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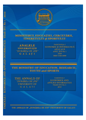

Fuel-Specific Carbon Dioxide Emissions and GDP Elasticities of Energy Consumption: a Bounds Test Analysis for Israel

Veysel M. KAYA*, Bayram Veli DOYAR**

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ABSTRACT

Current paper investigates the short-run and the long-run relationships between energy use, GDP and fuel-specific CO_2 emissions (namely solid, liquid and gas) by developing separate models for each emission for Israel in 1971-2011. ARDL Bounds Test is utilized for cointegration and we find that each model has cointegrating relationship. Then the short-run and the long-run coefficients are estimated. Error-correction models for all models suggest that long-run equilibriums take about 15-19 months. According to the long-run coefficient estimates, when elasticities of CO_2 emissions from solid, liquid and gas fuels are 0.04, 0.30 and -0.02, respectively; GDP elasticities for all models vary between 0.66 and 0.96.

1. Introduction

As is known, energy has been a substantial input of production ever since Industrial Revolution. However, energy usage process has some adverse effects on environment by releasing CO_2 emissions into the atmosphere. Somehow, its pros and cons should be balanced for a healthy future. Then, we can say that energy use has certainly "vital" importance for human race besides all other life forms. Therefore, factors that affect energy consumption should be examined.

There are countless studies investigating environmental Kuznets curve hypothesis or the effects of CO_2 emissions on energy usage for various countries. Yet, there are no works, to the best of our knowledge, examining the impacts of CO_2 emissions by source on energy consumption for Israel or any other single country. In this regard, current work extends the existing literature on energy use and CO_2 emissions relationship by employing CO_2 emissions by source, namely solid, liquid and gas fuels. GDP is also utilized as an independent variable as well as CO_2 emissions by source. In this way, three different models are set up. More clearly, we define energy use as functions of GDP and CO_2 emissions from solid, liquid and gas fuels separately. The data regarding the variables in question consist of annual time series covering 1971-2011 period. After determining integration orders of the variables whereby unit root tests, ARDL bounds test is run for cointegration analysis. Then, the long-run and the short-run elasticities of the variables are estimated.

The rest of the paper organized as follows: section two reviews the related literature, section three shows data, model and methodology, section four presents empirical results and final section concludes.

2. Related Literature

Undoubtedly that, energy, has vital importance for the modern world. As an input, it has wide ranging effects on economy. Therefore, effects of energy on economic variables has been studied empirically over the years by countless authors. Especially, these studies focus on economic growth and energy consumption relationship (e.g. see: (Al-Iriani, 2006), (Ghali & El-Sakka, 2004), (Lean & Smyth, 2014), (Mehrara, 2007), (Narayan & Smyth, 2008), (Ocal & Aslan, 2013), (Soytas, Sari, & Ozdemir, 2001)). Also, some studies extend the literature by adding air pollutants such as carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxide (NO_x) emissions (e.g. see: (Apergis, Payne, Menyah, & Wolde-Rufael, 2010), (Kivyiro & Arminen, 2014), (Menyah & Wolde-Rufael, 2010), (Ozturk & Acaravci, 2013), (Zhang & Cheng, 2009)).

When we look at the models used in energy economics papers, we generally observe three models and their extensions. The first model is nothing but adding energy consumption to conventional production function. Starting with Kraft and Kraft (1978), mentioned literature has been still expanding. For example, Karanfil (2008) takes into consider unrecorded economy as well as official GDP in analyzing effects of energy consumption on GDP in Turkey. By doing so, he reveals cointegrating relationship between official GDP and

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*,**Kirikkale University, Kirikkale, Turkey. E-mail addressess: mveyselkaya@yahoo.com,(V. M. Kaya), bvdoyar@gmail.com (B. V. Doyar)

energy use whereas neither long-run relationship nor causality between true GDP and energy consumption. ECM (error correction model) based Granger causality test results show that one-way causality running from official GDP to energy consumption both in the long-run and the short-run. The another example can be the paper of Apergis and Payne (2009) which finds cointegration between real GDP and energy use for six central American countries and implement panel Granger causality test. They find one-way causality from energy use to real GDP in the long-run and the short-run. Belloumi (2009) runs VECM (vector error correction model) based Granger causality tests for Tunisia after finding per capita energy use and per capita GDP are cointegrated. According to the results there is bidirectional causality between per capita GDP and per capita energy use in the long-run and unidirectional causality from per capita energy use to per capita GDP.

The second model is known as EKC (environmental Kuznets curve). In this model, EKC hypothesis that suggests inverted U-shaped (or quadratic) relationship between emissions and income is tested. For this purpose, when emission variable is used as dependent, energy consumption, GDP and GDP^2 variables are added the equation as independent variables. Results from some studies testing EKC hypothesis can be summarized as follows: Shahbaz, Lean, and Shabbir (2012) examine relationship between CO_2 (carbon dioxide) emissions, GDP, energy consumption and trade openness for Pakistan for 1971-2009 period. Using Bounds test and Granger causality test they find EKC hypothesis is supported for Pakistan. Lean and Smyth (2010) investigate the validity of EKC hypothesis in respect to electricity use for five ASEAN (Association of Southeast Asian Nations) countries covering 1980-2006 period. Johansen Fisher panel cointegration test reveals that the variables are cointegrated. EKC hypothesis is found valid by implementing panel DOLS (dynamic ordinary least squares) estimation. Finally, there is a long-run unidirectional causality from electricity use and CO_2 emissions to GDP as Granger causality tests suggested. Ang (2007) tests EKC hypothesis for France spanning 1960-2000 period. Johansen cointegration and ARDL (autoregressive distributed lag) bounds tests show long-run relationship among the variables and quadratic relationship confirmed by long-run coefficients. Long-run causality test results show that output growth causes CO_2 emissions and energy use. In the short-run, energy use growth causes output growth. In their analysis, Aslan and Gozbasi (2016) investigate validity of EKC hypothesis by separating CO_2 emissions for China for 1977-2013 period. Using FMOLS (fully modified ordinary least squares) and Granger causality test they find that an increase in per capita energy use leads an increase in eight different sub-elements of CO_2 emissions in China.

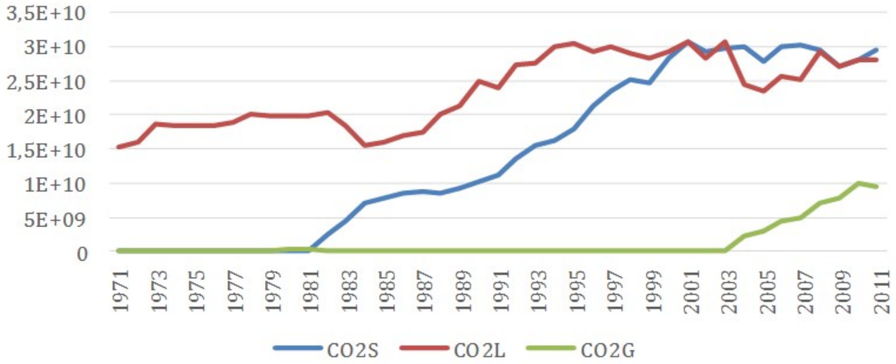
Using emissions and economic growth as explanatory variables, the last model establishes functional relationship between them and dependent variable which is energy consumption. This part has limited number of studies relatively. To illustrate, Saidi and Hammami (2015) investigate the effects of CO_2 emissions and GDP on energy consumption for 58 countries for 1990-2012 period. Using GMM (generalized method of moments), they find GDP and CO_2 emissions have positive effects on energy consumption. Farhani and Rejeb (2012) examine the linkages among energy use, GDP and CO_2 emissions for 15 MENA (Middle East and North Africa) countries for 1973-2008 period. Implementing some cointegration tests they find the variables are cointegrated. According to panel causality tests there is only one-way long-run causality from GDP and CO_2 emissions to energy consumption. They also estimate long-run elasticities using FMOLS and DOLS for each country and the whole panel. Accordingly, GDP and CO_2 coefficients are found positive for the panel and Israel. This paper contributes to the latter part of the literature. We define energy use as functions of GDP and, differently from many paper, CO_2 emissions from solid, liquid and gas fuels separately.

3. Data, Model and Methodology

3.1. Data

We use annual data for Israel spanning 1971-2011 on energy use (kg of oil equivalent), GDP (constant 2005 US$) and CO_2 emissions (kg) by source (namely solid fuel, liquid fuel and gas fuel). All the data are sourced from World Bank (2016) web site. We also utilize population data from same source to convert per capita series to totals. CO_2 data are also converted to kilograms from kilotons.

Figure 1. CO_2 emissions for Israel



Values of CO_2 emissions from solid (CO2S), liquid (CO2L) and gas fuels (CO2G) can be followed on Figure 1. As seen, solid fuels have the highest share in CO_2 emissions in 2011 when liquid fuels have before 2001. Finally, CO_2 emissions from gas fuels have the lowest share in total.

3.2. Model

Following model is used to estimate the relationship between the variables:

$$ENG = f(GDP, CO2_i) \tag{1}$$

If we rewrite this closed functional relationship empirically, separate CO_2 emissions by fuel and take natural logarithms of the variables we get:

$$\ln ENG_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln CO2S_t + \epsilon_t \tag{2}$$

$$\ln ENG_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln CO2L_t + \varepsilon_t \tag{3}$$

$$\ln ENG_t = \gamma_0 + \gamma_1 \ln GDP_t + \gamma_2 \ln CO2G_t + \epsilon_t \tag{4}$$

$\ln ENG$ and $\ln GDP$ represent natural logarithms of energy consumption and GDP. $\ln CO2S$, $\ln CO2L$ and $\ln CO2G$ stand for natural logs of CO_2 emissions from solid, liquid and gas fuels. ϵ, ε and ϵ are stochastic error terms for each model. Subscript t represents time. For simplicity, ln notation for natural logarithm is not used in the rest of the paper.

3.3. Methodology

Augmented Dickey-Fuller (ADF) (Dickey & Fuller, 1981) unit root test is used before cointegration analysis. Phillips-Perron (PP) (Phillips & Perron, 1988) unit root test is also implemented for each series.

ARDL bounds test developed by Pesaran, Shin, and Smith (2001) is utilized for cointegration analysis. They created two sets of critical values. If the calculated *F*-statistics is higher than the upper bound, the null hypothesis of no cointegration is rejected. If the calculated *F*-statistics is smaller than the lower bound, the null hypothesis of cointegration cannot be rejected.

There is no conclusion if the calculated *F*-statistics lies between the bounds. ARDL representation for any CO_2 equation stated above can be written as follows:

$$\Delta ENG = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta ENG_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta CO2_{t-i} + \theta_1 ENG_{t-1} + \theta_2 GDP_{t-1} + \theta_3 CO2_{t-1} + \sigma_t \tag{5}$$

Optimal lag length is chosen by using Akaike information criterion (AIC). The null hypothesis of no cointegration $H_0 = \delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$, whereas alternative hypothesis of cointegration is $H_0 \neq \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq 0$.

4. Empirical Results

Results from unit root tests are presented on Table 1. It can be seen that the null hypothesis of unit root cannot be rejected for both tests when the variables are used in their levels. But tests on first differenced data show that the null hypothesis is rejected at 1% significance level.

Table 1. Unit root tests

	ADF without trend		ADF with trend		PP without trend		PP with trend	
	Level	1st difference	Level	1st difference	Level	1st difference	Level	1st difference
ENG	-0.771	-11.78***	-3.417*	-11.67***	-0.609	-11.70***	-3.473*	-11.55***
GDP	-0.796	-6.101***	-2.605	-5.945***	-0.793	-6.531***	-2.316	-6.486***
Co2SOL	-1.313	-5.567***	-1.240	-5.610***	-1.313	-5.678***	-1.348	-5.603***
Co2LIQ	-1.680	-6.590***	-1.888	-6.576***	-1.700	-6.580***	-2.109	-6.567***
Co2GAS	-0.541	-5.740***	-1.109	-6.002***	-0.703	-5.740***	-1.109	-6.000***

*, **, and *** show 10%, 5%, and 1% significance levels, respectively. Lag length is chosen by Schwarz information criterion (SC) for ADF test. Bandwidth is chosen by Barrlett Kernel for PP test.

Table 2 shows the results of ARDL bounds tests. Since the calculated *F*-Statistics values for all models are higher than the upper bound at 5% significance (1% for solid model), the null hypotheses of no cointegration are rejected. So, every single model has cointegrating relationship. As for lag length selection, AIC proposes ARDL (2,0,4) for solid model, ARDL (3,0,2) for liquid model (CUSUMQ test for the first estimation of the model shows that the CUSUMQ line lies above of the upper 5% critical line from 1990 to 1994. To tackle this problem, we add a dummy variable named *DUMMY* that takes the value of one for 1990 to 1994 and zero for other years and repeat the whole ARDL procedure) and ARDL (3,0,0) for gas model.

Table 2. Bounds test for cointegration.

Model	*F*-Statistics	*k*	Decision
Solid Model	10.743***	2	Cointegration
Liquid Model	4.908**	2	Cointegration
Gas Model	5.410**	2	Cointegration

According to critical values obtained from Pesaran, Shin and Smith (2001). ** and *** show 5% and 1% significance, respectively.

For short-run analysis, error-correction models are estimated. Results are shown on Table 3. First of all, every single lagged error-correction term is found negative and statistically significant at 1% level. For solid model, 62% of previous year's disequilibrium is corrected every year. For liquid model, 82% of the disequilibrium is corrected in a year. Finally, 72% of the disequilibrium is completed every year for gas model. Roughly talking, when we take into consider all models, achievements of the long-run equilibriums take about 15-19 months.

Table 3. Error-correction models based on selected ARDL models

	Variable	Coefficient	Std. Error	t-Statistic
Solid Model	*Δ(ENG(-1))*	-0.1685*	0.0985	-1.7101
	Δ(GDP)	0.4132***	0.1130	3.6546
	Δ(CO2S)	0.0034	0.0089	0.3797
	Δ(CO2S(-1))	-0.0070	0.0124	-0.5684
	Δ(CO2S(-2))	0.0005	0.0122	0.0475
	Δ(CO2S(-3))	-0.0337***	0.0098	-3.4269
	ECT(-1)	-0.6267***	0.1293	-4.8471
Liquid Model	*Δ(ENG(-1))*	-0.1125	0.1757	-0.6401
	Δ(ENG(-2))	0.1454	0.1188	1.2245
	Δ(GDP)	0.6824***	0.1578	4.3238
	Δ(CO2L)	0.4939***	0.1072	4.6068
	Δ(CO2L(-1))	0.1849	0.1220	1.5147
	ECT(-1)	-0.8286***	0.2004	-4.1349
Gas Model	*Δ(ENG(-1))*	-0.0514	0.1546	-0.3326
	Δ(ENG(-2))	0.2136*	0.1228	1.7400
	Δ(GDP)	0.7036***	0.1554	4.5282
	Δ(CO2G)	-0.0150***	0.0053	-2.7830
	Δ(DUMMY)	0.0440	0.0268	1.6421
	ECT(-1)	-0.7297***	0.1648	-4.4264

* and *** show 10% and 1% significance levels, respectively.

Estimated long-run coefficients are shown on Table 4. All variables are significant at 1% level but for constant term and dummy variable of gas model that are insignificant. A 1% increase in CO_2 emissions from solid fuels leads to 0.04% increase in energy consumption. In the relevant model, a 1% increase in GDP offers 0.66% rise in energy consumption. In liquid model, a 1% increase in CO_2 emissions from liquid fuels increases energy consumption by 0.30%. GDP coefficient from relevant model is 0.82. Finally, a 1% increase in CO_2 emissions from gas fuels reduces energy consumption by %0.02. GDP coefficient of this model is found 0.96.

Table 4. Long-run coefficients from selected ARDL models

	Variable	Coefficient	Std. Error	t-Statistic
Solid Model	*GDP*	0.6592***	0.0622	10.5853
	CO2S	0.0393***	0.0098	3.9887
	C	5.8585***	1.3869	4.2240
Liquid Model	*GDP*	0.8235***	0.0380	21.6316
	CO2L	0.2960***	0.0849	3.4836
	C	-4.5496***	1.3171	-3.4541
Gas Model	*GDP*	0.9642***	0.0284	33.8771
	CO2G	-0.0205***	0.0070	-2.9236
	DUMMY	0.0604	0.0376	1.6056
	C	-0.6381	0.6650	-0.9595

*** shows 1% significance level.

All models are tested by a series of diagnostic tests presented on Table 5. Solid and gas models pass all the tests and have very good R^2 values. Liquid model passes all the tests but suffers from functional form misspecification, although its R^2 values show that the data fit the model well.

Table 5. Diagnostic tests

Test	Solid Model Value [Prob.]	Liquid Model Value [Prob.]	Gas Model Value [Prob.]
Serial correlation[a] (χ^2)	5.5771 [0.2330]	7.2593 [0.0641]	2.1592 [0.5400]
Heteroskedasticity[b] (χ^2)	5.6165 [0.6901]	19.426 [0.1493]	17.567 [0.4844]
Normality[c] (χ^2)	1.0561 [0.5897]	1.0217 [0.5999]	2.3721 [0.3054]
Functional form[d] (F)	0.9837 [0.3301]	7.9139 [0.0087]	0.1623 [0.6898]
CUSUM	+	+	+
CUSUMQ	+	+	+
R^2	0.9930	0.9910	0.9880
Adjusted R^2	0.9910	0.9889	0.9857

[a] Breusch-Godfrey serial correlation LM test
[b] White test
[c] Jarque-Bera test
[d] Ramsey RESET test

CUSUM (cumulative sum) and CUSUMQ (cumulative sum of squares) graphs are located in appendix (See Figures 2-7). As seen on the figures, related lines for every single model are in 5% significance lines.

5. Conclusion

In this paper, we analyze the relationship between energy use, GDP and fuel-specific CO_2 emissions for Israel using ARDL technique in 1971-2011. Estimated error-correction terms are found negative, as desired, and statistically significant. Accordingly, long-run equilibriums take about 15 to 19 months. In the long run, it is observed that coeffcents of GDP for all models are statistically significant and range between 0.66 and 0.96. In brief, energy consumption increases as the economy grows. We can say that this result is proper for theoretical expectations. When the long-run coefficients of CO_2 emissions from solid and liquid fuels are found positive (0.04 and 0.3) and significant, coefficient of CO_2 emissions from gas fuels is found negative (-0.02) and significant. Positive CO_2 coefficients mean that CO_2 emissions and energy use are complementary as Saidi and Hammami (2015) state. In our case, it can be said that energy consumption and CO_2 emissions from solid and liquid fuels are complementary for Israel. But negative coefficient on CO_2 emissions from gas fuels reflects contrariwise relationship. It is possible that relatively lower values of CO_2 emissions from gas fuels (as stated in data section above) could lead this result. Our results from solid and liquid models are consistent with the results of Saidi and Hammami (2015) and Farhani and Rejeb (2012).

There are limited number of studies in this arm of energy literature. Therefore, future papers can examine different countries, even country groups using different methods.

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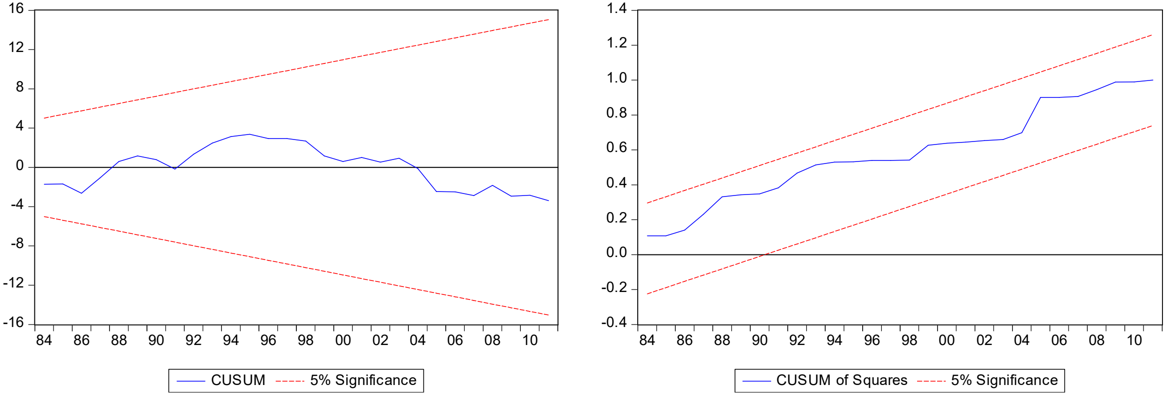
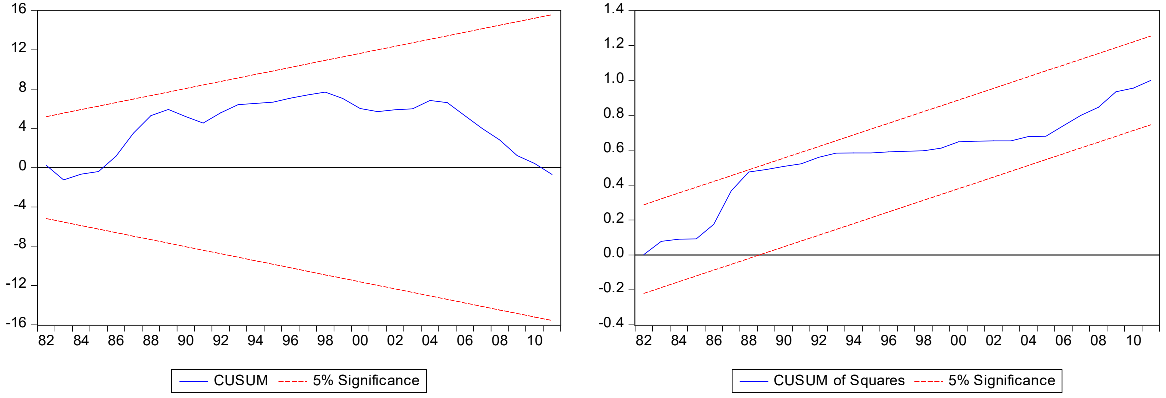
Appendix

Figures 2-3. CUSUM and CUSUMQ tests for solid model



Figures 4-5. CUSUM and CUSUMQ tests for liquid model



Figures 6-7. CUSUM and CUSUMQ tests for gas model