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Causality Relationship between Energy Consumption and Economic Growth in the European Union Countries

Younes Gholizadeh*

Abstract This study presents the causality relationship between energy consumption and economic growth as a scope of Cobb Douglas production function by using Dynamic Panel Data Analysis for 28 European countries in the 1990-2014 period. The Dynamic Panel Data Analysis method proposed in this study considers the real Gross Domestic Production (GDP) as a dependent variable, while Capital, Labor, and Energy Consumption parameters are considered as independent variables. To indicate the causality relation between GDP and Capital, Labor and Energy Consumption parameters, Arellano-Bond autocorrelation test is applied by taking the first difference of the defined parameters. Furthermore, the Generalized Method of Moments (GMM) is used to validate the obtained results of the Arellano-Bond autocorrelation test. The results of this study show that the GDP has a direct relationship with all independent variables-i.e. Capital, Labor, and Energy Consumption. By a predefined value for the increase in these independent variables, each of the dependent variables demonstrates a unique amount of increase.

Keywords: Neoclassic Economy, Cobb-Douglas Production Function, Dynamic Panel Data, Arellano-Bond GMM Method

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1. Introduction

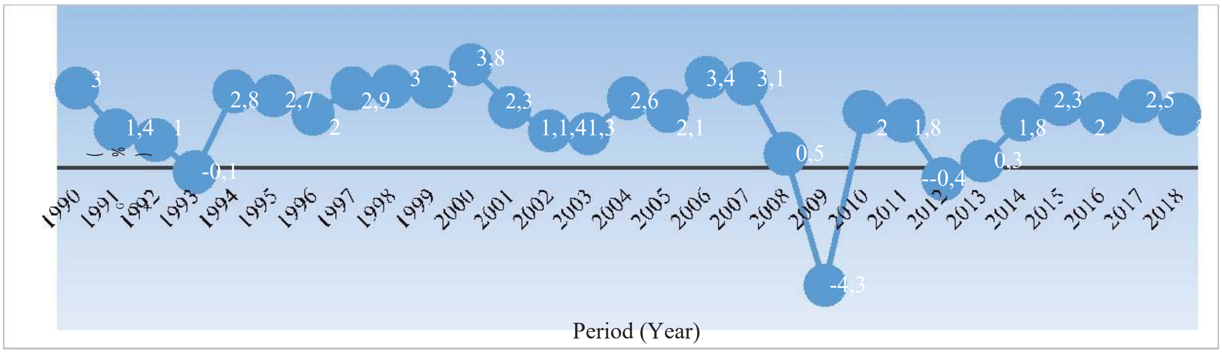
The relationship between energy consumption and economic growth is one of the subjects on which numerous researches have been done in recent years. The main focus of this topic is the impact of the energy demand on the economic growth of the European Union (EU) in terms of the energy supply security and sustainability of energy supply. Since the demand for energy has increased significantly as a result of the economic growth of the EU, energy demand and the dependency on external energy resources have both expanded accordingly. Consequently, the average speed of production declined [1]. The relationship between energy demand and economic growth has been explained based on two differences of economic opinions. Firstly, within the scope of the Neoclassical Economic Theory, it is argued that economic growth and energy demand are independent of each other. In other words, in econometrics terminology energy demand thought to be impartial from economic growth. It is suggested by Neo Classics that the share of energy resources is low in economic growth due to impartiality [2].

The second view considers the energy to be an integral input in economic growth. This view rejected the argument of Neoclassic and arguing that there is either a one-way or two-way relationship between the two variables. According to the energy economists, the fact that energy is an essential input in the production process and its use in the production of final goods are the elements that establish the indispensable correlation between the two variables [3]. Also, argued that the two variables are mutually affected by defending the argument that energy has to substitute the labor force as an external source in the technological process, which in turn indicates that relationship between energy consumption and economic growth is even stronger than what was previously thought. Generally, energy economists have regarded energy as an input, arguing that energy, as well as capital stock and labor, should also be taken into account as a third production factor and the other two production factors will not function effectively without energy. Furthermore, Ghali and El-Sakka argued that energy is essential for economic and social development and is a limiting factor in economic growth [2].

Another view that supports the second theory is of those economists who advocate the idea of economics based on production. According to this view, labor, capital and land are the main inputs of the production process, and energy functions as the intermediate goods / intermediate input. The main inputs used in the production process exist before production and are not consumed during production, whereas the intermediate inputs are both consumed and produced during the production process [4]. Stern, by concentrating on production inputs in the context of production theory, argued that energy is an important factor in economic growth besides capital and land. In other words, the role of energy demand has been explored by explaining economic models, especially in growth theories [3]. This research advocates a strong relationship between economic growth and energy consumption. In this context, the amount of energy consumption in EU countries was included in the Cobb-Douglas production function, and its relationship with economic growth was tested, along with capital and labor. This study aims to evaluate the validity of energy economist view in the EU by using econometric model.

The data related to 28 EU countries between 1990 and 2014 data was used in the proposed empirical analysis. There are two main reasons for choosing the data related to this period for the econometric model. Firstly, as shown in Figure 1, due to the economic and monetary union in the 2000s, the GDP demonstrated a significant increase in this period [5].

Figure 1. EU-28, GDP (constant 2010 US$), %, (1990-2018)

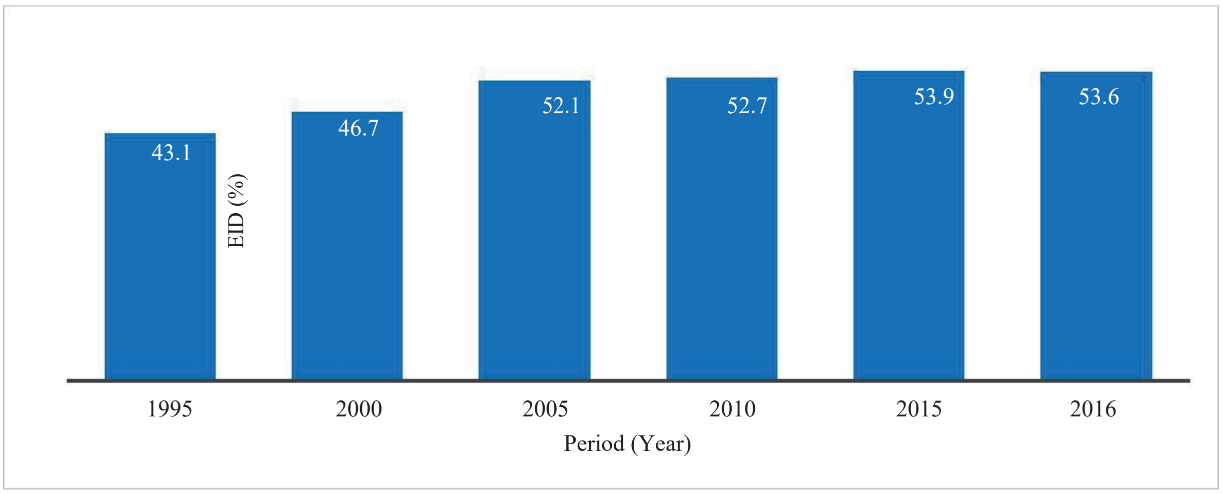


Source: World Bank Data: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD. ZG?Loc ations=EU/, (24.07.2019).

Except for the financial crisis in 2008 to be explained in Figure 1, the economic growth rate in EU countries has always been on an increasing trend. Energy consumption has increased with the rise of this trend. Because economic growth can be achieved by increasing production capacity. Energy consumption has increased with the increase in production capacity.

Secondly, joining the Eastern European countries to the EU, continuing until 2007, resulted in an increase in both energy consumption and the total energy demand of Europe in this period (Eurostat, 2019). This trend is demonstrated in Figure 2.

Figure 2. EU-28, Energy Import Dependency (by fuel), %, (1995-2016)

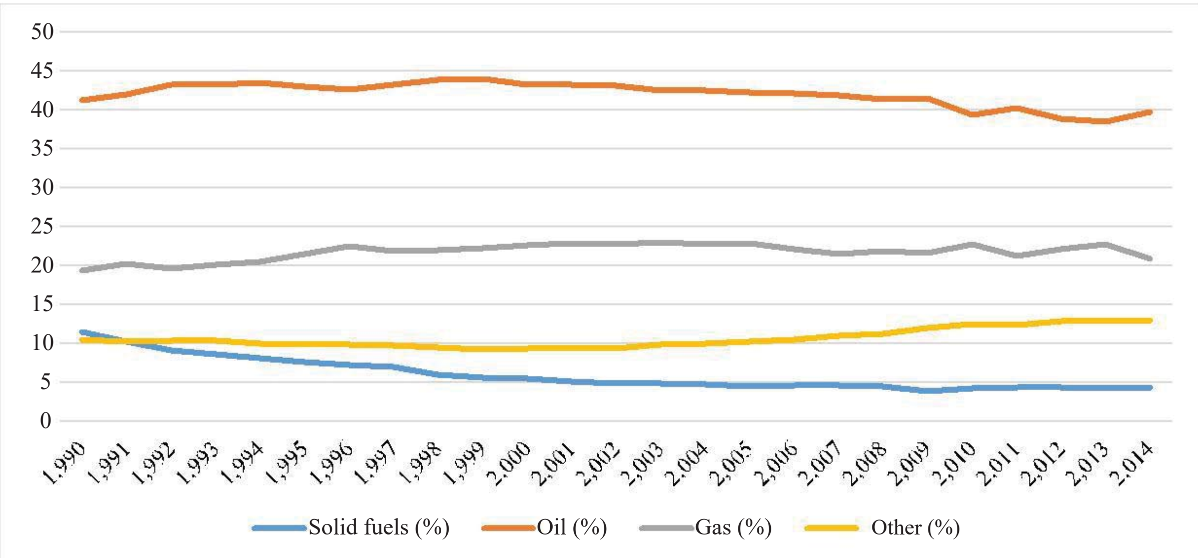


Source: Eurostat: https://ec.europa.eu/eurostat/databrowser/view/sdg0750/default/table?lang=en/, (24.07.2019).

As shown in Figure 2, in the period covered by the empirical study, there has been an increase of approximately 11% in energy import dependency of EU countries. It is estimated that this rate will increase further in the next years. This trend can be attributed to the fact that EU countries need to increase their energy imports in order to maintain their sustainable economic growth. Also, these countries are trying to ensure energy supply security by turning to alternative energy sources outside Russia. Therefore, the relationship between economic growth and energy consumption has been determined again with the increase in economic growth dependency on energy imports. In this paper, within the scope of the econometric model and using the theoretical knowledge, the relationship between the two variables is investigated both economically and statistically.

Finally, as shown in Figure 3, the most significant rate of final energy consumption by sectors in the EU countries belongs to crude oil. This source is followed by natural gas and solid fuels, respectively.

Figure 3: Final Energy Consumption by Fuel Type in EU (28), (1990-2014)



Source: European Environment Agency: https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-9/assessment-1/, (23.02.2020).

As observed in Figure 3, the EU countries dependency on primary energy sources contributes to a considerably high proportion of the overall energy consumption. This high dependency necessitates the estimation of its relationship with the economic growth by econometric estimate approach within the EU region.

This paper is organized as follows. The next chapter provides a brief review of the most relevant research studies on the topic. The third chapter is devoted to explaining the methodology applied in this study and the data used to evaluate the proposed method. The following chapter includes the numerical results obtained from modeling the proposed method. The paper is concluded in the fifth chapter, in which the implications of the test results are discussed.

2. Literature Review

There are numerous research studies done on the relation between energy consumption and GDP. The findings of the empirical studies have been investigated within the scope of country samples and multi-country samples. For instance, Kraft and Kraft (1978) could be considered as one of the most important studies which is considered as the pioneer of the subsequent researches within this area. Kraft and Kraft examined the relationship between GDP and energy demand in the United States (US) in the period of 1947-1974 by using the Granger Causality Analysis method [6]. Gathered results of the study determined a one-way relationship from GDP to energy demand. Abosedra and Baghestani (1989) used US data between 1941 and 1987 periods by applying the Granger Causality method and co-integration method together and demonstrated a one-way relationship from GDP to energy demand [7]. One of the important studies on EU countries was done by Menegaki and Öztürk (2013). In this study, Dynamic Error Correction Model was applied for two variables using data from 1971-2011 for 26 EU member countries [8]. As a result of the test, a long-term relationship has been found from fossil fuel consumption to economic growth.

This relationship shows that there is a significant role in fossil fuels in economic growth. In their study on Croatia, Dizdarevic and Zikovic (2010) concluded that economic growth has affected energy consumption in 1993-2006 periods. In this test, the Granger Causality and Error Correction Model are used and the results also reveal the characteristics of the economic production infrastructure [9]. Because the content and quantity of energy imports and the applied energy policies in each economy change according to the production structure, it is inevitable that different research studies conclude with different and occasionally contradicting results. In the case of Croatia, the change in the direction of the relationship between the two variables results from different energy policies, especially the production structure of the countries.

Kasperowicz (2016) uses the panel data approach to investigate the relationship between energy consumption and economic growth for V4 countries and the 14 EU "old" Member States from 1995 to 2012 [10]. This study defines the differences between the estimated results for these two groups of countries. As a result, there is a bidirectional positive relationship between energy use and economic growth. Furthermore, energy consumption is a pro-growth variable, which means that the increase in energy consumption causes the increase in economic growth. Also, the energy consumption related to GDP growth in the V4 countries seems to be more efficient than in the "old" EU countries. Finally, these results point to the individual growth rate effect of GDP for every country that was not captured by the estimated model.

Dritsaki and Dritsaki (2014) applies the panel unit root tests, panel cointegration methods and panel causality test in order to investigate the relationship between energy consumption (EC), economic growth (GDP) and CO2 emissions for three countries of Southern Europe (Greece, Spain, and Portugal) covering the annual period 1960-2009 [11]. In this study, FMOLS and DOLS are used to estimate the long-run relationship between the variables. The results of the study show that there is a short-run bilateral causal link between the examined variables. In the long run, there is a bilateral causality between energy consumption and economic growth. The results of the study also demonstrate that energy is a force for economic growth both in the short and long run as it is driven by economic growth.

Kahouli (2019) investigated the relationship between economic growth (EG) and energy consumption (EC) for the 34 OECD (Organization for Economic Cooperation and Development) countries over the period 1990–2015 [12]. By using three models to examine growth–energy nexus, energy–growth nexus and the two-way linkages between them, Kahouli investigated the direction of the relationship between the two variables of interest. Moreover, empirical results support a feedback effect between EG and EC. These results are suggestions and recommendations which hold significant energy and economic policy implications for OECD policymakers. The results of the research examples of many countries and regions on the subject are given in Table 1.

Table 1. Relationship between GDP and Energy Demand, Example Countries

Author(s)	Sample	Period	Methodology	Result
Yu & Jin (1992)[13]	USA	1974-1990	Co-integration Granger Causality	GDP --- EC
Cheng & Lai (1997)[14]	Taiwan	1954-1993	Granger Causality	GDP → EC
Wolde-Rufael (2004)[15]	Shanghai	1952-1999	Granger Causality, Modified Version of Todo & Yamamoto	EC → GDP
Hatemi-J. & Irandoust (2005)[16]	Swedish	1965-2000	Granger Causality	GDP → EC
Lee & Chang (2007)[17]	Taiwan	1955-2003	Granger Causality, Co-Integration,VECM	EC → GDP (If low energy demand)
Zamani (2007)[18]	Iran	1967-2003	Co-integration, Granger Causality,VECM	GDP → EC
Lee & Chang (2008)[19]	16 Asia Countries	1971-2002	Panel Co-Integration, Panel ECM	EC → GDP (In the long term) GDP --- EC (In the short term)
Zhang & Cheng (2009)[20]	China	1960-2007	Granger Causality	GDP → EC
Kakar & Khiliji (2011)[21]	Pakistan	1980-2009	Co-integration, Error Correction, Granger Causality	EC→ GDP

Borozan (2013)[22]	Croatia	1992- 2010	Johansen-Juselius, no Cointegration, VAR, Block Exogeneity Wald test, IR, VD	GDP←EC
Doğan (2014)[23]	Benin, Congo, Kenya, Zimbabwe	1971-2011	Granger Causality Analysis	EC → GDP (Kenya) GDP --- EC (Benin, Congo, Zimbabwe)

Note: GDP → EC (There is one-way causality relation from GDP to EC.)
EC → GDP (There is one-way causality relation from EC to GDP)
GDP --- EC (There is no relation between the variables)

As illustrated in Table 1, the economic and financial infrastructures of countries differ from each other. Similar to Roodman (2009) in which the dependency level of two variables was discovered to be significantly deeper than what had previously been thought, this study adopts Arellano-Bond GMM method to investigate dependency level of two variables [24].

In this study, a different method is applied in terms of the reliability of the used variables. It is determined that flexibility of economic growth is limited by the amount of energy consumption. Despite the strong interdependence and causality relationship between economic growth and energy consumption, the direction of causality is still not clearly defined. Generally, all papers could be divided into two groups. The first group argues that energy is a crucial input of production and a necessary requirement for economic and social development. The second group argues that energy has no significant impact on economic growth. This contradiction could be originated from different econometric methodologies, data sets, or countries' characteristics. A lack of concurrence on what kind of causal relationship actually exists can result in the inadequate implementation of appropriate economic and energy policies. Therefore, the aim of this paper is to give an overview of the existing literature with subsequent conclusions and guidelines for future research.

3. Methodology and Data

Capital (K), labor (L) and energy consumption (EC) are considered to be the inputs of the production Cobb Douglas function. The definitions of inputs and data sources of the variables which are integrated into the empirical analysis are presented in Table 2. In this table, all variables except GDP are defined as independent variables.

Table 2. Defining Variables

Variables	Descriptions	Source
GDP	Fixed prices of 2011,millions of dollar	Penn World Table
K	Fixed prices for 2011, gross fixed capital formation, millions of dollars	Penn World Table
L	Number of employment in the context of human capital, million people of efficient labor force.	The World Bank
EC	Fixed prices of 2011, per kilogram of crude oil equivalent, as share of GDP in the 1,000 Dollar	The World Bank

Sources: https://www.rug.nl/ggdc/productivity/pwt/, https://data.worldbank.org/indicator/NE. GDI.FTOT.KD/, http://data.worldbank.org/indicator/EG.USE.COMM.GD.PP.KD/, (01.07.2019).

As an econometric model, the Cobb-Douglas production function examines the share of EC in GDP in order to evaluate coefficient flexibility between dependent and independent variables. Furthermore, the firstly taken test should be used to assure the estimation results accuracy in the model. In this paper, the following equation is employed to verify the bidirectional relationship between the EC and GDP.

$$GDP = AK^{\alpha} L^{\beta} EC^{\delta} \tag{1}$$

In the Cobb Douglas Production Function (1), since the rates related to all variables are affected by past circuit rates, the Dynamic Panel Data Analysis technique is selected. In addition, the confidence interval related to the variables should be formed in consistent and meaningful time intervals, the natural logarithm of the production function is obtained by equation (2);

$$LnGDP_{it} = \alpha LnK_{it} + \beta LnL_{it} + \delta LnEC_{it} + \theta LnGDP_{i,t-1} + \mu_i + \lambda_t + u_{it} \quad (2)$$

Where; α, β, δ and θ: Parameters to be estimated.

μ_I : Unit effects, λ_t : Time effects, u_{it} : error term

3.1. Preliminary Predictions

This section of the article is devoted to the unit root test to determine whether there is a unit root or not in the model. For this purpose, there are various methods which could be applied to the unit root test. However, the second-generation unit root test is selected since there is a cross-sectional dependency between the variables of the model. So, the Pesaran CADF unit root test should be applied. Both cross-sectional dependency and changing variance assumptions are applied [25]. Furthermore, Pesaran CADF is suitable for macro panels and time series which include 20-30-year periods. This test is applied to all variables separately. The results are indicated in Table 3.

Table 3. Results of Pesaran CADF Unit Root Test

Variables	T - Bar	cv10	cv5	cv1	Z[T-Bar]	Lags	P - Value
Log GDP	-2.296	-2.580	-2.660	-2.810	0.082	1	0.533
D. Log GDP	-3.116	-2.580	-2.660	-2.810	-4.584	1	0.000
Log L	-2.243	-2.580	-2.660	-2.810	0.382	1	0.649
D. Log L	-3.043	-2.580	-2.660	-2.810	-4.171	1	0.000
Log K	Augmented by 1 lags (average)				-0.890	1(ort.)	0.187
D. Log K					-5.648	1(ort.)	0.000
Log EC					5.382	1(ort.)	1.000
D. Log EC					-11.174	1(ort.)	0.000
H0: Variables are stationery.							

Z-bar test and P-value which are presented in Table 3, indicate that H_0 hypothesis is rejected. This result shows that the variables are not stationary in logarithm forms. At this stage, by taking the first difference of the variables within the model, they become stationary. As a result of the previous tests, it is observed that the variables of a particular year are affected by the variables of the previous year [26].

In the next stage, by considering the results of the Wald Test, it is observed that error terms variance of the estimated parameters is not identical (Table 4) .

Table 4. Heteroscedasticity Test (Changhed Wald Test) Results

Variables	Chi 2 (28)	Prob. > F	R-Square	F(27,631)
The Function	5233.58	0.0000	0.8557	35.31
H0: Sigma (i)^2 = Sigma^2 (For all i)				
Changhed Wald Test (Fixed Effect Regression)				

According to the results in Table 4, error terms variance in the panel of 28 EU countries is not fixed and the model has a heterogeneous structure. It has been determined that the proposed model is a fixed effect model which includes the assumed variances.

In this stage, the cross-sectional dependency is tested. In Hoechle (2005) the author has applied the Pesaran ABS estimation method to cross-sectional dependence test [27]. Since the proposed model is the fixed-effect model and includes heteroscedasticity, applying Pesaran ABS method is appropriate for the cross-sectional test in Table 5.

Table 5. Pesaran ABS Cross Sectional Dependency Test Results

Log GDP	Coefficient	Standard Errors	T - Statistics	P-Value	Confidence Range %95	
Log L	0.6014477	0.0296075	20.31	0.000	0.5433065	0.6595889
Log K	0.4637557	0.0120982	38.33	0.000	0.4399981	0.4875132
Log EC	-0.0416788	0.0405726	-1.03	0.305	-0.1213524	0.0379948
Sigma u	0.12064288					
Sigma e	0.07971365					

rho	0.69609856	(fraction of variance due to u_i)
F(27 , 631)	35.31	F test that all u_i=0
F(3 , 631)	1247.48	
R Square	0.8557	
Prob. > f	0.000	
Pr		0.0000
Pesaran's test of cross sectional independence		20.359
Average absolute value of the off-diagonal elements		0.465
Fixed Effect (Regression - Within)		

As shown in Table 5, the *H0* hypothesis (no cross-sectional dependency) proposed for all logarithmic variables is rejected by the test method. According to the acquired results from the test, which is also demonstrated in Table 6, the P-value of the variables is less than the error margin which is (0.05). Hence, applying the Pesaran CCEMG (Common Correlated Effects Mean Group Estimator) method which was also suggested by Markus is preferred when P-value is less than the error margin which is stated in Table 6.

Table 6. Pesaran CCEMG Test Results

Log GDP	Coefficient	Standard Errors	Z – Value	P - Value	Confidence Range %95	
Log L	0.4060375	0.0631469	6.43	0.000	0.2822719	0.5298032
Log K	0.1518743	0.0188512	8.06	0.000	0.1149266	0.1888221
Log EC	0.1025319	0.0238053	4.31	0.000	0.0558743	0.1491895
M - Log GDP	0.987222	0.1041574	9.48	0.000	0.7830772	1.191367
L – Log L	-0.3684437	0.2161358	-1.70	0.088	-0.792062	0.0551746
L – Log K	-0.1522559	0.0545285	-2.79	0.0105	-0.2591299	-0.0453819
L – Log EC	-0.090375	0.0446185	-2,03	0.043	-0.1778257	0.0026124

In order to determine the relations between both dependent and independent variables, the cross-sectional dependency is applied. According to the obtained results, P-value is greater than the error margin (0.05). Consequently, the main hypothesis (H_0) is rejected which means there is the cross-sectional dependency among the variables. Consequently, dynamic panel analysis is an appropriate method for data or calculation estimation.

3.2. Dynamic Panel Data Analysis and Arellano-Bond GMM Method

In order to make more proper assumptions in a dynamic panel model, two main assumptions should be tested. First of all, the internality problem of the model should be checked (correlation between the term error and delayed variables in the explanatory variables). Balestra and Nerlov (1966) stated that correlation should be applied to check the existence of the problem internality [28]. WU-Hausman internality test consists of two stages, which are the least-squares method (Table 7) and the process of checking whether the error terms have autocorrelation or not.

Table 7. Balestera/Nerlove and WU-Hausman Internality Test Results

Log GDP	Coefficient	Standard Errors	Z - Statistics	P – Value	Confidence Range %95	
L1. Log GDP	0.8741568	0.0104375	83.75	0.000	0.8536997	0.894614
Log L	0.0600669	0.005626	10.68	0.000	0.0490401	0.0710936
Log K	0.065648	0.0059054	0.000	0.000	0.0540736	0.0772224
Log EC	-0.0100056	0.0040705	-2.46	0.014	-0.0179837	-0.0020275

Wu – Hausman Test Results	
İnternality Test	Ho: Variables are externality.
Durbin (Score) chi2(1)	123.132 (p = 0.000)
Wu-Hausman F(1,613)	152.218 (p = 0.000)

As illustrated in Table 7, the P-value (0.05) is lower than the margin of error. So, the H0 hypothesis (Variables is externality) is rejected. As a result, the internality problem is detected in the model. To solve the internality problem, tool variables should be used. However, it is necessary to check whether the tool variables are valid or not. So, Arellano-Bond suggested the Sargan test to check the validity of the tool variables. The Sargan test results are presented in Table 8.

Table 8. Sargan Test Results

Arellano-Bond Sargan limitations of over identification	H0: There are limitations of over identification
chi2(273)	27.87337
Prob. > chi2	1.0000

The null hypothesis (No autocorrelation) of this test is "there are limitations of over-identification". The rejection of this hypothesis means that the tool variables are invalid. In this test, the H0 hypothesis is accepted since the P-value is greater than the margin of error (0.05) and the tool variables are valid to use. Also, in the GMM method, there should not be a second autocorrelation for effective parameter estimators. Therefore, testing of the second-order autocorrelation subject is needed. Table 9 shows the results of the Arellano-Bond autocorrelation test on the parameters or estimations. This test was applied base on the GMM method by using the tool variable.

Table 9. Arellano-Bond Autocorrelation Test Results

Rank	Z	Prob. > z
1	-3.3372	0.0008
2	-2.8787	0.0040

Table 9 contains both the first and the second order autocorrelation tests. Since z-statistic and p-value are lower than the margin error, H_0 hypothesis (autocorrelation) is rejected. Also, it is observed that the model has both the first and second order autocorrelations. However, to use GMM method, there should not be the second order autocorrelation. To determine the first and second autocorrelation in the model, two-stage GMM Robust method is recommended since the robust model is not affected by the changing variance [24]. Since the deviation was observed in the results of the robust prediction, different methods should be applied to make the estimations. Since the deviation was observed in the results of the robust prediction

3.3. Final Results and Discussion

To make a more proper prediction, different methods [29] have been suggested. For instance, First Degree Differences and Durbin-Watson statistics methods could solve the autocorrelation problem. In this study, Arellano-Bond autocorrelation test is used by applying the first-order difference method. The test results are illustrated in Table 10.

Table 10. Results of Two-Stage Arellano-Bond Autocorrelation Test with First Difference, Results

Two – Stage Results						
Fd Log GDP	Coefficient	Standard Errors	Z - Statistics	P - Value	Confidence Range %95	
L1. Fd Log GDP	0.0787014	0.0082249	59.82	0.000	0.0625809	0.09448219
Fd Log L	0.4220323	0.0184582	2.70	0.000	0.3858549	0.4582096
Fd Log K	0.1666576	0.003193	33.04	0.000	0.1603995	0.1729158
Fd Log EC	0.1426774	0.0036208	2.11	0.000	0.1355809	0.149774
GMM	L(2/.).fd log gdp					
Standard	D.fd logl D .fd log k D. fd log ec					
Tool variables number	255					
Wald chi2(4)	12564.24					
Prob. > chi2	0.0000					

Autocorrelation Test Results		
Rank	Z	Prob. > z
1	-3.6945	0.0002
2	-0.5021	0.6156

Therefore, as shown in Table 12, by using two-stage Arellano-Bond method, the first difference of the logarithmic variables taken is evident. In this test, the P-value of L, K and EC are statistically significant. Besides, the coefficient values are statistically significant and affirmative.

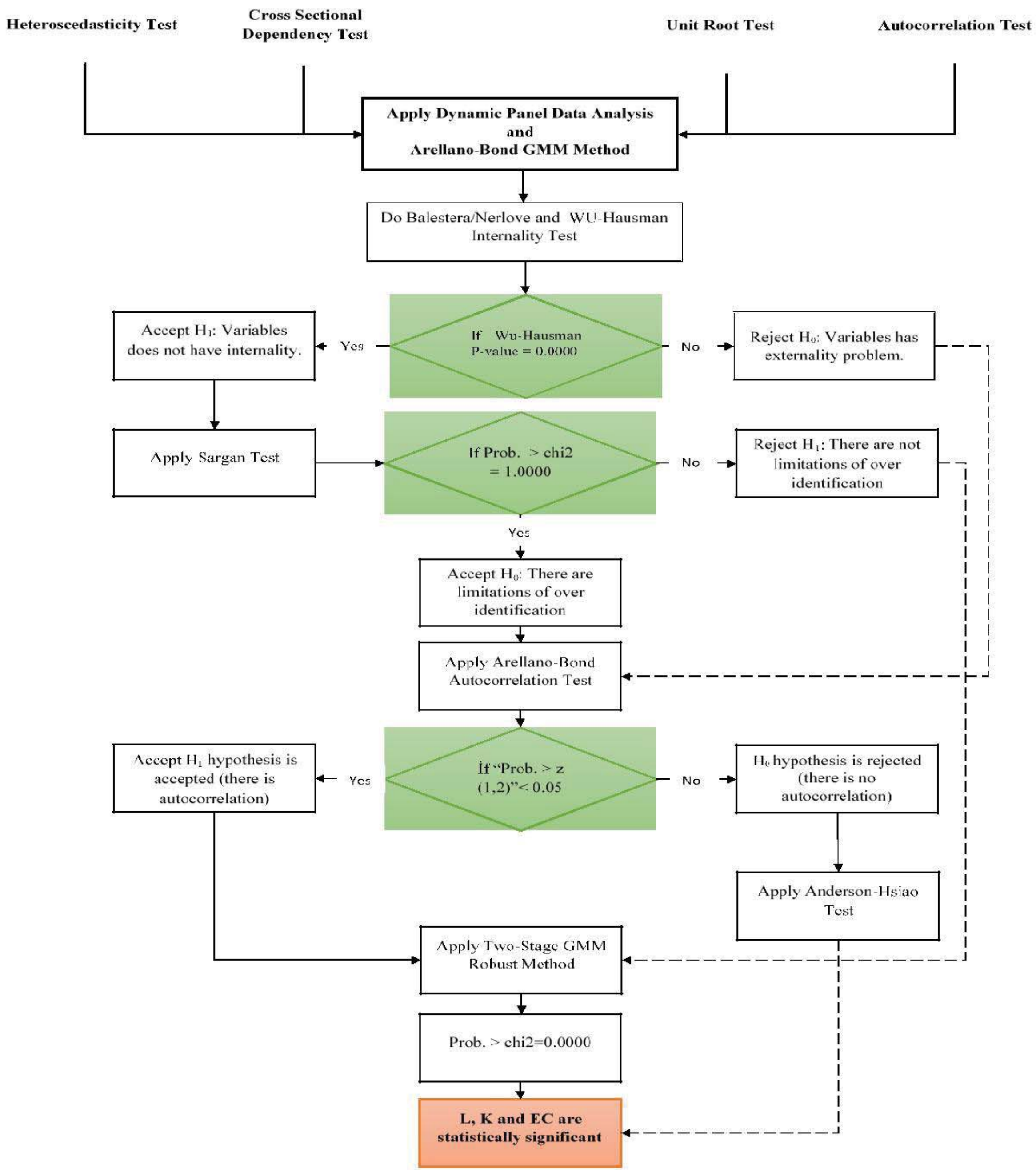
As a result, all independent variables affect the dependent variable positively. In this test method, as described in the previous autocorrelation test, the basic hypothesis was based on the lack of correlation. According to the test results in Table 12, there was the first-degree autocorrelation. The P-value (0.05) was lower than the margin of error. Hence, the basic hypothesis is rejected. However, in the mentioned test, there is no second-degree autocorrelation. Also, the P-value (0.05) is greater than the margin of error. So, the basic hypothesis is accepted. The absence of second-order autocorrelation indicates that the GMM is a more valid method to be used in the estimation of parameters.

Although the coefficient values of the variables in Table 12 are positive and significant, the coefficient values may not be proper for evaluation because the coefficient values have variance problem. However, “z” values are more appropriate for evaluation since they do not demonstrate any variance. It shows that this coefficient value is greater than the independent variables and it is more effective for the GDP. In other words, K, L, and EC variable affect the GDP of the EU economy.

In the study, analysis of the econometric model shows that K, L, and EC have a significant and positive effect on the economic growth of the EU. In other words, economic growth is limited by the demand for energy. Besides such restriction, the EU's authorized bodies also affect the content and form of the EU's energy policy.

A summary of all tests performed in the study is provided in Figure 4. As a result of the preliminary estimations, it is concluded that the model is more compatible with the dynamic panel structure.

Figure 4. Flowchart of Econometric Model Predictions



4. Conclusion

This study examines the relationship between energy consumption and economic growth in 28 European Union countries over the period 1990-2014 by using the Arellano-Bond GMM testing approach. Wu-Hausman test was applied to estimate the parameters. Afterward, to solve the internality problem, tool variables approach was adopted. In this context, the Sargan test was used to determine the validity of the tool variables. According to the results of the Sargan test, tool variables were validated. Besides, the GMM method was used to make a more effective estimation for the parameters. Hence, the first difference of the parameters was taken. Then, Arellano-Bond test was applied to identify whether there is autocorrelation among the parameters or not. As a result of this test, the GMM is a valid and proper method for parameter estimation. Because there is no second-degree autocorrelation among the parameters, the GMM method has been proven to be the appropriate method for estimations.

In the final step, the Arellano-Bond GMM method was used to make effective parameter estimations. So, the first difference of the parameters was taken once again and was stabilized. After this step, the Arellano-Bond autocorrelation test was applied. The results of the statistical method can be listed as:

i) As a result of a 1% increase in K value, the GDP value increased by approximately 0.17%.

ii) As a result of a 1% increase in L value, the GDP value increased by approximately 0.42%.

iii) As a result of a 1% increase in EC value, the GDP value increased by approximately 0.14%.

The results show that there is an appropriate relationship between GDP and K, L, and EC. As a result of the econometric model by considering the general hypothesis of the research, economic growth is restricted by the demand for energy. In other words, to make an independent energy policy in the EU, the share of energy consumption should be reduced in economic growth.

The main contribution of this study is the application of various hierarchical methods to identify the relationship among the dependent variable i.e. GDP and independent variables i.e. K, L, and EC. As illustrated by the results of this paper, the opinion of energy economists who advocate energy consumption as an important input in economic growth is approved. Also, coefficient flexibility in all variables affects the independent variable (GDP). It is evident that EC is an important input in economic production, especially due to the fact that the energy consumption coefficient of flexibility deeply affects economic growth. However, most of the studies in the literature fail to find any result reflecting the intensity of this relationship. This research study reveals that the change in energy consumption causes a significant change in economic growth. Therefore, the fact that there is such a deep relationship between the two variables for EU countries is considered as the most important reason for the acceleration in the search for alternative energy resources in the region. According to the obtained results, the share of renewable energy sources in energy consumption should be increased and the transition to efficient energy consumption should be ensured. The other alternative is to increase the energy efficiency aiming for decrease in dependency on EC. This topic has the potential to be thoroughly investigated in future research studies.

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