Raport Badawczy
Research Report

RB/06/2001

Environmental Kuznets Curve for Some Countries

Paweł Bartoszczuk

Instytut Badań Systemowych
Polska Akademia Nauk

Systems Research Institute
Polish Academy of Sciences

POLSKA AKADEMIA NAUK

Instytut Badań Systemowych

ul. Newelska 6

01-447 Warszawa

tel.: (+48) (22) 8373578

fax: (+48) (22) 8372772

Pracę zgłosił: prof. dr hab. Zbigniew Nahorski

Warszawa 2001

INSTYTUT BADAŃ SYSTEMOWYCH PAN

PRACOWNIA MODELOWANIA KOMPUTEROWEGO
I IDENTYFIKACJI

A 7 - 06/2001

Paweł BARTOSZCZUK

Environmental Kuznets Curve for Some Countries

Zadanie badawcze:

Modele matematyczne w ochronie środowiska i zdrowia

- kierownik: prof.dr hab.inż. Zbigniew NAHORSKI

Podzadanie:

Modelowanie wybranych wpływów procesów technicznych i biologicznych na środowisko naturalne

WARSZAWA , grudzień 2001

ENVIRONMENTAL KUZNETS CURVE FOR SOME COUNTRIES

Pawel Bartoszczuk

1) Japan Advanced Institute of Science and Technology
School of Knowledge Science, Hokuriku, Japan
2) Systems Research Institute of the Polish Academy
of Science, Warsaw, Poland

Abstract: In the past few years there has been a lot of research on the topic of environmental quality and economic growth. This paper describes the theory of Environmental Kuznets Curve and illustrates the concept with special reference to some European countries. One of the objectives of this study is to test the shape of the relationship between income and environmental degradation. The paper emphasises ecological consequences of economical development.

Key words: Curves, Economics, Ecology, Environment Pollution, Polynomials, Regression Analysis

1. INTRODUCTION

The relation between economic development and pollution is a very complex issue. Natural resources serve as inputs into production of many goods and services. If the methods of production were not changed then damage to the environment would be linked to the scale of global activity. For this reason, in the last few years several studies have tried to characterize this problem as an empirical reduced form relationship.

Some evidence suggests that the forces leading to change in the composition and techniques of production may be sufficiently strong to offset the adverse effects of increased economic activity on the environment. At very low levels of economic activity environmental impacts are generally low but as development proceeds, pollution increases rapidly. At higher level of development, structural changes lead to decrease of pollution. Economic growth eventually redress the environmental impact of the early stages of economic development and that growth lead to further environmental improvements in developed countries or tend to fix environmental problems.

This has come to the relationship called the Environmental Kuznets Curve. This correlation draws its inspiration originally from the income distribution theory developed by Kuznets (1955), who found an inverted-U shape between an indicator of income inequality and the level of income. Environmental Kuznets Curve proposes there is an inverted U shape relation between various indicators of environmental degradation and income per capita (Fig. 1).

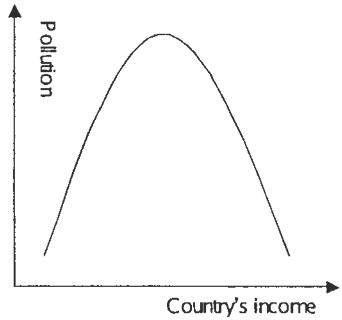


Fig. 1
Relation between environmental pollution and income (Environmental Kuznets Curve)

The objective of this work is to critically review existing knowledge from the literature about relation between income and pollution, and attempt to find the relationship between economic growth and the pollution for some developed countries from available data.

2. THEORETICAL BACKGROUND OF ENVIRONMENTAL KUZNET' S RELATION

The origins of the Environmental Kuznets Curve (EKC) hypothesis are somewhat ambiguous, and appear to be product of various studies conducted in early 1990s. The first of studies were made by Grossman and Krueger (1991), and by Shafik and Bandyopadthyay (1992) of air pollution measures in cross section of countries for different years.

Shafik and Bandyopadthyay, cited by Panayotou (2000), discovered a turning point for deforestation around 2000 dollars. Two air pollutants conform to EKC hypothesis and the turning point was found between 3000-4000 dollars. Lack of clean water and lack of urban sanitation do not correspond to EKC, but decline monotonically. Grossman and Kreuger (1993) found turning point for SO_2 and dark matter for about 4000-5000 dollars. For water quality indicator the turning point is at least 7500 dollars and for dissolved oxygen - 10000 dollars.

Nemat and Shafik (1994), using data from a wide range of countries at different levels of development, found an inverted U relationship for the following pollutants: suspended particulate matter (SPM) and sulphur dioxide. They observed the turning point for SO_2 around 3000 dollars. In another paper Grossman and Kreuger (1995) found the turning point for an income of country equalled to 8000 dollars. The EKC curve was found also for ambient levels of air pollutants, SO_2 and SPM, with turning point in the range 3000 to 5000 dollars of per capita GDP.

A number of explanations exist for the observed inverse-U relationship. First, it could be explained by transformation from agrarian economies through industrial economies to clean service ones (Arrow et al., 1995). At low level of economic development, the share of industry first is very low and rises with income increase. Corresponding environmental pollution first rise and then, when there is a transformation from industry to service, falls with income growth, controlling for all other influences transmitted through income.

The other most common explanation is that demand for environmental quality rises faster with income than demand for other goods and services. This would be the case, for instance, if there exists a threshold level of income below which resources are devoted to environmental protection. Countries living on low level of economic development may find it extremely difficult to protect environment. When income grows, people presumably become both more able and more willing to sacrifice some consumption to protect the environment. Income-elastic demand for environmental quality is therefore one element that could generate a pollution path that eventually turns downward.

Some researchers note that decisive evidence of an EKC relationship applies only to a few pollutants, thus making it difficult to use this evidence to speculate more generally. Others have pointed out that, even for those pollutants displaying EKC characteristics, aggregate global emissions are projected to rise over time, demonstrating that existence of an EKC relationship for such pollutants does not necessarily imply that, at the global level, any associated environmental damage is likely to disappear with economic growth (Selden and Song, 1994). There are some evidence that turning points of global pollutants, such as CO_2 emissions and other greenhouse gases, are estimated at considerably higher incomes than more local ones. One interpretation of this is that people do not care much about global warming and climate change. Global warming and depletion of the ozone layer are rather recent public concerns.

Based on existing examinations, some policy analysts have concludes that developing countries will automatically become cleaner as their economics grow. Others have argued that it is natural for the poorest countries to be more polluted as they develop.

From the other side, many authors articulate that economic growth is not a panacea for environmental quality. Protecting the capacity of ecological systems to sustain welfare is of as much of importance to poor countries as it is to those that are rich.

A lot of researchers claim that the turning point achieved by developed countries, if not yet in all environmental indicators could be a result of the migration of polluting industries to developing countries. That is, some of the dirtier industries, especially mining and raw materials processing, are now disappearing from the richer countries but becoming more important to the poorest ones.

Because, eventually, there will be no countries, to which pollution making will be exported, there may be a limit to the ability of nations to reduce pollution, or at least the costs will be more obvious for later entrants into the game. Therefore, the process of environmental improvement will not be indefinitely replicable, as the world's poorest countries will never have even poorer countries to which they can export their pollution.

From the other side, it can be opposite case. Developing countries may find it easier to pass the peak of the EKC, because of technologies that were not available at the time the developed countries were at the same stage of development. However, the are lots of other questions arising, like: at what level of per capita income is the turning point and if irreversible damages take place before environmental degradation turns down, and how they can be avoided (Dinda et al, 2000).

4. MODEL SPECIFICATIONS

Basically all researchers assume that empirical reduced-form relationship between per capita CO_2 emissions and GDP can be adequately described by parametric model, and specifically by a polynomial function of income (Panayotou, 2000). The equation is either quadratic or cubic. It is estimated econometrically using cross-section data, i.e. from many countries at a single point of time, or panel data. Up most, an average income per capita is taken as the income variable. The environmental variable may be explicitly averaged, as by taking all reported hourly polluter concentrations reading for a country in the year and calculating their mean. The results of statistical estimation of the relationship are presented usually in following form:

$$Pollution = f(x_1, x_2, ...), \qquad (1)$$

where :

$x_1, x_2,...$ are hypothesized influences on pollution, like income per capita or other parameters.

The most simple model specification shows a relationship between an environmental indicator (E) and the income per capita (y). The following linear, quadratic, log-linear and log quadratic forms are normally present in the studies on Environmental Kuznets Curve (2)-(5).

$$E_{it} = B_0 + B_1 y_{it} + \varepsilon_{it} \qquad (2)$$

$$E_{it} = B_0 + B_1 y_{it} + B_2 y_{it}^2 + \varepsilon_{it} \qquad (3)$$

$$E_{it} = B_0 + B_1 \ln(y_{it}) + \varepsilon_{it} \qquad (4)$$

$$E_{it} = B_0 + B_1 \ln(y_{it}) + B_2 (\ln(y_{it}))^2 + \varepsilon_{it} \qquad (5)$$

where:

E-environmental indicator
y-income per capita
ε -error term
B -parameter to be estimated
t-time trend.

Moreover, there are equations using both variables: income per capita and population. The most common specification includes population density (P_{it}) and is in a log-quadratic form (6).

$$E_{it} = B_0 + B_1 \ln(y_{it}) + B_2 (\ln(y_{it}))^2 + B_3 \ln(P_{it}) + B_4 (\ln(Py_{it}))^2 + \varepsilon_{it} \qquad (6)$$

In addition, some other models include geographic characteristics in order to reflect the dispersal properties of the local atmosphere. The most general specification is presented in a quadratic form (7).

$$E_{it} = B_0 + B_1 \ln(y_{it}) + B_2 (\ln(y_{it}))^2 + B_3 \ln(P_{it}) + B_4 (\ln(Py_{it}))^2 + B_5 \ln(G_{it}) + B_6 (\ln(G_{it}))^2 + \varepsilon_{it} \qquad (7)$$

Several other specifications include income per capita (y), population (P), policy (p), and growth variable (g). The most popular model equations have a cubic form (8).

$$E_{it} = B_0 + B_1 y_{it} + B_2 y_{it}^3 + B_4 P_{it} + B_5 Py_{it}^2 + B_6 Py_{it}^3 + B_7 g_{it} + B_8 g_{it} y_{it} + B_9 p_{it} + B_{10} g_{it} y_{it} + \varepsilon_{it} \qquad (8)$$

There are other models using trade variables and institution related variables and macro-policy models, which are beyond the scope of this paper. Now the linear-in variables model will be considered:

$$E_{it} = B_0 + B_1 y_{it} + B_2 y_{it}^2 + B_3 x^3 \qquad (9)$$

Two first derivatives are of special interest. By setting them to zero, the so-called turning point is received. The first and second derivatives are:

$$\begin{aligned} \frac{dy}{dx} &= B_1 + 2B_2 x + 3B_3 x^2 \\ \frac{d^2y}{dx^2} &= 2B_2 + 6B_3 x \end{aligned} \qquad (10)$$

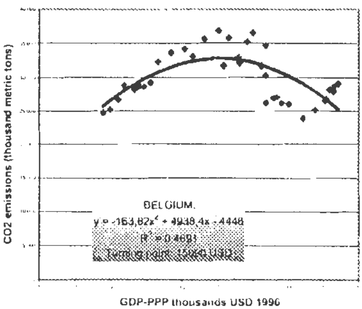
Let assume the coefficient of B_3 in equation is equal to zero. In this case function (9) exhibits an inverted U-shape, if additionally $B_2<0$. If also $B_1 + 2B_2x=0$, on can obtain the abscissa of the turning point.

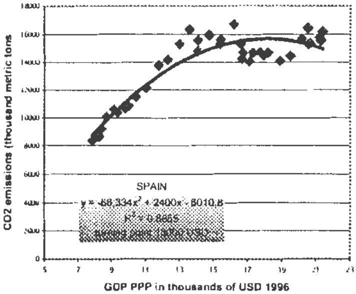
$$x_{tp} = -\frac{B_1}{2B_2} \qquad (11)$$

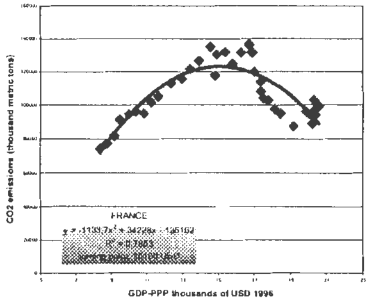
This x_{tp} is positive as long as $B_2<0$. Hence the appearance of the EKC hinge upon the sign of B_2. It is seen that linear in variables form emerges a closed form for the turning point of EKC equation.

5. EMPIRICAL EVIDENCE FOR INDIVIDUAL COUNTRIES

This study also uses more current data to try and capture some of the effects that have happening in recent years in some countries.







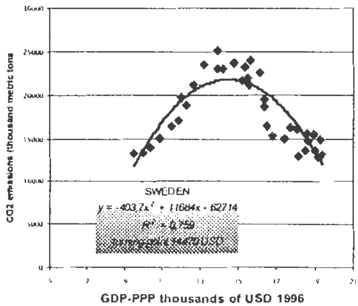


Fig 2
Emissions of CO_2 from Fossil Fuel in relation to GDP in Power Purchasing Parity in some European countries (Belgium, Spain, France, Austria) in 1960-1996 years

It is very risky to take cross section data, while this can be similar to the result of regressing market data on quantity purchased per period on price data from the same period. In the absence of other data, the prognosis can be very hazardous. Therefore, in conducted research a time –series data of carbon dioxide emission are applied. Carbon dioxide is global pollutant and measured in thousand metric tons.

The data set we employ consists of observations on countries over 36 years period beginning in 1960 and ending in 1996. The data concerning income are described by Gross Domestic Product Per Capita Purchasing Power Parities (GDP PPP) come from demographia from 1960-1996 years[1]. Purchasing power parity eliminate the differences in price levels between countries. The PPPs' are given in national currency unit per US dollar. The data relating to CO_2 emissions from fossil fuels comes from Oak Ridge National Laboratory.

The data were approximated by polynomial equation. This study has identified a bell shaped curve for the pollution intensity of GDP. The behavior of presented data implies that, starting from low income levels, emissions or concentrations start to increase. After reaching so called turning point they start to decline as income further increase (Fig. 2). Every analyzed country has its own relationship between income and environmental abuse. The turning point is around 15 000 USD- PPP in three from fourth analyzed countries. Nevertheless, emissions of CO_2 in that point differ from country to country. They equal 16000 for Spain, but are much higher for France 120000. It was found that environmental quality deteriorates with increase of income and then is improved.

6. CONLUSIONS

The results of this paper are in agreement with the theory and previous research and seem to show that Environmental Kuznets Curve exists, at least for some developed countries. Therefore, the idea of trying to stop development to protect the environment is not correct. Both the shape of the inverted U-curve and pollution level corresponding to GDP value of turning point is varying among countries.

However, empirical relationship between country's GDP and the emissions of a major greenhouse gas CO_2, ought to undergo a more careful examination. Simplistic arguments that income growth will by itself take care of the pollution problems of the world are inaccurate. If the economic incentives facing producers and consumers do not change with higher incomes, pollution will continue to rise unchecked alongside the increasing scale of economic activity.

More regular figure of the EKC curve is seen for countries where environmental issues are concerned, like for example Sweden. This suggests that other things besides GDP are important in predicting emissions levels (like policy).

An important policy implication that comes from the results is that the low-income countries have an opportunity to learn from this history and avoid mistakes of developed countries.

REFERENCES

Arrow K. et al. (1995), Economic growth, carrying capacity and the environment. *Science*. **268**, 520-521, reprinted in *Ecological Economics* **15**, 91-95

Dinda S. Coondoo D. and M. Pal (2000). Air quality and economic growth: an empirical study. *Ecological Economics* **34**, 409-423

Grossman G. M. and A. Kreuger. (1995). Economic growth and the Environment. *Quarterly Journal of Economics*. 110, Issue 2, 353-377

Panayotou T. (2000). Economic growth and the environment. Environment and Development Paper 4, *Working paper 56*, Center for International Devolpment at Harvard University.

Shafik, Nemat (1994). Economic Development and Enviromental Quality: An Econometric Analysis. *Oxford Economic Papers*, 46, 757-773

[1] Available also in the web