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Lech Gruszecki*

Socioeconomic Policy and Its Impact on the Relationship Between Economic Growth and the State of the Environment: The Significance of the Environmental Kuznets Curve

ABSTRACT

This article outlines the role of the environmental Kuznets curve in research on the relationship between economic development and the state of the environment. It analyzes the sensitivity of the curve's course and its implementation in time intervals to various aspects of social and economic policy. It also discusses the importance of the Pareto principle in shaping the market through such instruments as taxes.

KEYWORDS: environmental Kuznets curve; economic growth; Pareto principle

INTRODUCTION

The state of the environment, climate change, and attempts to counter the devastation of our planet's ecosystems by human industrial activity are among the main topics of contemporary global public debate, and the economic sciences, in particular, are involved in it. One of the main theoretical tools that economics

* Correspondence regarding this paper should be sent to Lech Gruszecki (ORCID: 0000-0001-7392-5985), Institute of Economics and Finance, John Paul II Catholic University of Lublin, e-mail: lech.gruszecki@kul.pl.

uses in this regard is the so-called environmental Kuznets curve, which expresses the relationship between economic growth measured by GDP per capita and the level of environmental pollution. Of course, given various indicators describing the devastation of nature, such as figures showing the volumes of greenhouse gas emissions like CO_2, indicators of soil contamination, or the degree of deforestation, it is possible for a given considered area (region, country, group of countries) to study many environmental Kuznets curves relating to different aspects of the phenomenon of degradation of Earth's ecosystems. In what follows I discuss the fundamental issues related to the curve above. I will point out the role of social and economic policies in shaping its course.

The article is theoretical in nature, and my goal is to describe in the language of mathematical economics the relationship between economic growth and the state of the environment. The equations and diagrams presented below are therefore elements of a certain, inherently simplified, model of the economic phenomena under study. Mathematical modeling is nowadays an important tool of description in environmental economics. At the same time, it should be noted that the mere formulation of a model is only the first, yet necessary, step toward a full understanding of the phenomenon under consideration. The theory-model approach must be complemented by empirical research, which is not the subject of this article.

GDP PER CAPITA AS A MEASURE OF ECONOMIC DEVELOPMENT

The choice of GDP per capita to measure a country's economic development may be more controversial now than in the early 1990s, when the environmental Kuznets curve hypothesis was formulated. Today, the social science literature offers plenty of criticism of GDP per capita as an indicator of economic growth.

It is noted, for example, that GDP does not provide information on whether the income produced in a country is actually consumed in that country. Nor does GDP account for the so-called shadow economy and overlooks the external costs of productive activities, such as environmental costs. In addition, according to some, GDP inappropriately accords the same importance to those branches of the economy, such as defense, which do not directly affect economic well-being, and even on the contrary – by absorbing funds from the budget – diminish spending on education, health, and reduce social transfers. We should also add that the volume of GDP, usually expressed in USD, is subject to changes due to exchange rate fluctuations. The above-mentioned criticisms can be found in numerous studies on this topic (cf. Kołodko, 2008; Stiglitz et al., 2009). The Stiglitz, Sen, and Fitoussi Commission, acting at the invitation of French President Nicolas Sarkozy – after a deep critical analysis of the adequacy of GDP per capita – aimed in 2009 to replace this measure of economic growth with a more appropriate one. To date, the new methods of measuring the state of the economy have not been widely adopted.

Various types of measures of well-being and quality of life, which take into account the importance of social capital, such as HDI (Human Development Index), IHDI (Inequality-adopted Human Development Index), IPI (Integrated Prosperity Index) proposed by Kołodko (2008), or the Better Life Index that captures life satisfaction among citizens of OECD countries, are often taken into account in the social sciences. The most popular of the above indices, HDI, considers three spheres of human functioning: 1) the sphere related to health, 2) the area of education and competencies, and 3) the area that defines strictly economic standards of existence. Spheres one and two refer to issues such as life expectancy or average time spent on school education. At the same time, for area three, the primary indicator is GDP per capita in purchasing power parity. The HDI measure is sometimes expanded, for example, to the form of IHDI by including an index of social inequality. Between the above-mentioned indicators – they can be joined by the MPI (Multidimensional Poverty Index) or indexes expressing the issue of inequality in different ways, such as the GII (Gender Inequality Index) or life satisfaction – there is a similarity expressed in the emphasis of the personal dimension and social dimensions in understanding state welfare.

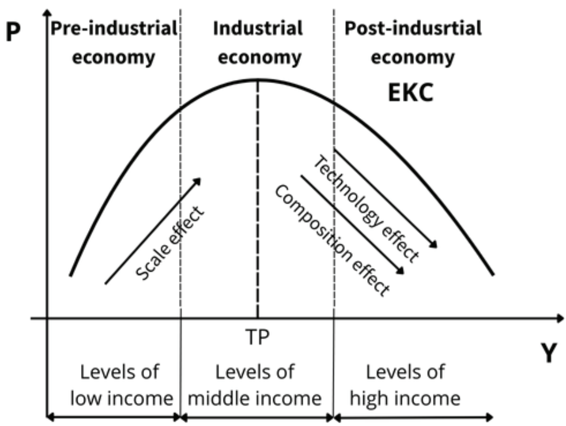
However, it should be noted that GDP per capita, or specific variants of it like GDP per capita in purchasing power parity of a country, which play a key role in the foundations of economic theory, have an important advantage over indexes that also take into account human and social capitals. Specifically, it is grounded in "hard" figures, such as a country's GDP and population, which are central to the foundations of economic theory. Consequently, the significance of GDP per capita persists, which is also reflected in the conceptual framework of the environmental Kuznets curve hypothesis.

THE CONCEPT OF THE ENVIRONMENTAL KUZNETS CURVE

The concept of the environmental Kuznets curve (EKC for short) first appeared in the scientific literature in an article by Grossman and Krueger (1991). The article's political and economic background was related to liberalization in trade between the United States and Mexico. The EKC curve itself follows its course from the curve proposed in the 1950s by Simon Kuznets, which describes the hypothetical relationship between economic growth measured by GDP per capita and social inequality in income. Thus, the EKC curve, like Kuznets' original curve, takes the form of an inverted U: initially, pollution levels increase as society's wealth increases, to fall after exceeding a certain amount of GDP per capita, referred to as the turning point (TP). This course of the EKC curve is determined by three economic effects, which act in different proportions and with varying intensity at different times: 1) the scale effect, 2) the composition effect, and 3) the technology effect. The first of these effects involves a directly proportional, relative to the volume of production, increase in the levels of environmental pollution. The second effect is associated with an increasing share in the national product of those sectors of the economy, such as services, that place less of a burden on the earth's ecosystems. The third effect is the result of a technological revolution introducing new, more nature-friendly techniques for producing goods. Three significant epochs in economic history also influence the Kuznets environmental curve's shape:

– the pre-industrial era, characterized by low production levels, and agriculture's dominance, accompanied by minimal pollution;
– the industrial era, when development was primarily driven by heavy industry, particularly mining, and metallurgy, resulting in significant environmental degradation;
– and the post-industrial era, where modern, comparatively more environmentally friendly production methods prevail (Figure 1).

Figure 1. Environmental Kuznets curve.



Note. Y stands for GDP per capita and P denotes the level of pollution (Kaika & Zervas, 2013, p. 1394).

Numerous articles have attempted to provide a theoretical justification for the existence and nature of EKC variability. In their explanations, the authors of these publications have employed a variety of arguments based on different, albeit complementary, conceptual structures.

Some authors derive the shape of the EKC curve (an inverted U) from research on production functions (cf. Lopez, 1994; Antweiler et al., 2001), while others base their considerations on utility function maximization (cf. McConnell, 1997; Selden & Song, 1995; Lieb, 2002). Some authors refer to demographic models, such as the OLG (overlapping generations) model; the works of John and Pecchenino (1994) and Wang, Fu, and Zang (2015) belong to this trend. In turn, the role of income inequality is alluded to by Boyce and Torras (1998), Kasuga and Takaya (2017) or Liu et al. A review of mathematical models for the environmental Kuznets curve is devoted to the publications of Kijima et al. (2010), and Gruszecki and Jóźwik (2019). An interesting classification of factors that may influence the shape of EKC was presented by Copeland and Taylor (2004). They treat environmental quality as a normal good. In their view, the inverted U shape of the environmental Kuznets curve can be explained by pointing to the role of the following factors:

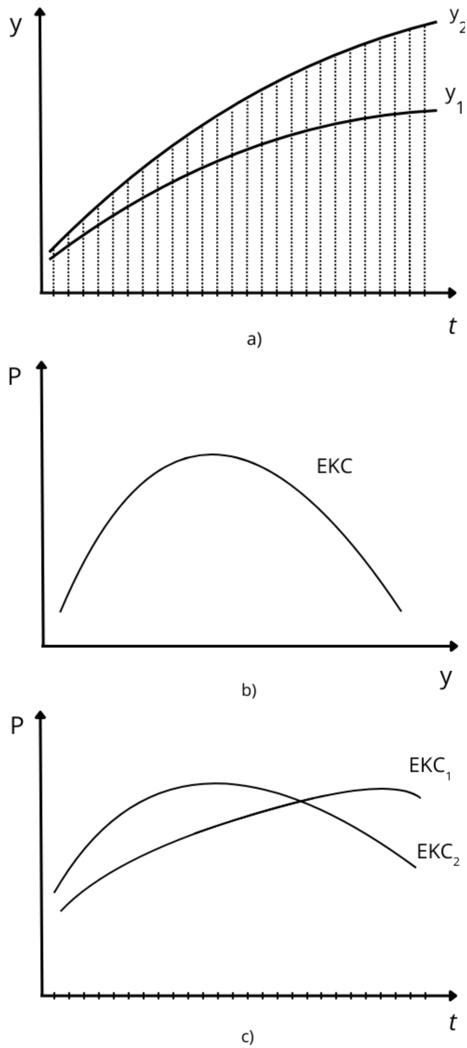
- the steady increase in the importance of human capital throughout economic history; in the early stages, development is based on capital in the traditional sense, to use mainly human capital in later stages;
- the increasing income elasticity of marginal environmental damage;
- the benefits of good environmental quality, which increase with GDP per capita;
- the abrupt change in socioeconomic policies aimed at improving the state of Earth's ecosystems.

It is more than three decades since the EKC hypothesis was formulated. During this period, a substantial number of empirical studies have been conducted, yielding inconclusive results regarding the confirmation of the hypothesis for various measures of environmental quality. These measures include, but are not limited to, CO_2 emission levels, emission levels of other greenhouse gases and toxins, water and soil quality, and deforestation. In a substantial proportion of cases, the hypothesis was validated (the EKC hypothesis for Poland was confirmed in the article by Jóźwik et al., 2021). In other instances, curves of a distinct form were obtained, and in some studies, no curve was obtained at all (cf. Shahbaz & Sinh, 2018). The findings do not refute the hypothesis but may lead to its reformulation. Consequently, the EKC hypothesis remains pivotal in research examining the relationship between economic growth and the state of the environment.

MODELING EKC CURVES

From the perspective of mathematical economics, environmental Kuznets curves illustrate the functional dependence of environmental pollution measures, denoted P, on GDP per capita, symbolized by y. However, it is important to note that GDP per capita is subject to temporal fluctuations. Consequently, the magnitude of y at a specific time can be designated as y_t. Over the past two centuries, disregarding brief periods of recession triggered by various factors, the value of y_t has been on an upward trend. This phenomenon will be a central consideration in the construction of time courses of environmental Kuznets curves, which should be distinctly delineated from the EKC itself (see Figure 2).

Figure 2. Two growth paths of GDP per capita (a) and EKC graph (b); EKC_1 and EKC_2 curves (c) result from the superposition of the respective lines in (a) and (b).



Note that for a real assessment of the level of pollution at a given moment as well as at specific time intervals, the realizations of the EKC curve corresponding to actual changes in GDP per capita, that is, the curves EKC_1 and EKC_2 (Figure 2c), play a vital role. The volumes of cumulative pollution generated at the time interval [$t1$, $t2$] are equal to the fields of the areas bounded from above by the curves EKC_1 or EKC_2:

(1) $$\int_{t_1}^{t_2} EKC_i\,(t)\,dt = \int_{t_1}^{t_2} EKC\,(y_{it})\,dt\ , \quad i\ =\ 1{,}2.$$

However, when assessing actual environmental impacts, it is important to consider that pollutants biodegrade at an agent-specific rate. Assuming that biodegradation occurs at an exponential rate, then the corrected volume of cumulative pollutants is

(2) $$\int_{t_1}^{t_2} e^{-k(t_2-t)} EKC_i\,(t)\,dt\ , \quad i\ =\ 1{,}2,$$

where $k > 0$ is a coefficient that determines the rate at which the biodegradation of toxins occurs over time.

It should be added to the above considerations that the level of environmental degradation considered not in a time interval but at a specific moment in time, say t_2, is equal to

(3) $$EKC_i(t_2) + \int_{t_1}^{t_2} e^{-k(t_2-t)} EKC_i\,(t)\,dt\ , \ \ i = 1{,}2,$$

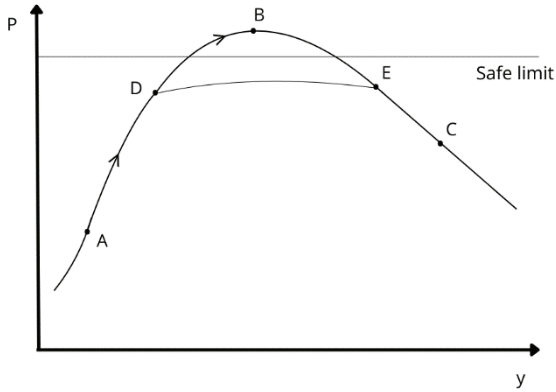
as indicated in the article by Gruszecki, Jóźwik, and Kyophilavong (2020).

Of course, the magnitudes (1)–(3) depend both on the economic growth rate, i.e., the path of y_t, and on the relationship described by the environmental Kuznets curve, which is region-specific. Socioeconomic policies, in particular, can affect the change in the path of economic development and, thus, the time course of the EKC curve.

POLITICAL-ECONOMIC DECISIONS AND THE EKC CURVE

Munasinghe (1999) wrote about how social and economic policy decisions can affect the shape of the environmental Kuznets curve, pointing to a potentially positive effect associated with changing these policies in a more pro-development direction, which he referred to, by analogy with quantum mechanics, as tunneling. The effect is shown in Figure 3.

Figure 3. Tunneling effect for the environmental Kuznets curve.



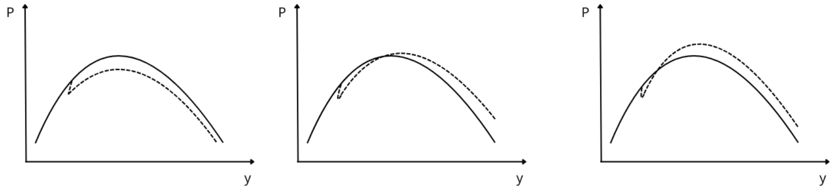
Note. From Munasinghe (1999, p. 95).

The bifurcation seen in Figure 3 at point D is related to the possible adjustment of economic and social policies. This adjustment is a consequence of policy choices made to avoid the risk of the EKC curve "piercing" the line that marks the boundary between acceptable levels of pollution and levels that cause environmental catastrophe. A possible policy change is made at point D, corresponding to a certain level of GDP per capita. At the same time, however, policy decisions, including this one, are made at a specific historical moment, in this case, at t_D. Therefore, the reasoning presented by Munasinghe can also be applied to the time path of the environmental Kuznets curve. Political decisions regarding economic actions can also be incorrect, causing the EKC curve to rise. The government may also behave opportunistically by failing to address the challenges posed by the current social and economic situation, leading to a line through point B.

The DE path is consistent with the policy of sustainable development, which, on the one hand, calls for the creation of favorable conditions for the use of new, more environmentally friendly energy sources, including the promotion of innovation in energy production technologies and, on the other hand, expects the authorities to implement comprehensive measures for intergenerational solidarity that take into account the future effects of decisions made today. Studies indicate the significant role of human and social capital. Measures in education and healthcare, as well as the reduction of excessive social inequalities, also lead to more pro-environmental attitudes, with a feedback effect on social debate and subsequent decisions.

Particularly challenging, calling into question the continuation of existing economic and social policies, are unforeseen events that cause severe perturbations in the economic field in the short term, leading to a significant jump in GDP per capita. Such events are economic and financial crises that occur periodically but are nevertheless difficult to predict, such as the one that began in 2008 in the US mortgage and structured asset market. Another unexpected event, exogenous to economics and finance, was the COVID-19 outbreak. Three paths out of the crisis are presented by Jóźwik and Gruszecki (2020). They are illustrated in Figure 4.

Figure 4. Three possible waveforms of the Kuznets environmental curve.



Note. From Jóźwik and Gruszecki (2020, p. 30).

Thus, the crisis can put the economy on a sustainable development path by implementing appropriate economic policies that stimulate environmentally friendly innovations in industry, agriculture, and services. It is also possible, in the absence of investment opportunities and with a lack of understanding of the seriousness of the economic challenges, to retreat to solutions that have produced results in the past but are no longer adequate at the current stage of development. It is also possible for the economy to remain on its current development trajectory, failing to make creative use of the opportunity that is a consequence of the crisis.

THE ISSUE OF ENVIRONMENTAL EXTERNALITIES AND THEIR VALUATION

Environmental externalities, such as air, water, or soil pollution, deforestation, and noise, indicate, as is well known, market imperfections. These imperfections are expressed in the lack of coordination in the allocation of resources, which in the case of a well-functioning market is based on prices determined by balancing supply and demand in the process of free exchange of goods. However, externalities disrupt this process, causing prices to no longer accurately reflect the actual costs and profits incurred.

An economic policy based on the principle of optimality formulated by Wilfred Pareto can be used to address market imbalances in price coordination. According to this principle, the result of the operation of an economic system is considered optimal in the Pareto sense if it is impossible to improve the welfare of any of the system's participants without worsening the material situation of at least one other actor contributing to the system. It should be noted that the above principle does not explicitly refer to the moral sphere, so it does not present and promote any concept of fair distribution of produced goods (including fair distribution in terms of covering external costs arising from economic activities that contribute to environmental devastation).

The Pareto concept encourages the expansion of the stock of distributable wealth while not indicating specific methods of distributing said resources. In other words, this principle is the basis of efforts to increase gross domestic product and, if the population size is not increasing rapidly, to increase GDP per capita. The Pareto principle is currently integrated with welfare economics, as demonstrated by the following two theorems (see Phaneuf & Requate, 2017). The first of these theorems states that in a perfectly competitive and complete market with freely formed prices and profit-maximizing behavior, there is an optimal allocation of resources in the sense of Pareto. The second theorem, in turn, presents the thesis that assuming a complete and perfectly competitive market, the optimal state in the Pareto sense can also be achieved with the participation of appropriate social transfers and taxes reflected in the price system (modified by social policy).

How is social policy made according to the Pareto principle of optimality when environmental externalities are present? This question is answered by a reinterpreted model presented by Lindahl and Samuelson (cf. Lindahl, 1958; Samuelson, 1954). On the formal side, the model is presented as follows (see, e.g., Phaneuf & Requate, 2017, pp. 7–9). It is assumed, for simplicity, that the economy consists of two actors and that it produces only two goods: a good whose production does not cause adverse environmental effects and a "dirty" good whose production causes environmental pollution. With the symbols x_i and y_i, i = 1,2, we denote the consumption of the "clean" good and the "dirty" good by each market participant. Let us use the symbol to represent the toxic emissions associated with the production of the "dirty" good y, whose production function is given by the relations

(4) $$y = f(l_y, e)\ ,$$

where l_y denotes the labor required to produce the "dirty" good. Similarly, l_x denotes the labor needed to produce good x. The condition

(5) $$l = l_x + l_y\ ,$$

where l symbolizes the total labor resource.

To the list of limiting conditions we still need to add conditions on the production and consumption of both goods (condition (6) is a consequence of (4))

(6) $$y_1 + y_2 = f(l_y, e)$$

and

(7) $$x_1 + x_2 = g(l_x)\ ,$$

where g is the production function of the "clean" good.

As illustrated, the only resource utilized in the production process is labor, with environmental resources being a factor in the production of the second good. Capital is not included in this analysis.

The following symbols denote the utility functions of the two market participants:

(8) $$U_i(x_i, y_i, e)\ , i = 1{,}2\ .$$

We are adding a limiting condition to conditions (5), (6) and (7), thus expressing the Pareto principle

(9) $$U_2(x_2, y_2, e) - u^* \geq 0\ ,$$

where u^* is some acceptable level of utility of the other actor participating in the market. Due to the ambiguity of the choice of this level, one can speak of multiple solutions to the problem of maximizing the utility function $U_1(x_1, y_1, e)$ with the limiting conditions (5), (6), (7), and (9).

As a result of solving the optimization problem, one gets the relation

(10) $$-\frac{\frac{\partial U_1}{\partial e}}{\frac{\partial U_1}{\partial y_1}} - \frac{\frac{\partial U_2}{\partial e}}{\frac{\partial U_2}{\partial y_2}} = \frac{\partial f}{\partial e}\ ,$$

As a result of solving the optimization problem, one gets the relation that indicates the optimal level of toxic environmental impacts, as viewed through the lens of the utility function. It should be noted that this level cannot be equal to zero due to the demand for "dirty" goods. Thus, equation (10) should be read in such a way that the sum (on the left side of the equation) of the marginal willingness to give up the "dirty" good y due to the desire to reduce its harmful environmental impact, is equal to the real cost associated with the production of this good with reduced adverse environmental effects (the expression on the right side of (10)). The aforementioned equation can also provide a foundation for addressing the limitations and imperfections of markets by incorporating environmental externalities into socioeconomic policy. At the same time, we must remember that proper economic policy, aimed at establishing adequate charges for environmental devastation, primarily aims to improve market mechanisms leading to economic growth. Looking at the issue from the point of view of the methods and concepts of environmental economics, and in particular referring to the environmental Kuznets curve, a properly functioning market generates an increase in GDP per capita, which can mean a faster transition from the rising to the falling part of the EKC curve. This is especially true for developing countries. For developed countries, a shift toward the lower values of the environmental Kuznets curve indicates benefits for the planet's ecosystems.

CONCLUSIONS

The article presents the thesis that the environmental Kuznets curve is an important tool for describing the relationship between economic growth and the state of the human environment. Its course and specific realizations over time are related to decisions on choosing the most appropriate social and economic policies possible on a national and international level. The reasoning presented in this publication is sufficiently general to apply to environmental Kuznets curves that deviate from the inverted U-shaped curve. This is because the article considers the local behavior of the curve trajectory in the vicinity of significant decision points. The results show that applying the right solutions at the right time in economic policy, including tax policy, contributes significantly to improving the quality of the environment. This improvement occurs not so much as a consequence of redistributing resources but in connection with adopting an agenda for sustainable economic development based on well-functioning markets.

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