Preliminary communication/Prethodno priopćenje
UDC/UDK 330.4:504(497.5)

# Testing the environmental Kuznets curve in the case of Croatia

# Testiranje Kuznetsove krivulje okoliša na primjeru Hrvatske

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## Abstract

The environmental Kuznets curve is a relationship between various indicators of environmental degradation and income per capita. The EKC hypothesis states that environmental degradation worsens as economic development increases, however after reaching a certain level of GDP per capita, it begins to decrease. The aim of the paper is to test the validity of the environmental Kuznets curve in Croatia in the period from 1990 to 2013. This paper required constructing and testing linear, quadratic and cubic models using a liner regression model. The results of the analysis have shown that economic growth affects $CO_2$ emissions in Croatia, indicated however by is very weak linear relationship and applying only to short-term model dynamics. Furthermore, the measured carbon intensity of GDP for Croatia indicates that Croatia uses its anthropogenic resources relatively efficiently.

**Keywords:** $CO_2$ emissions, environmental Kuznets curve, Croatia

**JEL classification:** Q53, Q56

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## Sažetak

Kuznetsova krivulja okoliša predstavlja odnos između različitih pokazatelja ekološke degradacije i dohotka po stanovniku. Prema EKC hipotezi degradacija okoliša se povećava u korak s gospodarskim razvojem, ali nakon postignute određene razine BDP-a po glavi stanovnika, počinje se smanjivati. Cilj rada je ispitati valjanost Kuznetsove krivulje okoliša u Hrvatskoj za razdoblje od 1990. do 2013. godine. U tu svrhu kreiran je linearni, kvadratni i kubični model koji su testirani modelom linearne regeresije. Rezultati analize pokazali su da gospodarski rast utječe na emisiju $CO_2$ u Hrvatskoj, ali je prisutna vrlo slaba linearna veza koja vrijedi samo za kratkoročnu dinamiku pojave. Osim toga, izmjerena ugljična intenzivnost BDP-a Hrvatske pokazuje da Hrvatska relativno učinkovito koristi svoje antropogene resurse.

**Ključne riječi:** emisije $CO_2$, Kuznetsova krivulja okoliša, Hrvatska

**JEL klasifikacija:** Q53, Q56

## 1. Introduction

The environmental Kuznets curve (EKC) is a relationship between various indicators of environmental degradation and income per capita. It was named after the famous Russian economist Simon Kuznets who hypothesized the relationship between income inequality and economic devel-

1 The views expressed in this paper are the author's personal views and not necessarily those of the institution in which he is employed.

opment (Kuznets, 1955). The main question that Kuznets wanted to answer was does inequality in the distribution or income increase or decrease during a country's economic growth. He tested his theory on data for three industrialized countries (United States, England and Germany). Although the results of his analysis showed that income inequality at first rises and then falls preceding economic development, Kuznets was not satisfied with his theory. He warned that the hypothesis on the relationship between income inequality and economic development should not be taken for granted and that further investigation was needed.

The environmental Kuznets curve was introduced in the early 1990's with Grossman and Krueger's path-breaking study of the potential impacts of NAFTA (Grossman, Krueger, 1991) and the concepts of popularization in the 1992 World Bank Development Report (Stern, 2004). At the early stages of economic development, environmental pollution rises with an increase in national per capita income as people are more interested in jobs and income than clean air and water, and consequently there is inadequate environmental regulation. At higher levels of income and economic development, environmental degradation decreases as people increasingly value environment and regulation standards which in turn become more effective, leading to the characteristic inverted U- shaped curve. This concept explains carbon dioxide emissions based on linear, quadratic and cubic polynomial functions of income per capita.

Since the 1990s, many authors have analyzed the existence of the EKC for various pollutants, when empirical literature on the link between economic growth and environmental pollution became abundant. Numerous reasons led to the development of the environmental Kuznets curve. The most important being rapid climate change in the last few decades and the problem of global warming. The Kyoto protocol was signed in 1997 and came into force in 2005, and its objective has been to reduce greenhouse gases that cause climate change. The protocol provides constraints on environmental pollution levels, mainly carbon dioxide ($CO_2$) emissions given that it is the major environmental pollutant. The EKC has been estimated for a variety of environmental indicators including air pollution, water pollution, deforestation, hazardous waste and toxins, carbon dioxide, biodiversity conservation and ecological footprints (Wang et al.., 2013).

The aim of this paper is to investigate empirically the validity of the environmental Kuznets curve in the case of Croatia using time series data for carbon dioxide emissions and gross domestic product per capita between 1990 and 2013. The structure of the paper is organized into specific sections. Section two analyzes the origins and theoretical concept of the EKC, whereas section three gives an overview of the literature on EKC. Thereafter, section four presents economic and econometric issues relating to EKC, followed by section five which explains the methodology and data we used in the analysis. Section six discusses the study findings. The final section of the paper contains remarks and conclusions.

## 2. The origins and theoretical concept of the environmental Kuznets curve

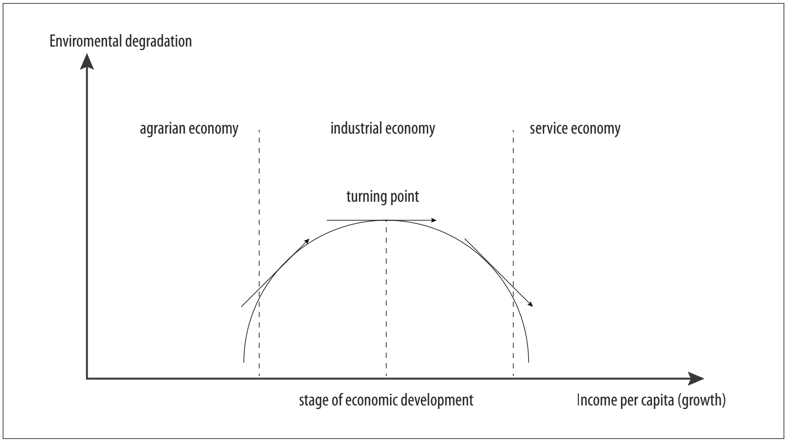
The origins of the environmental Kuznets curve were laid down back in the 1950's and is work of the famous Russian economist, Simon Kuznets. In 1955, at the sixty-seventh annual meeting of the American Economic Association, Simon Kuznets delivered his presidential address, entitled "*Economic Growth and Income Inequality*." The main question that Kuznets wanted to answer was does inequality in the distribution of income increase or decrease during a country's economic growth? He tested the theory on data for three industrialized countries (United States, England and Germany). Kuznets's general conclusion was that *"the relative distribution of income, as measured by annual income incidence in rather broad classes, has been moving toward equality – with these trends particularity noticeable since the 1920's but beginning perhaps in the period before the first world war*" (Kuznets, 1955: 4). The relationship between per capita income and income inequality can be represented with bell-shaped curve known as the Kuznets curve. Although the results of his analysis showed that income inequality at first rises then falls during economic development, Kuznets was not satisfied with his theory. He was acutely conscious of the meagerness of the presented reliable information and concluded that the paper was "*perhaps 5 per* *cent empirical information and 95 per cent speculation, some of it possibly tainted by wishful thinking*" (Kuznets, 1955: 26). He warned that the hypothesis on the relationship between income inequality and economic development should not be taken for granted and that further investigation was needed.

Grossman and Krueger (1991) were the first to conduct an empirical study on the relationship between environmental degradation and development based on measurements of air quality in certain countries during different years. They investigated the effects of NAFTA (the trade agreement between USA, Canada and Mexico) and the impact on environmental degradation. According to their study, economic growth tends to alleviate pollution problems once a country's per capita income reaches about $4,000 to $5,000 U.S. dollars[2]. Mexico, with GDP per capita of $5,000 was at the critical juncture in its development process, where further growth would generate further political pressures for instigating environmental protection (Grossman, Krueger, 1991). At the time, many people feared that opening markets with Mexico would cause a race to the bottom and that environmentally intensive companies would attempt to implement the lowest environmental standards with which they could get away and in turn escape the stricter environmental standards in Canada and the United States (Yandle et al., 2002).

A study by Shafik and Bandyopadhyay (1992) was the background paper for the World Bank inquiry into growth and environment relationships for the IBRD's *1992 World Development Report* which shed new light on the EKC problem. The Report stated that continued, and even accelerated, economic and human development is sustainable and can be consistent with improving environmental conditions, but will require major policy, programs and institutional shifts (IBRD, 1992). Moreover, positive links between efficient income growth and the environment are to be aggressively exploited. Panayotou (1993) was one of the first to graphically illustrate the relationship between various pollutants and income per capita.

According to the EKC hypothesis, a country's income per capita increases during the process of economic development, and pollution increases but only after reaching a specific level of economic development does pollution begin to decrease (Figure 1).

**Figure 1** The environmental Kuznets curve




**Source:** the authors.

2 Sulphur dioxide and dark matter (smoke) concentrations increased and then decreased with low and high levels of per capita incomes respectively.

The first stage of economic development is called an agrarian economy where most activities are based on agriculture without causing a significant environmental impact. Economies from all developed countries were at some time in the past based on agriculture and farming. The industrial revolution and development has brought about environmental degradation due to a greater use of natural resources, increased emissions of pollutants, extensive use of land, deforestation, dirty industries, and the like. However, in recent decades, there has been a visible shift from an industrial economy to a service-based economy. In this stage of economic development, many developed economies have reached and passed a turning point representing a level of income per capita where environmental degradation decreases. The main reasons for this environmental decrease is evident in the shifting of dirty industries to third world countries, as well as technological progress, innovation and a decline in overall industrial production. The second main reason is that the 'income effect' creates a greater consumer demand for a cleaner environment. At this turning point, consumer preference for environmental quality outweighs the favoring of additional income (Paraskevopoulos, 2009).

According to Panayotou (2003: 17), there are three main structural forces that have an impact on the environment: *the scale or level effect, the structure or composition effect and the income or abatement effect.* The scale effect on pollution states that the more an economy produces, the more environmental degradation increases and is expected to be monotonically increasing function of income. The composition effect represents the changing share of industry in GDP or structural change of an economy over time. This is graphically represented by the non-monotonic (inverted-U) function of GDP, where environmental pollution follows changes in income. The third effect is the income or abatement effect, which represents 'pure' income effects on the demand and supply of environmental quality. At higher income levels, income increases lead to a higher demand for environmental quality, with pollution being a non-increasing function of income and graphically represented by the inverted J- curve.

The general form of the environmental Kuznets curve is the following:

$$\ln(E/P)_{it}=\alpha_1+\beta_1\ln(GDP/P)_{it}+\beta_2(\ln(GDP/P))^2_{it}+\beta_3\ln(GDP/P))^3_{it}+\beta_4 z_{it}+\varepsilon_{it} \quad (1)$$

where $E$ is emissions, $P$ is population, $GDP$ is gross domestic product or national income and $z$ relates to other variables of influence on environmental degradation such as population density or trade openness, investment shares, debt per capita, etc. Here, the index $i$ is the respective country, $t$ is time and $\alpha_1$ is a constant.

If we exclude variable Z from the equation (1), there are seven forms that represent the relationship between environment and income (Stern, 2003; Dinda, 2004):

$(i)$ $\beta_1=\beta_2=\beta_3=0$ no relationship between income and pollution

$(ii)$ $\beta_1>0$ and $\beta_2=\beta_3=0$ linear relationship between variables

$(iii)$ $\beta_1<0$ and $\beta_2=\beta_3=0$ a monotonic decreasing relationship between variables

$(iv)$ $\beta_1>0$, $\beta_2<0$ and $\beta_3=0$ an inverted U-shape relationship, i.e., EKC

$(v)$ $\beta_1<0$, $\beta_2>0$ and $\beta_3=0$ a U-shaped relationship

$(vi)$ $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$ a cubic polynomial or N-shaped figure

$(vii)$ $\beta_1<0$, $\beta_2>0$ and $\beta_3<0$ opposite to the N-shaped curve

The environmental Kuznets curve is represented by the model $(iv)$. The turning point is calculated using the expression $(GDP/P)TP=\exp(\frac{-\beta_1}{2\beta_2})$. A large number of econometric studies have used this model to test the presence of EKC for various pollutants such as carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen oxide, lead, DDT and other types of pollutants. Our study will focus on carbon dioxide as the major greenhouse gas pollutant.

## 3. Studies on the environmental Kuznets curve

Since 1991, numerous theoretical and empirical papers have tested the environmental Kuznets curve hypothesis including the ground-breaking Grossman and Krueger (1991) study. Early studies were based on panel data analysis making use of random, fixed and pooled effects, while later studies included cross-country and time series regression models. Most studies agree on the existence of an inverted U-shape curve (EKC) for some pollutants, but disagree on the turning point values. A summary of the most important studies on EKC is given in Table 1. in the Appendix 1.

Grossman and Krueger (1991) tested EKCs for sulfur dioxide, dark matter (fine smoke), and suspended particles (SPM). In their panel data analysis, which allowed for random effects, they used data on sulfur dioxide from 42 countries, dark matter from 19 countries and suspended particles from 29 countries for the years 1977, 1982 and 1988. Each regression involved a cubic function of the levels of PPP per capita GDP and various related variables. The results of the analysis failed to verify the EKC in the case of sulfur dioxide and dark matter, but confirmed the existence of the EKC for SPM with a turning point estimated at $9,000.

Shafik and Bandyopadhyay's (1992) study was a background paper for the *1992 World Development Report* which focused on the environment. They explored the relationship between economic growth and environmental quality by analyzing patterns of environmental transformation for 149 countries of different income levels for the period between 1960 and 1990. They estimated the EKC for eight indicators of environmental quality using three different functional forms. Their conclusion was that income provided the most consistent, significant effect on all indicators of environmental quality, however the relationship is not simple given that the lack of clean water and urban sanitation were found to have declined uniformly with increasing income and over time, and deforestation regressions showed no relation between income and deforestation.

Selden and Song (1994) investigated the EKC using a cross-national panel of data on emissions of sulfur dioxide, SPM, as well as oxides of nitrogen and carbon monoxide for 130 countries for the period 1951-1986. Panel data analysis used quadratic and cubic specifications in levels and logs and allowed for fixed and country specific effects. They discovered that capita emissions of all four pollutants exhibited an inverted U-relationship with respect to GDP per capita. While this suggests that emissions decrease in the long run, they also forecast continued rapid growth in global emissions in subsequent decades. Tucker (1995) tested the EKC hypothesis for 137 countries for the period 1971-1991 using panel data analysis. The results of the analysis confirmed the existence of EKC for the majority of countries. Moomaw and Unruch (1997) compared the EKC models to structural transition models of $CO_2$ emissions per capita and GDP per capita using a sample of 16 developed OECD countries for the period 1950-1992. Using a panel data framework, they concluded that neither the U-shaped nor the N-shaped relationship between $CO_2$ emissions and income provide a reliable indication of future behavior but instead the inverted V-shape curve.

De Bruyn et al. (1998) used a specified alternative growth model for four countries (UK, USA, West Germany and Netherlands) from 1961 to 1993 and three types of emissions (carbon dioxide, nitrogen oxide and sulfur dioxide). They discovered that the time patterns of emissions correlate positively with economic growth and that emission reductions may have been achieved as a result of structural and technological changes in the economy. Roca et al. (2001) analyzed the validity of the EKC hypothesis for Spain for six atmospheric pollutants. Time series data for carbon dioxide covered the period from 1972 to 1996 while data on other five pollutants covered the period from 1980 to 1996. The OLS model with a cubic specification confirmed the EKC hypothesis only in the case of sulfur dioxide and not for other pollutants. Friedl and Gelzner (2003) explored the relationship between economic development and carbon dioxide in Austria for the period from 1960 to 1999. A cubic relationship between GDP and $CO_2$ was found to fit the data most appropriately, hence the EKC hypothesis was not confirmed. Two variables were also significant: import shares reflecting the pollution haven hypothesis and share of service sector in total production accounting for structural changes in the economy. Emission projections derived from the study support the widely-held opinion that significant policy changes are sought when implementing the Kyoto Protocol.

Galeotti et al. (2006) reassessed the robustness of the EKC for $CO_2$ emissions by performing the analysis in a different parametric setup by using alternative emission data for the 1960-1998 period. The model was based on panel data using a standard cubic log-linear EKC relation. The econometric results led to two conclusions: firstly, the published evidence on the EKC does not appear to depend upon the source of the data and secondly, when an alternative functional form is employed, there is evidence of an inverted U-pattern for the group of OECD countries with a reasonable turning point. For non-OECD countries, the EKC basically increases. Ang (2007) examined the dynamical causal relationship between pollutant emissions, energy consumption and output for France using cointegration and vector error-correction modeling techniques. The results provide evidence for the existence of fairly robust long-run relationship between these variables for the period 1960-2000. The results pointed out that economic growth exerts a causal influence on growth of energy use and population growth in the long run.

Wang (2011) performed an empirical test to validate the EKC hypothesis on a sample of 138 countries during 1971 to 2007 period. The empirical results indicated a stable long-run relationship between global carbon dioxide emissions and GDP, long-run elasticity declines along with the rise of carbon dioxide emission quantiles and the higher the quantiles the faster and more stable of the short-run correction mechanism of the adjustments from short-run disequilibrium to long-run equilibrium. Liao and Cao (2013) using panel data sets examined the historical relationship between economic development and carbon dioxide emission for 132 countries in the period from 1971 to 2009. They also investigated the historical relationship of economic development and $CO_2$ emission as well as its robustness from three aspects: data sources, model specifications and estimation methods. Empirical results indicated that factors such as urbanization, population density, trade, energy mix and economic environment impact the absolute level of carbon dioxide emission.

Ahmad et al. (2013) investigated whether the EKC hypothesis held for two groups of economies; developed vs. developing countries using data from 40 countries in the period between 1961 and 2009. In applying the panel data approach, they showed that the EKC does not hold in all countries when detecting the existence of U-shape and an increasing trend. It was also observed that developing countries have higher turning points than developing countries. The results revealed that $CO_2$ and SPM10 are a good data to proxy for environmental pollutant and they can be explained well by GDP. Osabuohien et al. (2014) analyzed the EKC hypothesis for 50 African countries in the period from 1995 to 2010. The empirical analysis suggested a long-term relationship between $CO_2$ and particulate matter emissions with per capita income and other variables including institutional factors and trade. Mishra et al. (2015) re-examined the EKC hypothesis by introducing the role of institutional quality and distributional heterogeneity and running panel quantile regression over the period from 1960 to 2003 for 127 countries. They demonstrated that once endogeneity bias is corrected and heterogeneity in the effects of income and institutional quality is introduced, the EKC tends to disappear at higher quantiles of emission but its existence is proven at lower quantiles.

## 4. Validity of the environmental Kuznets curve

Although over one hundred studies on the EKC hypothesis have been published in the last three decades, no uniform conclusion on the relationship between income and various environmental pollutants has been drawn. This can be explained by the fact that each country has its own specific environmental and economic characteristics requiring insight and acknowledgement. All these studies have provided numerous theoretical and methodological concepts. One of the key criticisms of the EKC hypothesis has been that the model presumes no feedback from environmental damage to income which is otherwise deemed to be an exogenous variable. Environmental damage does not reduce economic activity to the extent of stopping growth.

Stern (2003) has argued that the EKC is essentially an empirical phenomenon, however most of the literature on the EKC is econometrically inadequate given that little or no attention has been given to the statistical properties of the relevant data. Econometric criticisms of the EKC has been based on problems of homo/heteroskedasticity, simultaneity, omitted variable bias and cointegration issues. On the other hand, Lieb (2003) has stated that econometric criticism of the EKC is related to simultaneity bias, other functional forms, time trends, multicollinearities, lagged effects and homogeneity tests. Alstine and Neumayer (2010) have noted a number of caveats that should be considered when looking at the results of empirical studies, such as: for some environmental aspects there is no turning point in sight ($CO_2$ emissions, direct material flows and biodiversity loss); econometric evidence captures historical evidence but it is not deterministic; even if an EKC relationship is found, there is the possibility of a second turning point; country-specific fixed and year-specific time effects are often required but sometimes are not included; if the environmental indicator and GDP per capita are both trending over time, then spurious regression results are possible; the existence of the EKC could be partly due to a trade effect, etc. According to Paraskevopoulos (2009), the most important factors responsible for various studies having led to different outcomes concerning the EKC hypothesis are as follows: different pollution indicators, different functional forms (linear, cubic, quadratic), different econometric techniques, different set of explanatory variables, different framework analysis (panel data, cross-country, time series regressions), different time periods and sample size sets, etc.

Critics of the EKC often argue that if certain pollutants are decrease as income increases, industries will create new, unregulated pollutants and the overall environmental risk from the new pollutants may intensify. Other reasons as to why the EKC hypothesis does not hold in practice are: the signing of the Kyoto Protocol (requiring countries to reduce $CO_2$ emissions), the impact of the economic crisis on the global reduction of $CO_2$ emissions, government regulations and environmental awareness of citizens, increased use of renewable energy sources as opposed to combustion of fossil fuels, and so on.

In 1997, the Kyoto Protocol was adopted as an international agreement signed by industrialized and transition economies with the aim of reducing GHG emissions and their own $CO_2$ emissions below the 1990 levels. Iwata and Okada (2010) have investigated the role of Kyoto Protocol in the reduction of various GHG emissions. The main finding of their study was that the Kyoto Protocol had a significant effect on reducing $CO_2$ emissions. The global economic crisis began in late 2007 and led to a somewhat reduction of global GHG emissions. This was due to a decline in overall economic activity which in turn had a positive effect on the environment given that factors influencing carbon dioxide emissions are also factors likely to change during an economic crisis[3]. Baiij (2011) has investigated the effects of the global economic crisis on $CO_2$ emissions and has concluded that the impact of economic crisis on lessening environmental degradation is not so straightforward, and this in turn is due to a reduction in environmental investments by government and companies, the short duration of the crisis and the fact that developing countries continue to have increasing carbon dioxide emissions.

Government regulations or policies should provide incentives for innovation aimed at reducing emissions and slowing environmental degradation. Innovations can lead to the use of less-polluting and more energy-efficient technologies. Today, there is an evident contrast between modern societies harboring a growing concern about environmental issues and developing countries which are experiencing fast and increasing pollution problems. Since the negotiation of the Kyoto Protocol, there has been a strong emphasis on the need to replace fossil fuels with renewable energy sources. The Protocol has obliged industrialized countries to limit their greenhouse gas emissions, mainly that of $CO_2$. Sadorsky (2009) has explained that renewable energy can ensure a sustainable electricity supply and at the same time can reduce $CO_2$ emissions. Panel cointegration estimates have shown that an increase in real income per capita has a positive and statistically significant impact on renewable energy consumption per capita. Many countries have shifted away from a dependency on fossil fuels towards

3 Such as GDP, energy consumption, government policy, business investment and oil prices.

the use of more renewable energy sources.

## 5. Methodology and data

This chapter presents and explains the methodology and data used in the empirical testing of the EKC hypothesis for Croatia. The analyses of individual country's framework has advantages in regard to panel data analysis. Individual countries can have different economic characteristics and the EKC hypothesis may not account properly for crucial historical developments and unique events such as the oil crisis in the mid-1970s (Friedl and Gelzner, 2003). EKC hypothesis testing for Croatia is performed using the following regression equation (2):

| | |
|---|---|
| $\log(E/P)_t = \alpha_1 + \beta_1 \log(GDP/P)_t + \beta_2 (\log(GDP/P))_t^2 + \beta_3 \log(GDP/P))_t^3 + \beta_4 \log f_t + \beta_5 \log pd + \varepsilon_t$ | 2 |

where $E$ represents emissions, $P$ is the population, $GDP$ is gross domestic product, $f$ is variable trade openness which is often used as a proxy for foreign trade, $pd$ is population density, $t$ is time, $\alpha_1$ is a constant, $\beta$ is a regression coefficient and $\varepsilon$ is the regression error term. All variables in equation (2) are transformed into logarithms.

Expected signs of $\beta$ in equation (2) under the EKC hypothesis should be: $\beta_1 > 0$ and $\beta_3 = 0$. The turning point is $(GDP/P) = \exp(\frac{-\beta_1}{2\beta_2})$. The expected sign of for the case of developed countries is negative whereas for developing countries it is expected to be positive as they tend to have unclean industries with a heavy share of pollutants. The sign of this coefficient for Croatia is expected to be slightly positive. Variable trade openness is calculated as the value of imports plus exports divided by the GDP $\left(\frac{X+M}{GDP}\right)$. Some authors use only values of imports or exports when differentiating the effect of pollution haven hypothesis, where higher imports should lead to lower $CO_2$ emissions. Population density $pd$ is an explanatory variable which has a significant effect on environmental degradation according to the well-known Malthusian theory of population[4].

Time series data used in this study cover the period from 1990 to 2013. All data are an annual frequency and expressed in logarithms. Table 1 presents the descriptive statistics of variables (carbon dioxide emissions per capita, GDP per capita, trade openness and population density) used in the analysis.

Data for carbon dioxide emissions[5] have been taken from the Carbon Dioxide Information Analysis Center (CDIAC) http://cdiac.ornl.gov/ and the Croatian Environment Agency http://www.azo.hr/English while data for GDP have been taken from the Croatian Bureau of Statistics http://www.dzs.hr and the Croatian National Bank http://hnb.hr Data on population density and values of imports and exports have been taken from the World Bank's titled the World Integrated Trade Solutions (WITS) TradeState database http://wits.worldbank.org/CountryProfile.

A specific methodological approach was applied in this paper. First, variables were tested for stationarity in a time series. We then analyzed whether the carbon dioxide emissions and GDP per capita were cointegrated. Testing variables for stationarity is im-

**Table 1** Descriptive Statistics, 1990-2013

| Variable | Minimum | Maximum | Mean | Median | Std. Dev. |
|---|---|---|---|---|---|
| Carbon dioxide emissions (per capita) | 3.629 | 5.498 | 4.570 | 4.586 | 0.576 |
| GDP (per capita) | 2,300 | 16,345 | 8,298,08 | 5,946,50 | 4,419,19 |
| Trade openness | 0.49169 | 0.88106 | 0.59812 | 0.57430 | 0.09221 |
| Population density | 75.15 | 84.46 | 79.09 | 78.45 | 2.19 |
| Observations | | | 24 | | |

**Source:** the authors.
Note: Carbon dioxide emissions per capita are measured in metric tons, GDP per capita is measured in US dollars (2000).

4 The human population tends to grow exponentially when food production grows at an arithmetic progression, which ultimately leads to scarcity and future environmental degradation.

5 Carbon dioxide emissions are those stemming from the burning of fossil fuels and the production of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

portant given that if variables have a unit root, the results of the analysis may be spurious. Otherwise, no cointegration of the variables means that the EKC hypothesis of a long run relationship between the main variables does not hold. In such cases, the differentiated values of the variables should be used in representing only short-term effects. Finally, the environmental Kuznets curve hypothesis for Croatian $CO_2$ emissions is tested.

## 6. Results of the analysis

Figure 2 shows a graphical representation of the time series data for Croatia in the period from 1990 to 2013.

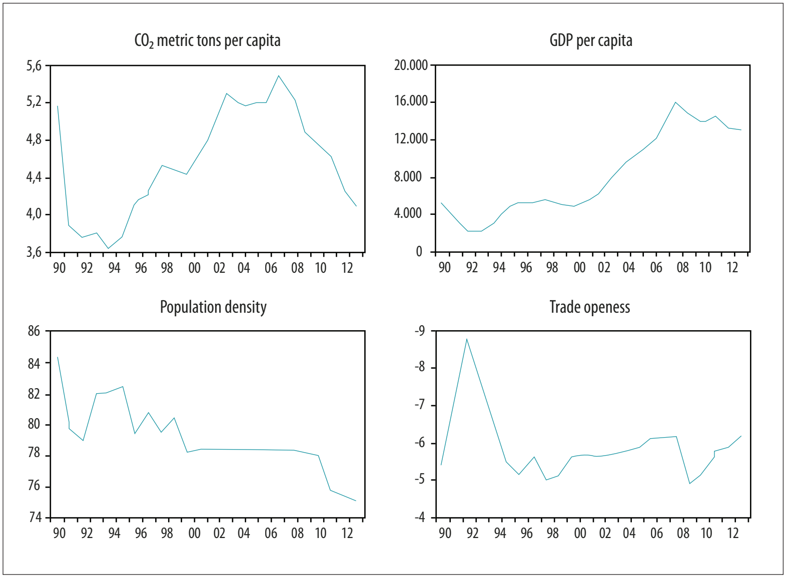
A quick look at the time series reveals that variables for $CO_2$ emissions and GDP per capita are non-stationary at the level and indicate a significant trend[6], whereas for variables relating to population density and trade openness, this is not so clear. The Augmented Dickey-Fuller (ADF test) was applied to test for stationarity in the time series of the dependent and independent variables.

The results of ADF test indicate that there is econometric evidence of non-stationarity in the time series data for both the dependent and explanatory variables. The exception is the population density variable (POPDENS) which is stationary at the level along with the respectvie constant and trend under a 5% significance level. After differentiating the variables, all variables were integrated at the same order of integration one (1). Given that the variables are of the same order of integration, the test for cointegration between the main variables $CO_2$ and GDP can be performed. If the residuals of the cointegrating regression are stationary, the time series are cointegrated and OLS is an adequate estimation procedure.

Appendix 2 contains the summarized results of testing for cointegration between GDP and



**Figure 2** Graphical presentation of the time series data for Croatia 1990-2013




**Source:** the authors.

6 By not incorporating trend in stationarity testing can lead to misleading results.

**Table 2** Unit root (ADF) test for stationarity of variables

| Variable | Constant | Constant and trend |
|---|---|---|
| $CO_2$ | -1.736864 | -2.023306 |
| GDP | -0.499696 | -1.565666 |
| POPDENS | -0.266853 | -3.568925** |
| TRADEOP | -2.112706 | -2.416056 |
| **Variable (in first differences)** | **Constant** | **Constant and trend** |
| D($CO_2$) | -5.987341*** | -6.472422*** |
| D(GDP) | -3.173859** | -3.030339** |
| D(POPDENS) | -6.845531*** | -6.709115*** |
| D(TRADEOP) | -4.131488*** | -4.102766*** |

**Source:** the authors.
***, **, * denote significance at 1%, 5% and 10%, respectively. The optimal lag length was selected based on Schwartz information criteria. The critical values of the ADF test for 1%, 5% and 10% significance levels are -3.75, -2.99 and 2.63.

$CO_2$ emissions per capita. The cointegration regression is estimated to be:

$$\log(E/P)_t = \alpha_1 + \beta_1 \log(GDP/P)_t + \varepsilon_t \quad (3)$$

Possible cointegration between GDP and $CO_2$ emissions is tested in two ways: using the Engle-Granger test based on the ADF test for unit root testing of the residuals resulting from the estimating equation (3) and the Johansen procedure[7]. The value of the ADF test for stationarity of the residuals from the cointegrating equation is (-0.37085), which is well above the significance level of 10% (critical value -2.64224), hence a null hypothesis of no cointegration is accepted. Another way of testing cointegration between $CO_2$ emissions and GDP is to apply the Johansen procedure. There are two types of Johansen tests, one with a trace and the other with the maximum eigenvalue statistic. The unrestricted cointegration rank test (trace) indicated no cointegration between $CO_2$ and GDP at the 0.05 level. In addition, the maximum eigenvalue test also confirmed a lack of cointegration between the main variables. This allows us to summarize as follows: Engle-Granger test for unit roots on residuals of the cointegration equation show that the residuals are not stationary which in turn indicates that there is no cointegration (long-term relationship) between $CO_2$ and GDP per capita. The same conclusion was made using the Johansen procedure (trace and maximum eigenvalue test statistics).

To correctly estimate the environmental Kuznets curve for Croatian $CO_2$ emissions, the variables are transposed into first differences. Table 3 shows the estimation of the environmental Kuznets Curve for Croatian $CO_2$ emissions. All variables are expressed in first differences and logarithms.

The three basic linear regression models have different GDP forms in terms of an independent variable: linear GDP, quadratic GDP and cubic GDP. All other variables have a linear form. Before estimating the model, the main assumptions of the linear regression model were tested for violation. Subsequently, the appropriate econometric tests for checking normality in residuals, homoscedasticity of variance and the potential problem of autocorrelation of residuals were conducted. Normality of residuals in the estimated model was tested using the Jarque-Bera test. The JB test showed that the null hypothesis of normality in residuals is acceptable, given that the empirical level of significance equals 0.735835. White's test for homoscedasticity of variance also showed that a null hypothesis of homoscedasticity cannot be rejected (prob. F and prob. chi-square equals 0.4678 and 0.6320, respectively). Lastly, the Breusch-Godfrey test for autocorrelation of residuals was conducted. The results of the B-G LM test (prob. F and prob. chi-square equals 0.7594 and 0.7201, respectively) showed that a null hypothesis cannot be rejected. The conclusion is that the results of the Jarque-Bera, White and Breusch-Godfrey LM tests showed that the model assumptions were met at a 95% confidence level, leading to the conclusion that the results of the

7 The Johansen test permits more than one cointegrating relationship, hence generally it is more applicable than the Engle-Granger test.

**Table 3** Estimation of an Environmental Kuznets Curve for Croatian $CO_2$ emissions

| Dependent variable D(LOG($CO_2$)) | Model | | |
|---|---|---|---|
| Explanatory variables | Linear GDP | Quadratic GDP | Cubic GDP |
| Constant | -0.018130<br>(-1.236190) | -0.020810<br>(-1.175587) | -0.015642<br>(-1.028681) |
| DLOG(GDP) | 0.194000***<br>(2.613113) | 0.200587<br>(2.527570) | 0.457986***<br>(3.440667) |
| DLOG(GDP)^2 | | 0.061872<br>(0.285051) | -0.369052<br>(-1.636345) |
| DLOG(GDP)^3 | | | -2.086952***<br>(-2.957769) |
| DLOG(POPDENS) | | | 0.566904<br>(0.748934) |
| DLOG(TRADEOP) | | | -0.153572<br>(-1.091423) |
| Adjusted R-squared | 0.20944 | 0.17327 | 0.44775 |
| S.E. of regression | 0.068848 | 0.070405 | 0.057542 |
| Akaike info criterion | -2.43090 | -2.34800 | -2.65313 |
| Schwartz criterion | -2.33216 | -2.19989 | -2.35692 |
| F-statistic | 6.82836 | 3.30544 | 4.56744 |
| Log likelihood | 29.95538 | 30.00200 | 36.51101 |
| Durbin-Watson stat. | 1.622762 | 1.56211 | 1.423026 |
| Observations | 24 | 24 | 24 |

**Source:** the authors.

OLS estimates indicate White heteroskedasticity - consistent standard errors and covariances; t-statistics in parentheses; significant at the 1 percent level: ***; at the 5 percent level: **; at the 10 percent level: *.

analysis were valid.

The results of the cubic GDP model do not support the N-shaped curve form because the differentiated value of GDP squared is not significant in the model. This is also evident based on Figure 3 which represents the environmental Kuznets curve for Croatia in the period from 1990 to 2013. In addition, the population density (POPDENS) and trade openness (TRADEOP) variables are not significant in the model, and are therefore excluded from the quadratic and linear specification[8]. In quadratic GDP model, none of the explanatory variables are significant, hence they can be dismissed. Lastly, the results of the linear GDP model point out to the significance of the differentiated variable GDP. The value of adjusted R-squared is very low (0.20944) indicating a weak linear relationship between GDP and $CO_2$ emissions. The linear regression model is estimated using differentiated values is:

$$d\log(E/P)_t = 0.194\, d\log(GDP/P)_t \qquad (4)$$

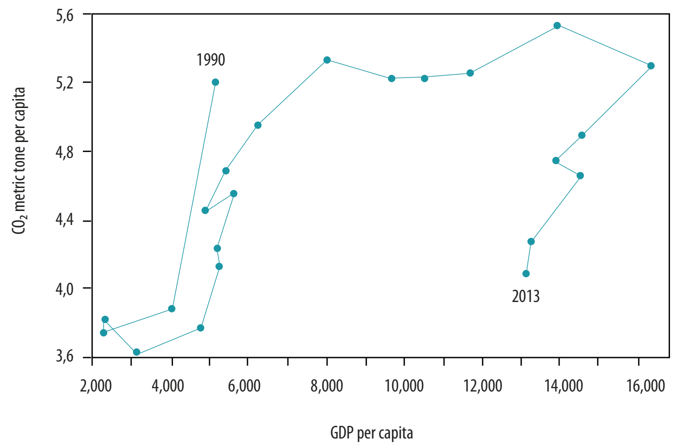
Therefore, economic growth affects somewhat positively $CO_2$ emissions in Croatia, as a very weak relationship, and given that it was estimated using first differences, it applies only for short-term model dynamics. The main reason is the fact that Croatian GDP growth in the observed period was possible due mainly to an overextended process of consumption in all sectors of the economy and not due to industrial production which is the main cause of environmental pollution.

Shown in Figure 3 is the constructed environmental Kuznets curve for Croatia in the period from 1990 to 2013. At first glance, it appears that the EKC for Croatia does not have a 'normal' form due to hard GDP structural brakes as is evident in the years 1992 and 2009[9]. A useful tool to track the dynamics of $CO_2$ emissions process in Croatia is the phase

8 Population density decreased over the observed period due to three key processes: aging, depopulation and spatial polarization of the population.

9 In 1992, Croatian GDP decline during the Croatian War of Independence. In 2009, the drop was caused by the global financial and economic crisis that began in late 2008.

**Figure 3** The environmental Kuznets curve for Croatia 1990-2013




**Source:** the authors.

diagram[10]. The dynamics of the system traces out the trajectory phase space which reveals whether the measure is changing in a systematic or irregular fashion (Moomaw and Unruh, 1997). The system is often attracted to a region of the phase space indicating that emissions fluctuated around an average value. Figure 4 illustrates the phase diagram for $CO_2$ emissions in Croatia in the period from 1990-2013. The emissions declined until 1994, when the first attractor developed, which was thereafter followed by a period of steady rise in $CO_2$ emissions. The second attractor developed in 2007, after which a decline in overall $CO_2$ emissions until 2013 is evident.

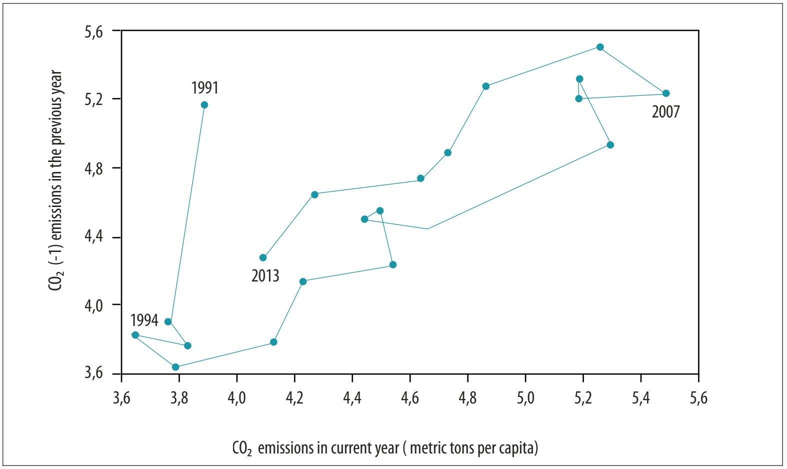
To get a complete picture of the environmental degradation in Croatia, the value of carbon dioxide emissions in Croatia is compared to other countries in the world (Figure 5). Although in absolute terms China is the highest pollutant in the world followed by USA, nonetheless, the highest pollutant per capita in the world is Qatar. Croatia falls below the average carbon dioxide emissions per capita in the European Union, amounting to 7.5 metric tons per capita in the 2011.

The transition from wasteful, energy-intensive planned economies to market economies in the last decade of the 20th century shifted to less carbon-intensive energy sources, such as an increased usage of gas instead of coal and lower energy usage per unit of GDP (IBRD, 2011). Similarly, this transition also occurred in Croatia after shifting to a market economy in the early 1990's. Figure 6 shows the carbon intensity[11] of GDP defined as the ratio of $CO_2$ emissions and GDP in Croatia from 1990-2013. The index year is 1990 with a reference value of 100. Figure 6 shows a steady decline in carbon intensity of GDP (the exception is the period between 1991 and 1993 when GDP fell dramatically) in the observed period. In 2008, the value of the carbon intensity index was 32.3, well below the 1990 index. This result can be compared to the study by International Bank for Restructuring and Development titled *The Low Carbon Transition* (IBRD, 2011) which arrived at similar results (the value of the carbon intensity index for Croatia in

10 It is a time-based space useful approach for comparing emissions in the previous year (on y-axis) with those in the current year (on x-axis).

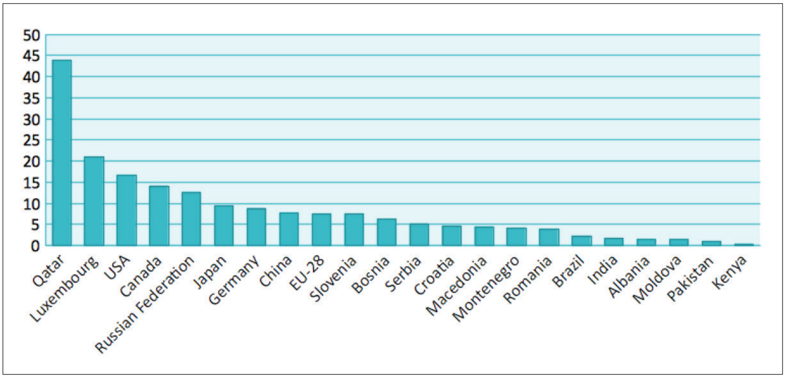
11 In 1992, Croatian GDP decline during the Croatian War of Independence. In 2009, the drop was caused by the global financial and economic crisis that began in late 2008.

**Figure 4** Phase diagram: $CO_2$ emissions for Croatia (1990-2013)




**Source:** the authors.

**Figure 5** $CO_2$ emissions by country (metric tons per capita, 2011)




**Source:** CDIAC and the authors.

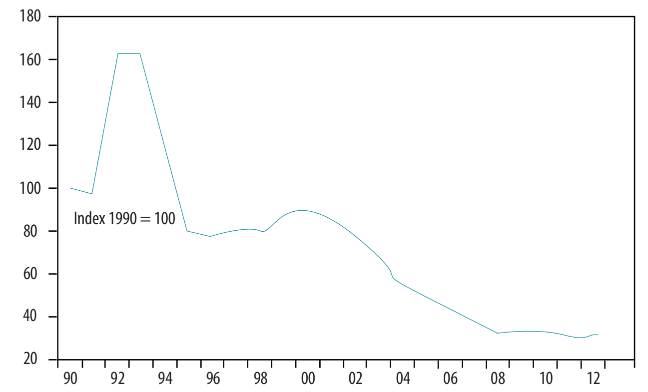
2008 was estimated to be 0.31)[12].

Importantly, when referring to policy measures focused on reducing $CO_2$ emissions, Croatia ratified the Kyoto Protocol in April 2007. Based on the Kyoto Protocol, Croatia accepted the obligation to reduce emissions of greenhouse gases from anthropogenic sources by at least 20 percent by the year 2020 with respect to emissions in 1990[13]. According to the Croatian Ministry of Economy

12 For comparison purposes, value of this index for EU-15 countries was 0.28.

13 The European Commission aims to reduce GHG values by 40 percent with respect to 1990 and by at least 80 percent by the year 2050.

**Figure 6** Carbon intensity of GDP ($CO_2$/GDP) for Croatia 1990-2013




**Source:** the authors.

(2014), $CO_2$ emissions decreased in the period from 2008 to 2013 by an average annual rate of 4.6 percent. This was a consequence of implementing energy efficiency measures, increasing the use of renewable energy sources and also the economic downturn.

## 7. Conclusion

The concept of the environmental Kuznets curve was introduced in the early 1990's and stemmed from the Grossman and Krueger's path-breaking study of the potential impacts of NAFTA and the concepts popularized in the *1992 World Bank Development Report*. In the early stages of economic development, environmental pollution rises with an increase in national income per capita given that people are more interested in jobs and income than clean air and water, and consequently environmental regulation is inadequate. At a higher level of income and economic development, environmental degradation decreases because people increasingly value the environment and regulation standards become more effective, thus providing the characteristic inverted U- shaped curve. Since the 1990s, numerous authors have analyzed the existence of the EKC for various pollutants. Although over one hundred studies on the EKC hypothesis have been published in the last three decadesno uniform conclusion on the relationship between income and various environmental pollutants has been drawn. This is explained by the fact that each country has its own environmental and economic specifics that are to be acknowledged and investigated. The aim of the paper was to test the validity of the environmental Kuznets curve in Croatia in the period from 1990 to 2013. The results of the ADF test indicate that there is econometric evidence for non-stationarity in the time series data for both the dependent and explanatory variables. The Engle-Granger test for unit roots on residuals of the cointegration equation indicate that the residuals are not stationary, which in turn implies that there is no cointegration (long-term relationship) between the $CO_2$ and GDP per capita. The same conclusion was made using the Johansen procedure (trace and maximum eigenvalue test statistics). To test the EKC hypothesis, a linear, quadratic and cubic model was constructed using differentiating variables. The results of the analysis show that that economic growth affects somewhat positively $CO_2$ emissions in Croatia. The relationship is confirmed in the linear regression model with GDP in its linear form and applies only for short-term model dynamics. In addition, population density (POPDENS) and trade openness (TRADEOP) variables were not significant in the model. The main reason for this is that growth of Croatian GDP was possible mainly due to an over-extended process of consumption of all sectors of the economy and not industrial production, which is the main cause of environmental pollution. After constructing the EKC for Croatia, it becomes obvious that the EKC for Croatia does not have a 'normal' form due to GDP structural brakes evident in the years 1992 and 2009. To get a complete picture of environmental degradation in Croatia, the value of carbon dioxide emissions in Croatia was compared relative to other countries in the world. Croatia is below the average carbon dioxide emissions per capita in the European Union which amounts to 7.5 metric tons per capita in the 2011. Furthermore, the measured carbon intensity of GDP for Croatia indicates that Croatia use its anthropogenic resources in a relatively efficient manner.

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**Appendix 1** Summary of empirical studies on EKC

| Author(s) | Year of publication | Sample and time period | Model specification | EKC Hypothesis |
|---|---|---|---|---|
| Grossman and Krueger | 1991 | 1977, 1982, 1988, various countries | Panel dana analysis, cubic specification | EKC hypothesis confirmed only for SMP with turning point at $9.000 |
| Shafik and Bandyopadhyay | 1992 | 1960-1990, 149 countries | Linear, quadratic and cubic model | EKC not confirmed, monotonic rising function |
| Selden and Song | 1994 | 1951-1986, 130 countries | Panel data analysis, quadratic and cubic specifications in levels and logs | EKC hypothesis confirmed for level with turning point at $35,428. For logs EKC not confirmed |
| Tucker | 1995 | 1971-1991, 137 countries | Panel data analysis | EKC is confirmed for the majority of countries |
| Moomaw and Unruh | 1997 | 1950-1992, 16 OECD countries | Panel data analysis | EKC hypothesis confirmed but with inverted – V shape |
| de Bruyne et al. | 1998 | 1961-1993, UK, US, Netherlands, Western Germany | Dynamic OLS model | Economic growth has a positive effect on emissions |
| Roca et al. | 2001 | 1972-1996, Spain | Time series model, cubic specification | EKC hypothesis confirmed for $SO_2$ but not for $CO_2$ |
| Friedl and Getzner | 2003 | 1960 – 1999, Austria | Linear, quadratic and cubic model | EKC hypothesis not confirmed. N-shaped relationship between GDP and $CO_2$ |
| Galeotti et al. | 2006 | 1960-1998, UN framework countries | Panel dana, cubic model | EKC confirmed for OECD countries |
| Ang | 2008 | 1960-2000, France | Time series model, quadratic specification | EKC confirmed |
| Wang | 2011 | 1971-2007, 138 countries | Standard cubic log linear model | EKC confirmed |
| Liao and Cao | 2013 | 1971-2009, 132 countries | Times series, cubic specification | Trend saturation |
| Ahmad et al. | 2013 | 1961-2009, 40 developed and developing countries | Panel dana cubic regression | EKC confirmed |
| Osabuohien et al. | 2014 | 1995-2010, 50 African countries | Panel dana regression | Long term relationship between CO2 and particulate matter emissions |
| Mishra et al. | 2015 | 1960-2003, 127 countries | Panel dana regression | EKC confirmed at lower quantiles |

**Source:** the authors.

**Appendix 2** Testing for cointegration between GDP and $CO_2$ emissions

| Explanatory variable LOG(GDP) | Dependent variable LOG($CO_2$) | Johansen cointegration test | | | | |
|---|---|---|---|---|---|---|
| Constant | 0.236667 (0.787144) | Unrestricted | Cointegration | Rank (Trace) Test | | |
| LOG(GDP) | 0.143843*** (4.250188) | Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
| Adjusted R-squared | 0.42592 | None | 0.262550 | 6.715462 | 15.49471 | 0.6109 |
| S.E. of regression | 0.09699 | At most 1 | 0.000690 | 0.015194 | 3.841466 | 0.9018 |
| Akaike info criterion | -1.74887 | Trace test indicates no cointegration at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-value | | | | |
| Schwartz criterion | -1.65070 | | | | | |
| F-statistic | 18.06410 | Unrestricted | Cointegration | Rank Test | (Maximum Eigenvalue) | |
| Log likelihood | 106 | None | 0.26255 | 6.70027 | 1.42646 | 0.52520 |
| Durbin-Watson statistic | 0.52029 | At most 1 | 0.00069 | 0.01519 | 3.84147 | 0.90180 |
| ADF test of residuals | -0.37085 | Max-eigenvalue test indicates no cointegration at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-value | | | | |
| Observations | 24 | | | | | |

**Source:** the authors.
OLS estimates show White heteroskedasticity- consistent standard errors and covariances; t-statistics in parentheses; significant at the 1 percent level: ***, at the 5 percent level: **, at the10 percent level: *.