Relationship between energy consumption and economic growth in 30 countries in Europe – panel

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Abstract

In this paper, we study the link between energy consumption and economic growth for the thirty surveyed countries in Europe. Although there are many articles on this topic, the difference between them and this one is that we study countries that have not yet been studied together. The variable that is used for consumption is the final energy consumption, which includes the consumption of all forms of energy. In this paper, we use panel data analysis that studies the connections based on the methods of fixed effect. The data used were collected from European databases, Eurostat. Based on the results of the panel data regression, we can conclude that there is a strong correlation between the observed variables. What is needed for further research is to study the correlation between variables in the long and short-term. Equally interesting would be to study the way of integration with countries that have their power sources and those that do not.

Keywords: Energy consumption, Panel data regression, fixed effect, GDP.[1]

JEL: C230, O520, O400, Q430

Introduction

In recent years, there has been a very large number of papers which study the correlation between economic growth and energy consumption. However, there is a very significant difference between the results obtained in these different papers. That is because all these papers are made in various techniques, with different approaches and different procedures in the analysis. The main hypothesis of this paper is to establish the link between energy

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consumption and economic growth for all countries in Europe. We will use all the countries in Europe regardless of their development or energy independence. Although there are many types of research on this topic, there is no research that covers all the countries in Europe that have available statistical data. The main issue of this paper is to study the link between the final energy consumption and economic growth. We assume correlation of economic growth with energy consumption. However, it is necessary to determine the direction of this association, which is not always clearly defined. What is not certain is the time when the state increased power consumption, which resulted in an increased economic growth and to what extent is it a reference to the increase. The central question posed in this paper is crucial because it reveals how much is necessary to increase the power consumption that would occur as a change in the economic growth. We show the link between economic growth and the final energy consumption in 30 countries in Europe. In this paper, the data were collected for the observed countries for final energy consumption, which is made up of energy consumption arising from solid fuels, oil, gas, nuclear power, heat, renewable energy sources, and waste. With this information, we observe gross domestic product expressed in market prices. Using panel data analysis, we will analyze the relationship between the variables in thirty countries in Europe. The observed countries are members of the European Union, and we also used several States that are significant to the analysis but are not members of EU.

There are a very large number of studies dealing with this analysis. One of the many papers on this topic is the work of Kasperowicz (2014), entitled "Economic growth and energy consumption in 12 European countries: a panel data approach". This paper studies the link between energy consumption and economic growth in 12 countries of the European Union in 13 years. The hypothesis of this article, which was later confirmed, is that there is a positive correlation between energy consumption and economic growth. The evaluated regression model includes growth rates of energy consumption and growth rates of gross fixed capital at real prices. The analysis states that energy consumption is not neutral to economic growth in the analyzed countries.

The following work written on this subject is by Ucan and others (2014), Energy consumption and economic growth nexus: Evidence from developed countries in Europe. This paper analyzes the relationship between the use of renewable and non-renewable energy sources and economic growth for 15 countries of the European Union over a period of 22 years. The cointegration test panel shows a long-term equilibrium correlation between real GDP and consumption of energy from renewable and non-renewable sources. Belke and others (2011) studied the long-term correlation between energy consumption and real GDP,

including energy prices. This paper outlined the use of methods of studying individual components which allow the study of the international and national impact on long-term growth.

With similar topic, Hu et al. (2015) studied the connection between energy consumption and economic growth in the case of industrial sectors in China. This paper used panel data observed for 37 different industry sectors in China. The paper concludes that in the short term there is a one-way influence of economic growth on energy consumption, while in the long term there is a unidirectional impact of energy consumption on economic growth. Bildirici (2014), in his work, explains the co-integration link between the consumption of energy derived from biomass and economic growth in transition countries. In this case, they are looking at the consumption of biomass as a substitute for energy derived from oil and other fossil fuels. The study confirmed a positive association between the consumption of energy derived from biomass and economic growth. Yang (2012) studies the link between energy consumption and economic growth in China. China, in an effort to turn to the sustainable green economy, attempts at reducing energy consumption in order to reduce environmental pollution and thus increase its sustainable GDP. The question that arises in this work is whether the reduction of the energy consumption has an impact on economic growth and to what extent. The result of the work shows a link between economic growth and energy consumption. Dedeoglu and others (2014) study the connection between economic growth and energy consumption in the former Soviet countries for ten years. The authors conclude that in the short term there is no connection between these two variables, while in the long run there is a connection. Heiko (2012) studied neutrality hypothesis between energy consumption and economic activity in the EU countries. What this work shows is that in developed old EU Member States the event of the reduction of energy consumption leads to an increase in economic growth, while in the new EU member states they came to the opposite conclusion, meaning that an increase in energy consumption leads to the growth of economic activity.

Data

The data used in this study were obtained from the database of Eurostat, which is the statistical office that collects data for the European Union. Data that we use in this paper are obtained for this countries: European Union (28 countries), Euro area (19 countries), Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain,

France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Russia, Slovenia, Slovakia, Finland, Sweden, United Kingdom, Iceland and Norway. We use a different type of countries that are developed and underdeveloped, that are in transition, that they have own energy production and those that depend on other countries in energy production. We use this different country to enrich our paper. The observed period is from 1994 to 2016., on a yearly basis. We look at two variables, the Gross Domestic Product at market prices and Final energy consumption in tons of oil equivalent. The data were collected for thirty-one countries, involving the European Union countries and countries which are in Europe, and whose energy consumption and energy production are distinct and interesting for this work. The paper intended to involve as many countries as possible, which are in Europe, in the model we are going to observe, but there is a problem that less developed countries do not have statistics on energy consumption. That is why they have not been considered. For GDP, we took data on GDP in all the countries observed at market prices. Total energy consumption is taken for the energy consumption variable, which is obtained by summing the energy consumption of all available energy sources, expressed in equivalent tons of oil. We observed countries that are developed and long-lasting states of the European Union or the transition countries that are less developed and subsequently became members of the European Union. On this basis, we can see that there will be differences in the impact of energy consumption on the economic growth between developed and less developed countries.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
gdp	640	954165.1	2392105	2829	1.40e+07
ene	640	96864.68	235392.9	364.8	1192622

Source: Authors calculation

Variable gdp represents the GDP at market prices, and variable ene represents the final energy consumption. From Table 1 we can see, we have 640 observations, that there is a big difference between the minimum and maximum observed variables, which tells us that we have a great diversity of countries that we include in this paper.

Empirical results

In this paper, we use a panel model with fixed-effect. We use the fixed-effect when we want to analyze the influence of variables that vary over time. FE studies the relationship between the predictor and the output variables within a single unit (country, person, company, etc.). Each unit has its characteristics that may or may not affect predictor variable (for example, being male or female can affect the answers given during questioning). When we use the FE or Fixed-effect method, we assume that the individual characteristics may influence the assessment of the predictor variables and output. FE method eliminates these time characteristics of the individual and thus gives us the effective net access to the dependent and independent variables. Another important assumption is that the FE model and the individual time characteristics of the individual are private and can not be brought into connection with other characteristics of other individuals. If these features are correlated to each other in this case, the FE model is not suitable for use.

The equation for the fixed effect model is:

$$Y_{it} = \beta_1 X_{it} + \alpha_i + u_{it} \quad (1)$$

Where:

- $\alpha_i \, (i = 1 \ldots . n)$ is the unknown intercept for each entity (n entity-specific intercepts)
- Y_{it} is the dependent variable (DV) where i= entity and t= time.
- X_{it} represents one independent variable (IV),
- β_1 is the coefficient for that IV,
- u_{it} is the error term.

The key insight is that if the unobserved variable does not change over time, then any variations in the dependent variable must be due to influences other than these fixed characteristics. Another way to see the fixed effects model is by using binary variables. So the equation for fixed effects model becomes:

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \cdots + \beta_K X_{K,it} + Y_2 E_2 + \cdots + Y_n E_n + u_{it} \quad (2)$$

Where:

- Y_{it} is the dependent variable (DV) where i= entity and t= time.
- $X_{k,it}$ represents one independent variable (IV),

- β_k is the coefficient for that IVs,
- u_{it} is the error term.
- E_n is the entity n. Since they are binary (dummies) you have n-1 entities included in the model.
- Y_2 is the coefficient for the binary repressors (entities).

Table 2. OLS regression

Source	SS	df	MS	Number of obs =	640
				F(1, 638) =	15196.57
Model	3.5091e+15	1	3.5091e+15	Prob > F =	0.0000
Residual	1.4732e+14	638	2.3092e+11	R-squared =	0.9597
				Adj R-squared =	0.9596
Total	3.6565e+15	639	5.7222e+12	Root MSE =	4.8e+05

gdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ene	9.95535	.0807577	123.27	0.000	9.796767	10.11393
_cons	-10156.69	20542.63	-0.49	0.621	-50496.04	30182.66

Source: Author calculation

OLS regression shows that the p-value is zero, which means that we can accept the hypothesis that all coefficients are different from zero. From this, we see that we cannot use ordinary OLS regression, but we have to apply a panel data with fixed effects or random effects. Using the Hausman test, the result of this test has shown us the obligation of using fixed effects methods in the panel.

Table 3. Panel data regression with fixed effects

```
Fixed-effects (within) regression               Number of obs      =       640
Group variable: country                         Number of groups   =        32

R-sq:  within  = 0.0187                         Obs per group: min =        20
       between = 0.9973                                        avg =      20.0
       overall = 0.9597                                        max =        20

                                                F(1,607)           =     11.54
corr(u_i, Xb)  = 0.9842                         Prob > F           =    0.0007
```

gdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ene	7.023809	2.067795	3.40	0.001	2.962908	11.08471
_cons	273806.1	201177.6	1.36	0.174	-121282.6	668894.8
sigma_u	711824.68					
sigma_e	475873.84					
rho	.69111938	(fraction of variance due to u_i)				

F test that all u_i=0: F(31, 607) = 1.41 Prob > F = 0.0733

Source: Author calculation

From Table 3 we see that the coefficient of 7.023 is for the ene variable, which indicates that if the energy consumption is changed by one unit to the observed variable GDP would change for 7.023 units. If we consider the t-value, we can see that it is greater than 1.96, with which we conclude that the variable energy consumption has a significant influence on the observed variable GDP. From the F-test, we can see that all the coefficients in the model are different from zero. P-test confirms the same as the t-test or the substantial significance of the ene variable on the observed variable. Using Breusch-Pagan LM test for cross-sectional dependence correlation we conclude that we have no cross-sectional dependence. After testing heteroscedasticity, we concluded that there is no presence of heteroskedasticity in the model.

In the following tables, we have calculated the impact of energy consumption on GDP in underdeveloped countries or transition countries and developed countries.

Table 4. Panel data regression with fixed effects – countries in transition and underdeveloped countries

```
Fixed-effects (within) regression               Number of obs      =       160
Group variable: country                         Number of groups   =         8

R-sq:  within  = 0.1689                         Obs per group: min =        20
       between = 0.9257                                        avg =      20.0
       overall = 0.4483                                        max =        20

                                                F(1,151)           =     30.69
corr(u_i, Xb)  = -0.9882                        Prob > F           =    0.0000
```

gdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ene	8.95602	1.616586	5.54	0.000	12.15007	5.761972
_cons	108134.2	13731.75	7.87	0.000	81003.01	135265.4
sigma_u	85281.334					
sigma_e	18265.277					
rho	.95614025	(fraction of variance due to u_i)				

F test that all u_i=0: F(7, 151) = 10.21 Prob > F = 0.0000

Source: Author calculation

In table 4, we have used all countries in transition like Croatia, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovenia, and Slovakia. From Table 4 we see that the coefficient of 8.956 is for the ene variable, which indicates that if the energy consumption is changed by one unit to the observed variable GDP would change for 8.956 units. If we consider the t-value, we can see that it is greater than 1.96, with which we conclude that the variable energy consumption has a significant influence on the observed variable GDP. From the F-test, we can see that all the coefficients in the model are different from zero. P-test confirms the same as the t-test or the substantial significance of the ene variable on the observed variable. Using Breusch-Pagan LM test for cross-sectional dependence correlation we conclude that we have no cross-sectional dependence. After testing heteroscedasticity, we concluded that there is no presence of heteroskedasticity in the model.

Table 5. Panel data regression with fixed effects – developed countries

Fixed-effects (within) regression — Number of obs = 480
Group variable: country — Number of groups = 24

R-sq: within = 0.0188 — Obs per group: min = 20
between = 0.9974 — avg = 20.0
overall = 0.9578 — max = 20

F(1,455) = 8.73
corr(u_i, Xb) = 0.9840 — Prob > F = 0.0033

gdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ene	2.062419	2.390501	0.95	0.203	2.364628	11.76021
_cons	369147.1	303048.7	1.22	0.224	-226401.6	964695.7
sigma_u	790194.91					
sigma_e	549476.64					
rho	.6740646	(fraction of variance due to u_i)				

F test that all u_i=0: F(23, 455) = 1.32 — Prob > F = 0.1496

Source: Author calculation

From Table 5 we see that the coefficient of 2.062 is for the ene variable, which indicates that if the energy consumption is changed by one unit to the observed variable GDP would change for 2.062 units. If we consider the t-value, we can see that it is smaller than 1.96, with which we conclude that the variable energy consumption has not a significant influence on the observed variable GDP. P-test confirms the same as the t-test that there is no substantial significance of the ene variable on the observed variable. Using Breusch-Pagan LM test for cross-sectional dependence correlation we conclude that we have no cross-sectional dependence. After testing heteroscedasticity, we concluded that there is no presence of heteroskedasticity in the model.

Conclusion

From the analysis conducted in this paper, we can conclude that there is a very strong correlation between energy consumption and economic growth. Based on the data examined and the results, we can confirm the original hypothesis in the work of the vast nexus of observed variables. We can also conclude that this association is present in all the monitored countries, regardless of their size and level of development. The data were collected for thirty countries involving the European Union countries and other European countries and their energy consumption, and energy production are distinct and attractive to this work. For GDP, we took data on GDP in all the countries observed in market prices. Total energy consumption is taken for the energy consumption variable, which is obtained by summing the energy consumption of all available energy sources, expressed in equivalent tons of oil. We observed countries that are developed and long-lasting states of the European Union or the transition countries that are less developed and became members of the European Union subsequently. Another problem that we have explored in this article is a comparison of developed and developing or transition countries, and we compared the results. According to some authors, like Ucan and others (2014), the link between energy and economic growth in the short term does not exist in developed countries. However, in the long run, there is a correlation between the observed variables for developed and underdeveloped countries. Based on the results obtained, we can confirm the very high correlation between observed variables for countries in transition. However, in developing countries, there is no correlation between observed variables, most likely because these countries have reached a level of development where energy consumption does not have a major impact on GDP.

There are a few drawbacks in this paper, for example, the number of the surveyed countries should be increased. This paper observed only EU countries and other European countries. We should do research involving all relevant countries in the world and observe them over a longer period. Interesting for future research is the comparability of these two observed variables between countries that are energy independent, producing enough energy from their resources, and those countries that are not. From this research, we should see if there is a difference between these countries or not, or whether there is an advantage to countries that are self-sufficient due to their power sources. In this paper, we didn't want to compare countries that have own energy production with those countries that don't have own energy production.

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Appendix

Table 3. Estimated fixed effects (using dummies and regress)

```
i.country         _Icountry_1-32      (naturally coded; _Icountry_1 omitted)

      Source |       SS       df       MS              Number of obs =     640
-------------+------------------------------           F( 32,   607) =  485.61
       Model |  3.5190e+15     32  1.0997e+14           Prob > F      =  0.0000
    Residual |  1.3746e+14    607  2.2646e+11           R-squared     =  0.9624
-------------+------------------------------           Adj R-squared =  0.9604
       Total |  3.6565e+15    639  5.7222e+12           Root MSE      =  4.8e+05
```

gdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ene	7.023809	2.067795	3.40	0.001	2.962908	11.08471
_Icountry_2	-521039.9	714819.6	-0.73	0.466	-1924860	882779.9
_Icountry_3	-3036798	2284934	-1.33	0.184	-7524134	1450539
_Icountry_4	-3130851	2339991	-1.34	0.181	-7726312	1464611
_Icountry_5	-3156288	2308197	-1.37	0.172	-7689310	1376733
_Icountry_6	-2987353	2329142	-1.28	0.200	-7561508	1586802
_Icountry_7	-2275528	1908504	-1.19	0.234	-6023600	1472543
_Icountry_8	-3096395	2354309	-1.32	0.189	-7719976	1527186
_Icountry_9	-3023926	2337323	-1.29	0.196	-7614148	1566295
_Icountry_10	-3042651	2321068	-1.31	0.190	-7600949	1515648
_Icountry_11	-2831547	2187604	-1.29	0.196	-7127739	1464645
_Icountry_12	-2441884	2044182	-1.19	0.233	-6456413	1572645
_Icountry_13	-3100033	2346518	-1.32	0.187	-7708312	1508245
_Icountry_14	-2569813	2101309	-1.22	0.222	-6696532	1556906
_Icountry_15	-3085704	2356504	-1.31	0.191	-7713594	1542186
_Icountry_16	-3100761	2352131	-1.32	0.188	-7720063	1518542
_Icountry_17	-3098893	2350716	-1.32	0.188	-7715416	1517630
_Icountry_18	-3084567	2352047	-1.31	0.190	-7703705	1534571
_Icountry_19	-3127420	2325893	-1.34	0.179	-7695194	1440353
_Icountry_20	-3085707	2359148	-1.31	0.191	-7718790	1547376
_Icountry_21	-2931388	2251237	-1.30	0.193	-7352547	1489770
_Icountry_22	-3016777	2306888	-1.31	0.191	-7547228	1513673
_Icountry_23	-3263444	2234284	-1.46	0.145	-7651310	1124421
_Icountry_24	-3061694	2324419	-1.32	0.188	-7626574	1503187
_Icountry_25	-3175186	2309937	-1.37	0.170	-7711626	1361253
_Icountry_26	-3092432	2350351	-1.32	0.189	-7708239	1523376
_Icountry_27	-3122607	2337203	-1.34	0.182	-7712592	1467378
_Icountry_28	-3102261	2308891	-1.34	0.180	-7636646	1432124
_Icountry_29	-3008804	2290484	-1.31	0.189	-7507039	1489431
_Icountry_30	-2413150	2058973	-1.17	0.242	-6456725	1630425
_Icountry_31	-3092944	2355592	-1.31	0.190	-7719045	1533156
_Icountry_32	-2969766	2322185	-1.28	0.201	-7530258	1590726
_cons	3087794	2357676	1.31	0.191	-1542397	7717986

Source: Author calculation

Table 4. The least square dummy variable model (LSDV)

Variable	ols	ols_dum
ene	9.9553498***	7.0238087***
_Icountry_2		-521039.88
_Icountry_3		-3036797.6
_Icountry_4		-3130850.6
_Icountry_5		-3156288.4
_Icountry_6		-2987353.1
_Icountry_7		-2275528.5
_Icountry_8		-3096395
_Icountry_9		-3023926.5
_Icountry_10		-3042650.6
_Icountry_11		-2831547.2
_Icountry_12		-2441884
_Icountry_13		-3100033.2
_Icountry_14		-2569813.1
_Icountry_15		-3085704
_Icountry_16		-3100760.6
_Icountry_17		-3098892.7
_Icountry_18		-3084567.4
_Icountry_19		-3127420.3
_Icountry_20		-3085707
_Icountry_21		-2931388.4
_Icountry_22		-3016777.5
_Icountry_23		-3263444.4
_Icountry_24		-3061693.9
_Icountry_25		-3175186.5
_Icountry_26		-3092431.5
_Icountry_27		-3122607.2
_Icountry_28		-3102261.4
_Icountry_29		-3008803.6
_Icountry_30		-2413150.4
_Icountry_31		-3092944.5
_Icountry_32		-2969766.1
_cons	-10156.686	3087794.1
N	640	640

legend: * p<0.05; ** p<0.01; *** p<0.001

Source: Author calculation

Table 5. Panel data fixed effects: common intercept and n-1 binary regressors

Source	SS	df	MS		
Model	3.5190e+15	32	1.0997e+14	Number of obs =	640
Residual	1.3746e+14	607	2.2646e+11	F(32, 607) =	485.61
				Prob > F =	0.0000
				R-squared =	0.9624
				Adj R-squared =	0.9604
Total	3.6565e+15	639	5.7222e+12	Root MSE =	4.8e+05

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_Icountry_5	-3156288	2308197	-1.37	0.172	-7689310	1376733
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_Icountry_13	-3100033	2346518	-1.32	0.187	-7708312	1508245
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_Icountry_17	-3098893	2350716	-1.32	0.188	-7715416	1517630
_Icountry_18	-3084567	2352047	-1.31	0.190	-7703705	1534571
_Icountry_19	-3127420	2325893	-1.34	0.179	-7695194	1440353
_Icountry_20	-3085707	2359148	-1.31	0.191	-7718790	1547376
_Icountry_21	-2931388	2251237	-1.30	0.193	-7352547	1489770
_Icountry_22	-3016777	2306888	-1.31	0.191	-7547228	1513673
_Icountry_23	-3263444	2234284	-1.46	0.145	-7651310	1124421
_Icountry_24	-3061694	2324419	-1.32	0.188	-7626574	1503187
_Icountry_25	-3175186	2309937	-1.37	0.170	-7711626	1361253
_Icountry_26	-3092432	2350351	-1.32	0.189	-7708239	1523376
_Icountry_27	-3122607	2337203	-1.34	0.182	-7712592	1467378
_Icountry_28	-3102261	2308891	-1.34	0.180	-7636646	1432124
_Icountry_29	-3008804	2290484	-1.31	0.189	-7507039	1489431
_Icountry_30	-2413150	2058973	-1.17	0.242	-6456725	1630425
_Icountry_31	-3092944	2355592	-1.31	0.190	-7719045	1533156
_Icountry_32	-2969766	2322185	-1.28	0.201	-7530258	1590726
_cons	3087794	2357676	1.31	0.191	-1542397	7717986

Source: Author calculation

Povezanost između potrošnje energije i ekonomskog rasta za 30 zemalja Europe – panel

Sažetak

U ovom radu proučavamo povezanost između potrošnje energije i ekonomskog rasta za trideset promatranih zemalja u Europi. Iako postoji mnogo radova na ovu temu, razlika je između njih i ovoga rada u tome što se u ovom radu proučavaju zemlje koje do sada nisu zajedno proučavane. Varijabla koja se koristi za potrošnju energije je finalna potrošnja energije u koju ulaze potrošnje iz svih oblika energije. Koristi se panel analiza koja proučava povezanost na temelju metode fiksnog efekta. Podaci koji se koriste su prikupljeni iz Europske baze podataka Eurostat. Na temelju rezultata panel data regresije možemo zaključiti da postoji velika povezanost između promatranih varijabli. Ono što je potrebno u daljnjem istraživanju je proučiti povezanost varijabli i u dugom i kratkom roku. Isto tako potrebno bi bilo i proučiti da li postoji povezanost između promatranih varijabli za razvijene i nerazvijene zemlje odnosno da li među njima postoji razlika. Jednako zanimljivo bi bilo i proučiti način povezanosti kod zemalja koje imaju vlastite izvore energije i onih koje to nemaju.

Ključne riječi: Potrošnja energije, Regresija panel podataka, fiksni efekt, bdp.