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ENERGY CONSUMPTION, URBANIZATION AND ECONOMIC GROWTH RELATIONSHIP: AN EXAMINATION ON OECD COUNTRIES

ABSTRACT

This research tends to present fresh empirical evidence on the energy consumption-urbanization-growth nexus in the case of 34 OECD countries in the period 1996-2015 by applying Panel VAR analysis. Bivariate Panel VAR models suggest a two directional positive response of energy consumption (EC) to GDP (real GDP per capita). Moreover, EC is found to response positively to the UR (urban total population). The trivariate VAR model shows a significant positive impact of lagged GDP on the energy consumption. Additionally, lagged energy consumption is found to have a negative impact on urbanization. Urbanization is found to have a positive impact of the consumption of energy as well as on the economic growth. IRFs suggest a positive increasing short-term response of urbanization to the consumption of energy. The response of urbanization to the economic growth is positive and increases exponentially in the short-run. However, the response of urbanization to the energy consumption is positive but decreases significantly in the long-run. GDP is found to have a positive response to energy consumption but this response is decreasing in the observed period. The results of this paper suggest the great awareness of the urban citizens in OECD countries on their role in contributing to sustainable development by promoting sustainable energy. Hence, the policy makers need to do necessary changes to promote the renewable energy in urban areas in order to reduce CO_2 emissions caused by energy based on fossil fuels.

Keywords: Economic Growth, Energy Consumption, Panel VAR, Urbanization

JEL Classifications: Q43; F43; O18

ENERJİ TÜKETİMİ, KENTLEŞME VE EKONOMİK BÜYÜME İLİŞKİSİ: OECD ÜLKELERİ ÜZERİNE BİR UYGULAMA

ÖZET

Bu araştırma, 34 OECD ülkesinde, Panel VAR analizini uygulayarak enerji tüketimi-kentleşme-büyüme ilişkisi hakkında 1996-2015 dönemi için yeni ampirik kanıt sunma amacını taşımaktadır. İki değişkenli Panel VAR analizi modeli, enerji tüketiminin (EC) GSYH'ye (kişi başına düşen reel GSYİH) iki yönlü pozitif bir tepkisini ortaya koymaktadır. Dahası, EC'nin UR'ye (kentsel toplam nüfusa) olumlu tepki verdiği bulunmuştur. Üç değişkenli VAR modeli, GSYİH'nın enerji tüketimi üzerindeki önemli olumlu etkisini göstermektedir. Buna ek olarak, enerji tüketiminin kentleşme üzerinde olumsuz bir etkisi olduğu görülmektedir. Kentleşmenin, enerji tüketiminin yanı sıra ekonomik büyüme üzerinde de olumlu bir etkisi olduğu bulunmuştur. Etki tepki fonksiyonları (IRF), kentleşmenin, enerji tüketimine karşı, kısa vadede artan olumlu tepkisini göstermektedir. Kentleşmenin ekonomik büyümeye verdiği tepki olumludur ve kısa vadede katlanarak artmaktadır. Kentleşmenin enerji tüketimine verdiği cevap olumludur, ancak bu etki uzun vadede önemli ölçüde azalmaktadır. GSYİH'nın enerji tüketimine olumlu bir tepkisi olduğu ancak gözlemlenen dönemde bu tepkinin azaldığı görülmektedir. Bu makalenin sonuçları, OECD ülkelerindeki kentli vatandaşların sürdürülebilir enerjiyi teşvik ederek sürdürülebilir kalkınmaya katkıda bulunmadaki rolleri konusunda büyük farkındalıklarını ortaya koymaktadır. Bu nedenle politika yapıcılar, fosil yakıtlara dayalı enerjinin neden olduğu CO^2 emisyonlarını azaltmak için kentsel alanlarda yenilenebilir enerjiyi teşvik etmek için gerekli değişiklikleri yapmalıdır.

Anahtar Kelimeler: Ekonomik Büyüme, Enerji Tüketimi, Panel VAR, Kentleşme

JEL Kodları: Q43; F43; O18

Introduction

Energy is one of the today's priority issues in terms of economic and social development by the fact that it continues to be used as the basic input in the production process. The importance of the energy for the economies is growing day by day. Moreover, energy plays an important role in influencing the level of development of countries and determining the international policies of the countries. In this context, it can be said that the use of energy resources and the increase in energy demand are the causes of economic growth. The empirical evidence on the link between the economic growth and energy consumption is an essential benchmark of coordinating energy arrangements. Conversely, in of causal connection between economic growth and energy consumption, environmental protection policies which diminish energy consumption can affect economic growth in a negative way.

Nowadays, energy is considered as a source that should be provided continuously and sustainably in order to ensure and sustain economic growth. Energy consumption is directly connected to economic growth performance. Urbanization is one of the factors that increase energy consumption. Countries need to have sustainable energy resources in terms of economic growth performance and protection and development of their competitiveness. Energy and economic growth can be seen among the indicators of a country's economic development. Urbanization, industrialization and technological developments provide new production opportunities and consequently energy consumption increases rapidly. The energy consumption-urbanization-growth nexus has turned into a key subject for researchers and has motivated the empirical research conducted in this paper.

While changing consumption habits, urbanization rates, increasing population, technological developments, the patterns of production and consumption change and new energy types emerge. Hence the energy sector has become an intensely discussed research topic due to the structural commitment of the economy to other subjects such as urbanization. Therefore, defining this relationship will provide useful results for the policies to be implemented.

There are a large number of empirical studies on the connection between economic growth and energy consumption. However, only a limited number of studies analyzes this role in the case of OECD countries and do not provide evidence based on the panel VAR model. Moreover, contrary to studies to date, this research presents empirical evidence on the matter in the case of both, short- and the long-run by presenting IRFs and takes into account the impact of urbanization. At last, this research differs from studies to date by presenting in detail the results of forecast-error variance decomposition. The next parts of this paper will present the empirical evidence to date on the link between energy consumption, urbanization and economic growth. Moreover, the methodology will be outlined together with the explanation of the variables. The empirical results section will present the findings of the research together with the interpretation and finally we provide the concluding remarks in the last chapter.

Literature review

Energy is vital for all kinds of production activities and is evaluated as leading force for economic growth. Both energy and economic growth can be interrelated and affect each other. Economic growth leads to an increase in energy demand and energy is one of the main inputs to achieve economic growth. With regard to USA, the empirical evidence to date provides the mixed evidence on the link between energy consumption and economic growth. The study by Kraft and Kraft (1978) is the first study, from the best of our knowledge, investigating this relationship. The authors provide the evidence on the link between the energy consumption and economic growth in the case u USA. Apart from these results, Akarca and Long (1980) provide no evidence on the link between the variables of interest in the case u USA. It is also important to emphasize the study of Erol and Yu (1987) suggesting a unidirectional relationship from GDP to energy consumption and Stern (1993) and (2000) suggesting the bidirectional relationship.

In terms of Turkey, Soytas and Sari (2003) have employed the econometrics of time-series in the period 1960-65 and 1950-92. The results suggest the evidence on the link between the variables interest as opposed to Altınay and Karagöl (2004) that indicate no causal relationship between energy consumption and economic growth in the period between 1950 and 2000. In this light, it is also important to emphasize that Kızılkaya (2018) has analyzed energy consumption-growth nexus in the period 1960-2005. Study results suggest no link between energy consumption and economic growth in the case of Turkey.

With regard to European countries, Al-Mulali et al. (2015) have analyzed the effect of sustainable power generation by source on CO_2 outflow for the time span 1990– 2013 in 23 European countries. Cointegration test results have demonstrated that renewable energy production, GDP growth, urbanization, CO_2 emission and financial development are cointegration.

Komal and Abbas (2015) have researched finance, growth and energy connection in Pakistan for the period 1972– 2012 by utilizing the GMM. The findings suggest a positive and substantial effect of economic growth and urbanization on energy consumption, whereas the effect of energy prices over energy consumption is prominent yet negative. Ali et al. (2016) investigated the impacts of economic growth, energy consumption, trade responsiveness and urbanization on CO_2 for Nigeria. Empirical results suggest the cointegrating link between the variables of the interest.

Yang et al. (2017) have explored the effect of urbanization on economic growth and energy consumption using information from China's 266 urban communities for the 2000–2010. The results display a positive impact of urbanization on economic growth for whole sample. Wang et al. (2018) empirically investigated the relationship between urbanization, monetary improvement, energy consumption, and CO_2 outflows. The have collected the annual panel data for 170 countries in the time span between 1980 and 2011. The results support the evidence on the cointegration.

Although there are many studies analyzing the economic growth and the energy consumption relationship in empirical literature, the number of treating the effect of urbanization is limited. Hence, it is thought that this study will contribute to the literature as it examines this trilateral relationship while employing the panel data methodology. Based on the results above, the link between the variables is expected to be positive.

Methodology and variables

Panel VAR model was introduced in 1980s (Sims, 1980). These models are similar to those applied using the time-series data. However, the main difference arises from the introduction of a cross sectional difference. Thus, VAR model become more effective in explaining long-standing economic questions. The appealing characteristic of the panel VAR is that they do not require the full arrangement of economy to be determined. Moreover, they are able to take into account the interdependencies that are both static as well as those that are dynamic (Canova and Ciccarelli, 2013). Additionally, these models enable us to deal simply with the time variations in the coefficients and very important feature is that these easily deal with the heterogeneity (cross-sectional). The panel VAR estimation is in accordance with Love and Zicchino (2006).

One important feature of VAR models is that all of the variables are assumed to be independent. Besides that, there are no exogenous variables; all of the variables are rather treated as endogenous. The VAR models can be formalized as following (Canova and Ciccarelli, 2013):

$$Y_t = A_0(t) + A(lag)Y_{t-1} + u_t \quad (1)$$

where Y_t represents endogenous variables, u_t are assumed to be IID and $A(lag)$ represents lag operator. The structure of panel VAR is the same as the one of VAR models. However, these models add the cross-sectional dimension. It can be formalized as:

$$y_{it} = A_{0i}(t) + A_i(lag)Y_{t-1} + u_{it} \quad (2)$$

where $i = 1, \dots, N \; and \; t = 1, \dots, T,$ u_{it} denotes the vector of disturbance. The three characteristic features of VAR are: 1. dynamic interdependencies indicating that lag values of all variables that are endogenous are introduced to the model for every individual; 2. static interdependence meaning there is a correlation among disturbances across individuals and lastly 3.

cross sectional heterogeneity indicating that the variance of the disturbances as well as the slope are allowed to be specific for every i. The models to be analyzed in this paper can be simplified as:

$$\boldsymbol{GDP_t} = \sigma + \sum_{\boldsymbol{i=1}}^{\boldsymbol{k}} \boldsymbol{\beta_i}\, \boldsymbol{GDP_{t-1}} + \sum_{j=1}^{k} \theta_j\, EC_{t-j} + \sum_{m=1}^{k} \varphi_m\, UR_{t-m} + u_{1t}$$

$$\boldsymbol{EC_t} = \alpha + \sum_{i=1}^{k} \beta_i\, GDP_{t-1} + \sum_{\boldsymbol{j=1}}^{\boldsymbol{k}} \boldsymbol{\theta_j}\, \boldsymbol{EC_{t-j}} + \sum_{m=1}^{k} \varphi_m\, UR_{t-m} + u_{2t}$$

$$\boldsymbol{UR_t} = d + \sum_{i=1}^{k} \beta_i\, GDP_{t-1} + \sum_{j=1}^{k} \theta_j\, EC_{t-j} + \sum_{\boldsymbol{m=1}}^{\boldsymbol{k}} \boldsymbol{\varphi_m}\, \boldsymbol{UR_{t-m}} + u_{3t}$$

where the dependent variable is a function of its lagged values and the lagged values of the other variables of interest. u denotes stochastic error terms often called impulses, or innovations or shocks. The proxy of economic growth (GDP) is real GDP per capita (Muslija et al., 2017; Satrovic, 2018). Energy consumption (EC) is approximate using energy use (kg of oil equivalent per capita) and lastly urbanization (UR) is measured using urban to total population. The data on annual basis are collected from The World Bank database. The criterion to select the time-frame was the data availability. The list of the OECD countries is obtained from https://www.oecdwatch.org/oecd-guidelines/oecd. In order to improve the efficiency, we have employed GMM estimation. Since, VAR is rarely interpreted by itself; forecast-error variance decomposition will be calculated as well as the IRFs.

Findings and interpretation

This part summarizes the most important findings of the empirical research. Table 1 presents the summary statistics. The measures indicate a mean value of GDP of 36447.54 constant 2010 US$. The highest reported value equals 111968 constant 2010 US$, while the lowest equals 6930.73. This data indicate significant difference among OECD member states in terms of real GDP per capita. Moreover, the average energy use (kg of oil equivalent per capita) is reported to be 4312.49. However, the maximum reported value is 18178.10 while the minimum is 1094.20. With regard to share of urban in total population, the summary statistics suggests the mean value of 76.27%; the maximum value of 98.77% and the minimum value of 50.65%. As expected, the distribution of these variables deviates from normal. Due to this reason and in order to ease the interpretation, the analysis to follow uses the natural logarithm variables.

Table 1: Descriptive statistics

Statistics	GDP	EC	UR
Mean	36447.54	4312.49	76.27
Sd	21048.47	2405.77	11.28
Max	111968.00	18178.10	97.88
Min	6930.73	1094.20	50.65
skewness	0.97	2.46	-0.42
kurtosis	4.23	12.69	2.48
countries	34		

Source: Authors

The rest of the empirical findings can be enclosed within the following few steps. Initially, we have tested for the stationary properties of the variables in level and first difference. In order to test whether or not the variables satisfy the I(0) requirement, we have employed three unit-root tests. Table 2 records the findings of the examination.

Table 2: Unit-root tests

Trend included in the model	lnGDP		D.lnGDP		lnEC		D.lnEC		lnUR		D.lnUR	
Method	Stat.	p-value	Stat.	p-value	Stat.	p-value	Stat.	p-value	Stat.	p-value	Stat.	p-value
Im–Pesaran–Shin test	0.430	0.667	-8.61	0.000	1.26	0.896	-18.34	0.000	-4.06	0.000	-3.27	0.000
ADF – Fisher inverse chisquare	62.87	0.653	227.42	0.000	55.54	0.861	280.14	0.000	237.59	0.000	155.70	0.000
Levin–Lin–Chu (LLC) t* test	-5.90	0.000	-11.76	0.000	-4.08	0.000	-20.58	0.000	-6.66	0.000	-14.37	0.000

Source: Authors

With regard to Im–Pesaran–Shin test, it can be concluded that level variables of lnGDP and lnEC do not satisfy the I(0) properties. These results are confirmed by ADF – Fisher inverse chisquare. However, these tests suggest that lnUR satisfies the assumption on stationarity. In terms of the first difference variables, all of the tests agree that all variables do satisfy the stationarity properties indicating that the null on unit-root is rejected for a 1% level of significance. Due to the fact that all of the first differences are found to be stationary, the assumptions of panel VAR are thus satisfied.

In the following steps, there is a need to determine the order of the panel VAR. The common procedure including Hansen's (1982) statistics, its p value as well as R square is employed. Additionally, panel VAR requires the determination of the moment conditions. Andrews and Lu (2001) give a brief description on the selection of moment conditions hence this paper follows this procedure. The results that help to select the order of the panel VAR are presented in the Table 3.

Table 3: Optimal lags determination

Order	CD	J	J p-value	MBIC	MAIC	MQIC
1	0.929523	55.52294	0.000987	-110.943	1.522939	-42.7007
2	0.939085	40.42977	0.001824	-70.5478	4.429772	-25.0526
3	0.942537	5.146342	0.821369	-50.3424	-12.8537	-27.5949

Source: Authors

Since the findings suggest first-order panel VAR to be appropriate following Andrews and Lu (2001) who rely on MQIC, MAIC and MBIC values, this research proceeds to the estimation of the models. In order to improve the efficiency, GMM estimation is considered to be appropriated (Satrovic and Muslija, 2018). Table 4 shows the results of the three models (bivariate).

Table 4: GMM estimation of VAR model (bivariate)

Independent variables	Dependent variables				
	D.lnGDP	D.lnEC		D.lnGDP	D.lnUR
Model 1: GDP and EC			Model 2: GDP and UR		
D.lnGDP$_{t-1}$	0.494 (0.053)***	0.268 (0.092)***	D.lnGDP$_{t-1}$	0.429 (0.056)***	0.001 (0.001)
D.lnEC$_{t-1}$	-0.041 (0.040)	-0.157 (0.065)**	D.lnUR$_{t-1}$	1.148 (1.048)	0.980 (0.028)***
Model 3: EC and UR					
	D.lnEC	D.lnUR			
D.lnEC$_{t-1}$	-0.107 (0.066)	-0.001 (0.001)			
D.lnUR$_{t-1}$	6.557 (2.250)***	0.993 (0.027)***			

Note: ***, **, * significant at 1%, 5% and 10% respectively.
Source: Authors

Model 1 shows that GDP responses positively and significantly to GDP (Table 4); moreover, EC is found to have a significant and positive response to the GDP. Besides these, EC is found to respond negatively to EC. The response of GDP on EC is not found to be positive. In terms of model 2, significant positive responses are recorded for the GDP to GDP and UR to UR. However, UR is not found to have a significant response on GDP as well as GDP on UR. With regard to model 3 it is important to emphasize a significant positive response of energy consumption on the urbanization. In addition, urbanization is found to response positively and significantly to the UR. However, the response of urbanization on energy consumption is not found to be significant. We have also tested for the stability of the models. The eigenvalues below 1 suggest the all models of the interest to be stable. Lastly, we have tested for the Granger causality of the bivariate models (Table 5). The results suggest that growth Granger causes the consumption of energy. However, the evidence on the bidirectional relationship is not found. In addition, urbanization is reported to have a unidirectional causal impact on the energy consumption. Taking into account the fact that we are interested to explore the dynamics in energy-urbanization-growth nexus, this research moves forward to a trivariate VAR model (Table 6).

Table 5: Results of Granger causality (2-variable VAR models)

Equation	Excluded	chi2	p-value
D.lnGDP	D.lnEC	1.080	0.299
D.lnEC	D.lnGDP	8.484	0.004
D.lnGDP	D.lnUR	1.199	0.273
D.lnUR	D.lnGDP	0.717	0.397
D.lnEC	D.lnUR	8.488	0.004
D.lnUR	D.lnEC	0.515	0.473

Source: Authors

Table 6: GMM estimation of VAR model (trivariate)

Independent variables	Dependent variables		
	D.lnGDP	D.lnEC	D.lnUR
$D.lnGDP_{t-1}$	0.479 (0.056)***	0.320 (0.111)*	0.001 (0.001)
$D.lnEC_{t-1}$	-0.048 (0.041)	-0.164 (0.076)**	-0.001 (0.001)*
$D.lnUR_{t-1}$	2.291 (1.240)*	10.980 (3.274)*	0.983 (0.026)***

Source: Authors

The trivariate VAR model shows a significant positive impact of lagged GDP on economic growth as well as on the energy consumption. Additionally, lagged energy consumption is found to have a negative impact on urbanization indicating the great awareness of citizens in OECD countries on the climate change caused by energy based on fossil fuels highlighting the need to introduce the sustainable energy and sustainable development. However, urbanization is found to have a positive impact of the consumption of energy as well as on the economic growth approximated using real GDP per capita. To explore the causality, this research employs Granger causality test in the case of trivariate model. Table 7 reports a unidirectional impact of urbanization on growth. Besides that, real GDP per capita is found to have a unidirectional causal impact on energy consumption. However, the link between energy consumption and urbanization is found to be bidirectional. In terms of the stability of the models, all the eigenvalues lie inside the unit circle, hence the model is found to be stable.

Table 7: Results of Granger causality (3-variable VAR models)

Equation	Excluded	
	D.lnEC	D.lnUR
D.lnGDP	1.366 (0.243)*	3.411 (0.065)
	D.lnGDP	D.lnUR
D.lnEC	8.345 (0.004)	11.244 (0.001)
	D.lnGDP	D.lnEC
D.lnUR	0.946 (0.331)	3.579 (0.059)

Note: * p-value

Source: Authors

Table 8: Forecast-error variance decomposition

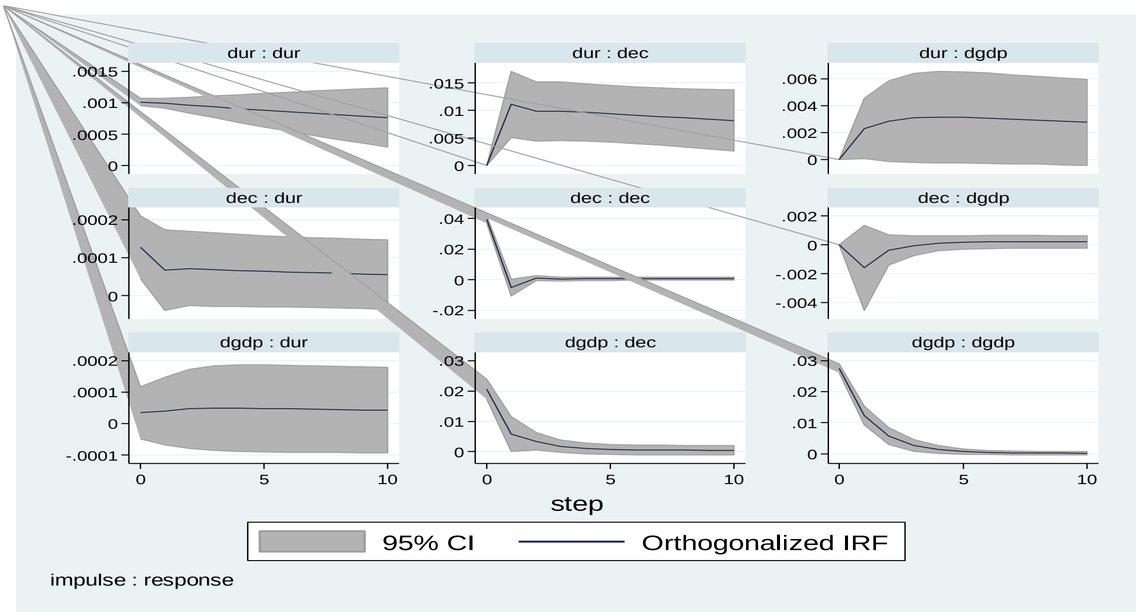
Response variable	Impulse variable			Response variable	Impulse variable			Response variable	Impulse variable		
D.lnGDP	D.lnGDP	D.lnEC	D.lnUR	D.lnEC	D.lnGDP	D.lnEC	D.lnUR	D.lnUR	D.lnGDP	D.lnEC	D.lnUR
0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000
1	1.000	0.000	0.000	1	0.215	0.785	0.000	1	0.001	0.016	0.983
2	0.991	0.003	0.006	2	0.213	0.731	0.057	2	0.001	0.010	0.988
3	0.983	0.003	0.014	3	0.207	0.696	0.097	3	0.002	0.009	0.990
4	0.974	0.003	0.024	4	0.200	0.666	0.134	4	0.002	0.008	0.990
5	0.964	0.003	0.033	5	0.193	0.641	0.166	5	0.002	0.007	0.990
6	0.954	0.003	0.043	6	0.186	0.619	0.195	6	0.002	0.007	0.991
7	0.945	0.003	0.052	7	0.180	0.599	0.221	7	0.002	0.007	0.991
8	0.937	0.003	0.060	8	0.175	0.582	0.243	8	0.002	0.007	0.991
9	0.929	0.003	0.068	9	0.171	0.566	0.263	9	0.002	0.007	0.991
10	0.922	0.003	0.075	10	0.166	0.552	0.282	10	0.002	0.006	0.991

Source: Authors

To end this empirical analysis, it is important to emphasize that panel VAR is very rare interpreted by itself. Hence, the researchers in general estimate and interpret the exogenous changes (Abrigo and Love, 2016). For this purpose, forecast-error variance decomposition IRFs are employed. The results of forecast-error variance decomposition (FEVD) are shown in the Table 8. FEVD suggests that GDP, EC and UR explain respectively about 92.2%, 0.3% and 7.5% of the variation in GDP. Moreover, these variables explain respectively about 16.6%, 55.2% and 28.2% of the variation in EC. Lastly, GDP, EC and UR are reported to explain respectively about 0.2%, 0.7% and 99.1% of total variation in UR.

We move forward to the interpretation of IRFs. Graph1 shows that positive increasing short-term response of urbanization to the consumption of energy. After the period 3, the response is still significant but very small. The response of urbanization to the economic growth is positive; increasing exponentially in the short-run. However, the response of urbanization to the energy consumption is positive but decreases significantly in the long-run. The reaction of urbanization to GDP is not found to be different from zero. GDP is found to have a positive response to the one standard deviation (SD) shock on energy consumption but this response is decreasing in the observed period.

Graph 1: IRF plots



Source: Authors

Conclusion

This present research investigates the link between economic growth, energy consumption and urbanization in the sample of 34 OECD countries by collecting panel data at annual bases in the time span between 1996 and 2015. Bivariate PVAR models suggest a bidirectional positive response of energy consumption (EC) to GDP (real GDP per capita). Furthermore, EC is found to response positively to the UR (urban total population). The trivariate VAR model outlines a significant positive impact of lagged GDP on the energy consumption. Impulse response functions suggest a positive increasing short-term response of urbanization to the consumption of energy. In addition, the response of urbanization to the energy consumption is found to be positive but decreases significantly over in the long-term.

The empirical findings of this paper suggest a great awareness of the urban citizens in OECD countries on their role in contributing to sustainable development by promoting sustainable energy. The similar findings are also advocated by Lebe and Akbaş (2015), Yang et al. (2017) and Wang et al. (2018).

The policy recommendations can be summarizes as follows. Firstly, the policy makers need to do necessary changes to promote the renewable energy in urban areas in order to reduce CO_2 emissions caused by energy based on fossil fuels. Therefore, policy makers shall develop energy saving policies in the short term and propose the new policies towards alternative energy sources in the long term which can decrease the energy dependence of the countries. Second, it is necessary to evaluate the existing energy reserves in the most efficient way and to increase the awareness on the importance of sustainable energy. Third, policy makers need also to identify strategies that take long-term energy policies into account by observing the country's energy potential, supporting technological and R&D activities, and improving the quality of urbanization and living standards. Thus the recommendation for future research includes the necessity to take into account the living standards as well as the potential role of economic freedom.

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