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# ENVİRONMENTAL KUZNETS CURVE (EKC): EVİDENCE FROM GHANA

ÇEVRESEL KUZNETS EĞRISI: GANA ÖRNEĞI

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## ABSTRACT

In this study, EKC hypothesis is examined for Ghana for the period between 1971 and 2014. EKC hypothesis is examined under two nexus which are GDP, $CO_2$ and energy consumption, and GDP, $CO_2$, energy consumption and the square of GDP. Causal and long-term relationships between GDP, $CO_2$ and energy consumption are examined for Ghana by Johansen cointegration and VAR Granger Causality/Block Exogeneity Wald Test. Long-term relationships between GDP, $CO_2$, energy consumption and the square of GDP are examined by Johansen cointegration test. EKC hypothesis is not confirmed for Ghana, no causal relationships are found between GDP and energy consumption, and unidirectional causality running from energy consumption to $CO_2$is found. Neutrality hypothesis is confirmed for Ghana.

**Keywords:** environmental Kuznets curve; Johansen cointegration test; VAR Granger Causality/Block Exogeneity Wald test; Ghana

## ÖZET

Bu çalışmada, çevresel Kuznets eğrisi Gana için 1971 ve 2014 yılları arasında incelenmiştir. Çevresel Kuznets eğrisi iki ilişki altında incelenmiştir. Birincisi ekonomik büyüme, $CO_2$ ve enerji tüketimi ilişkisi, ikincisi ise ekonomik büyüme, $CO_2$, enerji tüketimi ve ekonomi büyümenin karesi arasındaki ilişkidir. Ekonomik büyüme, $CO_2$ ve enerji tüketimi arasındaki nedensel ve uzun vadeli ilişkiler Johansen eşbütünleşme testi ve VAR Granger Causality/Block Exogeneity Wald Test ile incelenmiştir. Ekonomik büyüme, $CO_2$, enerji tüketimi ve ekonomik büyümenin karesi arasındaki uzun vadeli ilişki Johansen eşbütünleşme testi ile incelenmiştir. Çevresel Kuznets eğrisi Gana için doğrulanmamış olup, ekonomik büyüme ve enerji tüketimi arasında nedensel bir ilişki bulunmamıştır. Enerji tüketiminden $CO_2$'ye doğru tek yönlü nedensellik bulunmuşur. Neutrality hipotezi Gana için doğrulanmıştır.

**Anahtar Kelimeler:** çevresel Kuznets eğrisi; Johansen eşbütünleşme testi; VAR Granger Causality/Block Exogeneity Wald test; Gana

## 1. INTRODUCTION

Kuznets (1955) studied the relationship between economic growth and income inequality and found an inverse U relationship. In 1990s, Kuznets curve was examined as EKC which stated an inverse U relationship between emissions and income.

Many studies have examined the dynamic relationships between energy and income, income and emissions, and energy, income and emissions by taking EKC as a base in the academic literature. To examine these dynamic relationships, the researchers implemented many kinds of econometrical methods such as Multivariate Regressions, the Johansen cointegration test, the ADF unit root test, the VAR (Vector Autoregressive) model, variance decomposition analysis (VDA), panel data analysis, Granger causality test and impulse response analysis (IRA) in the methodology section of their articles. Researchers obtained different results for the validity of EKC relationships depending on different samples, methodologies and time periods.

The main purpose of this study is to reveal the stable long-term relationships and causal relationships between emissions, income and energy consumption (EN), test the EKC hypothesis for Ghana and expand literature for individual country studies of Ghana. There are limited individual country studies in the literature for Ghana, so the main new contribution of this study is to use time series data to test EKC for Ghana on the individual country level and to assess causal relationships between emissions, income and EN for Ghana.

For individual country studies for Ghana, Twerefou et al. (2016) examined the EKC relationship between $CO_2$, EN, foreign direct investment, GDP and trade openness in Ghana. Twerefou, Adusah-Poku and Bekoe (2016) did not confirm the EKC relationship for Ghana and found that trade openness and EN affected $CO_2$ emissions positively in the long run. Appiah et al. (2017) examined the EKC relationship between $CO_2$ and GDP in Ghana for the period 1970-2016. Appiah et al. (2017) did not confirm the EKC relationship in Ghana. Muhammad et al. (2016) examined the EKC relationship between $CO_2$, GDP, energy intensity and globalization in Ghana for the period 1971-2012. Muhammad et al. (2016) did not confirm the EKC relationship in Ghana and found that energy intensity and globalization had a positive impact on $CO_2$ emissions in the long run. Opoku et al. (2014) examined the EKC relationship between $CO_2$, GDP and trade openness in Ghana for the period 1970-2010. Opoku et al. (2014) confirmed the EKC relationship in Ghana and found that trade openness had a positive impact on $CO_2$ emissions. Adom et al. (2012) examined the relationships between $CO_2$, GDP, industrial structure and technical efficiency for Morocco, Senegal and Ghana. Adom et al. (2012) found that $CO_2$, GDP, industrial structure and technical efficiency were cointegrated, and there was bidirectional causality between economic growth and carbon emissions, and energy efficiency policies would have a significant impact on $CO_2$ emissions in Ghana. Asumadu-Sarkodie and Owusu (2016) examined the relationships between $CO_2$, EN, GDP and population in Ghana for the period 1980-2012. Asumadu-Sarkodie and Owusu (2016) found that there were bidirectional causality between $CO_2$ emissions and EN, and GDP and EN, and unidirectional causality running from GDP to $CO_2$ emissions. Aboagye (2017) examined the EKC relationship between $CO_2$, EN and GDP in Ghana for the period 1975-2015. There were bidirectional causality between GDP and EN, and GDP and $CO_2$ emissions. Asumadu-Sarkodie and Owusu (2017) examined the relationships between $CO_2$, GDP, energy use and population in Ghana for the period 1971-2013. Asumadu-Sarkodie and Owusu (2017) found that $CO_2$, GDP, population and energy use were cointegrated and there were unidirectional causality from population to energy use and $CO_2$, and unidirectional causality from energy use to $CO_2$.

For studies that verify the EKC hypothesis, Balibey (2015), Katircioglu (2017) and Ozturk and Oz (2016) examined the EKC hypothesis in Turkey. Balibey (2015) verified quadratic relationship between $CO_2$ and GDP. Katircioglu (2017) did not verify the oil-induced EKC relationship in Turkey but emission-income the EKC relationship in Turkey. Ozturk and Oz (2016) verified the EKC relationship in Turkey both in the short-run and the long-run.

For studies that do not verify the EKC hypothesis, Zoundi (2017), Wang (2012) and Saleh et al. (2014) tested and found no evidence for the EKC relationship for 25 countries, 98 countries and Iran respectively. Ghosh et al. (2014) and Amin et al. (2012) tested the EKC relationship and found no evidence for the EKC relationship in Bangladesh. Friedl and Getzner (2002) tested the EKC relationship in Austria and found no evidence for it.

In this study, the EKC hypothesis is examined between GDP, $CO_2$ and EN, and GDP, EN, $CO_2$, and the square of GDP. Causal relationships are examined between GDP, $CO_2$ and EN.

After introduction section, methodology is discussed in Section 2. Data is presented in Section 3. Empirical results and conclusion are presented in Section 4 and Section 5 respectively in this study.

## 2. METHODOLOGY

Augmented Dickey and Fuller (1981) Unit Root Test is applied to find stationary levels of each variable. Johansen (1991) Cointegration Test is applied to examine the cointegration relationship between variables since variables are at stationary levels with I(1).

VAR Model is applied for variables which are integrated at I(1) with no cointegration. AR Root Graph, VAR Residual Heteroskedasticity (VAR RS) test and VAR Residual Serial Correlation LM (VAR LM) test are applied to determine the stability of VAR model.

IRA and VDA are applied to find how each variable impact and influence the other variables.

VAR Granger Causality/Block Exogeneity Wald (VAR GC) Test is used to find the causal relationships between variables which are integrated at I(1) with no cointegration.

Two models in this study are used to examine the EKC relationship for Ghana. Causal relationships are examined between $CO_2$, GDP and EN. EKC relationships are examined between $CO_2$, GDP and EN, and $CO_2$, GDP, the square of GDP and EN.

$$\ln(CO_2)_t = \beta_0 + \beta_1 \ln(GDP)_t + \beta_2 \ln(EN)_t + e_t \quad (1)$$

$\beta_0$, $\beta_1$, $\beta_2$, are estimated parameters. t is time index. e is error term. $CO_2$ is carbon dioxide emissions per capita. GDP is gross domestic product per capita. EN is energy consumption per capita.

$$\ln(CO_2)_t = \beta_0 + \beta_1 \ln(GDP)_t + \beta_2 \ln(GDP)_t^2 + \beta_3 \ln(EN)_t + e_t \quad (2)$$

$\beta_0$, $\beta_1$, $\beta_2$ and $\beta_3$, are estimated parameters. t is time index. e is error term. $CO_2$ is carbon dioxide emissions per capita. GDP is gross domestic product per capita. EN is energy consumption per capita.

**Table 1.** ADF Unit Root Tests for Ghana.

| Variable | At Level | At first difference |
|---|---|---|
| | Intercept | Intercept |
| $LNCO_2$ Ghana | -0.000784(1) | -9.514818(0)* |
| LNEN Ghana | -1.614681(0) | -5.961521(0)* |
| LNGDP Ghana | 0.479792(1) | -4.222747(0)* |
| LNGDP2 Ghana | 0.572594(1) | -4.202418(0)* |

**Notes:** * and ** show the statistical significance at 1% and 5% levels, respectively.
The lag length is shown by the values in parentheses.
**Source:** Authors' Calculations.

## 3. DATA

The data is obtained from World Bank's official web site for $CO_2$ emissions (metric tons per capita), EN (kg of oil equivalent per capita) and GDP per capita (constant 2010 US$). Period for data is over 30 to carry out parametrical tests. Period for data in this study is determined according to the availability of data sets in data sources. Period for data in this study is from 1971 to 2014 for Ghana.

## 4. RESULTS

### 4.1 $CO_2$, GDP and EN Nexus

For Ghana, $LNCO_2$, LNEN and LNGDP are at I(1), I(1) and I(1) levels (see Table 1). Since variables are stationary at I(1), Johansen cointegration test is applied. According to Johansen cointegration test results, no cointegration is found between $CO_2$, GDP and EN (see Table 2). There is no long-run relationship between $CO_2$, GDP and EN. VAR model is established, and VAR GC Tests are applied for causality between $CO_2$, GDP and EN. VAR LM test and VAR RS test results show the model is stable (see Table 3 and Table 4). VAR satisfies the stability condition (see Figure 1). According to VAR GC Tests results, there is unidirectional causality running from LNEN to LNCO2. There is no causality from LNGDP to LNCO2, from LNCO2 and LNGDP to LNEN, and from LNCO2 and LNEN to LNGDP (see Table 5).

**Table 2.** Results for Johansen Cointegration Test of $CO_2$-GDP-EN for Ghana.

| Unrestricted Cointegration Rank Test (Trace) | | | | |
|---|---|---|---|---|
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Trace Statistic** | **0.05 Critical Value** | **Prob.**** |
| None | 0.312921 | 22.71867 | 29.79707 | 0.2601 |
| At most 1 | 0.138551 | 6.955828 | 15.49471 | 0.5828 |
| At most 2 | 0.016341 | 0.691990 | 3.841466 | 0.4055 |
| **Unrestricted Cointegration Rank Test (Maximum Eigenvalue)** | | | | |
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Trace Statistic** | **0.05 Critical Value** | **Prob.**** |
| None | 0.312921 | 15.76284 | 21.13162 | 0.2390 |
| At most 1 | 0.138551 | 6.263837 | 14.26460 | 0.5796 |
| At most 2 | 0.016341 | 0.691990 | 3.841466 | 0.4055 |

**Table 3.** VAR LM Test Results of $CO_2$-GDP-EN for Ghana.

| Lags | LM-Stat | Prob |
|---|---|---|
| 1 | 3.513286 | 0.9404 |

**Source:** Authors' Calculations.

**Table 4.** VAR RS Test Results of $CO_2$-GDP-EN for Ghana.

| Joint test | | |
|---|---|---|
| **Chi-sq** | **Df** | **Prob.** |
| 42.41823 | 36 | 0.2138 |

**Source:** Authors' Calculations.

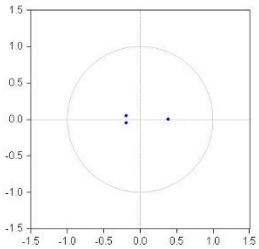


**Figure 1.** VAR Model Stability Results of $CO_2$-GDP-EN for Ghana.
**Source:** Authors' Calculations.

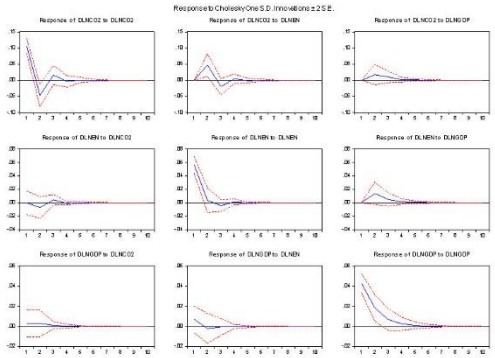

**Figure 2.** IRA of $CO_2$-GDP-EN for Ghana
**Source:** Authors' Calculations.

IRA is applied to find how each variable impact and influence the other variables. Firstly, EN has a positive impact on $CO_2$ in the short-term and then have a negative impact on $CO_2$ in the short-term. GDP affects $CO_2$ positively in the short-term (see Figure 2).

**Table 5.** VAR GC Tests Results of $CO_2$-GDP-EN for Ghana.

| Dependent Variable: DLNCO$_2$ | | | |
|---|---|---|---|
| **Excluded** | **Chi-sq** | **df** | **Prob.** |
| DLNEN | 6.844335 | 1 | 0.0089 |
| DLNGDP | 1.281343 | 1 | 0.2576 |
| All | 9.830359 | 2 | 0.0073 |
| | | | |
| **Dependent Variable: DLNEN** | | | |
| **Excluded** | **Chi-sq** | **df** | **Prob.** |
| DLNCO$_2$ | 1.139619 | 1 | 0.2857 |
| DLNGDP | 2.784538 | 1 | 0.0952 |
| All | 3.740984 | 2 | 0.1540 |
| | | | |
| **Dependent Variable: DLNGDP** | | | |
| **Excluded** | **Chi-sq** | **df** | **Prob.** |
| DLNCO$_2$ | 0.088819 | 1 | 0.7657 |
| DLNEN | 0.528939 | 1 | 0.4671 |
| All | 0.577426 | 2 | 0.7492 |

**Source:** Authors' Calculations.

Firstly, $CO_2$ affects EN negatively in the short-term, and then $CO_2$ affects EN positively in the short-term. GDP have a positive impact on EN in the short-term.

$CO_2$ have a positive impact on GDP in the short-term. First, EN has a positive impact on GDP in the short-term and then EN have a negative impact on GDP in the short-term.

VDA is applied to find how each variable impact and influence the other variables. EN can cause 15.59% fluctuation in $CO_2$ in the short-term and 15.59% fluctuation in $CO_2$ in the long-term. GDP can cause 2.47% fluctuation in $CO_2$ in the short-term and 2.48% fluctuation in $CO_2$ in the long-term (see Table 7).

$CO_2$ can cause 2.02% fluctuation in EN in the short-term and 2.02% fluctuation in EN in the long-term. GDP can cause 6.03% fluctuation in EN in the short-term and 6.05% fluctuation in EN in the long-term.

$CO_2$ can cause 0.84% fluctuation in GDP in the short-term and 0.84% fluctuation in GDP in the long-term. EN can cause 2.43% fluctuation in GDP in the short-term and 2.43% fluctuation in GDP in the long-term.

### 4.2 $CO_2$, GDP, Square of GDP and EN Nexus

For Ghana, LNCO$_2$, LNEN, LNGDP and LNGDP2 are at I(1), I(1), I(1) and I(1) levels (see Table 1). Since variables are stationary at I(1), Johansen cointegration test is applied. According to Johansen cointegration test results, no cointegration is found between Square of GDP, $CO_2$, EN and GDP (see Table 6). Since no long run relationship is found between Square of GDP, $CO_2$, EN and GDP, EKC hypothesis is not confirmed for Ghana.

**Table 6.** Results for Johansen Cointegration Test of $CO_2$-GDP-EN-SQUARE of GDP for Ghana.

| Unrestricted Cointegration Rank Test (Trace) | | | | |
|---|---|---|---|---|
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Trace Statistic** | **0.05 Critical Value** | **Prob.** |
| None | 0.316392 | 34.36739 | 47.85613 | 0.4818 |
| At most 1 | 0.226665 | 18.39182 | 29.79707 | 0.5372 |
| At most 2 | 0.165318 | 7.596010 | 15.49471 | 0.5096 |
| At most 3 | 0.000153 | 0.006415 | 3.841466 | 0.9356 |
| **Unrestricted Cointegration Rank Test (Maximum Eigenvalue)** | | | | |
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Trace Statistic** | **0.05 Critical Value** | **Prob.** |
| None | 0.316392 | 15.97557 | 27.58434 | 0.6679 |
| At most 1 | 0.226665 | 10.79581 | 21.13162 | 0.6677 |
| At most 2 | 0.165318 | 7.589595 | 14.26460 | 0.4220 |
| At most 3 | 0.000153 | 0.006415 | 3.841466 | 0.9356 |

**Source:** Authors' Calculations.

**Table 7.** VDA of $CO_2$-GDP-EN for Ghana.

| **Period** | **S.E.** | **DLNCO$_2$** | **DLNEN** | **DLNGDP** |
|---|---|---|---|---|
| 1 | 0.107520 | 100.0000 | 0.000000 | 0.000000 |
| 2 | 0.127787 | 84.17357 | 13.92428 | 1.902151 |
| 3 | 0.130676 | 82.06699 | 15.47453 | 2.458477 |
| 4 | 0.130835 | 81.93505 | 15.59018 | 2.474767 |
| 5 | 0.130854 | 81.91798 | 15.59638 | 2.485642 |
| 6 | 0.130855 | 81.91699 | 15.59658 | 2.486428 |
| 7 | 0.130855 | 81.91681 | 15.59657 | 2.486620 |
| 8 | 0.130855 | 81.91679 | 15.59656 | 2.486642 |
| 9 | 0.130855 | 81.91679 | 15.59656 | 2.486646 |
| 10 | 0.130855 | 81.91679 | 15.59656 | 2.486646 |
| | | | | |
| **Period** | **S.E.** | **DLNCO$_2$** | **DLNEN** | **DLNGDP** |
| 1 | 0.057079 | 4.89E-06 | 100.0000 | 0.000000 |
| 2 | 0.059282 | 1.498312 | 93.08874 | 5.412952 |
| 3 | 0.059787 | 2.006685 | 92.01301 | 5.980306 |
| 4 | 0.059824 | 2.020973 | 91.94185 | 6.037180 |
| 5 | 0.059831 | 2.024188 | 91.92472 | 6.051088 |
| 6 | 0.059832 | 2.024161 | 91.92324 | 6.052597 |
| 7 | 0.059832 | 2.024176 | 91.92294 | 6.052880 |
| 8 | 0.059832 | 2.024175 | 91.92291 | 6.052917 |
| 9 | 0.059832 | 2.024175 | 91.92290 | 6.052923 |
| 10 | 0.059832 | 2.024175 | 91.92290 | 6.052924 |
| | | | | |
| **Period** | **S.E.** | **DLNCO$_2$** | **DLNEN** | **DLNGDP** |
| 1 | 0.043877 | 0.462922 | 2.739739 | 96.79734 |
| 2 | 0.047709 | 0.795973 | 2.489746 | 96.71428 |
| 3 | 0.048220 | 0.838167 | 2.443780 | 96.71805 |
| 4 | 0.048295 | 0.841702 | 2.436629 | 96.72167 |
| 5 | 0.048307 | 0.842606 | 2.435697 | 96.72170 |

| | | | | |
|---|---|---|---|---|
| 6 | 0.048308 | 0.842698 | 2.435541 | 96.72176 |
| 7 | 0.048309 | 0.842716 | 2.435520 | 96.72176 |
| 8 | 0.048309 | 0.842718 | 2.435516 | 96.72177 |
| 9 | 0.048309 | 0.842719 | 2.435516 | 96.72177 |
| 10 | 0.048309 | 0.842719 | 2.435516 | 96.72177 |

**Source:** Authors' Calculations.

## 5. CONCLUSION

The EKC hypothesis states that economic growth will lead to reduction in emissions. Results of this study did not verify this statement. Our results are in line with Twerefou, Adusah-Poku and Bekoe (2016), Appiah et al. (2017) and Muhammad et al. (2016) for not verifying the EKC relationship for Ghana. Our results are different from Opoku et al. (2014) which confirmed the EKC relationship for Ghana.

Asumadu-Sarkodie and Owusu (2016) found that there were bidirectional causality between $CO_2$ emissions and EN, and GDP and EN, and unidirectional causality running from GDP to $CO_2$ emissions. According to our results, there are no causal relationships between $CO_2$ and GDP, and GDP and EN, and there is unidirectional causality running from EN to $CO_2$ for Ghana.

Aboagye (2017) found that there were bidirectional causality between GDP and EN, and GDP and $CO_2$ emissions. According to our results, there are no causal relationship between GDP and EN, and GDP and $CO_2$ for Ghana.

Main findings in this study are that there is no long run relationship between $CO_2$, GDP and EN, and between $CO_2$, GDP, EN and the square of GDP. The EKC hypothesis is not confirmed for Ghana for the period between 1971 and 2014, so there is no inverted U relationship between income and emissions. Neutrality hypothesis is confirmed for Ghana which states there is no causal relationship between GDP and EN. No causality is found between $CO_2$ and GDP, and $CO_2$ and EN variables. Unidirectional causality running from EN to $CO_2$ is found.

No causal relationship between GDP and $CO_2$ means that a country's economic growth will not have an effect on emissions. Ghana is likely to achieve further economic growth without causing environmental degradation since no causality is found between $CO_2$ and GDP.

No causal relationship between GDP and EN means that a country's economic growth will not have an effect on EN. The economic growth of Ghana is not dependent on oil consumption. Also, oil consumption is not a source for economic growth in Ghana.

For Ghana, EN causes emissions. Ghana should increase energy efficiency in industrial sector and replace oil usage with natural gas for electricity generation. Expansion of mass transportation will help to decrease the increasing emissions of transport sector which is caused by the increasing number of passenger vehicles. Ghana should collaborate with international community to invest in renewable energy. Share of renewable energy in electricity generation, industrial sector and transport sector should be increased. Waste and forest management should be improved, and reforestation policy should be continued.

Economic growth is not likely to help Ghana to fight climate change by itself. Improving energy efficiency and increases in the use of renewable energy in the transport, industry and energy sectors will help Ghana to fight climate change and meet emission targets. Authorities in Ghana should continue to invest in energy conservation and emission reduction policies since these policies are likely to not have a detrimental effect on economic growth. Ghana is likely to achieve further economic growth without causing environmental degradation since no causality is found between CO2 and GDP.

The Limitations of our study are that results are obtained for Ghana and the period between 1971 and 2014 is examined for Ghana.

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