

## A Critical Reading of Environmental Kuznets Curve: CO<sub>2</sub> Emissions in a Developing Country

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### Abstract

Environmental Kuznets Curve (EKC) proposes a non-monotonic relationship between the environment and economic level. It also tries to define another important reduced relationship along with economic development. Therefore it has become an attraction for empirical studies giving reference for almost all the areas of the subject of the relationship between economy and environment. An important empirical area of the hypothesis is between CO<sub>2</sub> emission which is a global emission and GDP per capita being the representative of economic development. The present and near future situations of the environmental pressure are evaluated by taking the CO<sub>2</sub> emission as a representative of environmental pressure. Being directly connected to energy, CO<sub>2</sub> emissions are generally evaluated differently than other emissions.

Our study critically analyzes main confusions in the literature in terms of the interpretation of the EKC applications on developing countries using primarily example of estimates for Turkey's CO<sub>2</sub> emissions. As for reduced form EKC time series analyses for Turkey, there are a few statistically robust analyses; and a main diversion cause from minor econometric analysis try to be clarified here.

As to the physical emission values, it is not difficult to predict a short term rise for the carbon dioxide emission level. Particularly, Turkey, as a developing country with lower values is very likely to show further environmental pressure increase in terms of carbon dioxide emission in the short-term. On the other hand, we analyze the main point need to be cleared for a developing country EKC is evaluation of longrun attractor, referring to the cointegration concept Engle and Granger (1991) introduced, which hints the shape of long run relationship. Therefore, we attempt to unite the mathematics of the theory, use analytic investigation and the inferences of the econometric estimations to respond to critiques raised.

**Key words:** *Environmental Kuznets Curve, EKC attractor, Environmental pressure, Economic development*

### Introduction

Since the industrial revolution, the world economy has been depending primarily on fossil fuel. Today carbon fuels such as petroleum, natural gas and coal are the only available large scale energy sources except for nuclear power. In these circumstances, world economies have ended up with a great deal of GHG and CO<sub>2</sub> emissions. As technology and industrial activity advance, the world encounters various environmental problems in different areas.

As environmental problems become more severe, the relationships between environmental pressure and economic development have become more and more important issues. Environmental Kuznets Curve (EKC) hypothesis proposes a non-monotonic relation between environmental deterioration and economic development has become a center of interest for empirical studies and a small literature developed for EKC applications (Neumayer, 2010, s.84-85). Among the reasons a very basic relationship of the theory, existence of regular emissions data and simple atomic structure of the model that is suitable to different modeling technics can be counted.

Evaluations on the hypothesis in the literature are not unanimous and controversial results can be proposed for similar models. An important critical point is also the excessive sensitivity of EKC models to model variation and different econometric methods (e.g. Cole & Neumayer, 2005; De Bruyn & Heintz., 1999; Ekins, 1997; Galeotti et al., 2009; Selden & Song, 1994; Suri & Chapman, 1998). Also, there are some critiques for insufficient econometric methods of especially first term EKC studies (e.g. Galeotti et al., 2009; Dinda, 2004; Perman & Stern, 2003).

Main motivation of this study is, by going through main contradictions on EKC applications of Turkey as an example a country, make main points clear which can be important in terms of policy results that come up from the estimations. Important determinations are used for evaluating EKC structure of developing countries. Second part summarizes the EKC theory, third part conducts the main analyzes and the last part contains use conclusion.

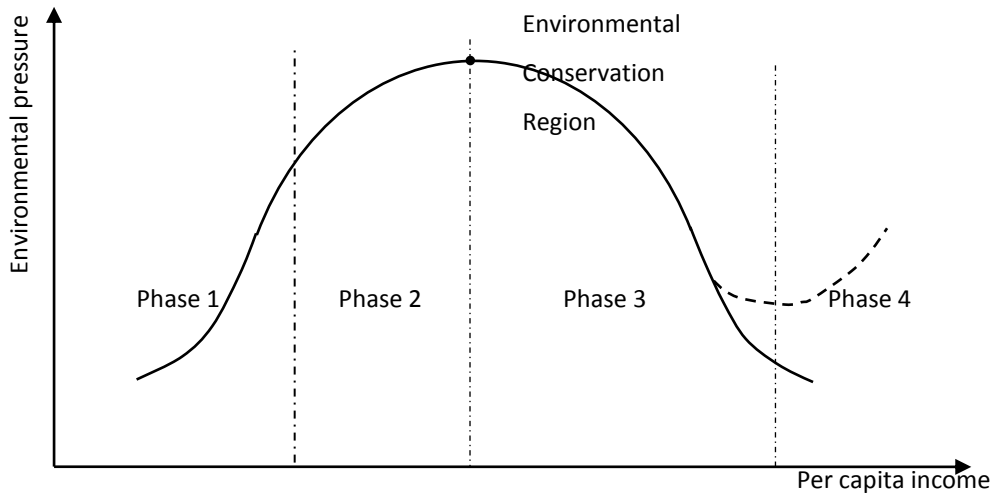
### Environmental Kuznets Curve

After Simon Kuznets' (1955) influential propositions on a relationship between economic development and the income inequality, the inverse-U curve became resonating with the well-known Kuznets Curve in economic literature. Inspired from Kuznets curve, Grossman and Krueger determined a similar relationship between the income and environmental quality. This new relationship is called as Environmental Kuznets Curve (EKC) by Panayotou (1993) and it has reached to a widespread recognition. Wider form models can reveal N form relationships as well as the originally defined inverse-U form relationship (Figure 1). The Equation (1) is the widest form of the EKC models (see De Bruyn & Heintz, 1999) which can be estimated for panel and time series data.

$$co_{i,t} = \alpha_{i,t} + \beta_1 \cdot y_{i,t} + \beta_2 \cdot y_{i,t}^2 + \beta_3 \cdot y_{i,t}^3 + \beta_4 \cdot Z_{i,t} + e_{i,t} \quad (1)$$

co: per capita CO2 emission, kg/population  
 y : gross domestic product per capita, USD/population  
 Z : non-structural other variables  
 i,t : country and time index

CO2 emissions which are directly related with fundamental sustainability problems such as climate change, global warming and energy are assumed as a basic environmental data. CO2 emissions represent environmental pressure in the Equation 1. GDP per capita represents the economic development in the model. Eq. 1 represents a reduced form EKC model. Consequently, the Z variable here represents non-structural other variables like population density etc. It is not included to represent the main relationship of the hypothesis but it is included to represent physical differences of the countries. Therefore, it should be represented in the widest EKC model.



Source: De Bruyn and Heintz, 1999, figure 46.1

Figure 1. Inverse U and N relationships of Environmental Kuznets Curve

Linear, quadratic and cubic form EKC models are estimated as different special form of the wide form. Quadratic form (Eq. 2) and cubic form (Eq. 3) EKC specifications are given below:

Quadratic form,

$$co_t = \alpha + \beta_1 \cdot y_t + \beta_2 \cdot y_t^2 + \beta_3 \cdot trend_t + e_t \quad (2)$$

Cubic form,

$$co_t = \alpha + \beta_1 \cdot y_t + \beta_2 \cdot y_t^2 + \beta_3 \cdot y_t^3 + \beta_4 \cdot trend_t + e_t \quad (3)$$

*co*: per capita CO<sub>2</sub> emissions, kg/population  
*y*: GDP per capita, USD/population  
*trend*: time trend

(Shafik and Bandyopadhyay, 1992)

The Notations are given for the level series in the equations; on the other hand, both level and logarithmic level series EKC models can be and have been estimated in the literature. De Bruyn and Heintz (1999) use following EKC models in a wide-form model:

$$EP_{i,t} = \alpha_{i,t} + \beta_1 \cdot Y_{i,t} + \beta_2 \cdot Y_{i,t}^2 + \beta_3 \cdot Y_{i,t}^3 + \beta_4 \cdot Z_{i,t} + e_{i,t} \quad (4)$$

*EP*: environmental pressure  
*Y*: economic development variable (i.e. income)  
*Z*: other variables  
*i, t*: country and time index  
 $\alpha, \beta$ : constant term and coefficient parameters  
*e*: error term

In equation (4), The EP can be translated as pressure caused by economic development on the environment. As an explanatory variable, income or per capita income is consistently used in the

literature. Different mathematical forms of the explanatory variable are used to determine the form of the relationship curve.  $i$  and  $t$  are used for country index and time index.  $\alpha$  is constant term, shows average environmental pressure when there is no important effect of income on the environment  $\beta_k$ ,  $k$  parameters showing relative weight of explanatory variables. As explained before,  $Z_{i,t}$  represents others variable like population intensity, lagged income, income inequality.  $e_{i,t}$  normally distributed residuals. The model is used to examine 7 different forms related to the environment–economic development relationship (De Bruyn & Heintz, 1999, p.659).

Parametric Conditions: (4a)

1.  $\beta_1 > 0$  and  $\beta_2 = \beta_3 = 0$  emission increase monotonically with income
2.  $\beta_1 < 0$  and  $\beta_2 = \beta_3 = 0$  emission decrease monotonically with income
3.  $\beta_1 > 0$   $\beta_2 < 0$  and  $\beta_3 = 0$  inverse U formed quadratic relationship (EKC relationship)
4.  $\beta_1 < 0$   $\beta_2 > 0$  and  $\beta_3 = 0$  U formed quadratic relationship (inverse of EKC)
5.  $\beta_1 > 0$   $\beta_2 < 0$  and  $\beta_3 > 0$  cubic polynomial N formed relationship
6.  $\beta_1 < 0$   $\beta_2 > 0$  and  $\beta_3 < 0$  cubic polynomial inverse N formed relationship
7.  $\beta_1 = \beta_2 = \beta_3 > 0$  straight line, no relationship between emission and income

There are different forms of relationship and the inverse U form the originally defined as EKC relation is only one of the possible seven forms. When  $\beta_3$  parameter is insignificant the quadratic form is confirmed and positive  $\beta_1$  with negative  $\beta_2$  parameter point out the inverse U relationship (De Bruyn & Heintz, 1999, p.659). Additionally it must be stated that positive  $\beta_1$  must be greater than than negative  $\beta_2$  in magnitude; in this circumstances the turning point of the inverse U is calculated with (5):

$$\begin{aligned} d/dY (EP) = 0 &= d/dY (\alpha + \beta_1 Y + \beta_2 Y^2 + Z) \\ 0 &= \beta_1 + 2\beta_2 Y_{TP} \\ TP &= -\beta_1 / 2.\beta_2 \end{aligned} \quad (5)$$

TP: turning point

For cubic N type curve similar condition can be stated. In addition to De Bruyn & Heintz's parameter condition in (4a),  $|\beta_1| > |\beta_2| > |\beta_3|$  must be complied and turning point can be calculated by (6):

$$\begin{aligned} d/dY (EP) = 0 &= d/dY (\alpha + \beta_1 Y + \beta_2 Y^2 + \beta_3 Y^3 + Z) \\ 0 &= \beta_1 + 2\beta_2 Y_{TP} + 3\beta_3 Y_{TP}^2 \end{aligned} \quad (6)$$

$Y_{TP}$ : turning point income or per capita income (Y) value

The roots of Equation (6) give the first and second turning points of the N type EKC.

### Critical Evaluation on Suggestion of EKC Analyses and Policy Results

As it is explained above in Part 2, the EKC relation is a reduced form relationship which tests the form of total relationships between economic development and emissions (or environmental

indicators under wider generalization). Therefore, including structural variables diminishes the total or reduced relationships to specific ones. Hence, including energy we can measure the direct effect of energy on the emissions but the remaining part is not an EKC relationship anymore. Therefore, these studies should be evaluated in another class (for example, Soytaş and Sarı, 2009; Atıcı ve Kurt, 2007; Halicioğlu, 2009).

Two main types of EKC applications are prevalent in the literature. Panel analysis for group of countries and time series analysis for single country are most common analyses. The panel analyses that carried out in the literature have wide-range results from no-relation to different relation types including short term and long term relations. Putting aside the no-relation results, if we look at the estimations which found EKC relations, first we see that the turning point results are higher for CO<sub>2</sub> emissions from other type of emissions. For example the turning points are more than \$30,000 USD in Tutulmaz et al. (2012), \$28,000\35,000 USD in Holtz-Eakin & Selden (1995) and \$26,000 in Luzzatti & Orsini (2010). These values are apparently higher than the GDP p/c values of developing countries in current state of world. This last point is also valid for Turkey with around \$10,000 USD income per capita value (the Figure 3 value is given around \$8,500 USD in terms of constant 2005 dollars).

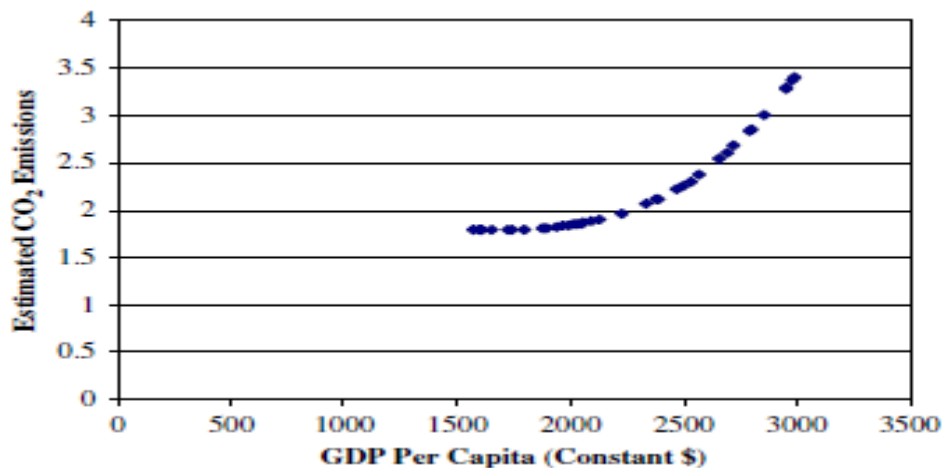
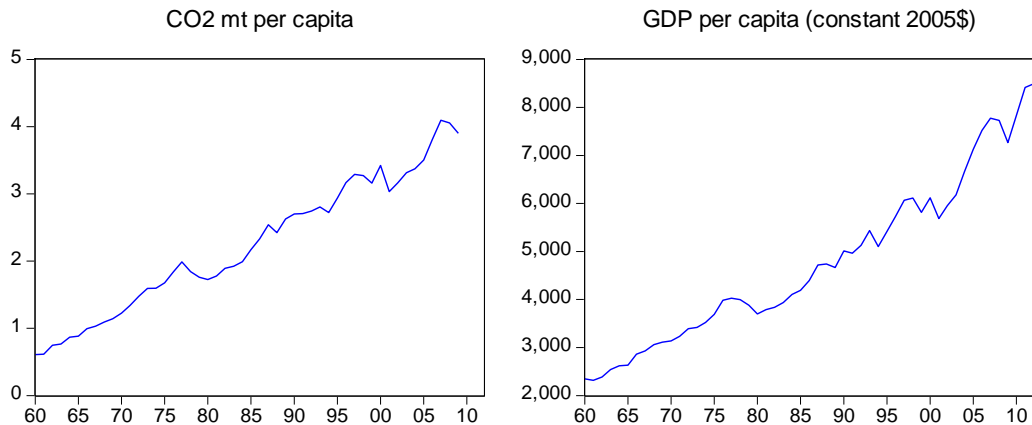


Figure 2. Estimated long-run EKC relationship in Akbostanci et al. (2009)

As for Turkey, the single country time series analyses are rare and the estimates are not unanimous about their results. Lise (2006) and Basar & Temurlenk (2007) studies found series stationary determining linear and N-form relationships consecutively. However, these results are not taken into consideration here because their findings of stationary income and emissions series are not consistent with the current reality that these series are not stationary as well-documented in literature. As a robust study, though, Akbostanci et al. (2009) found N-form EKC relationship with turning points values around \$1400 and \$1600 but with a sample starting after \$1500 values gives only the last rising part of the N-form relation (Figure 2). On the other hand, Tutulmaz (2011) find turning points between \$6000-7000 (in constant \$2005 dollars) with similar data and econometric methods<sup>1</sup>. Having a different level of turning points, it can be said that the common point shows an ongoing rising path for Turkey. However, the later study shows turning point for a value comparatively above the sample value. This can be translated as that we can see a turning point in CO<sub>2</sub> emissions for seeable future.

<sup>1</sup> The controversial results for Turkey are exclusively inspected in another study which is not published yet; the results, briefly, show that the method of determining the cointegration vector and the corresponding model structure could create this difference for Turkey case.



Source:

World Development Indicators-WDI, 2013

Figure 3:- CO2 emissions and GDP per capita series of Turkey, 1968-2009

If we try to combine the analysis with the result of the panel analysis in the literature, we can say that the pooling of countries show higher turning points for the world. This implies that the developing countries are expected to be in the first phases of the relationship given in Figure 1. That means literally an increasing curve. The CO<sub>2</sub> emission values with below 4 kg per capita in Figure 3 are also comparatively lower than developed country values which are mostly around 10 kg per capita. At this point it can also be argued that estimated increasing linear relationships for developing countries (for example see Lise, 2006) cannot be defined as controversial in terms of EKC hypothesis. But if we turn to Turkey, the emissions of the country are well below the world's estimated turning points values. Consequently, it is consistent to find the emissions of the country in the first or second phase of the Figure 1.

At this point, we want to speculate about the long-run EKC relationship estimation results as what we summarized in Figure 4. We can see the overall results of the EKC scrutiny are consistent with the notion of similarity in shapes (especially in terms of statistical estimation) of the long run EKC relationships for the developing countries which are currently under their turning points. This last point suggested above is consistent with the estimation results of the later study of Tutulmaz's (2011) as we put above. Moreover, the higher turning points (of around \$30000 for CO<sub>2</sub>) for world panel data studies are well above Turkey's income levels (e.g. \$28000\35000 turning points in Holtz-Eakin & Selden, 1995; \$26000 turning point in Luzzatti & Orsini, 2010a,b; \$35000-\$50000 turning points in Tutulmaz et al.,2012).

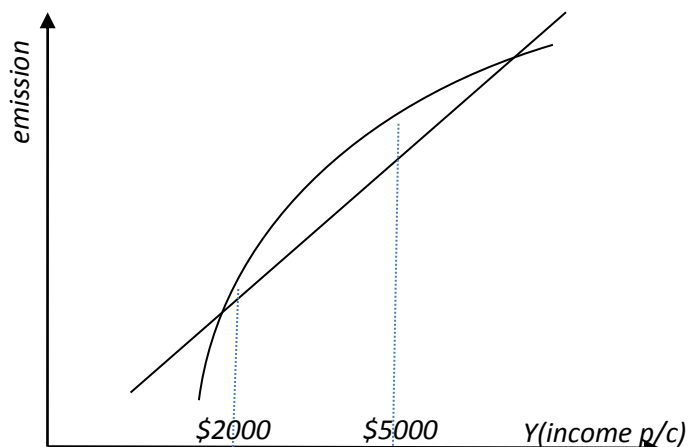


Figure 4:- EKC long term relations Turkey data may suggest

Developing countries, with low income per capita levels, have narrow band explanatory variable x-axis dimension which is also under turning points of EKC (see Figure 4). This structure of data makes the similar shapes open to be estimated significant as we speculate in Figure 4.

## Conclusion

A critical analysis of EKC can show significantly different and arguable features of the estimations in the literature. Some studies have already pointed many technical points for both panel and single country time series analyses. In this study, the result of EKC estimations for a developing country, Turkey, are analyzed and criticized. As stressed before, the first things need to be cleared is the reduced relationship feature of EKC. Including structural variables, such as energy, we can estimate more specific relationship but not total or reduced relationship as EKC suggests, hence a few studies in the literature should be evaluated in a different category.

Analyzing a few statistically robust estimations for Turkey, different results of estimations are noticed. As the common point, however, the emissions are found in the increasing part of the EKC relations that summarized in Figure 1. Despite the divided evaluations of the panel data of world countries, taking account of the result of high turning points for CO<sub>2</sub> emissions, Turkey's results of being in phase 1 or phase 2 are found consistent with the world panel studies in this manner.

As for the estimated shape of the increasing EKC relationship, a critique is raised here that estimated increasing linear relationships for developing countries having narrow band, lower income sample cannot be presented as a clear controversy for the hypothesis itself.

These results have important empirical and policy consequences. First of all, being under turning points, developing countries have upward trended EKC curves as we investigated in the Turkey case (similarity with the trends of other developing countries can be seen together in the panel data EKC studies, for example see, Tutulmaz et al., 2012). In addition, developing countries with low GDP per capita values have narrow-band explanatory variable dimensions. As we speculated in Figure 4, these features make similar shapes highly possible to be estimated as statistically significant in different estimations. While, in one hand, this conclusion means that the linear EKC estimations cannot be assumed as a controversy to the validity of the EKC hypothesis; in another hand, it means that in real life the developing countries haven't experienced yet the 'de-linking' factors which are defined in the literature as the reason of the non-monotonic changes.

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