

Environmental Kuznets curve. Evidence from Romania

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Abstract. *The definition of the environmental Kuznets curve is a hypothesized relationship between certain indicators of environmental degradation and income per capita. It has an inverse U shape which shows that pollution increases initially as a country develops its industry and thereafter declines after reaching a certain level of economic development. This paper tries to offer a critical description of the Environmental Kuznets Curve, to identify what kind of good is the environmental quality and to see if the data available from Romania verify the relationship between environmental quality and income per capita.*

Keywords: Kuznets curve, environmental quality, pollution, income per capita.

JEL Classification: C20, O44, Q56.

1. Introduction

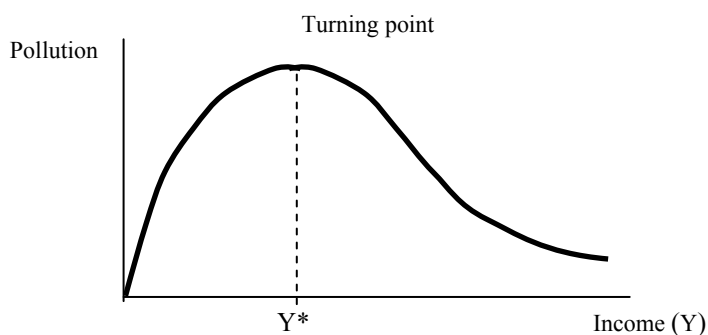
Environmental degradation has been a subject of great interest in economic literature and there are a lot of articles and theories that link economic growth to environmental degradation and to pollution in particular. This is known as the PIR (pollution-income relationship) and one of the most debated forms of relation between pollution and income is the Environmental Kuznets Curve.

The environmental Kuznets curve is an inverted-U relationship between the level of pollution and growth/income. The economist Simon Kuznets (1901-1985) graphically represented a curve in which inequality first increases as the average income increases, and then decreases after a certain average income is attained. In 1993, Grossman and Krueger put Kuznets's name on the curve because they noted that curve resembled with the Kuznets's inverted U relationship between income and inequality.

The theoretical EKC states that the pollution increases first and then decreases after a country reaches a certain level of development (Figure 1)

This curve shows that a certain negative impact on environment cannot be avoided in the initial stage of economic development of a country. Intuitively, people are more interested in income, revenues, and jobs than in clean environment. Moreover, societies are too poor to be concerned about environmental regulation and pollution abatement in the first steps of economic progress.

Figure 1. *The theoretical EKC*



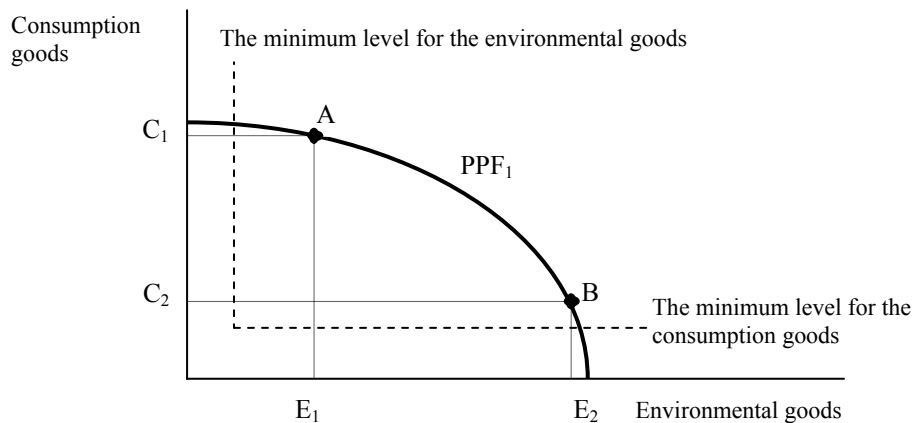
Source: Authors' interpretation.

Furthermore we can imagine the production – possibility frontier in an economy which products two kinds of goods: environmental goods and services (such as good quality of water, air, soil, low level of noise, etc) – E and consumption goods (all goods except environmental goods) – C. Given the certain level of resources that an economy has at a certain moment, a higher quantity of consumption goods goes to a lower quantity of the environmental goods that this economy can produce (opportunity cost). If the economy chooses to be in point A (low level of E and high level of C) on a long run the production – possibility frontier (PPF1) will probably shift to the left because an economy sustains

its development only if it is concerned about environmental issues as well. On the contrary, if an economy deals with environmental problems it probably chooses to be in the point B in the graph (lower level of C and higher level of E). On the long term, the PPF will probably shift to the left.

This curve completes the environmental Kuznets curve and reminds us about the turning point when an economy begins to have an environmental policy, regulations and criteria to be accomplished. The minimum levels for both environmental and consumption goods show that the practical choices of a society lay to the right of that levels (no matter how ecological an economy is, it has to produce a minimum level of consumption goods).

Figure 2. A production – possibility frontier in an economy with two kinds of goods



Source: Authors' interpretation.

The shape of EKC can be explained:

1. Pollution is a negative externality and its internalization needs powerful institutions in order to make decisions.
2. The average income is a measure of the living standard. When the income exceeds a certain level (many authors say that the turning point is around 8,000\$) people demand a better environment and the structure of the economy changes. Individuals consider environmental quality as a normal good, they put a higher value on it and their willingness to pay for a clean environment increases (Pezzey, 1989; Selden and Song, 1994; Baldwin, 1995; Roca, 2003).
3. Developed economies often export their environmental unfriendly production to less developed countries with lower ecological criteria.
4. The income elasticity of environmental quality demand is high: the demand of poor societies for environmental quality is low; as the societies become richer, the demand for cleaner and healthier environment shifts to the right.
5. Emergent economies have lower environmental standards to accomplish before the integration in European Union; but we should analyse the relationship between economic growth rates and the pollution levels after the integration in order to state if the reality confirms the conventional EKC.

6. As the economy changes its structure from rural (agricultural) to urban (industrial), its negative impact on environment increases; this impact starts falling again when the economy shifts from energy intensive industry to service and knowledge based technology (Grossman and Krueger, 1993).
7. Environmental friendly policies have an important role in the quality of life. But these policies are adopted after a society reaches a certain level of development and they always involve powerful institutions to put them into practice (Ng and Wang, 1993).

2. Literature review

The relationship between economic development and the environmental quality is still debated in scientific literature. Different authors have different approaches of the Environmental Kuznets Curve.

There are many empirical studies regarding EKC which emphasize the inverted –U shape of EKC. There are also some studies which point out that the EKC has a N – shape (the environmental degradation starts increasing again after a period of decreasing).

Among the authors of empirical studies about EKC we mention Cole et al. (2001), Borghesi (2001), Dinda (2004), He (2007). Our opinion is that no matter what the econometric model is chosen, the results of empirical studies depend on country, the period considered and the pollutant chosen for the model.

Besides the empirical studies, there are many authors which focus on theoretical models that could explain the shape of EKC.

DeBruyn and Heinz (2002), the factors which different authors take into account when analysing the relationship between economic growth and environmental quality / degradation and economic growth are:

- behavioural changes and preferences;
- institutional changes;
- technological changes;
- structural changes;
- international reallocation.

On the one hand, we can mention some studies about behavioural changes in which authors analyse certain utility functions (McConnell, 1997; Lieb, 2002). On the other hand, Jones and Manuelli (2001), Egli and Steger (2007) focus on institutional changes in their studies and try to measure the effect of the environmental policy. The effect of technological changes is examined in the theoretical models of Stokey (1998) or Tahvonon and Salo (2001), Smulders et al. (2011).

Other studies (Pearson, 1994) support that the factors which influence the quality of environment could be grouped into two categories:

- I. demand side group: 1) environmental quality price; 2) preferences; 3) information;

II. supply side group: 1) population and economic activity levels; 2) the structure of production and consumption; 3) efficiency; 4) use of new materials/energies; 5) external influences.

All theoretical models consider that pollution implies both benefits and costs. For example, a benefit of pollution could be an increase of consumption due to a higher level of the economic activity. On the other hand, the utility of the whole society decreases as the pollution level grows.

Some studies argue that the choice of datasets can produce different shapes of the EKC because pollution level depends on the indices chosen. Roca and Serano (2007) find different shapes when using “per capita income” or “household expenditures” for the income variable. Kim et al. (1999) uses different indices for pollution like “pollution intensity” and “per capita pollution” variables and finds that in some cases the EKC theory does not apply in Korea.

Some studies have tried to develop a better econometric technique for modelling the relation between income and pollution. Authors like Galeotti et al. (2004) Romero (2008) use spline functions (Weibull functions) in an attempt to better fit the data available and to further develop the relationship. Dinda (2006) Iwata et al. (2010) and Narayan (2010) use Granger causality test in order to prove the existence of EKC.

3. Data

In the empirical analysis we use data for Romania from 1960 to 2012. As an environmental indicator we chose to use per capita carbon dioxide CO₂ and as an economic indicator, per capita real GDP in US dollars. We also account for the political and structural changes in Romanian economy via a possible inclusion of a dummy variable receiving the value of 1 after the year 1989. All the data used is taken out from the World Bank’s World Development Indicators 2014. Even if we believe that a larger time span for the data would have provided more insight, we used data only from 1960 because there is no data collected for CO₂ per capita emissions before 1960 in Romania.

4. The model

The EKC literature states that empirical reduced form relationship between pollution and income can be described by a parametric model in the form of a polynomial function of income.

The large majority of the empirical studies use the following general reduced form model:

$$Y_t = \alpha_t + \beta_1 X_t + \beta_2 X_t^2 + \beta_4 Z_t + e_t, \quad t = 1, \dots, T \text{ years} \quad \text{Eq(1)}$$

In Eq(1), Y is the dependent variable denoting environmental degradation, X is the income variable, Z denotes other variables used to enhance the model, α is the constant

and β_i are the estimated coefficients. Some studies include the cubic term in order to examine the existence of a N shaped curve instead of the traditional inverted U shape.

Many authors use logarithmic transformation of the data, transforming the equation in a log-linear model. The log-linear model is used to avoid zero or negative value indicators, which is a reasonable condition as pollution cannot become negative indifferent of the level of economic activity. On the other hand the linear model has the advantage of simplicity and the fact that it yields constant marginal effects and variable elasticity, but loses the advantage of easy interpretation when estimated in cubic form.

The well-known inverted U shape EKC is just one specific form of probable output of EQ(1) and the condition imposed are $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$.

As the objective of the study is to investigate the relation between CO2 emissions and income, we chose not to include any additional variables as the inclusion of additional variables would not have solved possible problems of unit roots or modify the casualty of the relationship.

5. Empirical findings

In order to assess the stationarity proprieties of the series employed, we used the NG-Perron test with optimal point. We chose the Ng-Perron test over the more widely used unit root tests like ADF, PP and KPSS because of the superior performance of this test.

Table 1. NG-Perron test results for CO2 series

		MZa	MZt	MSB	MPT
Ng-Perron test statistics		-2.32869	-1.07245	0.46054	10.4764
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000
	5%	-8.10000	-1.98000	0.23300	3.17000
	10%	-5.70000	-1.62000	0.27500	4.45000
*Ng-Perron (2001, Table 1)					
HAC corrected variance (Spectral GLS-detrended AR)					0.588206

Source: Authors' calculations.

As the NG-Perron statistics are greater than the specific critical values we conclude that the variable is non-stationary in first level.

After taking into consideration the specific shape of the CO2 series graph, we chose to test the stationarity of the series with the hypothesis of structural breaks in intercept and trend. For that we used the Zivot-Andrews test with unknown break point.

The results are conclusive and the test choses the year 1990 as a break point. Admitting the hypothesis of a structural break in intercept and trend, we reject the presence of a unit root at a 5% level of confidence and admit that the CO2 series is stationary.

Figure 3. Zivot-Andrews Breakpoints for CO2 series

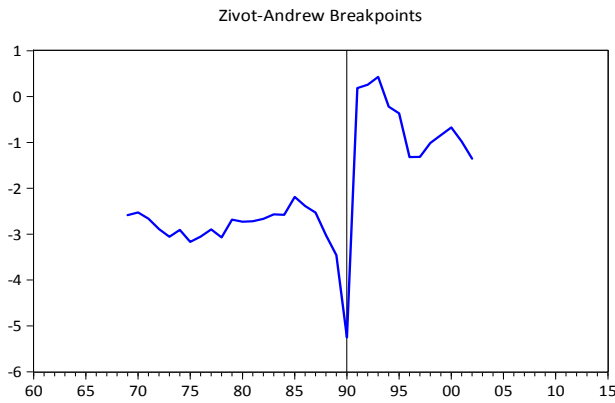


Table 2. Zivot-Andrews Test results for CO2 series

Null Hypothesis: CO2 has a unit root with a structural break in both the intercept and trend
 Chosen lag length: 1 (maximum lags: 4)
 Chosen break point: 1990

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-5.2520	5.76E-8
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Source: Authors' calculations

The same tests are used to see if the GDP series is stationary and if it also has a structural break point in intercept and trend. The NG-Perron test values are greater than the specific critical values so we have the confirmation that the GDP series is non-stationary and we proceed to differentiate the series. The results of tests are shown below.

Table 3. Zivot-Andrews Test results for GDP series

Zivot-Andrews Unit Root Test
 Null Hypothesis: Y has a unit root with a structural break in both the intercept and trend
 Chosen lag length: 1 (maximum lags: 4)
 Chosen break point: 1989

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-3.685168	0.003093
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Source: Authors' calculations.

Table 4. NG-Perron test results for GDP series

Null Hypothesis: D(Y) has a unit root
 Exogenous: Constant
 Lag length: 0 (Spectral GLS-detrended AR based on SIC, maxlag=10)
 Sample (adjusted): 1961 2010
 Included observations: 50 after adjustments

		MZa	MZt	MSB	MPT
Ng-Perron test statistics		-17.6319	-2.94939	0.16728	1.46215
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000
	5%	-8.10000	-1.98000	0.23300	3.17000
	10%	-5.70000	-1.62000	0.27500	4.45000
*Ng-Perron (2001, Table 1)					
HAC corrected variance (Spectral GLS-detrended AR)					162673.8

Source: Authors' calculations.

The Zivot-Andrews test is performed for the GDP series and it calculates the maximum probability or a structural break point in the year 1990. As the value of the test is larger than the critical values we chose to differentiate the GDP in order to make it stationary as the NG-Perron test suggests us.

If we admit the hypothesis of a structural break for the year 1990, than the CO2 series is stationary and the Y series is I(1) stationary in first difference.

Taking that into consideration we estimate the regression model using the BREAKLS – Least Squares with Breakpoints method. The model has the following form (Jula, Jula, 2014):

$$CO2 = (\text{before after}) \cdot \begin{pmatrix} c_{11} + c_{12}t + c_{13}t^2 \\ c_{21} + c_{22}t + c_{23}t^2 \end{pmatrix} + c_1d(Y_t) + c_2d(Y_t^2) + c_3d(Y_t^3) + e_t \quad \text{Eq(2)}$$

Where $t=1,2,..51$, corresponding to the years 1960-2010, e is the error term and the “before” and “after” are two variables constructed as follows: before = 1, for the period 1960-1990 and 0 for the period 1990-2010, and after = 0, for the period 1960-1990 and 1 for the period 1990-2010

For the breaking point we chose the year 1990, matching the breaking point of the CO2 series.

Dependent Variable: CO2
 Method: Least Squares with Breaks
 Sample (adjusted): 1961 2010
 Break type: Fixed number of user-specified breaks
 White heteroskedasticity-consistent standard errors & covariances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
1961 - 1990 -- 30 obs				
C	2.416551	0.295959	8.165148	0.0000
T	0.473198	0.043205	10.95242	0.0000
T ²	-0.008795	0.001702	-5.165950	0.0000
1991 - 2010 -- 20 obs				
C	24.29074	5.421548	4.480407	0.0001
T	-0.864073	0.259081	-3.335141	0.0018
T ²	0.009211	0.003024	3.046117	0.0040

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Non-Breaking Variables				
D(y)	-6.616918	2.259152	-2.928939	0.0055
D(y ²)	0.653626	0.235222	2.778760	0.0082
D(y ³)	-0.019391	0.007485	-2.590566	0.0132
R-squared	0.961318	Mean dependent var		6.045613
Adjusted R-squared	0.953770	S.D. dependent var		1.960887
S.E. of regression	0.421613	Akaike info criterion		1.272089
Sum squared resid	7.288042	Schwarz criterion		1.616253
Log likelihood	-22.80223	Hannan-Quinn criter.		1.403149
F-statistic	127.3653	Durbin-Watson stat		1.832570

Source: Authors' calculations.

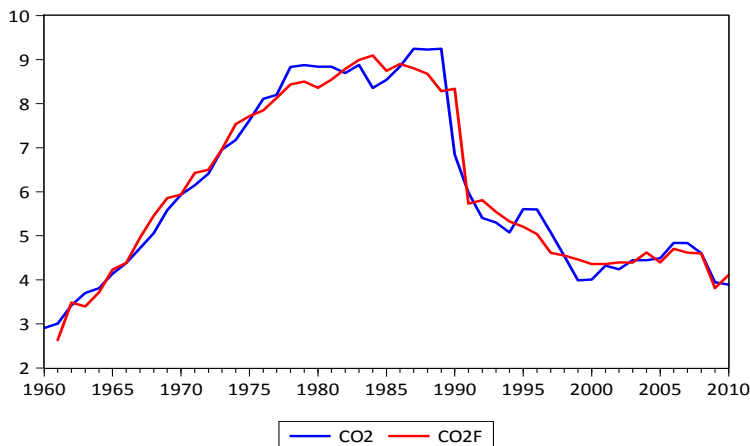
There is no autocorrelation in the error term (for $p=4$, $nR^2 = 7.457 < 9.488 = \chi^2(0.05; 4)$) and the error term follows a normal distribution ($JB = 28.36 > 5.991 = \chi^2(0.05; 2)$).

The final equation is written as follows:

$$\begin{aligned}
 CO2 = & BEFORE("1991") * (2.4165505552 + 0.473198139854 * T - \\
 & 0.00879467838655 * T^2) + AFTER("1991") * (24.29074444848 - \\
 & 0.864072694099 * T + 0.00921108942485 * T^2) - 6.61691767813 * \\
 & D(Y/1000) + 0.653626192075 * D(Y/1000)^2 - 0.0193907897629 * \\
 & D(Y/1000)^3
 \end{aligned}
 \tag{Eq(3)}$$

The actual values of the CO2 series and the estimated values (CO2F) are plotted in Figure 4

Figure 4. CO2 and CO2F series graph



As in our model the coefficients are $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 < 0$, we found evidence supporting an inverse N shaped relationship between economic growths and pollution with CO2.

6. Conclusions

This paper has investigated the long term relationship between economic growths for which we used GDP per capita as a proxy and CO₂ emissions per capita during the 1960-2010 period and found out that there is a robust long run relationship between the two variables. An inverted N shaped relationship between CO₂ emissions and GDP per capita was found in the long term by the econometric analysis performed on the available data. The results are in line with the EKC theory and support the EKC hypothesis for Romania.

Even if the results of the study support the existence of an inverted N shaped EKC, it is important to remember that the results of the econometric model do not explain or indicate the reasons that led to the observed inverse N shaped relationship. Some important factors that were not considered among the explanatory variables of the model, like the structure of the national economy in regard to the share of clean production technologies, share of imports in GDP and the proportion of imported goods that generate high CO₂ emissions in the production process and the changes in environmental legislation in Romania, all have an important role in setting the shape and future evolution of the relationship between income and pollution.

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