Environmental Kuznets Curve for CO2 Emission: A Literature Survey

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Abstract

This paper provides a survey of the empirical literature on Environmental Kuznets Curve (EKC) estimation of carbon dioxide (CO_2) emissions over the period of 1991-2017. This survey categorizes the studies on the basis of single country and cross-country contexts. It has been hypothesized that the EKC is an inverted U-shaped association between economic growth and CO_2 emissions. For both single country and cross-country contexts, the results of EKC estimation for CO_2 emissions are inconclusive in nature. The reasons behind this discrepancy can be attributed to the choice of contexts, time period, explanatory variables, and methodological adaptation. The future studies in this context should not only consider new set of variables (e.g., corruption index, social indicators, political scenario, energy research and development expenditures, foreign capital inflows, happiness, population education structure, public investment towards alternate energy exploration, etc.), but also the dataset should be refined, so that the EKC estimation issues raised by Stern (2004) can be addressed.

Keywords: Environmental Kuznets Curve; Carbon Emissions; Economic Growth

1. Introduction

When an economy starts moving along the growth trajectory, then at the earliest stage of economic development, environment deteriorates rapidly due to ambient air pollution, deforestation, soil and water contamination, and several other factors. With rise in the level of income, when economy starts to develop, the pace of deterioration slows down, and at a particular level of income, environmental degradation starts to come down and environmental quality improves. This hypothesized association between economic growth and CO_2 emissions is termed inverted U-shaped. This phenomenon is also referred as Environmental Kuznets Curve (EKC) hypothesis in environmental economics literature, named after Simon Kuznets (1955), who described an inverted U-shaped association between economic growth and income inequality. Grossman and Krueger (1991) later found its resemblance with Kuznets' inverted U-curve relationship while establishing a relationship between economic growth and environmental degradation.

Following the findings of Grossman and Krueger (1991), a number of researchers started estimating EKC in diverse contexts and using a wide range of methodologies. These studies were conducted on various ambient air pollutants, water and soil contaminations, and ecological footprints. The empirical results obtained from these studies differed largely in terms of model specifications, choice of explanatory variables, shapes of EKC, and turnaround points. Therefore, for any given context and any particular pollutant, there is no consensus among the researchers regarding the shape and nature of EKC. Various earlier studies on the EKC estimation considered income and population as the explanatory variables (Panayotou, 1993), and with graduation of time, several context-specific explanatory variables, e.g. energy consumption, petroleum consumption, trade, corruption index, political collaboration, literacy rate, mortality rate, and several others have been considered within the EKC framework. Therefore, for any particular country or any group of countries, some of the researchers have found the evidence in support of EKC hypothesis, whereas others did not find any evidence to support the EKC hypothesis.

By and large, the evidences of EKC hypothesis can be divided into two different categories, based on the results obtained in the studies. Following are those two categories:

(a) *Absence of EKC hypothesis*: This condition is visible particularly for the underdeveloped and developing economies. In these countries, economic growth has not reached the level, at which environmental degradation can start coming down. Considering the case of these nations, environmental degradation rises with a rise in income, as achieving economic growth is the primary concern of these countries, more than environmental protection. One of the major reasons behind this scenario is that income elasticity of environmental demand in these contexts is low, and therefore, the level of environmental awareness in also low.

(b) *Presence of EKC hypothesis*: This condition is visible particularly for transitional, emerging, and developed economies. In these cases, the pattern of economic growth is ecologically sustainable, and countries are already in the process of either curbing down fossil fuel based energy consumption, or encouraging clean and renewable energy consumption. Though the chances of pollution export should not be overlooked, these economies are ahead of the others in terms of social development, which is a major catalyst for enhancement of environmental quality. One of the major reasons behind this scenario is that income elasticity of environmental quality demand in these countries is high and rising, and therefore, the level of environmental awareness in also high.

In the study by Dinda (2004) was also concentrated on the conceptual background and theoretical underpinnings of EKC, rather than the empirical evidences. One major contribution of this study was that it discussed the several facades of policy recommendations, which may come out of an EKC estimation study. The study was concluded with a generalized critique on the conceptual and methodological designs. In the published literature of energy and environmental economics, the latest study in our knowledge was carried out by Kijima et al. (2010), and this study was not very different from the previous two studies, apart from that it specifically focused on the model building exercises of the studies reviewed.

By far, a huge number of studies have been done on EKC estimation of various pollutants, irrespective of the pollutant is global or local in nature. The present study surveys the literature on EKC estimation for CO_2 emissions for the period of 1991-2017. The objective of the present study is to envisage the current state of knowledge about the EKC estimation for CO_2 emissions, from the perspective of model design, methodological adaptations, and fulfilment of objective. In this paper, all the selected studies are empirical in nature, and we have segregated the studies in terms of the model design (quadratic and cubic specifications), methodological adaptation (time series or panel data techniques), and fulfillment of objective (whether EKC is achieved or not). Apart from pointing out these distinguished features of the studies, we have discussed the impacts of different explanatory variables used in these studies, and how the EKC estimation results vary within a geographical context. This discussion has been done in keeping with the conceptual framework of EKC hypothesis in the background.

The rest of the paper is organized as per the following: Section-2 provides a conceptual background of EKC hypothesis, Section-3 reviews the literature on various model specifications, Section-4 reviews the literature on methodological adaptations, Section-5 reviews the literature on the various outcomes of EKC estimation studies, Section-6 presents the divergence in turnaround points in geographical contexts, Section-7 reviews the literature on various control variables, and Section-8 presents concludes the study with future directions.

2. The conceptual framework of EKC hypothesis

The premise of EKC hypothesis is based on the interaction between economic growth and environmental degradation, and how the pattern of economic growth can have an adverse effect on environmental quality. According to Grossman (1995), this effect can take place by means of three channels, namely scale effect, composition effect, and technique effect. When the economic growth sets pace, it exerts the scale effect on environment. In order to fuel economic growth, demand of natural resources rises, and consequently, the direct and indirect consumption of natural resources is translated into the production process. Once the production process starts, substantial amount of industrial waste is generated and this by-product of industrial and economic growth poses serious threat to environmental quality. In order to boost economic growth, policymakers overlook the damages to environmental quality, and as a whole, environmental degradation starts to rise with a rise in economic growth. This scenario is visible, especially when the economy is dependent majorly on the primary (agricultural sector) and secondary sectors (manufacturing and industrial sectors). Now, with the rise in income, the industrial structure of a nation starts undergoing a transformation, and therefore, the composition of an economy starts changing. This is where economic growth exerts the composition effect on environmental quality, and this is when the effect of economic growth on environmental quality starts to be positive. During this phase, the secondary sector starts maturing and the industries shift towards cleaner technologies. This industrial transformation is reflected in the urbanization pattern, and the demand for cleaner environment starts increasing. This is the time when the industries start to incorporate technologies for increasing energy efficiency. This progress in the path of technological innovation is the way, by which economic growth exerts the technique effect on environmental quality. During this phase, the tertiary sector (service sector) starts growing, and the economy gradually starts turning out to be knowledge-intensive, rather than capital-intensive. This is the time, when the economy starts investing more in the research and development based activities, and the obsolete and polluting technologies being used in the secondary sector start getting substituted. Therefore, in this phase, environmental quality gradually improves with the rise in economic growth. Now, if this entire phenomenon is graphically represented, then it can be seen that environmental degradation takes a bell-shaped or inverted U-shaped curve, when it is plotted against economic growth (Figure-1). This entire phenomenon is referred to as EKC hypothesis.

Now, income elasticity of environmental quality demand plays a significant role in determining the shape of an EKC, as indicated by several researchers (Beckerman 1992, Stern et al. 1996, Carson et al. 1997, McConnell 1997). The effect of income elasticity on environmental quality can be viewed in terms of the three channels already mentioned. As we have discussed, the scale effect exerts a negative impact on environmental quality during the early stages of economic growth, and it is offset by the positive impacts of composition and technique effects during the later stages of economic growth. This entire phenomenon can be described in terms of income elasticity of environmental quality demand. At the early stages of economic growth, raising the level of income is the primary concern for citizens and policymakers, and this increase in the level of income is achieved even at the cost of environment. When income starts increasing, the living standard of the people improves, and the demand for a better environmental quality starts rising. This demand starts rising which encounters for structural shift. This structural shift takes place in a bilateral manner, i.e. on one hand, the production houses replace their obsolete and polluting technologies with green and cleaner technologies and on other hand, government comes up with several environmental protection policies and regulations, along with reinstating the existing policy mechanisms. Therefore, the demand for better environment and the response from industrial sector and government encourage the enhancement of environmental quality. This shift becomes possible owing to the rising income elasticity of environmental demand, and it is largely responsible for inverted U-shaped of the EKC.

From another angle, this entire phenomenon can be looked into from the direction of the economists from *Club of Rome*, who came up with their idea of *Limits to Growth*, in the year 1972. According to them, economic growth cannot persist for an indefinite period owing to the inadequate availability of natural resources (Meadows et al. 1972). In 1992, with the publication of *The First Global Revolution*, the Club of Rome stated that, due to human intervention in the natural processes, problems like environmental pollution, scarcity of water, and climatic shifts had been taking place, which had been considered as the main symptoms of environmental degradation (King and Schneider, 1992). In spite of they have been contradicted by several economists based on various contexts and research design related issues (Turner, 2008), emergence of concepts, like intergenerational equity (Solow, 1974) and optimal natural resource extraction path (Stiglitz, 1974a, b) was showing that, the issues being raised by economists of the Club of Rome were noteworthy from sustainable economic growth perspective. An extension of this idea was reflected in the concept of endogenous self-regulatory market mechanism for natural resources (Unruh and Moomaw, 1998). During the early stage of economic growth, more importance is given to the primary (agriculture) and secondary (industrial and manufacturing) sectors, and therefore, natural resources are being faced with high level of exploitation. This overuse of natural resources results in faster depletion of natural resources. Provided the stock of the natural resources is constant at the beginning of economic growth and higher level of economic growth results in higher demand of natural resources, the price of natural resources starts to rise. This rise in the price level of natural resources discourage the industrial houses to utilize more natural resources, as it increases the cost of production, and therefore, they try to shift towards less resource consuming or resource-efficient technologies (Duflou et al. 2012). This shift takes place at the later stages of economic growth, and it is also responsible for the betterment of environmental quality. Therefore, we can also see that market mechanism is also responsible for determining the shape of the EKC.

3. Different Specifications of EKC

Though the number of studies on the EKC estimation for CO_2 emissions is extensive, those studies share some common characteristics in terms of the model specification. Most of the studies employed cross-sectional or panel data for the estimation of EKCs, and the model used by those studies can take the following generalized form:

$$C_{it} = \alpha_i + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + D_{it} + \epsilon_{it} \quad (1)$$

Where *C* is CO_2 emissions, *Y* is economic growth, *D* is the additional context specific explanatory variables, *i* is the cross sections, *t* is the time series, α is the constant term, β_k is the coefficients, and ϵ is the standard error term. The model represented in equation-1 can be used to obtain several forms of growth-CO_2 emissions association. Following specifications denote specific functional forms:

(a) $\beta_1 = \beta_2 = \beta_3 = 0$; no growth-$CO_2$ emissions association

(b) $\beta_1 > 0$, $\beta_2 = \beta_3 = 0$; linearly increasing growth-CO_2 emissions association

(c) $\beta_1 < 0$, $\beta_2 = \beta_3 = 0$; linearly decreasing growth-CO_2 emissions association

(d) $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 = 0$; inverted U-shaped growth-CO_2 emissions association

(e) $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 = 0$; U-shaped growth-CO_2 emissions association

(f) $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$; N-shaped growth-CO_2 emissions association

(g) $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$; inverted N-shaped growth-CO_2 emissions association

Out of these model specifications, generally accepted form of EKC is given by the specification (d). In this case, the value of the turnaround point is given by $Y^* = -\beta_1/2\beta_2$. For the case of N-shaped growth-CO_2 emissions association, the values of the turnaround points are given by $Y^* = \left(-\beta_2 \pm \sqrt{\beta_2^2 - 3\beta_1\beta_3}\right)/3\beta_3$. Now, if we look closely, then we can see that the model specifications and the corresponding turnaround points vary majorly vary in terms of the power of income. The higher powers of income help in identifying the further impacts of income on CO_2 emissions, i.e. finding out the sustainability of EKC in any given context by going beyond the traditional inverted U-shaped form of EKC.

The EKC estimation study on CO_2 emissions started with the work of Shafik and Bandyopadhyay (1992). They have analyzed the per capita carbon emissions for 149 countries over the period 1960-1990 using a number of explanatory variables, e.g. investment, income growth, electricity tariff, percentage of trade in GDP, parallel market premium, Dollar's index of openness, debt, political rights, and civil liberties. They used three model specifications, namely linear, quadratic, and cubic, and the EKC hypothesis was not supported. The researchers have attributed to the subsidized electricity in oil exporting countries, which were the major outliers in the dataset used for empirical analysis. Apart from that, it was also found that civil liberties add to the rise in CO_2 emissions, whereas the countries with higher political rights demonstrated reduction in CO_2 emissions. Similar models and dataset were used in the subsequent study by Shafik (1994) and the results obtained from the study were largely the same. These two studies are the ones to use the EKC estimation models with both lower and higher powers of income, and these studies brought forth the comparative scenarios based on the power of income. Therefore, we will review the literature based on the impact of power of income, and other explanatory variables.

3.1. EKCs with quadratic income

First ever study to consider only quadratic power of income was carried out by Holtz-Eakin and Selden (1995). The study was conducted for a panel of 130 countries over the period of 1951-1986. Using panel regression approach, they found the EKC to be inverted U-shaped, with the turnaround point at $35,428. Apart from income, no other explanatory variables were used in the study. In a subsequent study by Cole et al. (1997), the researchers tried to estimate the EKC of CO_2 emissions for 7 regions over the period of 1960-1991. Using panel regression technique, they found the EKC to be inverted U-shaped, with the turnaround points between $25,100 and $62,700. In this study, they have used energy use as an additional explanatory variable.

A summary of the studies on EKC estimation for CO_2 emissions is provided in Table-1. It can be seen that the EKC estimation exercise for CO_2 emissions has been carried out for a number of contexts over different periods of time. Nearly all of the studies considered different forms of energy consumption as explanatory variables, which is the major factor behind economic growth and environmental degradation. Over the years, the studies have been gradually shifting their focus from fossil fuel energy consumption to renewable energy consumption, along with the macroeconomic and social impacts of environmental degradation (see Table-2). Apart from energy consumption, a diverse set of explanatory variables have been used, as keeping with the respective research contexts. Some of these variables are government effectiveness (Osabuohien et al. 2014), FDI (Tang and Tan 2015, Zhang et al. 2017), financial development (Dogan and Turkekul, 2016), crude oil prices (Balaguer and Cantavella, 2016), urbanization (Farhani and Ozturk 2015, Dogan and Turkekul 2016), government effectiveness (Ozturk and Al-Mulali, 2015), population growth (Begum et al. 2015), economic liberalization (Tiwari et al. 2013) and many others.

The gradual shift from scale effect to composition and technique effects can be seen in terms of energy consumption and energy use patterns in this scenario. Starting with Cole et al. (1997), researchers started to consider energy consumption within the EKC framework, and the nature of this energy consumption has undergone a change over the years. By using standard OLS model, Lindmark (2002) analyzed the EKC for CO_2 emissions in Sweden over the period of 1870-1997. Though this study did not found the evidence of any EKC, but it demonstrated the effect of fossil fuel consumption on CO_2 emissions, within an EKC framework. Soon, the researchers started to include renewable energy consumption within the EKC framework, as across the world, energy consumption pattern was undergoing a transformation. The study by Richmond and Kaufmann (2006) considered both fossil fuel and renewable energy consumption within the EKC framework. They have analyzed the EKC for CO_2 emissions for 20 developed and 16 developing countries over the period of 1973-1997, and using OLS approach, they have found the EKC to be inverted U-shaped, with the turnaround points between \$29,687 and \$110,599. In this study, energy consumed from coal, oil, and gas were considered as fossil fuel energy consumption, and energy consumed from hydro and nuclear power were considered as renewable energy consumption. Subsequent to this, a number of studies considered both of the forms of energy into consideration. The first study to consider only renewable energy consumption within an EKC framework was carried out by Iwata et al. (2011). The study was conducted for 28 countries over the period of 1960-2003, and they applied mean group (MG), pooled mean group (PGM), and panel regression techniques to estimate the EKCs. They found the EKC to be inverted U-shaped, with the turnaround points between \$77,126.73 and \$141,682.59.

3.2. EKCs with cubic income

First ever study to consider only cubic power of income was carried out by Moomaw and Unruh (1997). The study was conducted for a panel of 16 countries over the period of 1950-1992. Using panel regression approach, they found the EKC to be N-shaped, with the turnaround points at $12,813 and $18,133. Apart from income, no other explanatory variables were used in the study. In a subsequent study by Suri and Chapman (1998), the researchers tried to estimate the EKC of CO_2 emissions for 33 countries over the period of 1970-1991. Using feasible generalized least squares technique (FGLS), they found the EKC to be inverted U-shaped, with the turnaround points between $55,535 and $143,806. In this study, they have used trade openness as an additional explanatory variable.

A summary of the studies on EKC estimation for CO_2 emissions using cubic income in the EKC framework is provided in Table-1. It can be seen that the EKC estimation exercise for CO_2 emissions has been carried out for a number of contexts over different periods of time, and the results are mostly inconclusive. A number of studies have used energy consumption as an explanatory variable in their empirical models, but the shift from fossil fuel energy consumption to renewable energy consumption has not been much visible in this case (see Table 2). Apart from energy consumption, a diverse set of explanatory variables have been used, as keeping with the respective research contexts. Some of these variables are FDI (Alshehry 2015, Pal and Mitra 2017), public budget in energy research (Álvarez-Herránz et al. 2017), population growth (Akpan and Abang 2015, Shahbaz et al. 2016a), globalization (Shahbaz et al. 2016a), financial development (Moghadam and Dehbashi, 2017) and several others.

The studies in this case also demonstrate the gradual shift from scale effect to composition and technique effects, by means of changes in energy consumption and energy use patterns. The study by Lee et al. (2009) was conducted on 89 countries over the period of 1960-2000. Using system GMM, they found the EKCs to be inverted U-shaped with turnaround point at $17,620, and N-shaped with turnaround points at $15,400 and $30,780. This was the first ever study to include fossil fuel energy consumption within the EKC framework with cubic income. Following this study, researchers started to include fossil fuel energy consumption within the EKC framework. During the second half of 2010, researchers started to include renewable energy consumption within the EKC framework. López-Menéndez et al. (2014) estimated the EKC for 27 EU countries over the period of 1996-2010, and it was the first ever study to include renewable energy consumption within the EKC framework with cubic income. Using panel cointegration technique, the EKC was found to be N-shaped with the turnaround points outside the sample space.

4. Impact of methodological adaptations

In this section, we provide the outcomes of the reviewed EKC estimation studies, which can be segregated into the following categories: (a) studies employing methods pertaining to time series data, and (b) studies employing methods pertaining to panel data. For both of the cases, studies have discovered various shapes of the EKCs, whereas some studies found no evidence of EKC. In the following sections, we will discuss about these two categories.

4.1. Impact of time series data methods

We summarize the findings of the reviewed EKC estimation studies for CO_2 emissions using time series data in Table-3 and 4. Out of the reviewed studies, quadratic form of EKC is the most prominent one among the entire strata. From methodological perspective, ARDL bounds test has been used the most in the studies, followed by cointegration test.

The first EKC estimation study for CO_2 emissions using time series data was carried out by Roca et al. (2001). The study was conducted on Spanish data over the period of 1973-1996, and

OLS was employed to estimate the EKC. However, no EKC was found for Spain. The study by Ang (2007) was the earliest one to find the evidence of EKC using time series data. Employing ARDL bounds test, the study was conducted for France over the period of 1960-2000. The turnaround point of the inverted U-shaped EKC was found to be 11,096.35 (measured in local currency). One of the latest EKC estimation studies carried out in 2017 was done by Ozatac et al. (2017), and this study was conducted for Turkey over the period of 1960-2013. By employing the ARDL bounds test approach, this study also found the evidence of inverted U-shaped EKC for CO_2 emissions, with turnaround point at USD 16,648.84.

Now, if we talk about the N-shaped EKC for CO_2 emissions, cointegration test comes into picture. This study was carried out by Akbostancı et al. (2009) for Turkey over the period of 1968-2003. They have employed cointegration technique to arrive at the inverted N-shaped form of the EKC, with the turnaround points at USD 1,437.80 and USD 1,603.90. This was also the first study on EKC estimation for CO_2 emissions to employ cointegration technique. The study by Chuku (2011) was the first one to provide an evidence of inverted U-shaped EKC. The study was carried out on Nigerian context over the period of 1960-2008, and the turnaround point was achieved at USD 280.84. This is also by far the last study to show the evidence of N-shaped EKC by employing cointegration technique.

During 1991-2017, nearly eight broad categories of time series data methods have been applied, and the results obtained from these studies have been inconclusive. The reviewed studies have demonstrated conflicting results and there is no consensus regarding the existence or shape of the EKC.

4.2. Impact of panel data methods

We summarize the findings of the reviewed EKC estimation studies for CO_2 emissions using panel data in Table-3 and 4. Out of the reviewed studies, quadratic form of EKC is the most prominent one among the entire strata. From methodological perspective, panel regression test has been used the most in the studies, followed by FMOLS.

The first EKC estimation study for CO_2 emissions using panel data was carried out by Holtz-Eakin and Selden (1995). This study was carried out for 130 countries over the period of 1951-1986, and using panel regression approach, this study showed the evidence of inverted U-shaped EKC, with the turnaround point at USD 35,428. Panel regression is the only method found in this review of literature to show the first evidence of all shapes of EKC. Though a number of sophisticated econometric techniques are being discovered for panel data models, panel regression has been proven to be successful for EKC estimation purpose.

Subsequent to panel regression approach, researchers have employed FMOLS the most to estimate the EKC using panel data. The first study to employ the FMOLS was carried out by Apergis and Payne (2009). The study was carried out for 6 Central American countries over the period of 1971-2004. Using FMOLS approach, this study found the evidence of inverted U-shaped EKC. During the last phase of 2017, a study by Zhang et al. (2017) was carried out for 10 Newly Industrialized countries over the period of 1971-2013. Using FMOLS, the study found the evidence of inverted U-shaped EKC, with turnaround point at USD 125.97. Apart from this, this study has also employed OLS and DOLS method, and showed the evidence of inverted U-shaped EKC, both with turnaround points at USD 127.97.

For the entire study period, nearly 23 broad categories of panel data methods have been applied, and the results obtained from these studies have been inconclusive. Similar to the studies pertaining to time series data models, in this case also the reviewed studies have demonstrated conflicting results and there is no consensus regarding the existence or shape of the EKC.

5. Model outcomes

In this section, we provide the outcomes of the reviewed EKC estimation studies, which can be segregated into the following categories: linear (monotonically increasing or decreasing), inverted U-shaped, U-shaped, inverted N-shaped, N-shaped, and no EKC. These studies are further segregated into the nature of data employed in these studies, i.e. time series and panel data. In the consecutive subsections, we will discuss about these two categories.

5.1. Model outcomes for time series data

We summarize the findings of the reviewed EKC estimation studies for CO_2 emissions using time series data in Table-5. Out of the reviewed studies, inverted U-shaped form of EKC is the most prominent one among the entire strata.

Roca et al. (2001) carried out the earliest EKC estimation study for CO_2 emissions using time series data, and the study was conducted on Spanish data over the period of 1973-1996. The researchers used the cubic specification for EKC estimation, and no EKC was found for Spain. The researchers attributed this phenomenon to the low volume of data for carrying out such an analysis. In this context, a latest study by Pal and Mitra (2017) needs special mention. The study was conducted on Indian and Chinese data over the period of 1971-2012, and the researchers employed ARDL bounds test for estimating the EKC for CO_2 emissions in these countries. Though the study concluded by a mere mention of an N-shaped EKC, the model specifications did not comply with the conditions outlined in section 3. Therefore, we had to conclude that the study did not actually find the evidence of any EKC.

One of the earliest studies to achieve the generally accepted inverted U-shaped form of EKC was carried out by Ang (2007). Using quadratic model specification, the study was conducted for France over the period of 1960-2000. The researchers employed ARDL bounds test of cointegration, and found the EKC to be inverted U-shaped with the turnaround point at 11,096.35 (measured in local currency). As per our knowledge, this was also the first study in the literature to consider the ARDL bounds test to estimate EKC for CO_2 emissions for any given context. On the other hand, the study by Omisakin (2009) on Nigerian data over the period of 1970-2005 was the first EKC estimation study for CO_2 emissions to arrive at a U-shaped form of EKC. The researcher employed OLS technique for the estimation purpose, and the turnaround point was estimated at 1,600 (measured in local currency).

The study by Abdallah et al. (2013) is one of the earliest studies to discover the inverted N-shaped EKC for CO_2 emissions using time series data. The study was conducted on Tunisian road transport sector over the period of 1980-2010. Using vector error correction method (VECM), the researchers found the EKC to be inverted N-shaped, with the turnaround points at 74.88 and 578.82 (measured in local currency). In this study, per capita transport value added was chosen as the indicator of economic growth. Ten years earlier, the study by Friedl and Getzner (2003) was one of the earliest studies to find the evidence of N-shaped EKC for CO_2 emissions using time series data. The study was conducted on Austrian data over the period of 1960-1999, and cointegration technique was used to estimate the EKC. In this study, the researchers found two sets of turnaround points: (a) ignoring the structural breaks, the points were 893.83 and 33,200.96 (measured in Euro), and (b) considering structural breaks, the points were 976.50 and 32,965.66.

5.2. Model outcomes for panel data

We summarize the findings of the reviewed EKC estimation studies for CO_2 emissions using panel data in Table-5. Out of the reviewed studies, inverted U-shaped form of EKC is the most prominent one among the entire strata.

Magnani (2001) carried out the earliest EKC estimation study for CO_2 emissions using panel data, and the study was conducted for 152 countries over the period of 1970-1990. Panel regression was employed to estimate the EKC for CO_2 emissions, and the no evidence of EKC was found in the study. In an earlier study, Shafik and Bandyopadhyay (1992) investigated the EKC for CO_2 emissions for 149 countries over the period of 1960-1990. Following the same methodological approach, the researchers found the EKC to be Monotonically Increasing.

The earliest study to find the evidence of generally accepted inverted U-shaped form of EKC was carried out by Holtz-Eakin and Selden (1995). The study was conducted for 130 countries over the period of 1951-1986. Following quadratic specification and panel regression approach, the researchers found the EKC to be inverted U-shaped, with the turnaround point at USD 35,428. On the other hand, the study conducted by Halkos and Tzeremes (2009) was one of the earliest one to find the evidence of U-shaped EKC for CO_2 emission using panel data. The study was conducted for 17 OECD countries over the period of 1980-2002, and the researchers employed panel regression method to estimate the EKC. Using fixed effect, the turnaround point was achieved at USD 11,151.96, and using random effect, the same was achieved at USD 15,949.37.

The study by Moomaw and Unruh (1997) was the earliest study to find the evidence of N-shaped EKC for CO_2 emissions using panel data. The study was conducted for 16 countries over the period of 1950-1992. Following a cubic specification and employing panel regression approach, the researchers found the evidence of N-shaped EKC, with turnaround points at USD

12,813 and USD 18,133. Later, a study by Dijkgraaf and Vollebergh (2005) on 24 OECD countries over the period of 1960-1997 was one of the earliest studies to find the evidence of inverted N-shaped EKC. The study employed panel regression approach, and study revolved around three models: (a) country-fixed effects model, (b) time and country-fixed effects model, and (c) country heterogeneity model. For the first two instances, the EKC was found to be inverted N-shaped, and for the third instance, EKC could not be achieved. For the first model, the turnaround points were USD 252.44 and USD 26,295.51, and for the second model, the turnaround points were USD 358.62 and USD 20,589.59.

6. Geographical context and divergence in turnaround points

In the literature of EKC hypothesis, it has been seen that the turnaround point of the EKC for any geographical location varies from one study to another. This divergence arises owing to the changes in study period, methodological adaptation, power of income, and choice of control variables. In this section, we will consider few geographical locations and the turnaround points achieved by the studies conducted in those locations. India, Turkey, and China have been chosen as the sample geographical locations.

For India, the earliest study to achieve an inverted U-shaped EKC was conducted by Pao and Tsai (2010). The study was conducted for BRIC countries over the period of 1971-2005, and using cointegration, the turnaround point was found to be at USD 427.80. By far, Nasreen et al. (2017) has conducted the latest study on EKC estimation for CO_2 emissions in India, and to arrive at an inverted U-shaped EKC. This study was carried out for 5 South Asian countries over the period of 1980-2012, and turnaround point was achieved at USD 788.40. The whole spectrum of turnaround points achieved for the studies conducted on CO_2 emissions in India is depicted in Figure-2. According to the studies reviewed by us, the lowest turnaround point (≈ USD 209.43) was achieved by Kanjilal and Ghosh (2013), and the highest turnaround point (≈ USD 26,517.29) was achieved by Tiwari et al. (2013).

Now, we will move towards Turkey. The earliest study to achieve an inverted U-shaped EKC for CO_2 emissions in Turkey was conducted by Halicioglu (2009). The study was carried out over the period of 1960-2005, and using ARDL bounds test, the turnaround point was found to be USD 1,661.81. A latest study by Ozatac et al. (2017) was carried out over the period of 1960-2013. Using ARDL bounds test, the turnaround point was found to be USD 16,648.84. The whole spectrum of turnaround points achieved for the studies conducted on CO_2 emissions in Turkey is depicted in Figure-3. According to the studies reviewed by us, the lowest turnaround point (≈ USD 1,661.81) was achieved by Halicioglu (2009), and the highest turnaround point (≈ USD 16,945.73) was achieved by Shahbaz et al. (2016b).

Lastly, we will move towards China. The earliest study to achieve an inverted U-shaped EKC for CO_2 emissions in China was conducted by Jalil and Mahmud (2009). The study was carried out over the period of 1975-2005, and using ARDL bounds test, the turnaround point was found to be RMB 12,992 (≈ USD 2,063.00). A latest study by Wang et al. (2017) was carried out over the period of 2000-2013 for 30 Chinese provinces. Taking panel regression approach, the turnaround points were found to be between USD 656.37 and USD 176,361.65, across mining, manufacturing, and electricity and heat production sectors. The whole spectrum of turnaround points achieved for the studies conducted on CO_2 emissions in China is depicted in Figure-4. According to the studies reviewed by us, the lowest turnaround point (≈ USD 204.51) was achieved by Liu et al. (2015), and the highest turnaround point (≈ USD 176,361.65) was achieved by Wang et al. (2017).

By far, we have looked into the contexts of three countries, where inverted U-shaped EKCs were achieved, and how the turnaround points vary for a single country. Similarly, the divergence can be seen in case of cross-country evidences. For this case, we will take the example of OECD countries. These studies have considered different samples of OECD member countries, different study periods, and various methodological adaptations. Consequently, the studies demonstrate different shapes of EKC, i.e. inverted U-shaped, U-shaped, inverted N-shaped, N-shaped, and linear. The study by Martínez-Zarzoso and Bengochea-Morancho (2004) was conducted on 22 OECD countries over the period of 1975-1998. They found the evidence of both inverted U-shaped and N-shaped EKCs. For the N-shaped EKCs, the first turnaround point ranges from USD 1,302.28 to USD 3,022.86, and the second turnaround point ranges from USD 8,466.38 to USD 59,264.58. For the inverted U-shaped EKC, the turnaround point was found at USD 403.05. Recently, the study by Álvarez-Herránz et al. (2017) provided the evidence of N-shaped EKC for 28 OECD countries over the period of 1990-2014. The turnaround points of the EKC found by the researchers were USD 20,885.38 and USD 67,309.06. On the other hand, the evidence of inverted N-shaped - EKCs were found by Dijkgraaf and Vollebergh (2005) and Vollebergh et al. (2005). For these studies, the first turnaround points range from USD 252.44 to USD 902.72, and the second turnaround points range from USD 15,835.30 to USD 26,295.51. A similar kind of divergence can be seen for the inverted U-shaped EKCs, as well. The maximum value of turnaround point for an inverted U-shaped EKC has been found to be USD 268,337.29 by Bilgili et al. (2016), whereas Martínez-Zarzoso and Bengochea-Morancho (2004) has found the turnaround point to be USD 403.05. Lastly, for U-shaped EKCs, the lowest turnaround point was found to be USD 11,151.96 in a study by Halkos and Tzeremes (2009), whereas the maximum value was found to be USD 206,249.55, as reported by Dogan et al. (2015).

Therefore, we have seen that the divergence in terms of shape and turnaround point of EKC not only varies across the geographical context, but also within the geographical context. However, within a geographical context, temporal boundary, methodological selection, and choice of control variables play significant roles. This finding is in the similar lines with the finding of Stern (2017).

7. Impact of other explanatory variables

The mathematical form of EKC given in equation-1 elucidates that the error term might include the influence caused by other explanatory variables. Now, if the scale, composition, and technique effects are considered, then apart from income, three other major explanatory variables come to pass, i.e. trade openness, fossil fuel consumption, and renewable energy consumption. There has been a wide array of control variables used in the EKC estimation studies. However, we have chosen these three variables, as researchers have been employing these three variables mostly in their empirical models.[1] Over the years, researchers are considering these variables within the EKC framework. We will now discuss these three explanatory variables one-by-one.

7.1. Impact of trade openness

The study by Agras and Chapman (1999) was the first one to consider the aspect of trade openness in an EKC framework. Following a quadratic specification, the study was conducted for the United Nations over the period of 1971-1989. Using panel regression technique, the EKC was found to be inverted U-shaped, with turnaround points between $51.65 and $101.03. In this study, the researchers found import to have negative impact on CO_2 emissions, whereas export has positive impact on CO_2 emissions. Atici (2009) analyzed the EKC for 4 countries over the period of 1980-2002. Following a quadratic specification and applying panel cointegration technique, the researcher found the EKC to be inverted U-shaped, with turnaround point between $2,077 and

[1] Out of 171 reviewed studies, 105 studies (Trade Openness - 61, Fossil Fuel Energy Consumption - 88, Renewable Energy Consumption - 19) have referred to these three variables.

$3,156. In this study, the researcher used trade openness index, and it found to have negative impact of CO_2 emissions. However, in the study of Halicioglu (2009), the impact was found to be positive. This study was conducted for Turkey over the period of 1960-2005, and using ARDL bounds approach, the EKC was found to be inverted U-shaped with turnaround point at $1,661.81.

The study by Jalil and Mahmud (2009) was the first stud to consider total trade volume as the indicator of trade openness. This study was conducted on China over the period of 1975-2005. Following quadratic specification and ARDL bounds approach, the EKC was found to be inverted U-shaped with turnaround point at $40.82. In this study, the impact of trade volume on CO_2 emissions was found to be negative. A subsequent study by Tamazian et al. (2009) introduced foreign direct investment (FDI) as a proxy for trade openness. In this study, they estimated the EKC for BRIC countries over the period of 1992-2004, and following panel cointegration, the EKC was found to be inverted U-shaped with turnaround point between $90.02 and $36,315.50. In this study, FDI stock has both positive and negative impact on CO_2 emissions.

A summary of the studies on EKC estimation for CO_2 emissions considering trade openness is provided in Table-2. It can be seen that the studies have used various indicators of trade openness and the results obtained from using those indicators are inconclusive in nature, irrespective of the nature of the empirical model or context.

7.2. Impact of fossil fuel energy consumption

Cole et al. (1997) conducted the first EKC estimation study on CO_2 emissions. Following a quadratic specification, this study was conducted for 7 countries over the period of 1960-1991. Using panel regression approach, the EKC was found to be inverted U-shaped, with turnaround points between $25,100 and $62,700. In this study, the impact of total energy use on CO_2 emissions has been found to be positive. Subsequent to this, the work by Lindmark (2002) is the EKC estimation study carried out on a single country. In this study, the researcher found the fossil fuel based energy consumption to have a direct positive impact on CO_2 emissions. However, both of these studies considered quadratic income in the empirical framework of EKC.

The first EKC estimation study for CO_2 emissions considering fossil fuel energy consumption within a cubic framework was carried out by Lee et al. (2009). The study was done for 89 countries over a period of 1960-2000. Using system GMM approach, the EKCs were found to be inverted U-shaped with turnaround point at $17,620, and N-shaped with turnaround points at $15,400 and $30,780. In this study, the researchers found the fossil fuel based energy consumption to have a direct positive impact on CO_2 emissions. First single country analysis in this context was carried out by He and Richard (2010). The study was conducted for Canada over the period of 1948-2002. Taking OLS approach, the EKC was found to be inverted U-shaped with the turnaround point at $22,615. In this study also, the researcher found the fossil fuel based energy consumption to have a direct positive impact on CO_2 emissions.

A brief summary of these studies are provided in Table-2. It can be seen that for all the cases, the impact of fossil fuel based energy consumption on CO_2 emissions has been positive.

7.3. Impact of renewable energy consumption

In the EKC estimation studies on CO_2 emissions, renewable energy consumption has been started to be considered since the mid-2000, and till now, it has been used in various forms and in aggregate form, as well. The first study to consider renewable energy consumption was carried out by Richmond and Kaufmann (2006). Following a quadratic specification, this study was carried out for 36 countries over the period of 1973-1997, and using OLS approach, the EKC was found to be inverted U-shaped, with turnaround points between $29,687 and $110,599. This study used hydro and nuclear energy consumption within the empirical framework. The study by Iwata et al.

(2011) considered only nuclear energy consumption within the EKC framework, and it had a negative impact on CO_2 emissions. This segment of result falls in line with the findings of Baek and Kim (2013).

The study by Sulaiman et al. (2013) considered total renewable energy production for the first time within the EKC framework. Following a quadratic model, this study was done for Malaysia over the period of 1980-2009, and using ARDL bounds test, the EKC was found to be inverted U-shaped, with turnaround point at $8.77K. In this case, the impact of renewable energy production on CO_2 emissions was found to be negative. This result was supported by Bölük and Mert (2015), Ben Jebli et al. (2015), Al-Mulali and Ozturk (2016), Dogan and Seker (2016), Jebli et al. (2016), and others, whereas contradicted by Bölük and Mert (2014), Farhani and Shahbaz (2014). Jebli and Youssef (2015) presented mixed results in this context. A brief summary of the studies is listed in Table-2.

7.4. Impact of socio-political parameters

Apart from the three variables mentioned, social parameters also play a pivotal role in EKC estimation studies. Several researchers identified the significance of social and political parameters in determining the shape of an EKC (Cantore 2009, Ibrahim and Law 2014, Sinha and Bhattacharya 2016). According to Panayotou (1993), when the economy reaches the newly industrialized phase, the high level of economic growth is ecologically threatened, and thereby, disequilibrium is created. In order to settle this disequilibrium, along with economic pressure, social and political pressures are also created for enforcing environmental regulations and ecological protection. Therefore, inclusion of socio-political parameters within an EKC framework can always bring forth significant policy implications.

Farzin and Bond (2006) analyzed the EKC for 45 countries over the period of 1980-1998. In this study, the researchers have theoretically shown the impact of societal preferences on environmental quality. They have included democracy and its interaction with income inequality, age composition, and education level within the empirical framework of EKC. Except democracy, rest of the three factors found to have positive impact on CO_2 emissions. This concept was also adapted by Mills and Waite (2009) in the form of democracy index. Dutt (2009) analyzed the EKC for 124 countries over the period of 1984-2002. The researcher included governance, political institutions, government expenditure on education, years of schooling, unemployment, poverty, and consumer confidence within the empirical framework of EKC. These parameters found to have negative impact on CO_2 emissions. Tamazian and Rao (2010) analyzed the EKC for 24 transition economies over the period of 1993-2004. They have included institutional quality as a measure for efficiency in the empirical framework, and it has found to have negative impact on CO_2 emissions. Taguchi (2013) analyzed the EKC for 19 Asian countries over the period of 1950-2009. They have included the later development of the economy within the empirical framework of EKC, and it has found to have a negative impact on CO_2 emissions. Farhani et al. (2014b) analyzed the EKC for MENA countries over the period of 1990-2010. They have included human development indicator (HDI) in their empirical framework, and found to have positive impact on CO_2 emissions. However, this segment of their results was contradicted by Sinha and Sen (2016). Osabuohien et al. (2014) analyzed the EKC for 50 African countries over the period of 1995-2010. They have included institutional quality in their empirical model, and it was measured by average value of rule of law, regulatory quality, and government effectiveness. For the oil-producing countries in the sample, institutional quality found to have positive impact on CO_2 emissions, whereas for the non-oil-producing countries, the institutional quality found to have negative impact.

These indicators have been mostly used in the EKC estimation studies on CO_2 emissions. It is evident that the impacts of these parameters are highly dependent on the context, as the nature of these parameters change in accordance with the context. Therefore, while choosing any context, the socio-political parameters need to be chosen carefully, as a parameter used in one context might not be a proper fit for the second context.

8. Conclusion and Future Directions

The objective of this study is to survey the literature dealing with the EKC estimation of CO_2 emissions, and to understand the existing body of knowledge from the perspective of methodological adaptation, model design, and outcome. The literature on this particular field is growing rapidly with the advent of latest technologies in the field of alternate energy sources, and the studies are focusing on emerging and developed economies. As the natures of growth in both of these cases are radically different from each other, therefore the policymakers should be aware of the dual impact of energy consumption pattern on economic growth and environmental degradation. A broad conclusion from the reviewed studies is that there is no consensus regarding the existence or shape of EKC, i.e. for any geographical context, researchers can come up with different and opposing set of results. These conflicting results may arise due to the time frame of the study, the choice of explanatory variables, and the methodological adaptation.

One observation that we can make from these empirical studies is that, almost all of the studies have by and large focused on analyzing the existence of EKCs, the occurrences of the turnaround points, and the shape of the EKCs. However, out of all the studies reviewed, we have encountered only a handful number of studies, which have also considered the height of the EKCs.

This is an aspect, which is largely missing in the recent empirical literature on the EKC estimation. There are possibilities that the emissions beyond a certain level might not be reversible, and that is the point, from where environmental degradation will only rise monotonically. This is one major aspect, which is largely missed out in empirical analysis carried out during estimation of EKC in any context. If the studies done for a particular country or a group of countries can be seen together, then it becomes visible that the EKCs estimated in that context is not stable, as a change in the time frame can change the shape of EKC, and sometimes even its existence (see Table-1). Saying this, it might be wrong to suggest policy implications based on mere empirical results, which just reveal the turnaround level of economic growth, because the policy recommendations should also take into account the height of the EKCs. Therefore, it will make the policymakers not to wait for the turnaround point to occur, but it will make them to intervene for flattening the EKC.

Environmental sustainability is a part of the broader sustainable development. The recent empirical literature on EKC estimation has been largely inclined towards considering the diverse aspects of economic growth, like international trade, financial development, research and development, globalization, crude oil price, population, etc. The definition of turnaround point in EKC hypothesis is based on the idea of environmental awareness, which is highly correlated with social sustainability. It signifies that without social sustainability, a nation can never achieve environmental sustainability. Therefore, the social indicators should be incorporated within the EKC framework. For example, a country with high literacy rate and low unemployment is expected to have lower level of environmental degradation compared to the country with low literacy rate and high unemployment. Perhaps that is the reason why the developed nations have been able to achieve the turnaround point of EKC, when the developing and emerging economies are yet to reach that. This is a lesson, which the developing and emerging economies should learn from the developed nations, rather than replicating their models in their own countries. In order to achieve the turnaround point in a sustainable manner, these economies should consider a people-public-private partnership approach, which can ensure an inclusive growth, a recipe for sustainable development.

While carrying out any EKC estimation study, it should be remembered that carrying out the study on similar contexts and using new time frame and methodologies might not prove to be fruitful, as it might not add any substantial contribution to the existing energy economics literature. Therefore, the future studies in this context should not only consider new set of variables, but also the dataset should be refined, so that the EKC estimation issues raised by Stern (2004) can be addressed. Considering new perspectives, new set of variables, and going beyond the time series evidences can produce more productive results, based on which the policymakers can come out with substantial policy recommendations for encountering environmental degradation, thereby flattening the EKCs.

The survey of the literature divulged that the number of studies pertaining using panel data is higher compared to those using time series data. While carrying out any EKC estimation study, it should be remembered that providing a cross-country analysis, or intra-provincial analysis for a country, or cross-sector analysis for any country can bring more insights. The major reason behind this is bringing forth comparable references within the geographical context will allow the policymakers to make an informed decision, as the results will depict a comparative scenario. As a future direction, it can be stated that employing robust panel data methods, like FMOLS and GMM might bring forth more significant insights. On the other hand, if the study is conducted on time series data, then the researchers should consider the ARDL bounds test approach, as it will allow the researchers to consider different lag lengths for the control variables, thereby bringing more flexibility in the study.

If the methodological adaptation is kept apart, future studies should consider the variables, like corruption index, social indicators, political scenario, investment in research and development for alternate energy exploration, economic complexity, exports diversity, foreign capital inflows (especially foreign remittances), economic, social and political cooperation etc. These variables might prove to be fruitful, while considering the developing or emerging economies, as these aspects largely influence the environmental degradation scenario in those nations. A number of studies are also considering the interaction variables, which are bringing forth more robustness to the studies (Balsalobre et al., 2015; Álvarez-Herránz et al., 2017; Sinha et al., 2017). This is an aspect, which should be remembered while designing the robust EKC models. Apart from that, the researchers should also consider the model specifications to go beyond the cubic income, as this can have some far-reaching consequences.

Table-1: Evidences of EKC estimation studies for CO_2 emissions

Author(s)	*Context*	*Power of Income*	*Type of Data*	*Methodology*	*Shape of EKC*	*Turnaround Point(s)*	
Shafik and Bandyopadhyay (1992)	149 countries (1960-1990)	Cubic	Panel	Panel regression	Monotonically Increasing	NA	
Shafik (1994)	149 countries (1960-1990)	Cubic	Panel	Panel regression	Monotonically Increasing	NA	
Holtz-Eakin and Selden (1995)	130 countries (1951-1986)	Quadratic	Panel	Panel regression	Inverted U-shaped	35,428	
Cole et al. (1997)	7 countries (1960-1991)	Quadratic	Panel	Panel regression	Inverted U-shaped	Model I	62,700
						Model II	25,100
Moomaw and Unruh (1997)	16 countries (1950-1992)	Cubic	Panel	Panel regression	N-shaped	a. 12,813 b. 18,133	
Agras and Chapman (1999)	United Nations (1971-1989)	Quadratic	Panel	Panel regression	Inverted U-shaped	Model I	3.94
					Inverted U-shaped	Model II	4.62
					Monotonically Increasing	Model III	NA
					Inverted U-shaped	Model IV	2.60
Galeotti and Lanza (1999)	110 countries (1960-1996)	Quadratic	Panel	Panel regression	Inverted U-shaped	All countries	16,646
							15,073
						Annex I Countries	17,855
							17,961
						Non-Annex I Countries	21,757
							19,340
Magnani (2001)	152 countries (1970-1990)	Cubic	Panel	Panel regression	No EKC	NA	
Roca et al. (2001)	Spain (1973-1996)	Cubic	Time Series	OLS	No EKC	NA	
Hill and Magnani (2002)	156 countries (1970-1990)	Cubic	Panel	Pooled OLS	N-shaped	a. 3,007.01 b. 721,919.40	
Lindmark (2002)	Sweden (1870-1997)	Quadratic	Time Series	Kalman Filter	No EKC	NA	
Day and Grafton (2003)	Canada (1958-1995)	Cubic	Time Series	OLS	N-shaped	a. 19,133.10 b. 20,760.86	
Friedl and Getzner (2003)	Austria (1960-1999)	Linear	Time Series	OLS	Monotonically Increasing	NA	
		Quadratic			Monotonically Increasing	NA	
		Cubic			N-shaped	a. 893.83 b. 33,200.96	
					N-shaped	a. 976.50 b. 32,965.66	

Shi (2003)	93 countries (1975-1996)	Linear	Panel	GLS	Monotonically Increasing	Model I	NA
					Monotonically Increasing	Model II	NA
					Monotonically Increasing	Model III	NA
		Quadratic			Inverted U-shaped	Model IV	4,591,065.28
York et al. (2003)	111 countries (1960-2000)	Quadratic	Panel	OLS	Inverted U-shaped	Model I	9.28
						Model II	12.15
						Model III	16.28
Martínez-Zarzoso and Bengochea-Morancho (2004)	22 OECD countries (1975-1998)	Cubic	Panel	MG	N-shaped	Model I	a. 1,302.28 b. 56,916.37
				PMG	No EKC	Model II	NA
				Fixed Effect	No EKC	Model III	NA
				MG	N-shaped	Model IV	a. 2,602.38 b. 19,040.74
				PMG	Inverted U-shaped	Model V	403.05
				Fixed Effect	No EKC	Model VI	NA
				MG	N-shaped	Model VII	a. 1,576.99 b. 32,366.41
				PMG	N-shaped	Model VIII	a. 3,022.86 b. 47,893.69
				Fixed Effect	No EKC	Model IX	NA
				MG	N-shaped	Model X	a. 1,772.15 b. 8,466.38
				PMG	N-shaped	Model XI	a. 1,604.56 b. 59,264.58
				Fixed Effect	No EKC	Model XII	NA
Aldy (2005)	The US (1960-1999)	Quadratic	Panel	OLS	Inverted U-shaped	Model I	15,581.60
				OLS	Monotonically Increasing	Model II	NA
				FGLS	Inverted U-shaped	Model III	16,279.70
				FGLS	Inverted U-shaped	Model IV	18,501.02
				OLS	Inverted U-shaped	Model V	19,979.04
				OLS	Inverted U-shaped	Model VI	26,903.19
				FGLS	Inverted U-shaped	Model VII	23,118.47
				FGLS	Inverted U-shaped	Model VIII	19,674.86
Dijkgraaf and Vollebergh (2005)	24 OECD countries (1960-1997)	Cubic	Panel	Panel regression	Inverted N-shaped	Model I	a. 252.44 b. 26,295.51
						Model II	a. 358.62 b. 20,589.59
					No EKC	Model III	NA

Vollebergh et al. (2005)	24 OECD countries (1960-2000)	Cubic	Panel	Panel regression (Parametric)	Inverted N-shaped	a. 387.47 b. 15,835.30	
				Panel regression (Semi-parametric)		a. 902.72 b. 23,944.04	
Farzin and Bond (2006)	45 countries (1980-1998)	Cubic	Panel	Panel regression	Monotonically Increasing	NA	
Galeotti et al. (2006)	OECD countries (1960-1998)	Cubic	Panel	Panel regression	Inverted U-shaped	Between 8,384.72 and 16,881.79	
Lantz and Feng (2006)	Canada (1970-2000)	Quadratic	Time Series	GLS	Monotonically Increasing	NA	
Richmond and Kaufmann (2006)	36 countries (1973-1997)	Linear	Panel	OLS	Monotonically Increasing	Model I	NA
		Linear			Monotonically Increasing	Model II	NA
		Quadratic			Monotonically Increasing	Model III	NA
		Linear			Monotonically Increasing	Model IV	NA
		Linear			Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA
		Linear			Monotonically Increasing	Model V	NA
		Linear			Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA
		Quadratic			Monotonically Increasing	Model VI	NA
		Quadratic			Inverted U-shaped		32,810.92
		Quadratic			Monotonically Increasing		NA
Ang (2007)	France (1960-2000)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	11,096.35	
Faiz-Ur-Rehman et al. (2007)	4 South Asian countries (1983-2006)	Quadratic	Panel	Pooled regression	Inverted U-shaped	With Trade	1,500.00
							1,650.00
						With Taxes	1,610.31
							598.80
						With Import Duties	994.04
							649.35
						With Export Duties	1,031.99
							769.23
Yaguchi et al. (2007)	Japan and China (1975-1999)	Quadratic	Panel	Panel regression	Inverted U-shaped	Japan	4,340.91
							4,348.66
					Monotonically Increasing	China	NA
							NA
York (2007)	14 EU countries (1960-2000)	Quadratic	Panel	Prais-Winsten regression	Monotonically Increasing	Model I	NA
					Inverted U-shaped	Model II	4.44K
						Model III	5.43K
Akbostancı et al. (2009)	Turkey (1968-2003)	Cubic	Time Series	Cointegration	N-shaped	Model I	a. 1,437.8

							b. 1,603.9
					No EKC	Model II	NA
Apergis and Payne (2009)	6 Central American countries (1971-2004)	Quadratic	Panel	FMOLS	Inverted U-shaped	1.79K	
Atici (2009)	4 countries (1980-2002)	Quadratic	Panel	Panel cointegration	Inverted U-shaped	Fixed effect	2,077
						Random effect	3,156
Dutt (2009)	124 countries (1984-2002)	Quadratic	Panel	Robust OLS	Inverted U-shaped	Model I	29,158.42
				Panel regression		Model II	29,822.46
						Model III	28,730.62
Halicioglu (2009)	Turkey (1960-2005)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	1,661.81	
Halkos and Tzeremes (2009)	17 OECD countries (1980-2002)	Quadratic	Panel	Panel regression	U-shaped	Fixed effect	11,151.96
						Random effect	15,949.37
Jalil and Mahmud (2009)	China (1975-2005)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	12,992	
Lee et al. (2009)	89 countries (1960-2000)	Cubic	Panel	System GMM	Inverted U-shaped	17,620	
					N-shaped	a. 15,400 b. 30,780	
Omisakin (2009)	Nigeria (1970-2005)	Quadratic	Time Series	OLS	U-shaped	1,600	
Tamazian et al. (2009)	BRIC countries (1992-2004)	Linear	Panel	Panel cointegration	Monotonically Increasing	BRIC	NA
						US, Japan and BRIC	NA
		Quadratic			Inverted U-shaped	BRIC	90.02
						US, Japan and BRIC	36,315.50
Acaravci and Ozturk (2010)	19 European countries (1960-2005)	Quadratic	Time Series	ARDL bounds	No EKC	Austria	NA
					No EKC	Belgium	NA
					Inverted U-shaped	Denmark	18,285.64
					No EKC	Finland	NA
					No EKC	France	NA
					No EKC	Germany	NA
					No EKC	Greece	NA
					No EKC	Hungary	NA
					No EKC	Iceland	NA
					No EKC	Ireland	NA
					Inverted U-shaped	Italy	11,362.86
					No EKC	Luxembourg	NA
					No EKC	Netherlands	NA
					No EKC	Norway	NA
					No EKC	Portugal	NA

					No EKC	Spain	NA
					No EKC	Sweden	NA
					No EKC	Switzerland	NA
					No EKC	UK	NA
Apergis and Payne (2010)	11 Commonwealth countries (1992-2004)	Quadratic	Panel	FMOLS	Inverted U-shaped	Without Russia	1.69
						With Russia	1.71
Bello and Abimbola (2010)	Nigeria (1980-2008)	Quadratic	Time Series	FMOLS	No EKC	NA	
Fodha and Zaghdoud (2010)	Tunisia (1961-2004)	Cubic	Time Series	Cointegration	N-Shaped	a. 600.33 b. 765.79	
He and Richard (2010)	Canada (1948-2002)	Cubic	Time Series	OLS	No EKC	Model I	NA
					No EKC	Model II	NA
					No EKC	Model III	NA
					No EKC	Model VI	NA
					No EKC	Model V	NA
					No EKC	Model VI	NA
Iwata et al. (2010)	France (1960-2003)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Model I	21,187.96
						Model II	20,620.03
						Model III	21,097.22
Lean and Smyth (2010)	5 ASEAN countries (1980-2006)	Quadratic	Time Series	DOLS	No EKC	Malaysia	NA
					No EKC	Singapore	NA
					Monotonically Increasing	Indonesia	NA
					Inverted U-shaped	Philippines	1,480.01
					No EKC	Thailand	NA
			Panel		Inverted U-shaped	2,197.32	
Lipford and Yandle (2010)	G8 and +5 countries (1950-2004)	Cubic	Time Series	OLS	No EKC	Canada	NA
		Cubic			N-shaped	France	a. 15,723.24 b. 24,832.32
		Cubic			N-shaped	Germany	a. 16,548.13 b. 25,797.54
		Cubic			No EKC	Italy	NA
		Cubic			No EKC	Japan	NA
		Linear			Monotonically Increasing	Russia	NA
		Cubic			N-shaped	UK	a. 13,613.37 b. 23,682.67
		Cubic			No EKC	US	NA
		Linear			Monotonically Increasing	Brazil	NA
		Cubic			No EKC	China	NA
		Linear			Monotonically Increasing	India	NA

		Quadratic			U-shaped	Mexico	2,356.78
		Quadratic			U-shaped	South Africa	3,105.31
Musolesi et al. (2010)	109 countries (1959-2001)	Quadratic	Panel	Bayesian estimation	Inverted U-shaped	Full sample	208,981.29
					Inverted U-shaped	G7	17,001.75
					Inverted U-shaped	EU15	14,870.62
					Inverted U-shaped	OECD	19,930.37
					U-shaped	Non-OECD	37.52
					U-shaped	40 Poorest	54.60
					Inverted U-shaped	Umbrella	54,671.12
		Cubic			Inverted N-shaped	Full sample	a. 144.76 b. Extremely large
					N-shaped	G7	a. 19,224.59 b. 22,026.47
					N-shaped	EU15	a. 17,692.21 b. 32,534.63
					N-shaped	OECD	a. 13,178.92 b. Extremely large
					Inverted N-shaped	Non-OECD	a. 186.72 b. Extremely large
					No EKC	40 Poorest	NA
					Inverted N-shaped	Umbrella	a. 167.04 b. 170,832.21
Pao and Tsai (2010)	BRIC countries (1971-2005)	Quadratic	Time Series	Panel cointegration	No EKC	Brazil	NA
					U-shaped	Russia	2,394.65
					Inverted U-shaped	India	427.80
					Inverted U-shaped	China	605.34
			Panel		Inverted U-shaped	BRIC	219.83
					Inverted U-shaped	BIC	304.35
Seetanah and Vinesh (2010)	Mauritius (1975-2009)	Quadratic	Time Series	OLS	Monotonically Increasing	NA	
Tamazian and Rao (2010)	24 transition economies (1993-2004)	Quadratic	Panel	System GMM	No EKC	Model I	NA
					Monotonically Increasing	Model II	NA
					Monotonically Increasing	Model III	NA
					Monotonically Increasing	Model IV	NA
					Monotonically Increasing	Model V	NA
					Monotonically Increasing	Model VI	NA
					Monotonically Increasing	Model VII	NA
					No EKC	Model VIII	NA
Chuku (2011)	Nigeria (1960-2008)	Cubic	Time Series	Cointegration	Inverted U-shaped	Standard Model	280.84

					N-shaped	Nested Model	a. 237.23 b. 583.33
Guangyue and Deyong (2011)	27 Chinese provinces (1990-2007)	Quadratic	Panel	Cointegration	Inverted U-shaped	All	59,874
					Inverted U-shaped	Eastern	73,130
					Inverted U-shaped	Central	54,176
					U-shaped	Western	6,002
Iwata et al. (2011)	28 countries (1960-2003)	Quadratic	Panel	MG	No EKC	NA	
				PMG	Inverted U-shaped	77,126.73	
				Panel regression	Inverted U-shaped	141,682.59	
Jalil and Feridun (2011)	China (1953-2006)	Linear	Time Series	ARDL bounds	Monotonically Increasing	Model I	NA
						Model II	NA
		Quadratic			Inverted U-shaped	Model III	24.59
						Model IV	27.50
Jobert et al. (2011)	55 countries (1970-2008)	Quadratic	Panel	OLS	Inverted U-shaped	Model I	10.33
						Model II	13.54
Nasir and Rehman (2011)	Pakistan (1972-2008)	Quadratic	Time Series	Cointegration	Inverted U-shaped	624.84	
Pao and Tsai (2011a)	Brazil (1980-2007)	Quadratic	Time Series	Cointegration	No EKC	Model I	NA
					Inverted U-shaped	Model II	1,489.08
					No EKC	Model III	NA
Pao and Tsai (2011b)	BRIC countries (1980-2007)	Quadratic	Panel	Panel Cointegration	Inverted U-shaped	281.01	
Pao et al. (2011)	Russia (1990-2007)	Quadratic	Time Series	Cointegration	No EKC	Model I	NA
					Monotonically Increasing	Model II	NA
					No EKC	Model III	NA
					Monotonically Decreasing	Model IV	NA
					U-shaped	Model V	496.42
Wang et al. (2011)	28 Chinese Provinces (1995-2007)	Quadratic	Panel	Panel Cointegration	U-shaped	3,287	
Ahmed and Long (2012)	Pakistan (1971-2008)	Cubic	Time Series	ARDL bounds	Monotonically Decreasing	NA	
Arouri et al. (2012)	12 MENA countries (1981-2005)	Quadratic	Time Series	CCE	Inverted U-shaped	Algeria	
					Inverted U-shaped	Egypt	6,514.00
					Inverted U-shaped	Jordan	3,706.00
					Inverted U-shaped	Lebanon	2.801.00
					U-shaped	Morocco	1413.53
					Monotonically Increasing	Tunisia	NA
					Inverted U-shaped	Bahrain	1,984.00
					Inverted U-shaped	Kuwait	2,697.00
					U-shaped	UAE	2977.36
					Inverted U-shaped	Oman	1,840.00

					Inverted U-shaped	Qatar	3,593.00
					Inverted U-shaped	Saudi Arabia	1,168.00
			Panel		Inverted U-shaped	37,263.00	
Asghari (2012)	Iran (1980-2008)	Cubic	Time Series	2SLS	U-shaped	With Openness	2,655.08
						With FDI	3,049.11
Du et al. (2012)	29 Chinese Provinces (1995-2009)	Quadratic	Panel	Panel regression	Monotonically Increasing	Model I	NA
				Panel regression	Monotonically Increasing	Model II	NA
				Panel regression	Inverted U-shaped	Model III	Extremely large
				Panel regression	Inverted U-shaped	Model IV	Extremely large
				Panel regression	Inverted U-shaped	Model V	Extremely large
				System GMM	Monotonically Increasing	Model VI	NA
				System GMM	No EKC	Model VII	NA
				LSDVC	Inverted U-shaped	Model VIII	Extremely large
				LSDVC	No EKC	Model IX	NA
Esteve and Tamarit (2012a)	Spain (1857-2007)	Linear	Time Series	Cointegration with structural breaks	No EKC	NA	
Esteve and Tamarit (2012b)	Spain (1857-2007)	Quadratic	Time Series	Threshold Cointegration	Inverted U-shaped	13,246.99	
						14,685.19	
Fosten et al. (2012)	The UK (1830-2003)	Cubic	Time Series	OLS	N-shaped	Without Energy Price	a. 9,565.58 b. 18,943.66
						With Energy Price	a. 13,678.16 b. 23,124.25
Hossain (2012)	Japan (1960-2009)	Cubic	Time Series	ARDL bounds	No EKC	NA	
Hussain et al. (2012)	Pakistan (1971-2006)	Cubic	Time Series	OLS	Monotonically Increasing	NA	
Jayanthakumaran et al. (2012)	India and China (1971-2007)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	China	417.06
						India	367.05
Saboori et al. (2012a)	Malaysia (1980-2009)	Quadratic	Time Series	Cointegration	Inverted U-shaped	4,789.70	
Saboori et al. (2012b)	Indonesia (1971-2007)	Quadratic	Time Series	ARDL bounds	U-shaped	774.89	
Shahbaz et al. (2012)	Pakistan (1971-2009)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Extremely large	
Wang (2012)	98 countries (1971-2007)	Quadratic	Panel	FMOLS	Monotonically Increasing	NA	
Abdallah et al. (2013)	Tunisia (1980-2010)	Cubic	Time Series	VECM	Inverted N-shaped	a. 74.88 b. 578.82	
Abdou and Atya (2013)	Egypt (1961-2008)	Quadratic	Time Series	VECM	U-shaped	Model 1	120.76
		Cubic			U-shaped	Model 2	401.19
					U-shaped	Model 3	384.76

					N-shaped	Model 4	a. 653.37 b. 1,862.33
Al Sayed and Sek (2013)	40 countries (1961-2009)	Quadratic	Panel	Panel regression	Inverted U-shaped	Developed countries	14,890.68
							67,846.30
						Developing countries	3,719.81
							8,673.26
Baek and Kim (2013)	Korea (1975-2006)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Case I	Extremely large
						Case II	
Chandran and Tang (2013)	5 ASEAN countries (1971-2008)	Quadratic	Time Series	Johansen cointegration	Monotonically Increasing	Indonesia	NA
					U-shaped	Malaysia	232.00
					No EKC	Singapore	NA
					U-shaped	Thailand	188.53
					No EKC	Philippines	NA
Kanjilal and Ghosh (2013)	India (1971-2008)	Quadratic	Time Series	Threshold cointegration	U-shaped	Base model	209.43
					Inverted U-shaped	Subsample 1	212.05
					No EKC	Subsample 2	NA
Kohler (2013)	South Africa (1960-2009)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	7.39	
Mehrara and ali Rezaei (2013)	BRICS countries (1960-1996)	Quadratic	Panel	Kao Panel cointegration	Inverted U-shaped	5,269.38	
Ozcan (2013)	12 MENA countries (1990-2008)	Quadratic	Time Series	FMOLS	U-shaped	Bahrain	11.84
					Inverted U-shaped	UAE	10.50
					No EKC	Iran	NA
					No EKC	Israel	NA
					Inverted U-shaped	Egypt	7.91
					U-shaped	Syria	6.72
					No EKC	Saudi Arabia	NA
					U-shaped	Turkey	8.47
					U-shaped	Oman	8.45
					No EKC	Jordan	NA
					Inverted U-shaped	Lebanon	10.73
					U-shaped	Yemen	11.93
			Panel		U-shaped	8.24	
Ozturk and Acaravci (2013)	Turkey (1960-2007)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	5,190.83	
Saboori and Sulaiman (2013a)	5 ASEAN countries (1971-2009)	Quadratic	Time Series	ARDL bounds	U-shaped	Indonesia	657.82
					Inverted U-shaped	Malaysia	116.27
					U-shaped	Philippines	1,215.62
					Inverted U-shaped	Singapore	5,731.08
					Inverted U-shaped	Thailand	1,752.81

Saboori and Sulaiman (2013b)	Malaysia (1980-2009)	Quadratic	Time Series	ARDL bounds	No EKC	Energy	NA
					Inverted U-shaped	Coal	5,214.23
					Inverted U-shaped	Gas	5,988.87
					Inverted U-shaped	Electricity	8,288.94
					Inverted U-shaped	Oil	5,851.41
Shahbaz (2013)	Pakistan (1971-2009)	Linear	Time Series	ARDL bounds	No EKC	NA	
		Quadratic			Inverted U-shaped	28,523.84	
Shahbaz et al. (2013a)	Romania (1980-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	197.25	
						201.63	
						105.48	
Shahbaz et al. (2013b)	Turkey (1970-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	4,797.18	
Shahbaz et al. (2013c)	South Africa (1965-2008)	Linear	Time Series	ARDL bounds	Monotonically Increasing	NA	
		Quadratic			Inverted U-shaped	3,463	
Sulaiman et al. (2013)	Malaysia (1980-2009)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	8.77	
Taguchi (2013)	19 Asian countries (1950-2009)	Quadratic	Panel	System GMM	Inverted U-shaped	51,102.94	
Tiwari et al. (2013)	India (1966-2009)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	26,517.29	
Arouri et al. (2014)	Thailand (1971-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	138,220.36	
Azlina et al. (2014)	Malaysia (1975-2011)	Quadratic	Time Series	OLS	Monotonically Increasing	NA	
Bölük and Mert (2014)	16 EU countries (1990-2008)	Quadratic	Panel	Panel regression	Inverted U-shaped	5,549.02	
Boutabba (2014)	India (1971-2008)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	19,370.36	
Cho et al. (2014)	22 OECD countries (1971-2000)	Quadratic	Time Series	FMOLS	Inverted U-shaped	Australia	77.13
					U-shaped	Austria	81.02
					U-shaped	Canada	79.11
					Inverted U-shaped	Denmark	74.91
					U-shaped	Finland	109.50
					No EKC	France	NA
					Inverted U-shaped	Germany	52.66
					Inverted U-shaped	Greece	52.57
					U-shaped	Hungary	40.72
					No EKC	Iceland	NA
					Inverted U-shaped	Ireland	40.14
					Inverted U-shaped	Italy	62.54
					No EKC	Japan	NA
					No EKC	Netherlands	NA

					No EKC	New Zealand	NA
					No EKC	Norway	NA
					No EKC	Portugal	NA
					U-shaped	Spain	68.80
					U-shaped	Sweden	86.86
					Inverted U-shaped	Turkey	28.27
					No EKC	UK	NA
					U-shaped	US	85.47
			Panel		Inverted U-shaped	60.87	
Farhani and Shahbaz (2014)	10 MENA countries (1980-2009)	Quadratic	Panel	FMOLS	Inverted U-shaped	296.02	
						34.03	
				DOLS		377.55	
						36.81	
Farhani et al. (2014a)	Tunisia (1971-2008)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	4,377.35	
Farhani et al. (2014b)	10 MENA countries (1990-2010)	Quadratic	Panel	FMOLS	Inverted U-shaped	31,929.55	
				DOLS		33,024.34	
Kivyiro and Arminen (2014)	6 Sub-Saharan countries (1971-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Congo Republic	1,080.43
					Inverted U-shaped	DRC	462.18
					Inverted U-shaped	Kenya	406.67
					No EKC	South Africa	NA
					No EKC	Zambia	NA
					No EKC	Zimbabwe	NA
Lapinskienė et al. (2014)	27 EU countries (1995-2010)	Cubic	Time Series	OLS	Inverted U-shaped	Between 9,517.02 and 83,973.75	
					U-shaped	Between 2,239.3 and 6,382.01	
					Monotonically Increasing Monotonically Increasing	NA	
Lau et al. (2014)	Malaysia (1970-2008)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	11,018.40	
López-Menéndez et al. (2014)	EU-27 countries (1996-2010)	Cubic	Panel	Random Effect	N-Shaped	a. 45.43 b. 25.05	
					U-Shaped	8.11	
					N-Shaped	a. 64.68 b. 31.47	
				Fixed Effect	Monotonically Decreasing	NA	
					U-Shaped	9.62	
					Monotonically Increasing	NA	
				Fixed & Time Effect	No EKC	NA	
					U-Shaped	2.77	

Onafowora and Owoye (2014)	8 countries (1971-2010)	Cubic	Time Series	ARDL bounds	Inverted U-shaped	Brazil	22.08
					Inverted U-shaped	China	17.05
					Inverted U-shaped	Egypt	16.59
					Inverted U-shaped	Japan	10.26
					Inverted N-shaped	South Korea	a. 9.12 b. Extremely Large
					Inverted U-shaped	Mexico	21.34
					Inverted U-shaped	Nigeria	32.86
					Inverted U-shaped	South Africa	22.96
Osabuohien et al. (2014)	50 African countries (1995-2010)	Quadratic	Panel	PDOLS	Inverted U-shaped	Oil Producing	2,147.45
					No EKC	Non-oil Producing	NA
Oshin and Ogundipe (2014)	15 West African countries (1980-2012)	Quadratic	Panel	Pooled OLS	No EKC	NA	
				Fixed Effect	Inverted U-shaped	1,041.68	
				Random Effect	Monotonically Decreasing	NA	
Shafiei and Salim (2014)	29 OECD countries (1980-2011)	Quadratic	Panel	AMG	Monotonically Increasing	NA	
Shahbaz et al. (2014a)	Tunisia (1971-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	1,740.56	
Shahbaz et al. (2014b)	The UAE (1975-2011)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	262,158.14	
Yavuz (2014)	Turkey (1960-2007)	Quadratic	Time Series	FMOLS	Inverted U-shaped	1960-1978	2,547.64
						1979-2007	3,849.94
				OLS		1960-1978	2,453.24
						1979-2007	4,958.79
Akpan and Abang (2015)	47 countries (1970-2008)	Quadratic	Panel	GLS	Inverted U-shaped	All	26,595.74
					Monotonically Increasing	High Income	NA
					Inverted U-shaped	Low Income	4,255.32
		Cubic			N-shaped	All	a. 30,650.45 b. 20,391.22
					N-shaped	High Income	a. 29,339.03 b. 24,212.89
					No EKC	Low Income	NA
Alshehry (2015)	Saudi Arabia (1970-2010)	Cubic	Time Series	OLS	N-shaped	a. 18,121.94 b. 13,528.31	
Apergis and Ozturk (2015)	14 Asian countries (1990-2011)	Quadratic	Panel	FMOLS	Inverted U-shaped	10,207.40	
				DOLS	Inverted U-shaped	10,841.80	
				PMGE	Inverted U-shaped	10,511.20	
				MG	Inverted U-shaped	11,695.60	

		Cubic		FMOLS	No EKC	NA	
				DOLS	No EKC	NA	
				PMGE	No EKC	NA	
				MG	No EKC	NA	
Baek (2015)	7 Arctic countries (1960-2010)	Linear	Time Series	ARDL bounds	Monotonically Increasing	Canada	NA
					Monotonically Decreasing	Denmark	NA
					No EKC	Finland	NA
					No EKC	Iceland	NA
					No EKC	Norway	NA
					No EKC	Sweden	NA
					Monotonically Decreasing	US	NA
		Quadratic			No EKC	Canada	NA
					Monotonically Decreasing	Denmark	NA
					No EKC	Finland	NA
					Inverted U-shaped	Iceland	2.31
					U-shaped	Norway	1.22
					No EKC	Sweden	NA
					U-shaped	US	4.24
		Cubic			Monotonically Decreasing	Canada	NA
					Monotonically Decreasing	Denmark	NA
					Monotonically Decreasing	Finland	NA
					No EKC	Iceland	NA
					No EKC	Norway	NA
					N-shaped	Sweden	a. 3.62 b. 1.57
					No EKC	US	NA
Balsalobre et al. (2015)	28 OECD countries (1994-2010)	Cubic	Panel	Panel EGLS	N-shaped	Model 1	a. 13,804.32 b. 54,882.55
						Model 2	a. 15,890.49 b. 72,697.08
						Model 3	a. 16,226.77 b. 71,007.27
Begum et al. (2015)	Malaysia (1970-1980)	Quadratic	Time Series	ARDL bounds	Monotonically Increasing	NA	
				DOLS	U-shaped	8.78K	
Bölük and Mert (2015)	Turkey (1961-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Extremely large	
Dogan et al. (2015)	27 OECD countries (1995-2010)	Quadratic	Panel	DOLS	U-shaped	206,249.55	
Farhani and Ozturk (2015)	Tunisia (1971-2012)	Quadratic	Time Series	ARDL bounds	Monotonically Increasing	NA	
Heidari et al. (2015)	5 ASEAN countries	Quadratic	Panel	PSTR	Inverted U-shaped	4,686	

Ibrahim and Rizvi (2015)	8 Asian countries (1971-2009)	Quadratic	Panel	DOLS	No EKC	All countries	NA
					No EKC		NA
					No EKC		NA
					Inverted U-shaped	All countries without China	6,572.34
					Inverted U-shaped		6,617.04
					Inverted U-shaped		6,489.92
					Inverted U-shaped	ASEAN countries	1,193.33
					Inverted U-shaped		1,190.49
					Inverted U-shaped		1,663.64
Jebli and Youssef (2015)	Tunisia (1980-2009)	Quadratic	Time Series	ARDL bounds	U-shaped	2,878.69	
						3,259.37	
Jebli et al. (2015)	24 Sub-Saharan Africa countries (1980-2010)	Quadratic	Panel	OLS	U-shaped	244.65	
						157.68	
				FMOLS		272.81	
						159.82	
Kasman and Duman (2015)	15 EU Member countries (1992-2010)	Quadratic	Panel	FMOLS	Inverted U-shaped	3,630.71	
						3,728.68	
Liu et al. (2015)	30 Chinese Provinces (1990-2012)	Quadratic	Panel	Pooled OLS	No EKC	Whole China	NA
					No EKC	Eastern China	NA
					U-shaped	Central China	1,183.93
					U-shaped	Western China	204.51
Nasr et al. (2015)	South Africa (1911-2010)	Cubic	Time Series	Co-summability	Inverted N-shaped	a. 1,036.84 b. 4,020.42	
Ozturk and Al-Mulali (2015)	Cambodia (1996-2012)	Quadratic	Time Series	2SLS	U-shaped	Extremely large	
				System GMM			
Seker et al. (2015)	Turkey (1974-2010)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	4,725.39	
Shahbaz et al. (2015)	13 African countries (1980-2012)	Quadratic	Time Series	Johansen Cointegration	Monotonically Increasing	Benin	NA
					Monotonically Increasing	Botswana	NA
					U-shaped	Cameroon	1,195.50
					Inverted U-shaped	Congo Republic	3,213.85
					Inverted U-shaped	Ethiopia	851.74
					No EKC	Gabon	NA
					No EKC	Ghana	NA
					No EKC	Kenya	NA
					U-shaped	Nigeria	518.09
					U-shaped	Senegal	1,118.07
					Inverted U-shaped	South Africa	2.42
					Inverted U-shaped	Togo	1,045.87

					No EKC	Zambia	NA
Tang and Tan (2015)	Vietnam (1976-2009)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Extremely large	
Tutulmaz (2015)	Turkey (1968-2007)	Linear	Time Series	Cointegration	Monotonically Increasing	NA	
		Quadratic			Inverted U-shaped	6,300	
						6,449	
						6,113	
						6,053	
		Cubic			No EKC	NA	
Xu and Lin (2015)	30 Chinese Provinces (2000-2012)	Linear	Panel	Nonparametric additive regression	Inverted U-shaped	Not specified	
Yaduma et al. (2015)	154 countries (1960-2007)	Cubic	Panel	Quantile regression	Inverted N-shaped	World	a. 182.59 b. 17,554.97
					Inverted N-shaped	OECD	a. 299.57 b. 24,398.62
					Inverted N-shaped	Non-OECD	a. 113.87 b. 35,611.87
					Inverted N-shaped	West	a. 495.32 b. 18,344.92
					No EKC	East Europe	NA
					No EKC	Latin America	NA
					Monotonically Decreasing	East Asia	NA
					No EKC	West Asia	NA
					Monotonically Decreasing	Africa	NA
Ahmad et al. (2016)	India (1971-2014)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	1,461.52	
						1,157.78	
						1,010.78	
						786.70	
						863.19	
Al-Mulali and Ozturk (2016)	27 countries (1990-2012)	Quadratic	Panel	FMOLS	Inverted U-shaped	Extremely Large	
Balaguer and Cantavella (2016)	Spain (1874-2011)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	8,103.08	
Bilgili et al. (2016)	17 OECD countries (1977-2010)	Quadratic	Panel	FMOLS	Inverted U-shaped	85,574.52	
				DOLS		268,337.29	
Chakravarty and Mandal (2016)	BRICS countries (1997-2011)	Quadratic	Panel	GMM	U-shaped	3,158.15	
				Panel Regression	Inverted U-shaped	4,822.33	
Destek et al. (2016)	10 CEECs (1991-2011)	Quadratic	Panel	FMOLS	Inverted U-shaped	6,609.56	
				DOLS		5,091.25	
Dogan and Seker (2016)		Quadratic	Panel	FMOLS	Inverted U-shaped	25.40	

	23 countries (1985-2011)					32.00	
				DOLS		31.88	
						30.88	
						35.33	
						28.80	
Dogan and Turkekul (2016)	The US (1960-2010)	Quadratic	Time Series	ARDL bounds	U-shaped	126.58	
Dong et al. (2016)	189 countries (1990-2012)	Cubic	Panel	OLS	Monotonically Increasing	Production based accounting	NA
		Quadratic			Inverted U-shaped		155,140.19
		Linear			Monotonically Increasing		NA
		Cubic			Monotonically Increasing	Consumption based accounting	NA
		Quadratic			Inverted U-shaped		146,956.52
		Linear			Monotonically Increasing		NA
		Cubic		Fixed effect	N-shaped	Production based accounting	a. 36,419.22 b. 74,042.12
		Quadratic			Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA
		Cubic			Monotonically Increasing	Consumption based accounting	NA
		Quadratic			Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA
		Cubic		Random effect	N-shaped	Production based accounting	a. 42,059.96 b. 72,300.01
		Quadratic			Inverted U-shaped		132,701.42
		Linear			Monotonically Increasing		NA
		Cubic			No EKC	Consumption based accounting	NA
		Quadratic			Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA
		Cubic		GMM	No EKC	Production based accounting (All countries)	NA
		Quadratic			Inverted U-shaped		112,612.61
		Linear			Monotonically Increasing		NA
		Cubic			Monotonically Increasing	Consumption based accounting (All countries)	NA
		Quadratic			Inverted U-shaped		179,321.49
		Linear			Monotonically Increasing		NA
		Cubic		GMM	N-shaped	Production based accounting (High income)	a. 38,288.89 b. 80,076.89
		Quadratic			No EKC		NA
		Linear			Monotonically Increasing		NA
		Cubic			Monotonically Decreasing	Consumption based accounting (High income)	NA
		Quadratic			Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA

		Cubic		GMM	Inverted N-shaped	Production based accounting (Middle income)	a. 7,506.39 b. 20,199.24
		Quadratic			Monotonically Decreasing		NA
		Linear			Monotonically Increasing		NA
		Cubic			No EKC	Consumption based accounting (Middle income)	NA
		Quadratic			U-shaped		6,957.55
		Linear			Monotonically Increasing		NA
		Cubic		GMM	No EKC	Production based accounting (Low income)	NA
		Quadratic			Inverted U-shaped		2,257.63
		Linear			No EKC		NA
		Cubic			No EKC	Consumption based accounting (Low income)	NA
		Quadratic			Monotonically Increasing		NA
		Linear			No EKC		NA
		Quadratic		CMG	Monotonically Increasing	Production based accounting	NA
		Linear			Monotonically Increasing		NA
		Quadratic		AMG	Inverted U-shaped		13,645.83
		Linear			Monotonically Increasing		NA
		Quadratic		CMG	Monotonically Increasing	Consumption based accounting	NA
		Linear			Monotonically Increasing		NA
		Quadratic		AMG	Monotonically Increasing		NA
		Linear			Monotonically Increasing		NA
Ertugrul et al. (2016)	10 Developing countries (1971-2011)	Quadratic	Time Series	ARDL bounds	No EKC	Malaysia	NA
					No EKC	Thailand	NA
					Inverted U-shaped	Turkey	6,863.63
					Inverted U-shaped	India	313.98
					No EKC	Brazil	NA
					No EKC	South Africa	NA
					No EKC	Mexico	NA
					Inverted U-shaped	China	2,527.41
					Monotonically Increasing	Indonesia	NA
					Inverted U-shaped	Korea	1,665.11
Jebli et al. (2016)	25 OECD countries (1980-2010)	Quadratic	Panel	FMOLS	Inverted U-shaped	72,264.18	
				DOLS		59,010.76	
Li et al. (2016)	28 Chinese Provinces (1996-2012)	Quadratic	Panel	PMG	Inverted U-shaped	12,008.06	
						4,094.98	
				MG	No EKC	NA	
				DFE	Inverted U-shaped	18,661.36	
						7,563.09	

				GMM	Inverted U-shaped	Between 3,267.68 and 3,990.48	
Lorente and Álvarez-Herranz (2016)	17 OECD countries (1990-2012)	Cubic	Panel	Fixed effect	N-shaped	With energy regulation	a. 21,917.18 b. 69,282.09
				2SLS		Without dampening effect	a. 24,497.41 b. 55,370.58
						With dampening effect	a. 21,917.18 b. 69,282.09
				PLS		With AR(1) correction	a. 22,193.98 b. 64,426.71
Sephton and Mann (2016)	The UK (1830-2003)	Quadratic	Time Series	OLS	Inverted U-shaped	9,052.67	
Shahbaz et al. (2016a)	Australia (1970-2012)	Cubic	Time Series	ARDL bounds	Monotonically Decreasing	NA	
Shahbaz et al. (2016b)	N11 countries (1972-2013)	Quadratic	Panel	OLS	Inverted U-shaped	Pakistan	5,267.95
							3,218.78
						Turkey	16,945.73
							5,275.43
Sinha and Sen (2016)	BRIC countries (1980-2013)	Quadratic	Panel	System GMM	Inverted U-shaped	Extremely Large	
Sugiawan and Managi (2016)	Indonesia (1971-2010)	Linear	Time Series	ARDL bounds	Monotonically Increasing	NA	
		Quadratic			Inverted U-shaped	7,729.24	
Xu and Lin (2016)	30 Chinese Provinces (2000-2013)	Linear	Panel	Nonparametric additive regression	Inverted U-shaped	Not specified	
Zambrano-Monserrate et al. (2016)	Brazil (1971-2011)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	2,240.06	
Ahmad et al. (2017)	Croatia (1992-2011)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	48.68K	
Álvarez-Herránz et al. (2017)	28 OECD countries (1990-2014)	Cubic	Panel	Panel Regression	N-shaped	a. 20,885.38 b. 67,309.06	
Apergis et al. (2017)	48 US States (1960-2010)	Quadratic	Panel	MG	Inverted U-shaped	2.26	
				MG-FMOLS		2.26	
				MG-DOLS		2.26	
				CCE-MG		2.51	
				CupBC		2.23	
				CupFM		2.21	
Gill et al. (2017)	Malaysia (1970-2011)	Quadratic	Time Series	ARDL bounds	Monotonically Increasing	NA	
Jaforullah and King (2017)	7 countries (1960-2010)	Linear	Time Series	ARDL bounds	No EKC	NA	
		Quadratic			No EKC	Norway	NA
						Sweden	NA
						US	NA

					Inverted U-shaped	Canada	25,168.12
						Denmark	28,638.29
						Finland	29,336.43
						Iceland	27,164.80
		Cubic			No EKC	Denmark	NA
						Iceland	NA
						Canada	NA
						Finland	NA
						Norway	NA
						US	NA
					N-shaped	Sweden a. 21,334.09 b. 36,527.51	
Moghadam and Dehbashi (2017)	Iran (1970-2011)	Cubic	Time Series	ARDL bounds	Inverted N-shaped	a. 2.36 Million b. 3.98 Million	
Nasreen et al. (2017)	5 South Asian countries (1980-2012)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	Pakistan	350.72
						India	788.40
						Bangladesh	512.86
						Nepal	589.93
						Sri Lanka	340.36
Neve and Hamaide (2017)	28 countries (1990-2010)	Cubic	Panel	OLS WLS	No EKC	NA	
Pal and Mitra (2017)	India and China (1971-2012)	Cubic	Time Series	ARDL bounds	No EKC	NA	
Rehman and Rashid (2017)	SAARC countries (1960-2015)	Quadratic	Panel	FMOLS DOLS	No EKC	NA	
Sapkota and Bastola (2017)	14 Latin American countries (1980-2010)	Quadratic	Panel	Panel Regression	Inverted U-shaped	2,692.05	
						3,157.99	
					U-shaped	1,288.83	
Ouyang and Lin (2017)	China (1978-2011)	Quadratic	Time Series	Johansen Cointegration	Inverted U-shaped	Extremely Large	
Ozatac et al. (2017)	Turkey (1960-2013)	Quadratic	Time Series	ARDL bounds	Inverted U-shaped	16,648.84	
Sinha et al. (2017)	N11 countries (1990-2014)	Cubic	Panel	System GMM	N-shaped	All countries	a. 2.78 b. 2,207.39
						Developed	a. 1.09 b. 2,290.36
						Industrialized	a. 1.43 b. 4,600.57
						Emerging	a. 1.71

						b. 6,355.17
Wang et al. (2017)	30 Chinese provinces (2000-2013)	Quadratic	Panel	Panel Regression	Inverted U-shaped	Between 656.37 and 176,361.65
Zhang et al. (2017)	10 Newly Industrialized countries (1971-2013)	Quadratic	Panel	OLS	Inverted U-shaped	127.97
				FMOLS		125.97
				DOLS		127.97
Zoundi (2017)	25 African countries (1980-2012)	Quadratic	Panel	DOLS	No EKC	NA
				System GMM	U-shaped	378.99
				Dynamic Fixed Effect	No EKC	NA
				MG	No EKC	NA
				PMG	No EKC	NA

Note:

2SLS: Two-Stage Least Square;

AMG: Augmented Mean Group;

ARDL: Autoregressive Distributed Lag;

CCE: Common Correlated Effects;

CupBC: Bias-Corrected Continuously Updated Estimator

CupFM: Fully-Modified Continuously Updated Estimator

DEA: Data Envelope Analysis;

DFE: Dynamic Fixed-Effects Estimator;

DOLS: Dynamic Ordinary Least Square;

EGLS: Empirical Generalized Least Squares;

FGLS: Feasible Generalized Least Squares;

FMOLS: Fully Modified Ordinary Least Square;

GLS: Generalized Last Square;

GMM: Generalized Method of Moments;

LSDVC: Least Square Dummy Variable Estimator;

MG: Mean Group;

OLS: Ordinary Least Square;

PDOLS: Panel Dynamic Ordinary Least Square;

PLS: Panel Least Square;

PMG: Pooled Mean Group;

PSTR: Panel Smooth Transition Regression;

VECM: Vector Error Correction Model;

WLS: Weighted Least Square

Table 2: EKC estimation studies on CO_2 emissions: Classification by explanatory variables

Explanatory Variables	*Studies with quadratic specification*
Trade Openness	Agras and Chapman (1999), Atici (2009), Halicioglu (2009), Jalil and Mahmud (2009), Tamazian et al. (2009), Bello and Abimbola (2010), Iwata et al. (2010), Tamazian and Rao (2010), Jalil and Feridun (2011), Nasir and Rehman (2011), Pao and Tsai (2011b), Du et al. (2012), Jayanthakumaran et al. (2012), Saboori et al. (2012b), Shahbaz et al. (2012), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Kohler (2013), Ozturk and Acaravci (2013), Shahbaz (2013), Shahbaz et al. (2013b, c), Sulaiman et al. (2013), Tiwari et al. (2013), Arouri et al. (2014), Boutabba (2014), Farhani et al. (2014a, b), Kivyiro and Arminen (2014), Lau et al. (2014), Osabuohien et al. (2014), Oshin and Ogundipe (2014), Shahbaz et al. (2014a, b), Akpan and Abang (2015), Ben Jebli et al. (2015), Dogan et al. (2015), Farhani and Ozturk (2015), Jebli and Youssef (2015), Kasman and Duman (2015), Ozturk and Al-Mulali (2015), Seker et al. (2015), Tang and Tan (2015), Al-Mulali and Ozturk (2016), Dogan and Seker (2016), Dogan and Turkekul (2016), Ertugrul et al. (2016), Jebli et al. (2016), Li et al. (2016), Sinha and Sen (2016), Ozatac et al. (2017), Sapkota and Bastola (2017), Zhang et al. (2017)
Fossil Fuel Energy Consumption	Cole et al. (1997), Lindmark (2002), Richmond and Kaufmann (2006), Ang (2007), Apergis and Payne (2009), Atici (2009), Halicioglu (2009), Jalil and Mahmud (2009), Tamazian et al. (2009), Acaravci and Ozturk (2010), Apergis and Payne (2010), Bello and Abimbola (2010), Iwata et al. (2010), Lean and Smyth (2010), Pao and Tsai (2010), Tamazian and Rao (2010), Nasir and Rehman (2011), Pao and Tsai (2011a, b), Pao et al. (2011), Wang et al. (2011), Arouri et al. (2012), Du et al. (2012), Jayanthakumaran et al. (2012), Saboori et al. (2012b), Shahbaz et al. (2012), Baek and Kim (2013), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Kohler (2013), Ozcan (2013), Ozturk and Acaravci (2013), Saboori and Sulaiman (2013a, b), Shahbaz (2013), Shahbaz et al. (2013a, b), Tiwari et al. (2013), Arouri et al. (2014), Bölük and Mert (2014), Boutabba (2014), Cho et al. (2014), Farhani and Shahbaz (2014), Farhani et al. (2014a, b), Kivyiro and Arminen (2014), Shahbaz et al. (2014a, b), Yavuz (2014), Akpan and Abang (2015), Dogan et al. (2015), Farhani and Ozturk (2015), Heidari et al. (2015), Jebli and Youssef (2015), Kasman and Duman (2015), Ozturk and Al-Mulali (2015), Seker et al. (2015), Shahbaz et al. (2015), Tang and Tan (2015), Ahmad et al. (2016), Al-Mulali and Ozturk (2016), Chakravarty and Mandal (2016), Dogan and Seker (2016), Dogan and Turkekul (2016), Ertugrul et al. (2016), Jebli et al. (2016), Li et al. (2016), Shahbaz et al. (2016b), Sinha and Sen (2016), Zambrano-Monserrate et al. (2016), Nasreen et al. (2017), Rehman and Rashid (2017), Sapkota and Bastola (2017), Ozatac et al. (2017), Ouyang and Lin (2017) , Wang et al. (2017), Zhang et al. (2017), Zoundi (2017)
Renewable Energy Consumption	Richmond and Kaufmann (2006), Iwata et al. (2011), Baek and Kim (2013), Sulaiman et al. (2013), Bölük and Mert (2014, 2015), Farhani and Shahbaz (2014), Ben Jebli et al. (2015), Jebli and Youssef (2015), Al-Mulali and Ozturk (2016), Dogan and Seker (2016), Jebli et al. (2016), Sugiawan and Managi (2016), Zambrano-Monserrate et al. (2016), Gill et al. (2017), Zoundi (2017)
Explanatory Variables	*Studies with cubic specification*
Trade Openness	Hill and Magnani (2002), Friedl and Getzner (2003), Lee et al. (2009), He and Richard (2010), Asghari (2012), Onafowora and Owoye (2014), Akpan and Abang (2015), Shahbaz et al. (2016a), Moghadam and Dehbashi (2017)
Fossil Fuel Energy Consumption	Lee et al. (2009), He and Richard (2010), Fosten et al. (2012), Hussain et al. (2012), Abdallah et al. (2013), Onafowora and Owoye (2014), Akpan and Abang (2015), Shahbaz et al. (2016a), Álvarez-Herránz et al. (2017), Moghadam and Dehbashi (2017), Sinha et al. (2017)
Renewable Energy Consumption	López-Menéndez et al. (2014), Lorente and Álvarez-Herranz (2016), Sinha et al. (2017)

Table 3: EKC estimation studies on CO_2 emissions: Classification by data, model specification, and outcome

Model Specification	*Time Series*	
Linear	*Monotonically Increasing*	*No EKC*
	Friedl and Getzner (2003), Lipford and Yandle (2010), Jalil and Feridun (2011), Shahbaz et al. (2013c), Baek (2015), Tutulmaz (2015), Sugiawan and Managi (2016)	Esteve and Tamarit (2012a), Shahbaz (2013), Baek (2015), Jaforullah and King (2017)
Quadratic	*Monotonically Increasing*	*Monotonically Decreasing*
	Friedl and Getzner (2003), Lantz and Feng (2006), Lean and Smyth (2010), Seetanah and Vinesh (2010), Pao et al. (2011), Arouri et al. (2012), Chandran and Tang (2013), Azlina et al. (2014), Begum et al. (2015), Farhani and Ozturk (2015), Shahbaz et al. (2015), Ertugrul et al. (2016), Gill et al. (2017)	Pao et al. (2011), Baek (2015)
	Inverted U-shaped	
	Ang (2007), Halicioglu (2009), Jalil and Mahmud (2009), Acaravci and Ozturk (2010), Iwata et al. (2010), Lean and Smyth (2010), Pao and Tsai (2010), Jalil and Feridun (2011), Nasir and Rehman (2011), Pao and Tsai (2011a), Arouri et al. (2012), Esteve and Tamarit (2012b), Jayanthakumaran et al. (2012), Saboori et al. (2012a), Shahbaz et al. (2012), Baek and Kim (2013), Kanjilal and Ghosh (2013), Kohler (2013), Ozcan (2013), Ozturk and Acaravci (2013), Saboori and Sulaiman (2013a), Saboori and Sulaiman (2013b), Shahbaz (2013), Shahbaz et al. (2013a, b, c), Sulaiman et al. (2013), Tiwari et al. (2013), Arouri et al. (2014), Boutabba (2014), Cho et al. (2014), Farhani et al. (2014a), Kivyiro and Arminen (2014), Lau et al. (2014), Shahbaz et al. (2014a, b), Yavuz (2014), Baek (2015), Bölük and Mert (2015), Seker et al. (2015), Shahbaz et al. (2015), Tang and Tan (2015), Tutulmaz (2015), Ahmad et al. (2016), Balaguer and Cantavella (2016), Ertugrul et al. (2016), Sephton and Mann (2016), Sugiawan and Managi (2016), Zambrano-Monserrate et al. (2016), Ahmad et al. (2017), Jaforullah and King (2017), Nasreen et al. (2017), Ouyang and Lin (2017), Ozatac et al. (2017)	
	U-shaped	*No EKC*
	Omisakin (2009), Lipford and Yandle (2010), Pao and Tsai (2010), Pao et al. (2011), Arouri et al. (2012), Saboori et al. (2012b), Abdou and Atya (2013), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Ozcan (2013), Saboori and Sulaiman (2013a), Cho et al. (2014), Baek (2015), Begum et al. (2015), Jebli and Youssef (2015), Ozturk and Al-Mulali (2015), Ozturk and Al-Mulali (2015), Shahbaz et al. (2015), Dogan and Turkekul (2016)	Lindmark (2002), Acaravci and Ozturk (2010), Bello and Abimbola (2010), Lean and Smyth (2010), Pao and Tsai (2010), Pao and Tsai (2011a), Pao et al. (2011), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Ozcan (2013), Saboori and Sulaiman (2013b), Cho et al. (2014), Kivyiro and Arminen (2014), Baek (2015), Shahbaz et al. (2015), Ertugrul et al. (2016), Jaforullah and King (2017)
Cubic	*Monotonically Increasing*	*Monotonically Decreasing*
	Hussain et al. (2012), Lapinskienė et al. (2014)	Ahmed and Long (2012), Baek (2015), Shahbaz et al. (2016a)
	Inverted U-shaped	*U-shaped*
	Chuku (2011), Lapinskienė et al. (2014), Onafowora and Owoye (2014)	Asghari (2012), Abdou and Atya (2013), Lapinskienė et al. (2014)
	Inverted N-shaped	*N-shaped*
	Abdallah et al. (2013), Onafowora and Owoye (2014), Nasr et al. (2015), Moghadam and Dehbashi (2017)	Day and Grafton (2003), Friedl and Getzner (2003), Akbostancı et al. (2009), Fodha and Zaghdoud (2010), Lipford and Yandle (2010), Chuku

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<tr><td rowspan="3"></td><td></td><td>(2011), Fosten et al. (2012), Abdou and Atya (2013), Alshehry (2015), Baek (2015), Jaforullah and King (2017)</td></tr>
<tr><td colspan="2">No EKC</td></tr>
<tr><td colspan="2">Roca et al. (2001), Akbostancı et al. (2009), He and Richard (2010), Lipford and Yandle (2010), Hossain (2012), Baek (2015), Tutulmaz (2015), Jaforullah and King (2017), Pal and Mitra (2017)</td></tr>
<tr><td>Model Specification</td><td colspan="2">Panel</td></tr>
<tr><td rowspan="4">Linear</td><td>Inverted U-shaped</td><td>No EKC</td></tr>
<tr><td>Xu and Lin (2015, 2016)</td><td>Dong et al. (2016)</td></tr>
<tr><td colspan="2">Monotonically Increasing</td></tr>
<tr><td colspan="2">Shi (2003), Richmond and Kaufmann (2006), Tamazian et al. (2009), Dong et al. (2016)</td></tr>
<tr><td rowspan="6">Quadratic</td><td>Monotonically Increasing</td><td>Monotonically Decreasing</td></tr>
<tr><td>Agras and Chapman (1999), Aldy (2005), Richmond and Kaufmann (2006), Yaguchi et al. (2007), York (2007), Tamazian and Rao (2010), Du et al. (2012), Wang (2012), Shafiei and Salim (2014), Akpan and Abang (2015), Dong et al. (2016)</td><td>Oshin and Ogundipe (2014), Dong et al. (2016)</td></tr>
<tr><td colspan="2">Inverted U-shaped</td></tr>
<tr><td colspan="2">Holtz-Eakin and Selden (1995), Cole et al. (1997), Agras and Chapman (1999), Shi (2003), York et al. (2003), Aldy (2005), Richmond and Kaufmann (2006), Faiz-Ur-Rehman et al. (2007), Yaguchi et al. (2007), York (2007), Apergis and Payne (2009, 2010), Atici (2009), Dutt (2009), Tamazian et al. (2009), Lean and Smyth (2010), Musolesi et al. (2010), Pao and Tsai (2010), Guangyue and Deyong (2011), Iwata et al. (2011), Jobert et al. (2011), Pao and Tsai (2011b), Arouri et al. (2012), Du et al. (2012), Du et al. (2012), Al Sayed and Sek (2013), Mehrara and ali Rezaei (2013), Taguchi (2013), Bölük and Mert (2014), Cho et al. (2014), Farhani and Shahbaz (2014), Farhani et al. (2014b), Osabuohien et al. (2014), Oshin and Ogundipe (2014), Akpan and Abang (2015), Apergis and Ozturk (2015), Heidari et al. (2015), Ibrahim and Rizvi (2015), Kasman and Duman (2015), Al-Mulali and Ozturk (2016), Bilgili et al. (2016), Bilgili et al. (2016), Chakravarty and Mandal (2016), Destek et al. (2016), Dogan and Seker (2016)</td></tr>
<tr><td>U-shaped</td><td>No EKC</td></tr>
<tr><td>Halkos and Tzeremes (2009), Musolesi et al. (2010), Guangyue and Deyong (2011), Wang et al. (2011), Ozcan (2013), Dogan et al. (2015), Jebli et al. (2015), Liu et al. (2015), Chakravarty and Mandal (2016), Dong et al. (2016), Sapkota and Bastola (2017), Zoundi (2017)</td><td>Tamazian and Rao (2010), Iwata et al. (2011), Du et al. (2012), Osabuohien et al. (2014), Oshin and Ogundipe (2014), Ibrahim and Rizvi (2015), Liu et al. (2015), Dong et al. (2016), Li et al. (2016), Rehman and Rashid (2017), Zoundi (2017)</td></tr>
<tr><td rowspan="6">Cubic</td><td>Monotonically Increasing</td><td>Monotonically Decreasing</td></tr>
<tr><td>Shafik and Bandyopadhyay (1992), Shafik (1994), Farzin and Bond (2006), López-Menéndez et al. (2014), Dong et al. (2016)</td><td>López-Menéndez et al. (2014), Yaduma et al. (2015), Dong et al. (2016)</td></tr>
<tr><td>Inverted U-shaped</td><td>U-Shaped</td></tr>
<tr><td>Martínez-Zarzoso and Bengochea-Morancho (2004), Galeotti et al. (2006), Lee et al. (2009)</td><td>López-Menéndez et al. (2014)</td></tr>
<tr><td>N-shaped</td><td>Inverted N-shaped</td></tr>
<tr><td>Moomaw and Unruh (1997), Hill and Magnani (2002), Martínez-Zarzoso and Bengochea-Morancho (2004), Lee et al. (2009), Musolesi</td><td>Dijkgraaf and Vollebergh (2005), Vollebergh et al. (2005), Musolesi et al. (2010), Yaduma et al. (2015), Dong et al. (2016)</td></tr>
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	et al. (2010), López-Menéndez et al. (2014), Akpan and Abang (2015), Balsalobre et al. (2015), Dong et al. (2016), Lorente and Álvarez-Herranz (2016), Álvarez-Herránz et al. (2017), Sinha et al. (2017)	
	No EKC	
	Magnani (2001), Martínez-Zarzoso and Bengochea-Morancho (2004), Dijkgraaf and Vollebergh (2005), Musolesi et al. (2010), López-Menéndez et al. (2014), Akpan and Abang (2015), Apergis and Ozturk (2015), Yaduma et al. (2015), Dong et al. (2016), Neve and Hamaide (2017)	

Table 4: EKC estimation studies on CO_2 emissions: Classification by data, methodological adaptation, and outcome

Time Series		
Method	*Shape of EKC*	*Studies*
2SLS	U-shaped	Asghari (2012), Ozturk and Al-Mulali (2015)
ARDL bounds	Monotonically Increasing	Jalil and Feridun (2011), Shahbaz et al. (2013c), Baek (2015), Begum et al. (2015), Farhani and Ozturk (2015), Ertugrul et al. (2016), Sugiawan and Managi (2016), Gill et al. (2017)
	Monotonically Decreasing	Ahmed and Long (2012), Baek (2015), Shahbaz et al. (2016a)
	Inverted U-shaped	Ang (2007), Halicioglu (2009), Jalil and Mahmud (2009), Acaravci and Ozturk (2010), Iwata et al. (2010), Jalil and Feridun (2011), Jayanthakumaran et al. (2012), Shahbaz et al. (2012), Baek and Kim (2013), Kohler (2013), Ozturk and Acaravci (2013), Saboori and Sulaiman (2013a, b), Shahbaz (2013), Shahbaz et al. (2013a, b, c), Sulaiman et al. (2013), Tiwari et al. (2013), Arouri et al. (2014), Boutabba (2014), Farhani et al. (2014a), Kivyiro and Arminen (2014), Lau et al. (2014), Onafowora and Owoye (2014), Shahbaz et al. (2014a, b), Baek (2015), Bölük and Mert (2015), Seker et al. (2015), Tang and Tan (2015), Ahmad et al. (2016), Balaguer and Cantavella (2016), Ertugrul et al. (2016), Sugiawan and Managi (2016), Zambrano-Monserrate et al. (2016), Ahmad et al. (2017), Jaforullah and King (2017), Nasreen et al. (2017), Ozatac et al. (2017)
	U-shaped	Saboori et al. (2012b), Saboori and Sulaiman (2013a), Baek (2015), Jebli and Youssef (2015), Dogan and Turkekul (2016)
	N-shaped	Baek (2015), Jaforullah and King (2017)
	Inverted N-shaped	Onafowora and Owoye (2014), Moghadam and Dehbashi (2017)
	No EKC	Acaravci and Ozturk (2010), Hossain (2012), Saboori and Sulaiman (2013b), Shahbaz (2013), Kivyiro and Arminen (2014), Baek (2015), Ertugrul et al. (2016), Jaforullah and King (2017), Pal and Mitra (2017)
CCE	Monotonically Increasing	Arouri et al. (2012)
	Inverted U-shaped	Arouri et al. (2012)
	U-shaped	Arouri et al. (2012)
Cointegration	Monotonically Increasing	Pao et al. (2011), Chandran and Tang (2013), Shahbaz et al. (2015), Tutulmaz (2015)
	Monotonically Decreasing	Pao et al. (2011)
	Inverted U-shaped	Chuku (2011), Nasir and Rehman (2011), Pao and Tsai (2011a), Esteve and Tamarit (2012b), Saboori et al. (2012a), Kanjilal and Ghosh (2013), Shahbaz et al. (2015), Tutulmaz (2015), Ouyang and Lin (2017)
	U-shaped	Pao et al. (2011), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Shahbaz et al. (2015)
	N-shaped	Akbostancı et al. (2009), Fodha and Zaghdoud (2010), Chuku (2011)

	No EKC	Akbostancı et al. (2009), Pao and Tsai (2010), Pao and Tsai (2011a), Pao et al. (2011), Esteve and Tamarit (2012a), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Shahbaz et al. (2015), Tutulmaz (2015)
DOLS	No EKC	Lean and Smyth (2010)
FMOLS	No EKC	Bello and Abimbola (2010), Ozcan (2013), Cho et al. (2014)
Kalman Filter	No EKC	Lindmark (2002)
OLS	No EKC	Roca et al. (2001), He and Richard (2010), Lipford and Yandle (2010)
		Panel
Method	*Shape of EKC*	*Studies*
2SLS	N-shaped	Lorente and Álvarez-Herranz (2016)
AMG	Monotonically Increasing	Shafiei and Salim (2014), Dong et al. (2016)
	Inverted U-shaped	Dong et al. (2016)
Bayesian estimation	Inverted U-shaped	Musolesi et al. (2010)
	U-shaped	Musolesi et al. (2010)
	Inverted N-shaped	Musolesi et al. (2010)
	N-shaped	Musolesi et al. (2010)
	No EKC	Musolesi et al. (2010)
CCE	Inverted U-shaped	Arouri et al. (2012), Apergis et al. (2017)
CMG	Monotonically Increasing	Dong et al. (2016)
Cointegration	Monotonically Increasing	Tamazian et al. (2009)
	Inverted U-shaped	Atici (2009), Tamazian et al. (2009), Pao and Tsai (2010), Guangyue and Deyong (2011), Pao and Tsai (2011b), Mehrara and ali Rezaei (2013)
	U-shaped	Guangyue and Deyong (2011), Wang et al. (2011)
CupBC	Inverted U-shaped	Apergis et al. (2017)
CupFM	Inverted U-shaped	Apergis et al. (2017)
DFE	Inverted U-shaped	Li et al. (2016)
DOLS	Inverted U-shaped	Lean and Smyth (2010), Farhani and Shahbaz (2014), Farhani et al. (2014b), Osabuohien et al. (2014), Apergis and Ozturk (2015), Ibrahim and Rizvi (2015), Bilgili et al. (2016), Destek et al. (2016), Dogan and Seker (2016), Jebli et al. (2016), Zhang et al. (2017)
	U-shaped	Dogan et al. (2015)
	No EKC	Osabuohien et al. (2014), Apergis and Ozturk (2015), Ibrahim and Rizvi (2015), Rehman and Rashid (2017), Zoundi (2017)
Panel regression	Monotonically Increasing	Shafik and Bandyopadhyay (1992), Shafik (1994), Agras and Chapman (1999), Farzin and Bond (2006), Yaguchi et al. (2007), López-Menéndez et al. (2014), Dong et al. (2016)
	Monotonically Decreasing	López-Menéndez et al. (2014), Oshin and Ogundipe (2014)
	Inverted U-shaped	Holtz-Eakin and Selden (1995), Cole et al. (1997), Agras and Chapman (1999), Galeotti et al. (2006), Yaguchi et al. (2007), Dutt (2009), Iwata et al. (2011), Du et al. (2012), Al Sayed and Sek (2013), Bölük and Mert (2014), Oshin and Ogundipe (2014), Chakravarty and Mandal (2016), Dong et al. (2016), Sapkota and Bastola (2017), Wang et al. (2017)
	U-shaped	Halkos and Tzeremes (2009), López-Menéndez et al. (2014), Sapkota and Bastola (2017)

	N-shaped	Moomaw and Unruh (1997), López-Menéndez et al. (2014), Dong et al. (2016), Lorente and Álvarez-Herranz (2016), Álvarez-Herránz et al. (2017)
	Inverted N-shaped	Dijkgraaf and Vollebergh (2005), Vollebergh et al. (2005)
	No EKC	Magnani (2001), Martínez-Zarzoso and Bengochea-Morancho (2004), Dijkgraaf and Vollebergh (2005), López-Menéndez et al. (2014), Dong et al. (2016), Zoundi (2017)
FGLS	Inverted U-shaped	Aldy (2005)
FMOLS	Monotonically Increasing	Wang (2012)
	Inverted U-shaped	Apergis and Payne (2009), Apergis and Payne (2010), Cho et al. (2014), Farhani and Shahbaz (2014), Farhani et al. (2014b), Apergis and Ozturk (2015), Kasman and Duman (2015), Al-Mulali and Ozturk (2016), Bilgili et al. (2016), Destek et al. (2016), Dogan and Seker (2016), Jebli et al. (2016), Zhang et al. (2017)
	U-shaped	Ozcan (2013), Jebli et al. (2015)
	No EKC	Apergis and Ozturk (2015), Rehman and Rashid (2017)
GLS	Monotonically Increasing	Shi (2003), Akpan and Abang (2015)
	Inverted U-shaped	Shi (2003), Akpan and Abang (2015)
	N-shaped	Akpan and Abang (2015)
	No EKC	Akpan and Abang (2015)
GMM	Monotonically Increasing	Tamazian and Rao (2010), Du et al. (2012), Dong et al. (2016)
	Monotonically Decreasing	Dong et al. (2016)
	Inverted U-shaped	Lee et al. (2009), Taguchi (2013), Dong et al. (2016), Li et al. (2016), Sinha and Sen (2016)
	U-shaped	Chakravarty and Mandal (2016), Dong et al. (2016), Zoundi (2017)
	Inverted N-shaped	Dong et al. (2016)
	N-shaped	Lee et al. (2009), Dong et al. (2016), Sinha et al. (2017)
	No EKC	Tamazian and Rao (2010), Du et al. (2012), Dong et al. (2016)
LSDVC	Inverted U-shaped	Du et al. (2012)
	No EKC	Du et al. (2012)
MG	Inverted U-shaped	Apergis and Ozturk (2015), Apergis et al. (2017)
	N-shaped	Martínez-Zarzoso and Bengochea-Morancho (2004)
	No EKC	Martínez-Zarzoso and Bengochea-Morancho (2004), Iwata et al. (2011), Apergis and Ozturk (2015), Li et al. (2016), Zoundi (2017)
Nonparametric additive regression	Inverted U-shaped	Xu and Lin (2015), Xu and Lin (2016)
OLS	Monotonically Increasing	Aldy (2005), Richmond and Kaufmann (2006), Dong et al. (2016)
	Inverted U-shaped	York et al. (2003), Aldy (2005), Richmond and Kaufmann (2006), Dutt (2009), Jobert et al. (2011), Dong et al. (2016), Shahbaz et al. (2016b), Zhang et al. (2017)
	U-shaped	Jebli et al. (2015), Liu et al. (2015)
	N-shaped	Hill and Magnani (2002)
	No EKC	Oshin and Ogundipe (2014), Liu et al. (2015), Neve and Hamaide (2017)
PLS	N-shaped	Lorente and Álvarez-Herranz (2016)
PSTR	Inverted U-shaped	Heidari et al. (2015)

Quantile regression	Monotonically Decreasing	Yaduma et al. (2015)
	Inverted N-shaped	Yaduma et al. (2015)
	No EKC	Yaduma et al. (2015)
WLS	No EKC	Neve and Hamaide (2017)

Table 5: EKC estimation studies on CO_2 emissions: Classification by data and model outcomes

EKC Model Outcomes	*Time Series*
Monotonically Increasing	Friedl and Getzner (2003), Lantz and Feng (2006), Lean and Smyth (2010), Lipford and Yandle (2010), Seetanah and Vinesh (2010), Jalil and Feridun (2011), Pao et al. (2011), Arouri et al. (2012), Hussain et al. (2012), Chandran and Tang (2013), Shahbaz et al. (2013c), Azlina et al. (2014), Lapinskienė et al. (2014), Baek (2015), Begum et al. (2015), Farhani and Ozturk (2015), Shahbaz et al. (2015), Tutulmaz (2015), Ertugrul et al. (2016), Sugiawan and Managi (2016), Gill et al. (2017)
Monotonically Decreasing	Pao et al. (2011), Ahmed and Long (2012), Baek (2015), Shahbaz et al. (2016a)
Inverted U-shaped	Ang (2007), Halicioglu (2009), Jalil and Mahmud (2009), Acaravci and Ozturk (2010), Iwata et al. (2010), Lean and Smyth (2010), Pao and Tsai (2010), Chuku (2011), Jalil and Feridun (2011), Nasir and Rehman (2011), Pao and Tsai (2011a), Arouri et al. (2012), Arouri et al. (2012), Esteve and Tamarit (2012b), Jayanthakumaran et al. (2012), Saboori et al. (2012a), Shahbaz et al. (2012), Baek and Kim (2013), Kanjilal and Ghosh (2013), Kohler (2013), Ozcan (2013), Ozturk and Acaravci (2013), Saboori and Sulaiman (2013 a, b), Shahbaz (2013), Shahbaz et al. (2013 a, b, c), Sulaiman et al. (2013), Tiwari et al. (2013), Arouri et al. (2014), Boutabba (2014), Cho et al. (2014), Farhani et al. (2014a), Kivyiro and Arminen (2014), Lapinskienė et al. (2014), Lau et al. (2014), Onafowora and Owoye (2014), Shahbaz et al. (2014 a, b), Yavuz (2014), Baek (2015), Bölük and Mert (2015), Seker et al. (2015), Shahbaz et al. (2015), Tang and Tan (2015), Tutulmaz (2015), Ahmad et al. (2016), Balaguer and Cantavella (2016), Ertugrul et al. (2016), Sephton and Mann (2016), Sugiawan and Managi (2016), Zambrano-Monserrate et al. (2016), Ahmad et al. (2017), Jaforullah and King (2017), Nasreen et al. (2017), Ouyang and Lin (2017), Ozatac et al. (2017)
U-shaped	Omisakin (2009), Lipford and Yandle (2010), Pao and Tsai (2010), Pao et al. (2011), Arouri et al. (2012), Asghari (2012), Saboori et al. (2012b), Abdou and Atya (2013), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Ozcan (2013), Saboori and Sulaiman (2013a), Cho et al. (2014), Lapinskienė et al. (2014), Baek (2015), Begum et al. (2015), Jebli and Youssef (2015), Ozturk and Al-Mulali (2015), Shahbaz et al. (2015), Dogan and Turkekul (2016)
Inverted N-shaped	Abdallah et al. (2013), Onafowora and Owoye (2014), Nasr et al. (2015), Moghadam and Dehbashi (2017)
N-shaped	Day and Grafton (2003), Friedl and Getzner (2003), Akbostancı et al. (2009), Fodha and Zaghdoud (2010), Lipford and Yandle (2010), Chuku (2011), Fosten et al. (2012), Abdou and Atya (2013), Alshehry (2015), Baek (2015), Jaforullah and King (2017)
No EKC	Roca et al. (2001), Lindmark (2002), Akbostancı et al. (2009), Acaravci and Ozturk (2010), Bello and Abimbola (2010), He and Richard (2010), Lean and Smyth (2010), Lipford and Yandle (2010), Pao and Tsai (2010), Pao and Tsai (2011a), Pao et al. (2011), Esteve and Tamarit (2012a), Hossain (2012), Chandran and Tang (2013), Kanjilal and Ghosh (2013), Ozcan (2013), Saboori and Sulaiman (2013b), Shahbaz (2013), Cho et al. (2014), Kivyiro and Arminen (2014), Baek (2015), Shahbaz et al. (2015), Tutulmaz (2015), Ertugrul et al. (2016), Jaforullah and King (2017), Pal and Mitra (2017)
EKC Model Outcomes	*Panel*

Monotonically Increasing	Shafik and Bandyopadhyay (1992), Shafik (1994), Agras and Chapman (1999), Shi (2003), Aldy (2005), Farzin and Bond (2006), Richmond and Kaufmann (2006), Yaguchi et al. (2007), York (2007), Tamazian et al. (2009), Tamazian and Rao (2010), Du et al. (2012), Wang (2012), Shafiei and Salim (2014), Akpan and Abang (2015), Dong et al. (2016)
Monotonically Decreasing	López-Menéndez et al. (2014), Oshin and Ogundipe (2014), Yaduma et al. (2015), Dong et al. (2016)
Inverted U-shaped	Holtz-Eakin and Selden (1995), Cole et al. (1997), Agras and Chapman (1999), Galeotti and Lanza (1999), York et al. (2003), Aldy (2005), Galeotti et al. (2006), Richmond and Kaufmann (2006), Faiz-Ur-Rehman et al. (2007), Yaguchi et al. (2007), York (2007), Apergis and Payne (2009), Atici (2009), Dutt (2009), Lee et al. (2009), Tamazian et al. (2009), Apergis and Payne (2010), Lean and Smyth (2010), Musolesi et al. (2010), Pao and Tsai (2010), Guangyue and Deyong (2011), Iwata et al. (2011), Jobert et al. (2011), Pao and Tsai (2011b), Du et al. (2012), Al Sayed and Sek (2013), Mehrara and ali Rezaei (2013), Taguchi (2013), Bölük and Mert (2014), Cho et al. (2014), Farhani and Shahbaz (2014), Farhani et al. (2014b), Osabuohien et al. (2014), Oshin and Ogundipe (2014), Akpan and Abang (2015), Apergis and Ozturk (2015), Heidari et al. (2015), Ibrahim and Rizvi (2015), Kasman and Duman (2015), Xu and Lin (2015), Al-Mulali and Ozturk (2016), Bilgili et al. (2016), Chakravarty and Mandal (2016), Destek et al. (2016), Dogan and Seker (2016), Dong et al. (2016), Jebli et al. (2016), Li et al. (2016), Li et al. (2016), Shahbaz et al. (2016b), Sinha and Sen (2016), Xu and Lin (2016), Apergis et al. (2017), Sapkota and Bastola (2017), Wang et al. (2017), Zhang et al. (2017)
U-shaped	Halkos and Tzeremes (2009), Musolesi et al. (2010), Guangyue and Deyong (2011), Wang et al. (2011), Ozcan (2013), López-Menéndez et al. (2014), Dogan et al. (2015), Jebli et al. (2015), Liu et al. (2015), Chakravarty and Mandal (2016), Dong et al. (2016), Sapkota and Bastola (2017), Zoundi (2017)
Inverted N-shaped	Dijkgraaf and Vollebergh (2005), Vollebergh et al. (2005), Musolesi et al. (2010), Yaduma et al. (2015), Dong et al. (2016)
N-shaped	Moomaw and Unruh (1997), Hill and Magnani (2002), Martínez-Zarzoso and Bengochea-Morancho (2004), Lee et al. (2009), Musolesi et al. (2010), López-Menéndez et al. (2014), Akpan and Abang (2015), Dong et al. (2016), Álvarez-Herránz et al. (2017), Sinha et al. (2017)
No EKC	Magnani (2001), Martínez-Zarzoso and Bengochea-Morancho (2004), Dijkgraaf and Vollebergh (2005), Musolesi et al. (2010), Tamazian and Rao (2010), Iwata et al. (2011), Du et al. (2012), López-Menéndez et al. (2014), Osabuohien et al. (2014), Oshin and Ogundipe (2014), Akpan and Abang (2015), Apergis and Ozturk (2015), Ibrahim and Rizvi (2015), Liu et al. (2015), Yaduma et al. (2015), Dong et al. (2016), Li et al. (2016), Neve and Hamaide (2017), Rehman and Rashid (2017), Zoundi (2017)

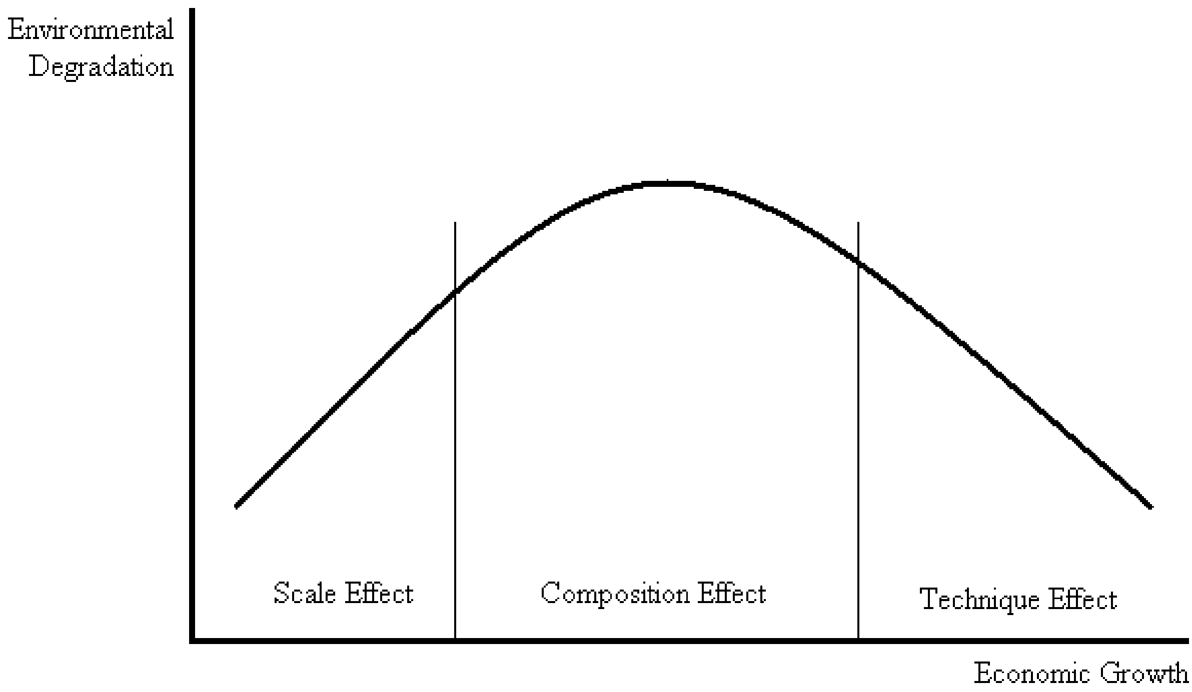

Figure-1: Environmental Kuznets Curve and channels of economic growth effect

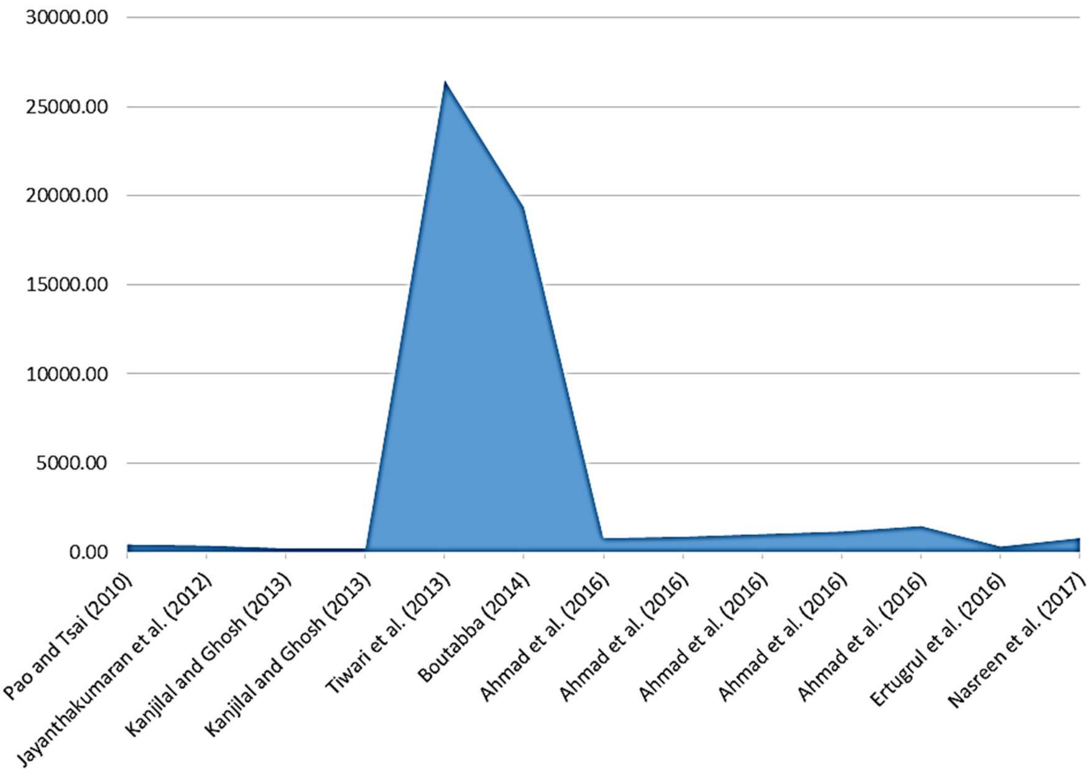

Figure 2: Divergence in turnaround points (in USD) for India

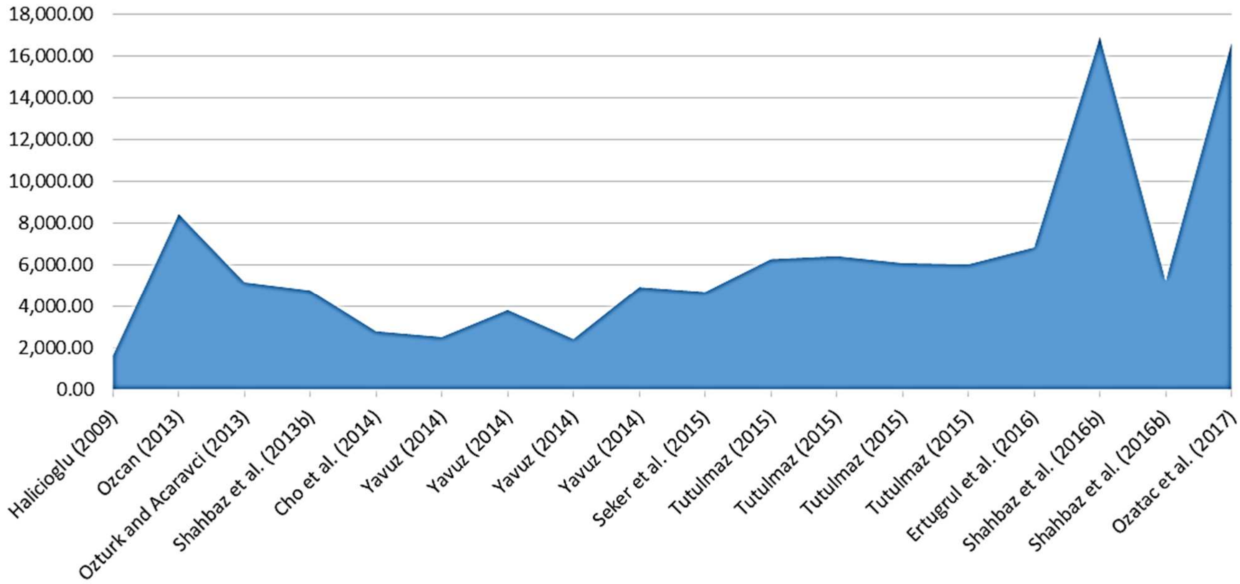

Figure 3: Divergence in turnaround points (in USD) for Turkey

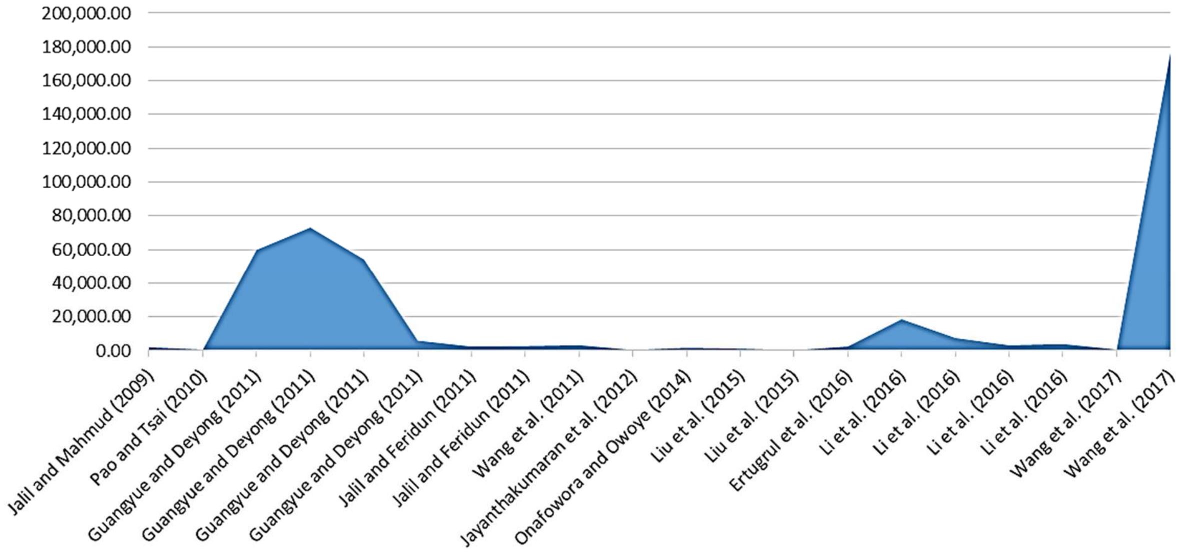

Figure 4: Divergence in turnaround points (in USD) for China

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