5).$

The ECI model does not satisfy stability criteria, even if lag length is extended to the maximum level permitted for the processed dataset (that is 6). In order to outline a possible correlation between the variables, the methodology was applied for the first differences of ECI and GDP (maximum DOI is 1, see Table 1). Upon estimating the VAR model, the optimum lag length was established at 1, but the model fails the residual heteroskedasticity test, even if passing the other tests.

The TCI model, even if stable, fails to comply with the normality at the initial setting, as VAR(2), becomes compliant with all tests at lag length of 3.

Given these results, the model is updated and becomes a VAR(5). According to Giles (2011), the additional two levels are defined in the software interface as exogenous variables. The new model has the following structure:

*GDP = C(1,1)*GDP(-1) + C(1,2)*GDP(-2) + C(1,3)*GDP(-3) + C(1,4)*TCI(-1) + C(1,5)*TCI(-2) + C(1,6)*TCI(-3) + C(1,7) + C(1,8)*GDP(-4) + C(1,9)*TCI(-4) + C(1,10)*GDP(-5) + C(1,11)*TCI(-5)*

*TCI = C(2,1)*GDP(-1) + C(2,2)*GDP(-2) + C(2,3)*GDP(-3) + C(2,4)*TCI(-1) + C(2,5)*TCI(-2) + C(2,6)*TCI(-3) + C(2,7) + C(2,8)*GDP(-4) + C(2,9)*TCI(-4) + C(2,10)*GDP(-5) + C(2,11)*TCI(-5)*

The updated model is tested for Granger causality, and the results are the following:

Table 2. VAR Granger Causality/Block Exogeneity Wald Tests

Sample: 1996 2017
Included observations: 17

Dependent variable: GDP

Excluded	Chi-sq	df	Prob.
TCI	0.946366	3	0.8142
All	0.946366	3	0.8142

Dependent variable: TCI

Excluded	Chi-sq	df	Prob.
GDP	5.501617	3	0.1385
All	5.501617	3	0.1385

To be noted, the variables tested do not have the same order of integration, and thus the test for cointegration does not apply (see Caraiani et al., 2015). Both *Chi-sq* values testify against the presence of Granger causality between TCI and GDP.

The next attempt was the analysis, on the same procedure, based on logarithm values, of the link between ECI and GDP, but the VAR model failed the normality tests.

Conclusions

In this paper, I have attempted to outline the existence of a Granger causality-type correlation between the energy (thermal and electrical, considered separately) consumption in industry and the Gross Domestic Product of Romania, aiming to capitalize the annual data for the interval 1996-2017. Given the fact that the variables are prone to non-stationarity, the Toda-Yamamoto method for Granger causality was the chosen instrument.

Upon computing the degrees of integration and designing optimum VAR models, the specification tests for VARs allowed the application of the Granger Causality test only for the consumption of thermal energy. Neither test displayed the existence of the pursued correlation. This is a confirmation of the neutral hypothesis for the case of Romania, of course, within the limits allowed by the applied data and methodology.

One of the limitations of the paper are residing in the structure of the dataset, which permitted the Wald test to be applied only for one model, also the degree of integration of the Gross Domestic Product is two, prohibiting the use of methods dedicated to stationary variables, even if the analysis based on the first difference would be acceptable.

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