ENVIROMENTAL KUZNETS CURVE – A TIE BETWEEN ENVIROMENTAL QUALITY AND ECONOMIC PROSPERITY

Jiří Mazurek

Introduction

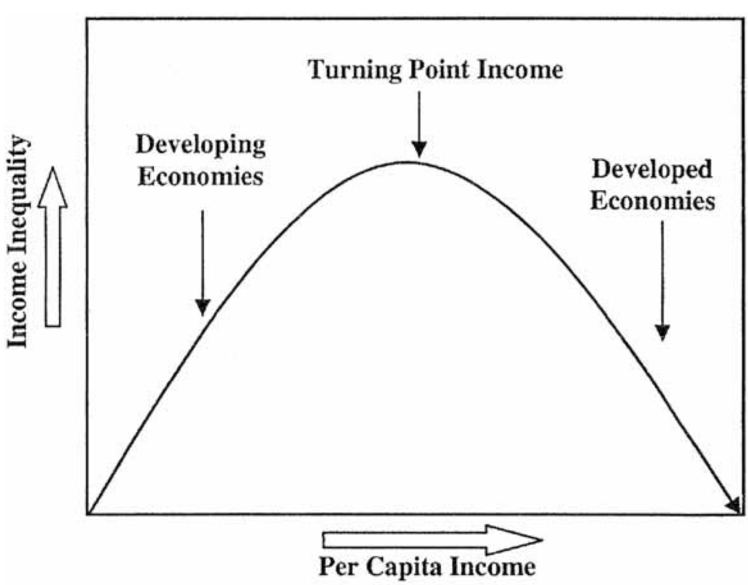
In 1954 Simon Kuznets, an American economist of Russian origin and 1971 Nobel laureate, suggested a following idea: as per capita income in a given country increases, income unequality also increases, but after some *turning point* it starts declining. This relationship is often demonstrated by an inverted U-shape curve – *Kuznets Curve* (Fig. 1).

In the 1970´s and 1980´s many people believed that richer economies such as Western Europe or the United States can grow only at the expense of environment degradation and natural resources depletion. Environmental quality was getting worse and it seemed the only solution was to reduce economic growth and industrialization.

However, in the early the 1990´s new empirical (and surprising) relationship emerged, this time connected with environmental quality. While countries develop, indicators of environmental quality such as air and water pollution, deforestation, access to clean water, etc. are getting worse from the beginning, but later improve. Until now many researchers brought evidence that the level of environmental quality and income per capita follow the same inverted U-shape curve, the *Environmental Kuznets Curve* (EKC, Fig. 2).

Yandle at al. [17, pp. 4] explain logic for EKC relationship in this way: "As the development and industrailization progress, environmental damage increases due to greater use of natural resources, more emissions of pollutants, the operation of less efficient and relatively dirty technologies, the high priority given to increase in material out-

Fig. 1: Kuznets Curve

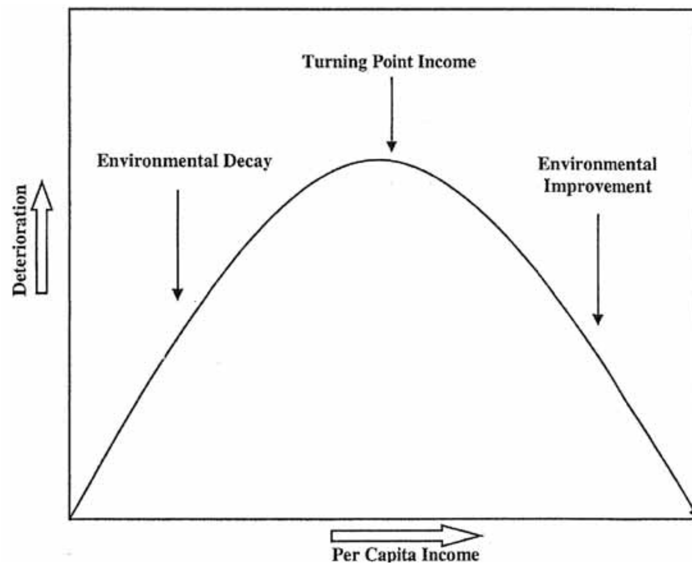


Source: [17]

put, and disregard for – or ignorance of – the environmental consequences of growth. However, as economic growth continues and life expectancies increase, cleaner water, improved air quality, and a generally cleaner habitat become more valuable..."

Above all, researches concentrated on air and water pollution. Strong statistical evidence for EKC was found for sulphur dioxide, oxides of nitrogen and dark matter (smoke). Evidence for particulate matter is mixed and no EKC was found for CO and CO_2, which are monotically increasing

Fig. 2: Environmental Kuznets Curve



Source: [17]

with GDP per capita. Dealing with water pollution, evidence for EKC is the strongest for biological oxygen demand, chemical oxygen demand, coliform, nitrates and some heavy metals (such as arsenic, cadmium or lead). Turning points of various pollutants are listed in Tab. 1 and Tab. 2.

1. Empirical Analysis of EKC

Probably the first research on EKC comes from the study of Grossman and Krueger in [8]. They investigated thesis that an economic growth within NAFTA (North American Free Trade Agreement) would result in an environmental degradation. However, they found that higher incomes lead to improving air quality.

Following studies [5], [9], [11], [12], [13] and many others confirmed these findings (see Tab. 1). Data they used came from annual *World Development Reports* by World Bank, World Health Organization, Global Environmental Monitoring System and from national air and water quality databases.

Empirical analysis of EKC focuses on the two points:

- If a given indicator of environmental quality obeys EKC.
- Calculation of a turning point of EKC.

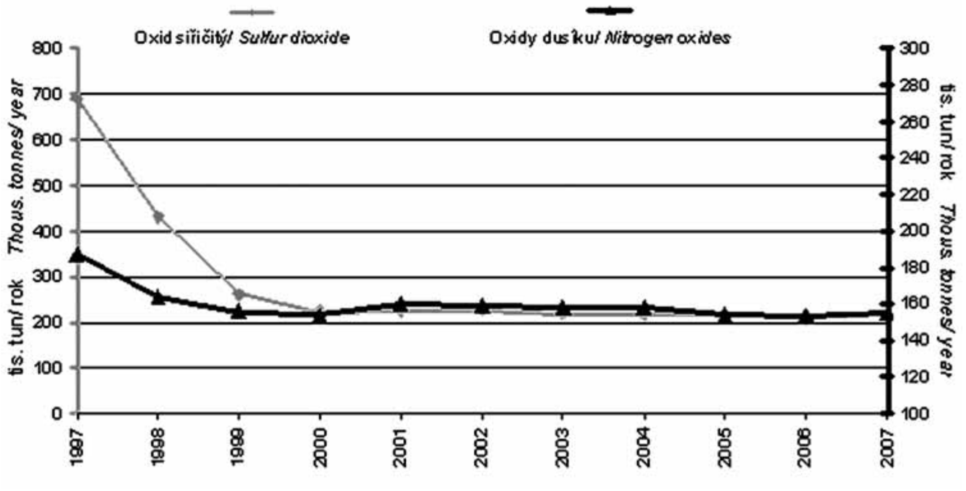
EKC in the Czech Republic was examined by Brůha and Ščasný in relation to proposed tax reforms [2]. Data from the Czech Hydrometeorological Institute REZZO databases suggest (Fig. 3) that the Czech Republic is on the right declining side of EKC for SO_2, NO_x and NH_3, much like other developed countries in Europe and North America. The examples of developing countries on the left side of EKC for the most pollutants are India and China.

There are two different approaches to study EKC, over time and space:

- The level of environment degradation in one country (region, city,...) during a certain time interval, e.g. from 1900 to 2000. As can be seen in Fig. 5, though US number of inhabitants and economic prosperity multiplied in the 20th century, due to new technologies a desire for clean air sulphur dioxide emissions declined.

- The level of environment degradation in many countries (regions, cities,...) in a fixed time (e.g. at present), as it is illustrated in Fig. 4 for worldwide SO_2 emissions.

Fig. 3: Air Pollution in the Czech Republic (REZZO 1-3)



Source: [7]

Tab. 1: Air Pollution. Turning Points in 2001 (US $)

Author(s)	Year	Pollutant	Turning point (US $)
Shafik and Bandopadhyay	1992	SO_2	6,100
		PM	5,400
Selden and Song	1994	PM	16,400
		SO_2	14,500
Grossman and Krueger	1995	SO_2	6,200–8,200
Panaytou	1995	SO_2	4,900
		PM	7,400
		NO_x	9,000
Cole, Rayner and Bates	1997	CO_2	37,000–57,000
		NO_x	25,600–41,000
		SO_2	9,400–11,300
		PM	12,000–13,000

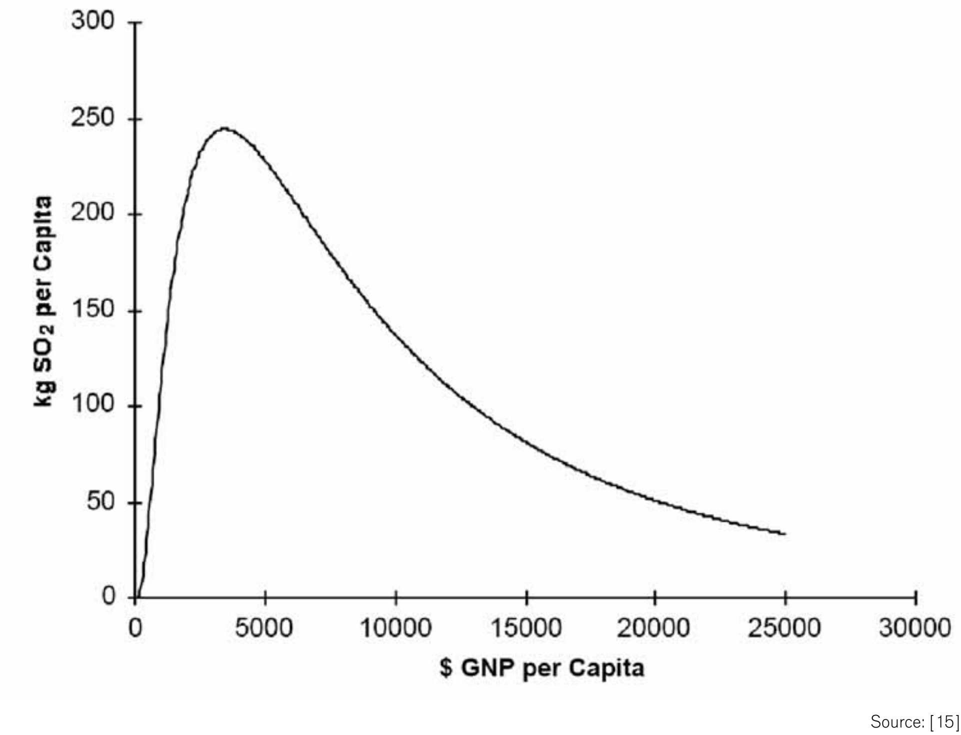
Source: [17]

Tab. 2: Water Pollution. Turning Points in 2001 (US $)

Pollutant	Turning points (US $)
Arsenic	8,000
Biological oxygen demand	12,500
Cadmium	8,200
Chemical oxygen demand	13,000
Dissolved oxygen	4,400
Coliform	4,900
NOx	3,300
Lead	17,200
Smoke	10,200
SO_2	6,700

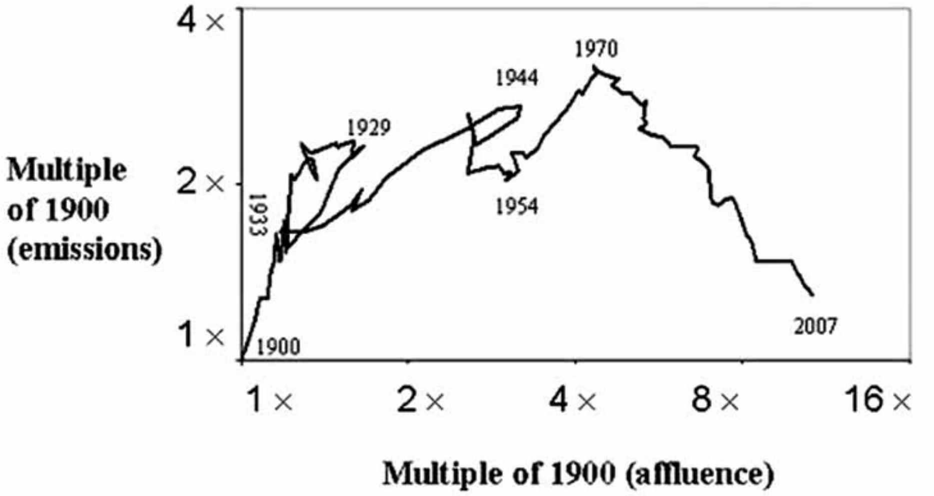
Source: [17]

Fig. 4: Environmental Kuznets Curve for World SO_2 Emissions in 90´



Source: [15]

Fig. 5: US Sulphur Emission in the 20th Century



Source: [16]

2. Theoretical Explanation of EKC and EKC Models

Theoretical explanation of EKC is yet at the beginning, though some theoretical models have been already derived.

Antle and Heidebrink [1] studied agriculture effect on environment. They developed a theoretical model which assigned prices to environmental and market goods. Price of environmental goods is low at the beginning of development and lot of resources is used. But as resources become scarce, price of environmental goods increases and environment gradually improves. So one possible explanation of EKC theory is the clean environment becomes a luxury good at the high level of income.

Another explanation of EKC deals with property rights (see [6] or [17]. When aspects of the environment (meadows, forests, water sources, etc.) are defined as property (which is the strongest incentive) the community increases efforts to improve environment quality. Thus in communities with commons there is no will to improve the state of environment, while communities with private property rights enhance environment preservation.

Munasinghe [10] provided a theoretical model with marginal costs and marginal benefits of pollution reduction. The main conclusion is that in the early phases of economic development benefits of environmental protection are negligible for decision makers, but as economic growth continues, after a certain point benefits will prevail.

Other authors ([3] and [15]) explain EKC through interaction of several effects, such as the scale effect, the composition effect and the technology (time) effect:

- *Scale effect* refers to the fact that an increase in production and consumption causes a proportionate increase in pollution,
- *Composition effect* is related to changing patterns in developed countries from resource and energy consuming economies toward more environmentally friendly economies based on knowledge, information and services. This effect is enhanced by international trade and specialization.
- *Technology (time) effect* provides more efficient, clean and energy-resource saving technologies (e.g. nuclear power plants).

Regression and econometric models were constructed to evaluate EKC. From the beginning, EKC was modelled by a simple quadratic regression model:

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \varepsilon, \qquad (1)$$

where y is emissions (concentrations) of a given pollutant, x is GDP per capita (or GDP per capita purchase power parity), β_i are parameters and ε residuals.

In this model, β_2 is negative, EKC has a shape of an inverted U (parabola) with a maximum in:

$$x_T = -\frac{\beta_1}{2\beta_2}, \qquad (2)$$

so x_T is a turning point of EKC in GDP per capita.

More sophisticated regression model uses logarithmic dependant variables (it substitutes *x* for *lnx*). The standard EKC regression model is [15, p. 3]:

$$\ln(E/P)_{it} = \alpha_i + \gamma_t + \beta_1 \ln(GDP/P)_{it} + \\ + \beta_2 (\ln(GDP/P))^2_{it} + \varepsilon_{it}, \qquad (3)$$

where *E* is emissions, *P* population, α_i and γ_t parameters for different countries *i* and different years *t*, and ε_{it} are residuals. The turning point in GDP per capita is:

$$x_T = e^{-\frac{\beta_1}{2\beta_2}} \qquad (4)$$

Instead of pollutant emissions it is possible to use pollution concentrations that can be directly measured, whilst emissions have to be estimated.

Some authors (e.g. [3]) introduced additional dependent variables into more complex econometric models. These variables include density of population, index of democracy, the percentage of GDP from industrial/service sector, openness of economy, etc.

Using such a complex model, Bouvier in [3] examined scale effect, sectoral composition effect (ratio of value added from industry to value added from service sector) and democracy effect for 4 pollutants: CO, CO_2, SO_2 and VOC (volatile organic compounds). She found the scale effect contributes to pollution increase in all four cases, while index of democracy had an opposite effect, mostly for CO_2 emissions. a higher ratio of service sector in economy led to a decline of emissions, especially SO_2 [3].

However, research on theoretical explanation of EKC is far from being finished. As Carson points out: „The difficulty is finding a common underlying process at work and linking specific changes in income to specific changes in pollution on the timescale of a few years." [4]

3. Example – Particulate Matter

Particulate matter (PM) refers to tiny solid particles suspended in the air. Some PM originate naturally from a volcano activity, large fires or dust storms, but significant amount of PM in the air is generated by fossil fuels combustion in power plants, factories and transportation. High levels of PM constitute serious health hazards, hence there exist air monitoring for PM worldwide. Particulate matter of a size under 10 micrometers is abbreviated as PM 10. Particles of this size are considered to be the most hazardous. Up to now research of EKC for PM 10 concentration has been rather neglected. Some studies have found EKC for PM generally, while other ones have not.

To illustrate the problem, PM 10 country levels of 91 countries were compared with their GDP per capita from World Bank database. Pollution (emission) data come from [19] and year 2006, economic data come from [18] and year 2008. Two-year difference between 2006 and 2008 data (the most up-to-date data available to the author) should not affect the results significantly due to small (a few percent) interannual changes in pollution and GDP. Dependence of the two sets of data is shown in Fig. 6, the scale is logarithmic and has an expected inverted U-shape.

Regression model (3) for *x = ln (GDP/per capita, PPP)* and *y = ln (country level of PM10)* gives the best fit:

$$y = -0.144x^2 + 2.066x - 3.479,\ R^2 = 0.227, \qquad (5)$$

where *R* is the coefficient of determination.

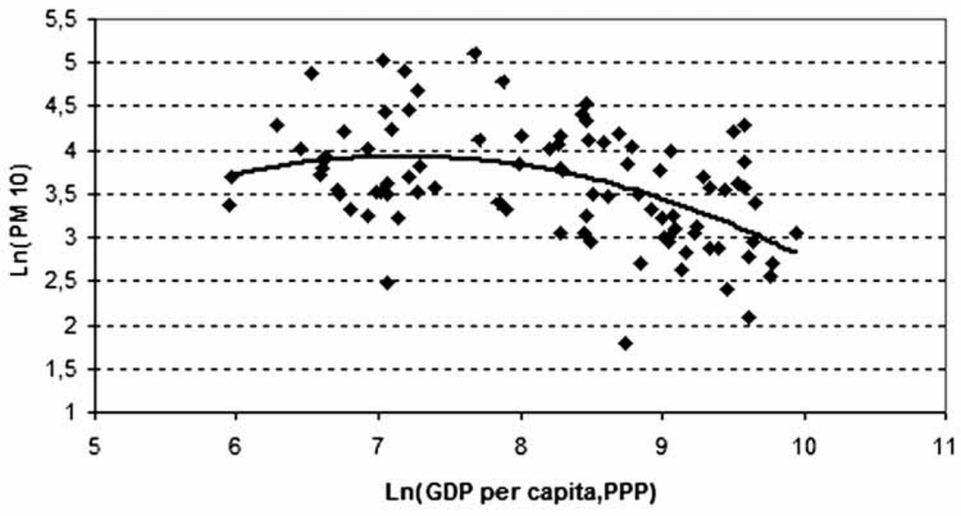
Turning point for PM 10 from (4): x_T = 1,308 US $ GDP per capita (PPP). This value for particulate matter is lower than in similar studies from the 1990´s (see Tab. 1), and probably can be attributed to the time effect – average PM 10 concentrations of 91 countries from this study fell from 69 μg/m³ in 1990 to 38 μg/m³ in 2006 [19]. Though regression coefficients in (5) were statistically significant at α = 0.05 level, coefficient of determination (thus model´s goodness-of-fit) is rather low in this particular case.

4. Critique of EKC

Environmental Kuznets Curve has not only proponents, but also critics ([3], [15]). The discussion is brisk and has not been resolved yet. The critique of EKC stems from the following points:

- Environmental quality depends on more factors than economic growth (GDP per capita) alone, relationship between EKC and GDP per capita is a simplification of complex reality. The other factors affecting environmental quality are: open economy, structure of econo-

Fig. 6: Relationship between GDP per capita (Purchase Power Parity) in 2008 US $ and Concentrations of PM 10 in µg/m3. Logarithmic x and y Scale



Source: own research

my (ratio between „clean" services and „dirty" industry), level of democracy, technological progress, political will to curb emissions, etc...

- Some studies on EKC are econometrically and statistically weak.
- EKC does exist only for a subset of environmental problems and it doesn´t exist even for some widespread pollutants (e.g. CO_2).
- Pollution levels have declined with economic growth in some developed countries in the past, but it does not imply that the same pattern will occur in developing countries.
- EKC might be a result of a specialization: wealthy countries specialize in human capital, services and information technologies, shifting dirty and expensive industries to developing countries with cheaper workforce, so emissions of developed countries drop while emissions of developing countries increase.
- EKC can be explained by comparison of the two effects: the scale effect and the time effect. In wealthy countries economic (and population) growth is slow, so the time effect outweighs the scale effect and environment improves, but in poor countries the scale effect dominates the time effect, thus environment gets worse.

Conclusion

Air pollution evidence for EKC existence is the strongest for sulphur dioxide, oxides of nitrogen and dark mater (smoke). But no EKC fits all substances; turning points for these pollutants are diverse and vary with different studies, investigated countries and time of the research. Some researchers do not consider studies of EKC to be statistically significant [15], other claim there is robust evidence that pollution levels typically fall at high income levels [4]. EKC wasn´t found for carbon dioxide, greenhouse gas that is a by-product of fossil fuels burning. Its emissions are monotonously increasing.

In water evidence for EKC is the strongest for biological oxygen demand, chemical oxygen demand, nitrates and some heavy metals (such as arsenic, cadmium or lead). The turning points for water pollutants are generally lower than turning points for air pollutants.

Standard EKC directly links economic growth (GDP per capita) with some indicator of environmental quality. But this relationship is more complex because there are other factors influencing EKC. For example in countries, where property rights are well established, EKC shifts to the left. The same is true for level of democracy. Both factors cause turning points to decline. Open economies improve their environment more than closed ones. In a broader context, existence of EKC implies inevitable environment degradation at the beginning of industrialization. On the other hand, when certain level of industrialization is reached, continuing economic growth (technological progress and peoples demand for clean and healthy environment) helps to reduce damage and is environmentally beneficial. Hence policy implication from EKC is simple: efforts to reduce economic growth to protect environment have the opposite effect...

Economist Julian Simon points out that humans are not only hungry mouths and cause of many (environmental) problems, they are also problem solvers due to their ingenuity, invention and imagination [14]. Existence of EKC seems to endorse Simons main thesis that people are capable of improving various aspects of their lives (e.g. environment) and that is an optimistic message.

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ABSTRACT

ENVIRONMENTAL KUZNETS CURVE – A TIE BETWEEN ENVIRONMENTAL QUALITY AND ECONOMIC PROSPERITY

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The goal of the article is an introduction of Environmental Kuznets Curve as a concept, discussion of its existence arising from empirical research for different pollutants and its theoretical explanation. The article includes own EKC research result concerning particulate matter in the air.

Economic growth, measured as GDP per capita in a given country, is connected with increasing pollution, but after some turning point pollution starts declining. This relationship has an inverted U-shape and is called Environmental Kuznets Curve (EKC). EKC was first identified in a research by Grossman and Krueger from 1991 [8], other studies came after soon. In the air pollution EKC was identified for SO_2*,* NO_x *a dark matter (smoke), in water pollution for biological oxygen demand, chemical oxygen demand, nitrates and some heavy metals (such as arsenic, cadmium or lead). EKC evidence for particulate matter (PM) is mixed, EKC wasn´t found for CO or* CO_2*. However, some authors consider evidence for EKC statistically weak. Standard explanation of EKC comes from [17]: „As the development and industrailization progress, environmental damage increases due to greater use of natural resources, more emissions of pollutants, the operation of less efficient and relatively dirty technologies, the high priority given to increase in material output, and disregard for – or ignorance of – the environmental consequences of growth. However, as economic growth continues and life expectancies increase, claner water, improved air quality, and a generally cleaner habitat become more valuable..."*

EKC research has important policy implications: from some point environmental quality improves with ecomic growth. Hence efforts to reduce economic growth to protect environment have in fact the opposite effect...

Key Words: *economic growth, Environmental Kuznets Curve (EKC), pollution.*

JEL Classification: *Q5, Q53, Q56, C01.*